# MAKING RELIEF LOAD ESTIMATES MATCH REALITY

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## Introduction

- When doing a Relief Systems Documentation Analysis, the ability to accurately model a "worst case" relief scenario is paramount to ensuring the system is protected from the overpressure event.
- The engineer is undoubtedly limited to the availability of equipment data and accuracy of the process simulation developed to predict upset conditions.
- If some conservative yet unrealistic assumptions are used, the relief device can be labeled as providing inadequate protection in the event of the initiating event. [1]
- Physically modifying the system to fix the problem, as well as the loss of profit from having to shut down the unit to perform the update, can cost the facility large sums of money.
- The ability to make relief load estimates match what may happen out in the field can still be accomplished, but knowing the difference between a realistic conservative assumption and an unrealistic conservative assumption is paramount.
- The pressure relief system designer should consult industry standards (e.g. API 521or NFPA) to see how to estimate relief loads for given overpressure scenarios and what assumptions for mitigating items/actions are acceptable.
- Often times relief estimates are based on normal operating flow rates, heat exchange, and/or flow paths continuing during the upsets.
- Equipment capacities that are right on the design limit may not be able to produce the same flow rate or heat transfer under upset conditions.

## Reduced Reboiler Duty

- When looking at a column system, the primary relief loads tend to consist of a combination of continued heat input with the loss of cooling.
- The ability to accurately model the relief scenario is paramount because an error could lead to events such as an unnecessary facility modification or a loss of containment from an undersized relief device.
- When a pressure relief system designer looks at the loss of overhead cooling on a column system, the scenario is a transient event.
- To estimate this relief condition, the column system is modeled as two steady state cases to bracket the relief load. Under either of these conditions, the bottoms temperature may increase due to the increase in system pressure, but this phenomenon may be offset by the reduction in separation; therefore, a reduced duty calculation should be performed for both calculation sets to ensure that the reboiler is capable of transferring the same heat into the column system as during normal operating conditions.
- Taking credit for the reduced duty is still a reasonable assumption as an upper conservative limit when the assumption is based on the maximum duty possible for the installed reboiler and is limited by equipment capacity. The design equation for heat exchangers is given below [2]:

$$Q = UA\Delta T_{LM}$$

- Reduced duty calculations, limited to process/process or process/utility exchangers (e.g. shell and tube exchangers), are not typically performed on fired heater reboilers.
- The reduced duty may reduce the relief load estimate, as there is less vapor generation as compared to using the process duty under normal conditions.

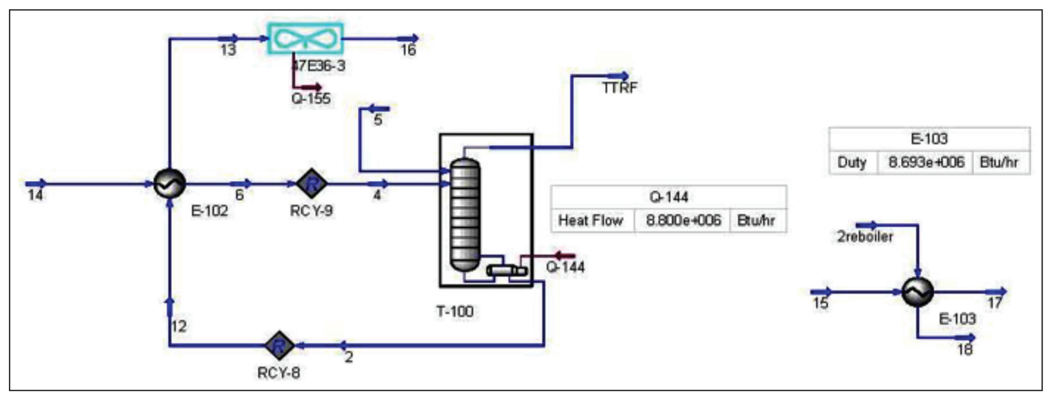


**Figure 1:** Example of a simulation for a column with loss of cooling and top-tower reflux failure with a reduced duty calculation performed.

## Inlet Control Valve Failure Credits

- Per API 521, this scenario is the complete failing open of a control valve (irrespective of its fail safe position).[3]
- Per API 521§ 5.10.2,

  "in evaluating relieving requirements due to any cause, any automatic control valves that are not under consideration as causing a relieving requirement and that would tend to relieve the system should be assumed to remain in the position required for minimum normal processing flow. In other words, no credit should be taken for any favourable instrument response." [3]
- If the outlets from the system are expected to remain open, the calculation may assume that some of the fluid will flow through the normal path.
- For example, if the outlets from the system are expected to remain open, the calculation may assume that some of the fluid will flow through the normal path, see Figure 2. This credit is usually at the minimum turndown rate, as common industry practice is to assume that other control system remains in place and does not respond (unless it exasperates the single failure).[3]
- As long as the pressure relief system designer verified the liquid could flow through the vapor line and accumulate in the downstream system, credit can be taken through the vapor line.
- Consideration should be given for the difference in the relief fluid and the normal fluid and to adjust the credit based on the actual volume rate.

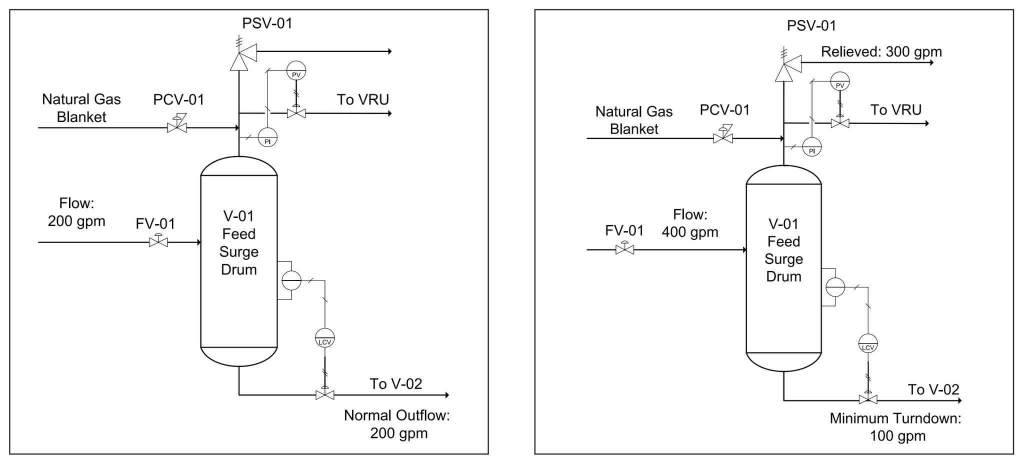


**Figure 2:** During normal operation (on the left), the pressure is regulated by the natural gas blanket on the overhead; thus, there is normally no vapor flow. During the upset condition (on the right), the control valve would fail open and credit can be taken for the minimum turndown rate through the bottoms control valve. Credit cannot be taken through the vapor line as there is normally no flow.

- When a liquid control valve fails open, the vessel may de-inventory and gas may flow through the liquid control valve into the downstream vessel.
- This scenario, typically called a gas blow-by, should be reviewed for all control valve failures where there is liquid and gas in the upstream vessel.

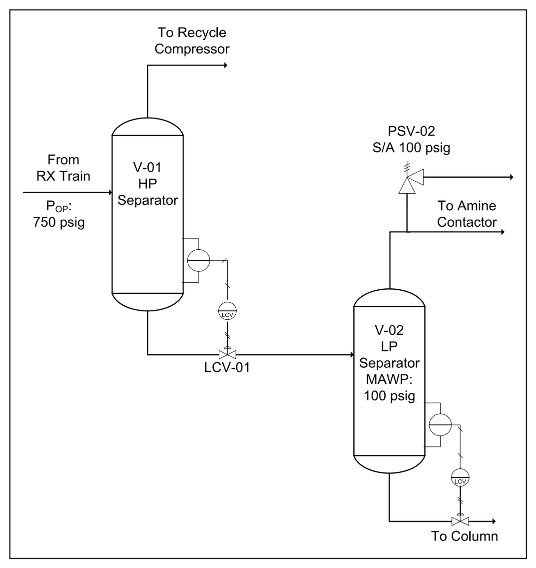


**Figure 3:** During the upset event, a liquid inventory needs to be analyzed. If the upstream vessel cannot overfill the downstream vessel, then gas blow-by may occur and the valve would be passing the overhead vapor downstream. Credit may be taken for the minimum vapor leaving and potentially sizing the control valve with two-phase as it is likely seeing liquid and vapor on the inlet.

## Compressors Downstream of the System

- In some instances, making relief load estimates match closer to reality may lead to a larger relief load estimate.
- There are many different assumptions that could cause this case to be true; the example that we are going to highlight is when the cascading effect of one failure causes the normal plant control system to take and action an increase the relief requirements for a pressure relief device.
- Depending on the scenario, the compressor may pass vapor at the upset conditions or the compressor could trip and result in a blocked outlet.
- Examples that may cause a compressor to trip under upset conditions include a higher inlet gas temperature trip, a high amp / power requirement trip (due to the increased suction pressure), high temperate trip (due to the potential loss of cooling to the compressor), vibration trips, and etc.[4,5]
- It is useful for the pressure relief system designer to discuss the scenario with personnel who are familiar with the operation of the compressor (usually either the operators or unit process engineer) to ensure that any assumptions made are consistent with operational history.

### Compressors Downstream of the System (Continued)

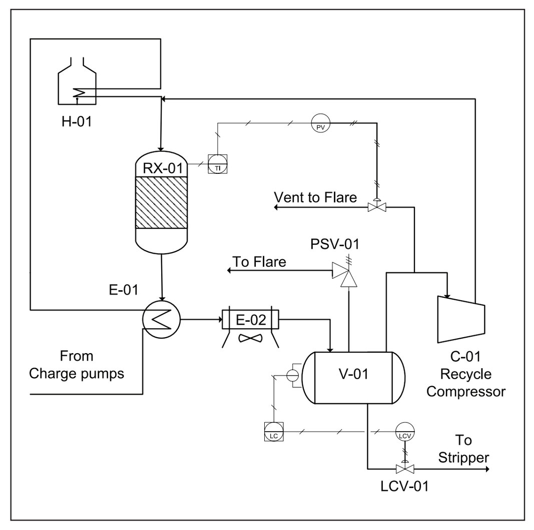


**Figure 4:** During an upset event due to the loss of the compressor, the relief load is not expected to be any larger as the recycle gas is lost. This source is not a feed source since it never enters or leaves the system. Also, the de-pressuring valve on the suction line to the compressor may open to vent to flare if a high temperature reading occurs.

## Example of Compressors Shutdown Analysis

- A larger estimated rate may occur in a scenario where there is a partial loss of cooling in a column system that uses a compressor to move the off gas from the overhead accumulator to the downstream system (e.g. a FCC Main Fractionator, Coker Bubble Tower, Atmospheric Tower, and etc.).
- The modified characteristics of the off gas (e.g. temperature, density) are consistent with conditions that trip the compressor.
- Additionally, the pressure relief system designer must ensure that the scenario itself (e.g. a unit wide power or cooling tower failure) could result in a compressor trip and result in this outlet being blocked.
- The relief load estimate would then need to include the cascading effects of the compressor shutting down and may be much larger than would be otherwise predicted.

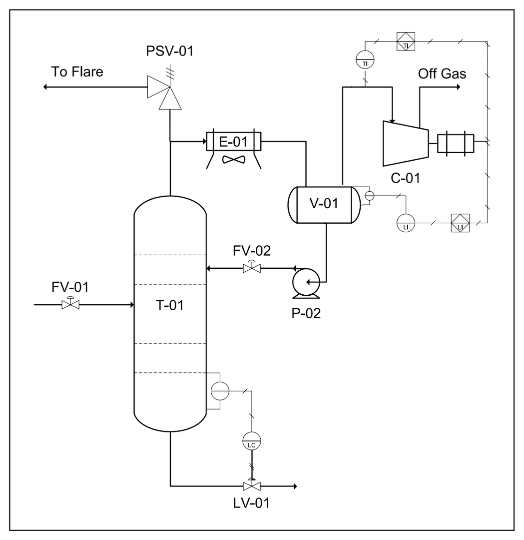


**Figure 5:** During a partial loss of cooling in E-01, the TI on the suction to C-01 may trip the motor to shutdown due to a high temperature reading. Due to the loss of the compressor, the credit for partial cooling cannot be taken as the vapor would accumulate and vapor lock the overhead condenser; thus, the partial loss of cooling would result in a completely blocked overhead outlet.

## Conclusion

- To realistically represent the relief load estimate:
  - The pressure relief system designer must understand the system
  - How it is operated
  - The limits and shutdowns of the associated equipment
  - How these parameters interact during the specific overpressure event being reviewed
- The pressure relief system designer must also ensure that all assumptions are consistent with industry, company, and regulatory requirements for the facility.
- Oftentimes, conservative/simplifying assumptions do result in deviations, and the pressure relief system designer must then use more realistic assumptions to generate the relief load.
- The pressure relief system designer must also be vigilant to not use simplifying assumptions that are not conservative. These assumptions tend to result in relief rates that may under-predict the true requirements in an overpressure event.
- Oftentimes industry, company, and regulatory requirements for the facility are set up to eliminate these scenarios, but the example with compressors illustrates the pressure relief system designer must check these assumptions (many of which can be implicit).

## References

[1]. Smith, Dustin and John Burgess, "Relief Valve and flare action items: What plant engineers should know," Hydrocarbon Processing, Volume 91, NO.11, 2012

[2]. Middleman, Stanley, An Introduction to Mass and Heat Transfer: Principles of Analysis and Design, John Wiley and Sons, New York, NY. 1998

[3]. ANSI/API Standard 521, "Pressure-relieving and Depressuring Systems," American Petroleum Institute, 5th ed., 2008.

[4]. GPSA, Engineering Data Book: Volume I 10th Edition, Gas Processors Suppliers Association, Tulsa, OK. 1987

[5]. Lieberman, Norman and Elizabeth Lieberman, A Working Guide to Process Equipment 3rd Edition, McGraw-Hill, New York, NY. 2008