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STUDY OF BACKPRESSURE VALUES OF DIRECT SPRING LOADED SAFETY VALVES

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ABSTRACT

Safety valves under operating have a backpressure value, which is working on the safety valves outlet area. If this backpressure value is higher than the 10% from safety valves set pressure then the safety valves will not working safety. In this paper, will be shown how can calculate and simulate this backpressure value when only one safety valve is working and when two safety valve are working at the same time and they venting in a common pipe system. It will also be presented, what is the effect of corrosion in the venting pipeline on backpressure.

LIST OF SYMBOLS

Latin letters

A_0	Pipe cross-section area [m^2]
d_0 , d_i	Pipe inner diameter [m]
k	relative roughness [-]
L	Length [m]
m	Mass flow rate [kg·s^{-1}]
M	Molar weight [kg·kmol^{-1}]
p_b	Backpressure [Pa]
p_{sb}	Superimposed backpressure [Pa]
R	Universal gas constant [J·kmol^{-1}·K^{-1}]
Re	Reynolds number [-]
T	Temperature [°C]

Greek letters

ε	Pipe surface roughness [m]
λ	Friction coefficient [-]
ξ	Minor loss coefficient [-]

1. INTRODUCTION

In the chemical industry and related industries, the protection of pressure systems and equipment against over pressure is an extremely important task from a safety, economic, environmental and technological point of view. In these factories, safety devices mostly direct spring-loaded safety valves. Many times these technologies work with toxic substances that may be harmful to health that is why these safety valves venting in a closed pipe system. During the operation of the safety valves, a

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backpressure value will be appeared at the outlet of the safety valve due to the flow in the venting system. This backpressure can be dangerous to normal operation of safety valves. If the backpressure is higher than the 10% from the set pressure, it can occurs an abnormal operation, the maximal venting capacity will be lower than at the design state.

1.1. EXAMINED SYSTEM

In this study, the calculation method will be presented through an example. The examined system is an experimental one. The sketch of the system can be seen in Figure 1. The system including one reactor (R), one mixer (M) and one column (C). For the protection against overpressure the system including two safety valves (SV). Set pressure of safety valves is 16 bar_g. The medium in the reactor including 80% of Hydrogen, 15% of Nitrogen and 5% water. The medium in the mixer including 80% of Hydrogen, 10% of Nitrogen and 10% water. The operating temperature and the maximum allowed pressure in both devices are 150 °C and 15 bar_g. Under normal operation, 200 kg/h medium is flowing from the reactor to the column through the N1 nozzle. Pressure in the column is atmospheric. For the study, three different malfunction are assumed. In the system ARI-SAFE-P921 safety valves are equipped. This type of safety valves are direct spring loaded, closed lifting and linear opening safety valves with closed bonnet. For this type of safety valve superimposed backpressure is not allowed and the built up backpressure is maximum 10% from set pressure [1–3].

- First malfunction, when the PIC01 controlling valve is closed and the SV1 will be opened.
- Second malfunction, when SV2 will be opened and the reactor has normal operation.
- Third malfunction, when PIC01 controlling valve is closed, SV1 and SV2 will be opened at the same time.

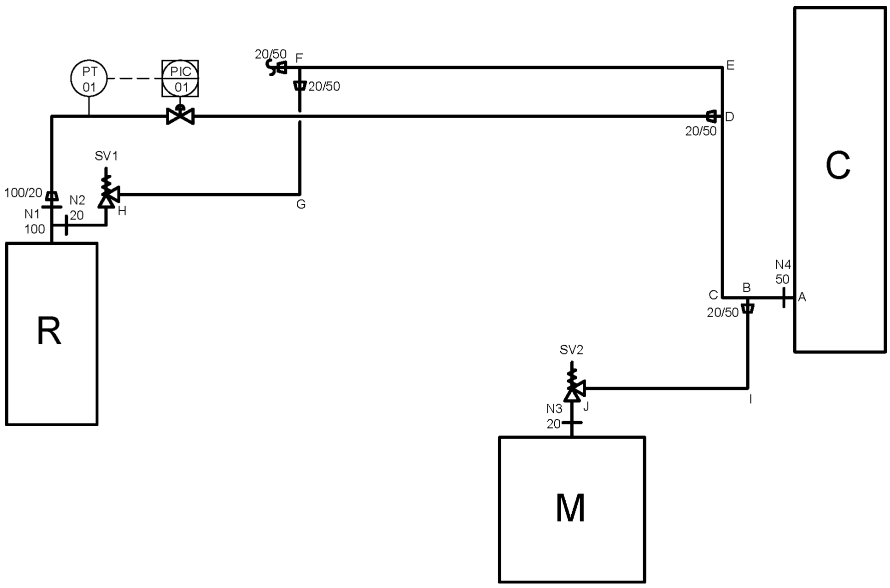

Figure 1. Experimental system

In Table 1 can be seen the geometrical size of the venting pipe system.

Table 1. Venting pipe system geometrical size

	A-B	B-C	C-D	D-E	E-F	F-G	G-H	B-I	I-J
Length [m]	1	0,5	1,5	0,5	3	1,5	1	0,5	1
⌀DN	50	50	50	50	50	20	20	20	20

2. CALCULATION

2.1. CALCULATION METHOD

The calculation can be used only for a designed system because the exact geometrical size of the venting system is required. For the calculation, the gas ideal and the flow isothermal are assumed. The backpressure is a static pressure that exists at the outlet of a safety valve. It is the sum of superimposed and built-up backpressures, and it potentially influences the set pressure and certainly the operation of the valve. Built-up backpressure occurs when the safety valve is open and medium is flowing in the venting pipe system. Superimposed backpressure occurs when the valve is closed and pressure already exists at the outlet of the valve. In this study, the superimposed backpressure is 0 bar_g because the column has atmospheric pressure. To calculate the backpressure value, Equation (1) should be used [4]. For the calculation, the maximum capacity of the safety valves has to be known. In this case SV1 maximal capacity is 266 kg/h and SV2 maximal capacity is 256,1 kg/h. For calculations, these maximum capacity values will be used. If the calculated backpressure value is higher than the 10% from the SVs set pressure then the geometry of the venting pipe system should be changed because the proper operation of the safety valves is not ensured or should be changed the type of the safety valve [5–7].

$$p_b = \sqrt{\frac{m^2 \cdot R \cdot T}{A_0^2 \cdot M} \cdot \left(\lambda \cdot \frac{\sum_{i=1}^{n} L_i}{d_0} + \sum_{i=1}^{n} \xi_i \right) + p_{sb}^2} \tag{1}$$

In the equation (1), the lambda friction coefficient calculated by the Haaland equation which can be seen in Equation (2) [8].

$$\frac{1}{\sqrt{\lambda}} = -1,8 \log \left[\left(\frac{k}{3,7} \right)^{1,11} + \frac{6,9}{\mathrm{Re}} \right] \tag{2}$$

In the equation (2), k is the relative roughness calculated by Equation (3).

$$k = \frac{\varepsilon}{d_i} \tag{3}$$

With these equations can be calculated directly the backpressure value when the nominal diameter of pipes in the venting pipe system is not changing. If the venting pipe system is including different nominal diameter of pipes or the mass flow rate is changing in the venting pipe system then the calculation should be done in several steps. The back pressure value should be calculated until the first diameter change or the first mass flow rate change, and in the next step this calculated backpressure value will be considered as a superimposed backpressure and the calculation shall be repeated for the next stage.

2.2. RESULTS OF CALCULATION

Calculations are made for the maximum capacity of the safety valves. Under normal operation medium is not flowing in the venting system, that is why corrosion was assumed in the wall of the pipe, which changes the roughness of the pipe. Calculations were made for non-corroded, novel pipes and corroded pipes as well. For non-corroded, novel drawn tubes, the roughness of pipe is 0.00152 m and for corroded drawn tubes the roughness of pipe is 0.15m [9–12].

Table 2. Backpressure results of calculations

		p_b [bar_g] for corroded pipe	p_b [bar_g] for non-corroded pipe
First malfunction	SV1	2,12	1,39
Second malfunction	SV2	1,63	1,12
Third malfunction	SV1	2,22	1,39
	SV2	1,62	1,10

As the results are shown, for non-corroded pipes backpressure values are right, because values are smaller than the 10% from set pressure which is 1,6 bar_g, but for corroded pipes the calculated backpressure values are higher than the backpressure limit.

3. SIMULATION

For making sure that, the results of the calculations are right, computer simulations were made for each types of malfunctions. Simulations were made with the UniSim Design software [13]. Simulations were made in dynamic state and Peng-Robinson fluid package was used. For the SVs settings API520 calculation method and linear valve type was used. For pipe segments, simple pipe friction model method and dynamic momentum were used. Simulations were also done for corroded and non-corroded pipes. In Figure 2, the model of the first malfunction can be seen.

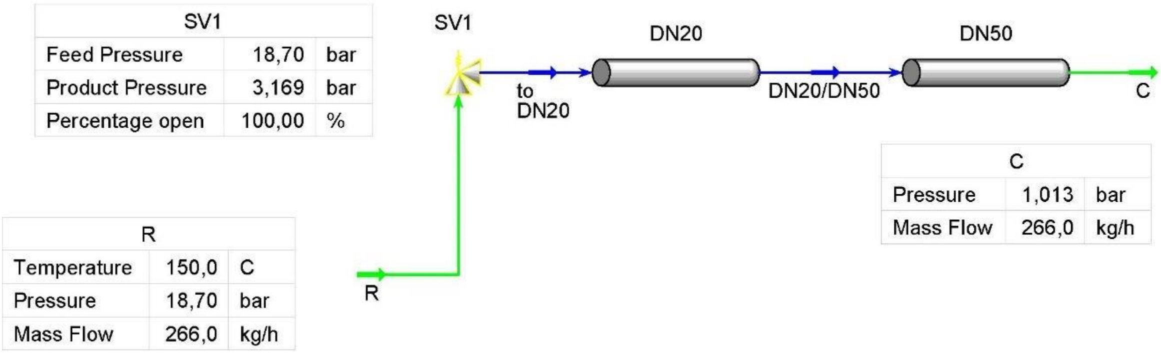

Figure 2. Model of the first malfunction for corroded pipes

For other cases, the modelling methods and settings were the same. In Table 3, modelled backpressure results can be seen.

Table 3. Modelled backpressure results

		p_b [bar_g] for corroded pipe	p_b [bar_g] for non-corroded pipe
First malfunction	SV1	2,169	1,396
Second malfunction	SV2	1,619	1,088
Third malfunction	SV1	2,174	1,373
	SV2	1,635	1,097

As the modelled results are shown, for corroded pipes the modelled backpressure values are higher than the allowed 10% from set pressure and for non-corroded pipes the modelled backpressure values are smaller than the 10% from set pressure.

4. COMPARISON

Calculated and simulated backpressure results converge well. Comparison of calculated and modeled results are showing that in each cases the difference is less than 5% between the two values. Comparing the corroded and non-corroded results are showing that backpressure values for corroded pipes are around 35% bigger than non-corroded pipes.

CONCLUSION

The study was made to an experimental system to calculate and simulate backpressure values for different malfunctions. Backpressure calculations and simulations were made to different cases like corroded and non-corroded venting pipes. Simulated and calculated backpressure values converge well, difference between calculated and simulates values were less than 5%. Backpressure results for non-corroded pipes are lower than the allowed 10% from the safety valves set pressure, which means in these cases the safety valves will operating well. Backpressure results for corroded pipes are higher than the 10% from the safety valves set pressure which means the safety valves will not operating well. Changes in the geometric size of the venting pipe system are justified because of the backpressure values of corroded pipes. The study is presented that the calculation of backpressure can be easily programed or simulated and the knowing the backpressure values is important for the proper operating of the safety devices.

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REFERENCES

[1] "https://www.ari-armaturen.com/_appl/files_tb/files/900005-2.pdf.", 25.03.2019.

[2] V. Kállai, J. Kerezsi, P. Mizsey, and G. L. Szepesi, "Ethane-ethylene rectification column's parametric examination," *Chem. Eng. Trans.*, vol. 70, pp. 1477–1482, 2018.

[3] M. Petrik and G. L. Szepesi, "Shell side CFD analysis of a model shell-and-tube heat exchanger," *Chem. Eng. Trans.*, vol. 70, pp. 313–318, 2018.

[4] G. Bozóki, *Nyomástartó rendszerek túlnyomáshatárolása*. Budapet: Műszkai Könyvkiadó, 1977.

[5] S. Zoltán, S. Bernadett, and S. Gábor, "Rugóterhelésú biztonsági szelep kísérleti és szimulációs vizsgálata," *GÉP*, vol. 67, no. 3, pp. 34–37, 2016.

[6] Z. Siménfalvi and M. Ortutay, "Safety valves for pressure vessel protection," *Proc. Conf. Mech. Eng.*, pp. 409–413, 1998.

[7] Z. Siménfalvi, "Investigation of flow-force characteristics for spring-loaded safety valve dynamic modelling," *CHISA 2006 - 17th Int. Congr. Chem. Process Eng.*, 2006.

[8] F. M. White, *Fluid Mechanic,* 7th ed. New York: McGraw-Hill, 2011.

[9] "http://www.engineeringpage.com/technology/pressure_drop/wall_ roughness.html.", 25.03.2019.

[10] V. Mikáczó, Z. Siménfalvi, and G. L. Szepesi, "Simulation of propane explosion in closed vessel," *Ann. Fac. Eng. HUNEDOARA - Int. J. Eng.*, vol. 15, no. 3, pp. 49–54, 2017.

[11] Z. Szamosi, P. Tóth, T. Koós, V. Z. Baranyai, G. L. Szepesi, and Z. Siménfalvi, "Explosion Characteristics of Torrefied Wheat Straw, Rape Straw, and Vine Shoots Fuels," *Energy and Fuels,* vol. 31, no. 11, pp. 12192–

12199, 2017., DOI: 10.1021/acs.energyfuels.7b01875

[12] M. Petrik, G. L. Szepesi, and T. Varga, "Numerical and Experimental Study of Finned Tube Heat Transfer Characteristicso Title," *Lect. NOTES Mech. Eng.*, pp. 563–570, 2018., DOI: 10.1007/978-3-319-75677-6_49

[13] "UniSim ® Design, User Guide." Honeywell, p. 567, 2017.