Instructions to Voters/Comments on API 520 Part I Ballot – "Annex C - Non-Equilibrium Flow"

- Action Item 2020-01
- Your comments should be limited to the **red-lines portions of the ballot only.**
- If you are voting negative, please indicate which of your comment or comments are the reason for your negative vote. API's Balloting system will categorize all of your comments as Negative.

Thanks to Casey Houston and his work group for their efforts.

Phil Henry
API 520 Task Force Chair

Annex C
(informative)

Sizing for Two-phase Liquid/Vapor Relief

C.1 Sizing for Two-phase Liquid/Vapor Relief

C.1.1 General

The methods for two-phase sizing, presented in this annex, are among several techniques currently in use and newer methods are continuing to evolve as time goes on. It is recommended that the particular method to be used for a two-phase application be fully understood. It should be noted that the methods presented in this annex have not been validated by test, nor is there any recognized procedure for certifying the capacity of PRVs in two-phase flow service.

C.1.2 Application of Equations

C.1.2.1 Many different scenarios are possible under the general category of two-phase liquid/vapor relief. In all of these scenarios either a two-phase mixture enters the PRV or a two-phase mixture is produced as the fluid moves through the valve. Vapor generation as a result of flashing shall be taken into account, since it may reduce the mass flow capacity of the valve. The methods presented in C.2.1 through C.2.3 can be used for sizing PRVs in two-phase liquid/vapor scenarios. In addition, C.2.1 can be used for supercritical fluids in condensing two-phase flow. Use Table C.1 to determine which section to consult for a particular two-phase relief scenario.

Table C.1—Two-phase Liquid/Vapor Relief Scenarios for Pressure-relief Valves

Two-phase Liquid/Vapor Relief Scenario	Example	Section
Two-phase system (liquid vapor mixtures, including saturated liquid) enters PRV and flashes. No noncondensable [a] gas present. Also includes fluids both above and below the thermodynamic critical point in condensing two-phase flow.	Saturated liquid/vapor propane system enters PRV and the liquid propane flashes.	C.2.1 or C.2.2
Two-phase system (highly subcooled [b] liquid and either noncondensable gas, condensable vapor, or both) enters PRV and does not flash.	Highly subcooled propane and nitrogen enters PRV and the propane does not flash.	C.2.1 or C.2.2
Two-phase system (the vapor at the inlet contains some noncondensable gas and the liquid is either saturated or subcooled) enters PRV and flashes. Noncondensable gas enters PRV.	Saturated liquid/vapor propane system and nitrogen enters PRV and the liquid propane flashes.	C.2.1 or C.2.2
Subcooled liquid (including saturated liquid) enters PRV and flashes. No condensable vapor or noncondensable gas enters PRV.	Subcooled propane enters PRV and flashes.	C.2.1 or C.2.3~~2~~

[a] A noncondensable gas is a gas that is not easily condensed under normal process conditions. Common noncondensable gases include air, oxygen, nitrogen, hydrogen, carbon dioxide, carbon monoxide, and hydrogen sulfide.
[b] The term "highly subcooled" is used to reinforce that the liquid does not flash passing through the PRV.

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C.1.2.2 The equations presented in C.2.1 are based on the Homogeneous Equilibrium Model (HEM) [7], which assumes the fluid mixture behaves as a "pseudo single phase fluid," with a density that is the volume averaged density of the two phases. This method is based on the assumption that thermal and mechanical equilibrium exist as the two-phase fluid passes through the PRV (other specific assumptions or limitations are presented in the appropriate section). For ~~high momentum~~ discharges of two-phase systems ~~in nozzles longer than 4 in. (10 cm)~~ mixtures with light ends that flash, both thermal and mechanical equilibrium can be assumed. These assumptions correspond to the HEM.

C.1.2.3 Rapid depressuring of two-phase fluids with vapor quality less than 0.05, including subcooled and saturated liquids that flash, may result in nonequilibrium flow. High-pressures, near the thermodynamic critical pressure, are more likely to result in non-equilibrium flow due to the contribution of flow acceleration leading to additional pressure drop in nozzles and piping.

C.1.2.4 Misapplication of the HEM to nonequilibrium flow may result in underestimating the relief flow, which may impact downstream piping and network equipment.

~~C.1.2.3~~C.1.2.5 In applications where the homogeneous equilibrium assumption is not valid, the user is encouraged to apply non-equilibrium methods. The Burnell bubble delay factor, if used, can remove some of the conservatism associated with the homogeneous equilibrium assumption [19]. Additional nonequilibrium models with consideration for boiling decay are available [20].

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Remainder of Annex C not provided

Bibliography

[1] Y.S. Lai, "Performance of a Safety Relief Valve under Backpressure Conditions," *Journal of Loss Prevention in the Process Industries* (1992), Vol. 5, No. 1, pp. 55–59

[2] L. Thompson and O.E. Buxton, Jr., "Maximum Isentropic Flow of Dry Saturated Steam through Pressure-relief Valves," *Transactions of the ASME Journal of Pressure Vessel Technology* (May 1979), Vol. 101, pp. 113–117

[3] D. Moncalvo and L. Friedel, "Single and Two-phase Flows of Shear-thinning Media in Safety Valves," *J. Hazardous Materials* 168 (2009), pp. 1521–1526

[4] D. Moncalvo, L. Friedel, and B. Jörgensen, "A Computational Investigation on the Flow of Non-Newtonian Polymers in Safety Valves," *Chemical Engineering & Technology*, 33 (2010), pp. 1825–1832

[5] D. Moncalvo and L. Friedel, "A Viscosity Correction Factor for Shear-thinning Liquid Flows in Safety Valves," *J. Loss Prevention in the Process Industries* 23 (2010), pp. 289–293

[6] *Guidelines for Pressure-relief and Effluent Handling Systems*, AIChE, New York, NY (1998)

[7] R. Darby, F.E. Self, and V.H. Edwards, "Properly Size Pressure-relief Valves for Two Phase Flow," *Chemical Engineering* (June 2002), pp. 68–74

[8] R. Darby, "On Two-phase Frozen and Flashing Flows in Safety Relief Valves—Recommended Calculation Method and the Proper Use of the Discharge Coefficient," *Journal of Loss Prevention in the Process Industries*, Vol. 17 (2004), pp. 255–259

[9] J.C. Leung, "A Theory on the Discharge Coefficient for Safety Relief Valve," *Journal of Loss Prevention in the Process Industries*, Vol. 17 (2004), pp. 301–313

[10] R. Diener and J. Schmidt, "Sizing of Throttling Device for Gas/Liquid Two-phase Flow—Part 1: Safety Valves," *Process Safety Progress*, Vol. 23, No. 4 (2004), pp. 335–344

[11] A.E. Shackelford, "Using the Ideal Gas Specific Heat Ratio for Relief Valve Sizing," *Chemical Engineering*, 12, 110 (November 2003), pp. 54–59

[12] D.W. Green, J.O. Maloney, and R.H. Perry, eds., *Perry's Chemical Engineering Handbook*, Seventh Edition, McGraw-Hill, New York, NY (1997), (Equations 26–29), pp. 26–30

[13] J.C. Leung, "The Omega Method for Discharge Rate Evaluation, International Symposium on Runaway Reactions and Pressure-relief Design," *American Institute of Chemical Engineers*, New York, pp. 367–393 (1995), ISBN No. 0-8169-0676-9

[14] J.C. Leung, "Easily Size Relief Devices and Piping for Two-phase Flow," *Chemical Engineering Progress* (December 1996), pp. 28–50

[15] M.A. Grolmes and J.C. Leung, "A Generalized Correlation for Flashing Choked Flow of Initially Subcooled Liquids," *AICHE Journa*l, Vol. 34 (April 1988), pp. 688–691

[16] Crane Technical Paper No. 410, *Flow of Fluids Through Valves, Fittings, and Pipe* (1985)

[17] J. Burgess and D. Smith, "Improve Relief-Device Sizing Under Supercritical Conditions," *Hydrocarbon Processing* (May 2015)

[18] R.B. Bird, W.E. Stewart, and E.N. Lightfoot, "Transport Phenomena," John Wiley & Sons (1960), ISBN No. 0-471-07392-X, p. 481

[19] J.G. Burnell, "Flow of Boiling Water Through Nozzles, Orifices, and Pipes," *Engineering*, London, 164, 572 (1947)

[20] G. Hendrickson, D. Smith, R. D'Alessandro, G. Melhem, M. Levin, H. Fisher, and L. Korelstein, "Geometric and Thermodynamic Considerations of Saturated and Slightly Subcooled Water Flow Through Nozzles," *Chemical Engineering Science*, Vol. 254 (June 2022), 117612

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