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A Comparison Regarding the Behaviour of the Horizontal and Vertical Expansion Loops of the Steam Collectors

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Abstract

In the paper are presented some differences that appear in the behaviour of the horizontal and vertical expansion loops of the steam collectors used in petrochemical plants. The flexibility calculation has been completed for sustained, expansion and occasional loads (wind, earthquake) in two main cases: a steam collector with a horizontal expansion loop and a steam collector with a vertical expansion loop. The results obtained illustrate the differences between the flexibility of the above loops.

Key words: *loop, thermal expansion, steam collector, sustained.*

General Aspects

In order to check the flexibility of an expansion loop of a steam collector, a 3" pipe has been considered. The collector has 7.62 mm thickness and is made of W 1.0345 steel. The pipe is insulated (110 mm) and has 3mm corrosion allowance. The maximum design temperature is 350 ^{o}C and the minimum design temperature is -29 ^{o}C. The span between supports is 4m and the collector is fixed at the ends by two anchor points. The steam collectors have been analysed in two geometrical configurations: with a horizontal (fig. 1) and a vertical expansion loop (fig. 2).

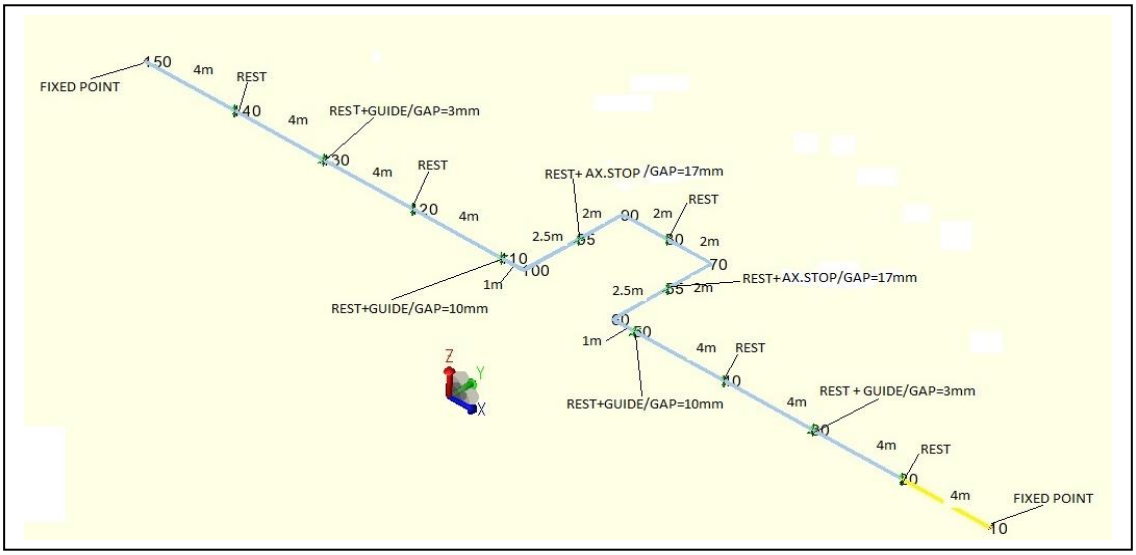

Fig. 1. Steam collector with a horizontal expansion loop

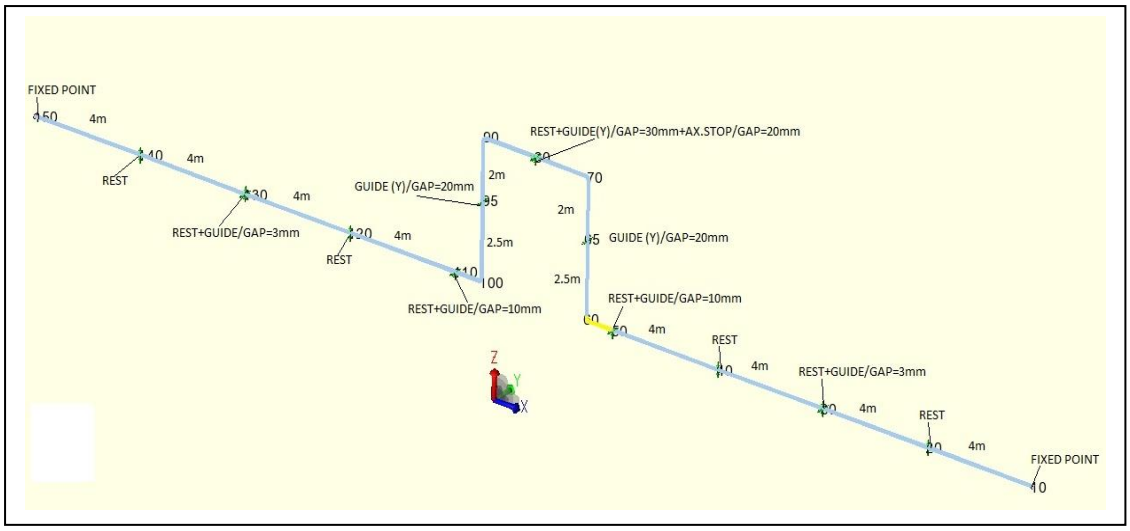

Fig. 2. Steam collector with a vertical expansion loop

From Figures 1 and 2 it can be noticed that the above collectors have the same geometry, the only differences between them being the position of the expansion loop: horizontal in the first case and vertical in the second one.

The flexibility of the above collectors has been analysed in three main load cases:

- sustained (SUS) when the pipe is loaded with gravity loads (steel, steam and insulated material) and internal pressure;
- expansion(EXP) when the pipe is loaded only with the difference of temperature between maximum (350 ^{o}C) and minimum (-29 ^{o}C) design temperature;
- occasional loads (OCC-wind, earthquake) superposed over the sustained loads.

The deformed shapes in the above three cases are presented respectively in Figures 3(SUS), 4(EXP) – for the collector with horizontal loop and 5(SUS), 6(EXP) – for the collector with vertical expansion loop.

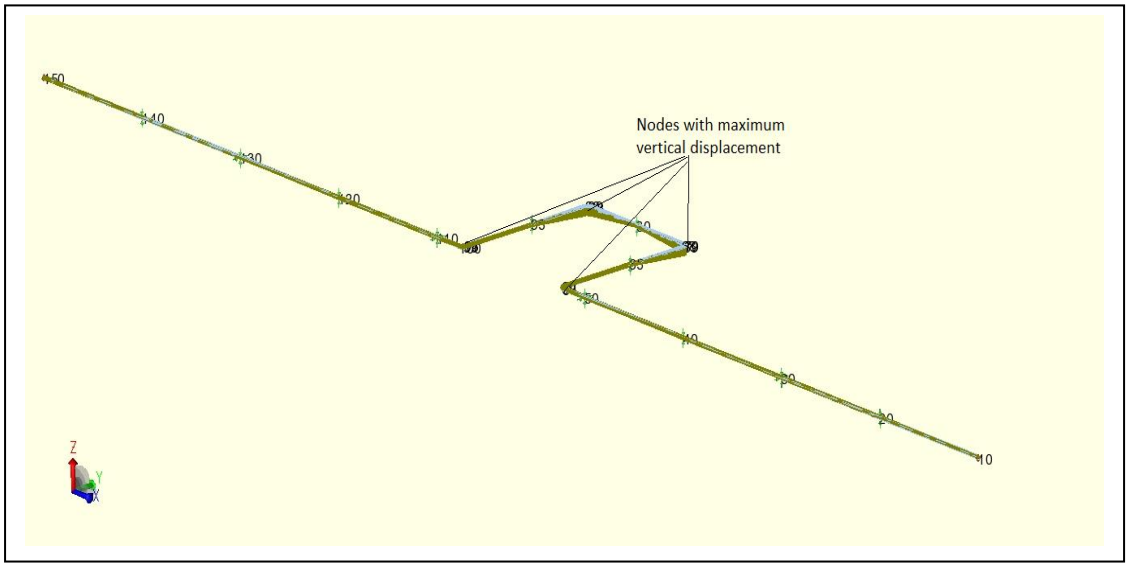

Fig. 3. The deformed shape of the collector with horizontal loop in SUS load case

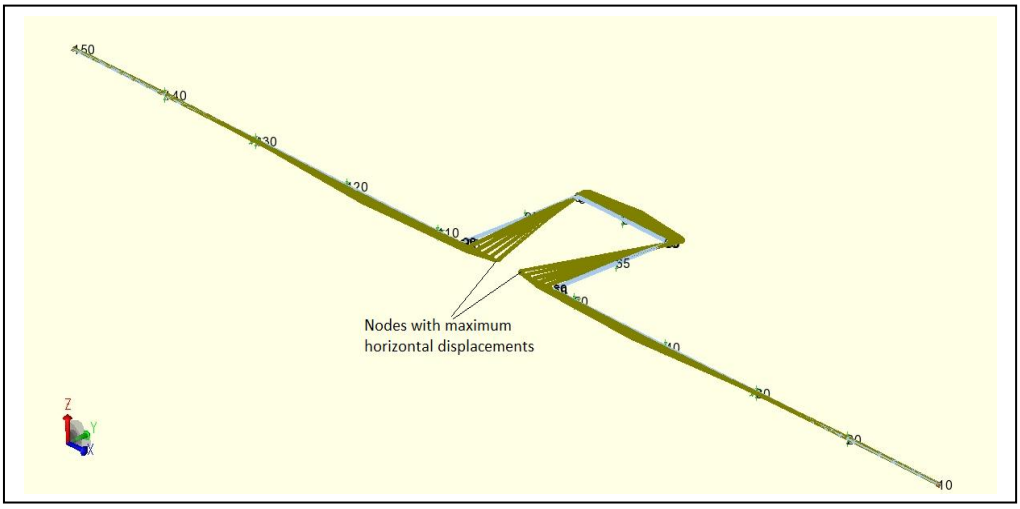

Fig. 4. The deformed shape of the collector with horizontal loop in EXP load case

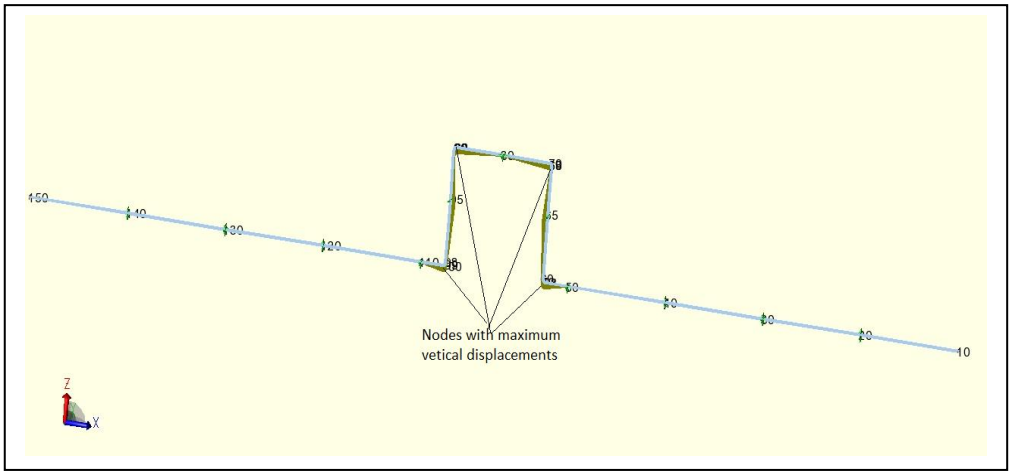

Fig. 5. The deformed shape of the collector with vertical loop in SUS load case

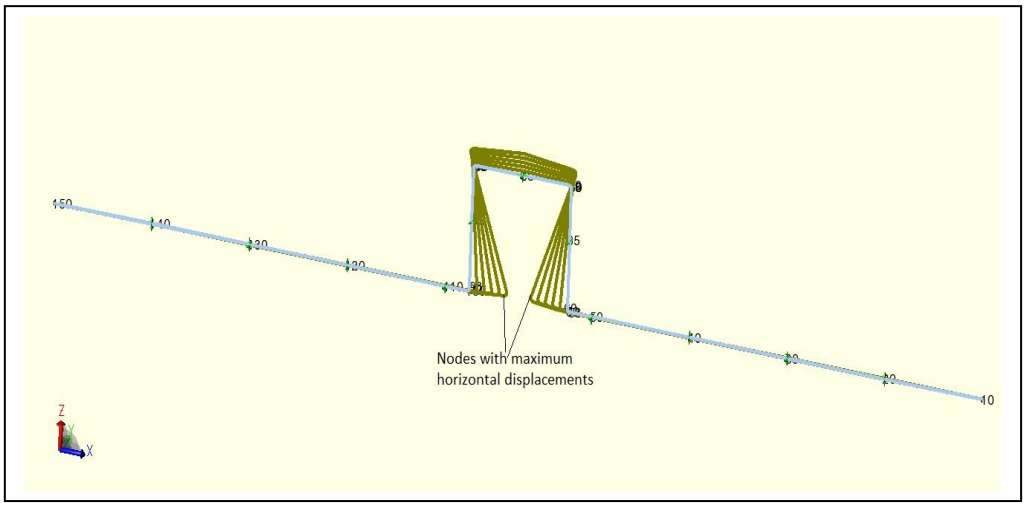

Fig. 6. The deformed shape of the collector with vertical loop in EXP load case

From the above figures (3, 4, 5 and 6), it can be noticed that the most loaded nodes from the both collectors are exactly the bends and the rests of the loops (the nodes 60, 70, 80, 90, 100). In Tables 1 and 2 are presented the displacements and the maximum stresses from the nodes located on the loops of the collectors.

Table 1. Main displacements and stresses for the collector with horizontal loop

Nodes		**60**	**70**	**80**	**90**	**100**
Maximum EXP displacements	ux [mm]	-76.59	8.56	0.00	-8.56	76.59
	uy [mm]	3.33	24.58	34.14	24.58	3.33
Maximum SUS stress [MPa]		10.68	10.59	34.2	10.59	10.68
Maximum EXP stress [MPa]		127.80	131.1	66.18	131.1	127.80
Maximum OCC stress [MPa]		41.73	37.90	51.24	37.90	41.73
Overstress		NO	NO	NO	NO	NO

Table 2. Main displacements and stresses for the collector with vertical loop

Nodes		**60**	**70**	**80**	**90**	**100**
Maximum EXP displacements	ux [mm]	-76.59	8.56	0.00	-8.56	76.59
	uz [mm]	7.19	28.56	38.89	28.56	7.19
Maximum SUS stress [MPa]		23.63	12.52	38.28	12.52	23.63
Maximum EXP stress [MPa]		163.83	175.40	18.05	175.40	163.83
Maximum OCC stress [MPa]		41.73	37.90	51.24	37.90	41.73
Overstress		110.9%	118.8%	NO	118.8%	110.9%

From the values presented in Tables 1 and 2, it can be noticed that the collector with vertical loop has less flexibility than the collector with horizontal loop because of gravity loads that are located in the same plane with the collector. This reduced flexibility produces overstress in the EXP load cases. The maximum overstress appears in a bend of the collector with vertical loop

and is 118.8% from the allowable limit of the material. In order to overpass the above disadvantage it is necessary to increase the length of the loop, exactly with a percent obtained from the overstress of the expansion stresses of the collectors with vertical loop. In this respect the initial length of the loop (4.5 m) has to be multiplied with at least the overstress percent (118.8%), reaching the final value of 5.5 m. For such a situation the values of main displacements and maximum stresses of the collector with vertical loop are presented in Table 3.

Table 3. Main displacements and stresses for the collector with vertical loop with increased length

Nodes		**60**	**70**	**80**	**90**	**100**
Maximum EXP displacements	ux [mm]	-76.73	8.59	0.00	-8.59	76.73
	uz [mm]	4.10	29.68	37.63	29.68	4.10
Maximum SUS stress [MPa]		25.18	13.05	45.14	13.05	25.18
Maximum EXP stress [MPa]		135.78	145.51	7.93	145.51	135.78
Maximum OCC stress [MPa]		54.21	39.96	55.48	39.96	54.21
Overstress		NO	NO	NO	NO	NO

Increasing the length of the collector with vertical loop (with around 20%) the overstress problem has been solved.

Conclusions

In this paper we have presented a numerical method used for calculating the flexibility of two steam collectors: one with a horizontal expansion loop and another one with a vertical expansion loop, both of them having the same geometry of the loops. The collectors have been loaded with gravitational loads, internal pressure and a difference between the maximum and minimum design temperatures. The results obtained have been exemplified for two 3" collectors (88.9 x 7.62). From the flexibility analysis has been illustrated that the collector with vertical loop has less flexibility than the collector with horizontal loop. This aspect can be explained because of gravitational loads that in the case of the collector with vertical loop act in the same plan with the collector and diminish the thermal flexibility.

In order to overpass this disadvantage it is necessary that the length of the loop of the vertical collector be increased with at least the overstress percent. For example if the initial length of the vertical loop is 4.5 m it is necessary to increase the length up to 5.5 m.

The results presented above illustrate that the geometry of the horizontal and vertical expansion loops, even if they are the same, do not assure the same flexibility, each time the flexibility of the vertical loop being lower than the flexibility of the vertical loop.

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O comparaţie privind comportarea lirelor de dilatare orizontale şi verticale ale colectoarelor de abur

Rezumat

În lucrare se prezintã diferenţe ce apar in comportarea colectoarelor de abur cu lire compensatoare orizontale si verticale, care se întalnesc în combinatele petrochimice. Calculul de flexibilitate al colectoarelor a fost realizat pentru cazurile clasice de încarcare, greutate proprie, expansiune termicã şi încarcari ocazionale (vânt, seism), în douã situaţii : un colector cu o lirã de dilatare orizontalã şi altul cu o lirã verticalã. Rezultatele obţinute pun în evidenţã diferenţele dintre flexibilitãţile celor douã lire de dilatare.