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Relief Rate Calculation for Control Valve Failure

Question Mark
Student

I've come across your article of relief rate calculation of PCV failure and I have following questions:

1. What does "C" stands for in the 60 V1/ (C Qwo – Qno) equation?

2. You've stated that operating pressure of upstream vessel should be taken for relief rate calculation due to CV failure. This contradicts what is being currently used in my Company; can you explain the philosophy behind your suggestion? What about pressure of downstream (low pressure) vessel?

3. You have referred to V2 as the "free volume" in downstream equipment above NLL. The volume is taken from NLL to full vessel volume or HHLL?

4. What is your reference for table 1?

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Saeid R. Mofrad
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1. I am surprised. there is no talk about C in the paper!
C is the flow overdesign factor to consider the flow rate through control valve bypass.
• C is 1.0 if there is no bypass (or assumed to be closed during control valve failure).
• C can be 2-3 depending on CV of bypass valve. This is inline with the design practice of selecting bypass valve size to have Cv at least equal to, but not more than twice, the Cv of the control valve.

This is to simplify the equation; nevertheless, you can calculate the flow through bypass (knowing its CV) and add to Qwo.

2. There are lots of methods about what to consider for HP and LP vessels pressures.
But I think the most realist assumption may be is to use:

> For upstream HP vessel, operating pressure can be used for all calculations (filling / emptying time and relief rate calculations) as the liquid control valve failure has nothing to do with the pressure in upstream vessel.

> For downstream LP vessel,

• for filling/emptying time calculation, which corresponds to the period of time after control valve failure in which liquid has not been completely drained from HP vessel and or completely filled LP vessel, the operating pressure of downstream LP vessel can be used. This is because liquid pipe between isolates HP vessel from LP one.

• for relief rate calculation, which corresponds to the period of time after control valve failure in which liquid has been completely drained from HP vessel (gas blow-by case) or completely filled LP vessel (liquid overpressurization case), the relief valve set pressure can be used.

3. Free volume of downstream vessel is the volume of vessel between NLL to top tangent line. To pressurize the LP vessel with liquid, you need to totally fill it up first!

4. Table 1 is based on the fact that if HP side volume should be high enough to pressurize the LP vessel (to justify relief study). If HP vessel is of small volume compared to LP side, the pressure will be equalized after control valve failure (kind of settle out pressure) and LP vessel pressure won't reach the relief valve set pressure. This table simply assumes that HP and LP volumes are constant and limited. However, in reality it is a bit hard to realize (limit) the volume of each side of control valve as these vessels are connected to entire system and in flowing condition. If you would like to know the actual behaviour of such system during control valve failure, a dynamic model including upstream system flow resistance is required to specify:

• The contribution of the system upstream of the HP vessel in supplying the extra gas.
• The contribution of the system downstream of the LP vessel in absorbing the extra gas.

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Question

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I have the following more questions:

5. We are considering that bypass is also open. I find this illogical as control valve failure will happen during normal operation when the bypass valve is supposed to be closed. Otherwise, I can't imagine how the control valve can function properly while bypass is open? I believe bypass valve would only be open when control valve is isolated for maintenance?

6. Can we take credit if bypass valve was designated as LC?

7. To calculate the CV of the control valve in fully open condition, we usually multiply the working condition Cv by the factor of 1.4 to 2, how would you select the overdesign factor, as per your experience?

8. If the gas blow-by takes place, what shall I consider for the inlet temperature to the control valve during valve failure to calculate relief rate?

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5. The basis of this assumption (bypass valve fully open at the time of control valve failure) is that operators sometimes use the bypass valves during start-up to bring the system online faster and may forget to close them. Furthermore, when control valve is undersized due to any reason (increased plant capacity, wrong design, etc), operators try to pass part of the flow through the bypass during normal operation and keep control valve functional.

About controllability of control valve, if bypass valve is large enough to pass a major portion of the flow, most likely control valve won't function very well. However, if it is partially open the system will work fine.

Bypass is going to be used after main control valve being taken on standby, however as long a there is no mechanism to prevent human mistake, it will remain a credible case.

6. The bypass valve can be made LC. Another solution can be to interlock the bypass with control valve isolation valve.

7. The CV factor depends on control valve characteristic. Normally, control valve is selected so that the required CV is achieved when control valve is 60 to 80% open.

If you take 70% travel as a reference point, CV factor is simply the ratio of 100 over CV at 70% opening. For example, the CV of a control valve at 100% opening (rated CV) is X times of CV at operating point. Where X is:
• Linear : 1.4
• Quick opening: 1.1
• Modified parabolic: 1.7
• Equal percentage: 3.0

The problem is that the control valve characterises is not known in the stage of project when relief study is done. Therefore, in the absence of control valve vendor data, 1.4 is usually used. I have also heard about overdesign factor of 2.0 if liquid flashes across the control valve but I have no clue why.

8. Based on control valve flow rate equation in gas service with fixed CV, lower temperature will produce higher flow. Therefore, higher Mw case and minimum operating temperature of upstream

HP vessel should be selected for gas blow-by flow rate calculation.
Temperature has no effect on liquid service flow rate.

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