Things Plant Engineers Should Know about Reviewing Relief Valve & Flare Action Items

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Abstract

This paper serves as a resource for Plant Engineers who are in the process of understanding and reviewing relief and flare system action items and the task of complying with regulatory compliance. Throughout the process of implementing and maintaining a PSM Program, action items are created. The methodology instructs the Plant Engineer on the basics of how to review these action items, what kind of action items to expect, how to quickly verify if the action items are correct and if corrective action is warranted.

1. Introduction

When most companies implement the Process Safety Management standard, they routinely or periodically review the relief systems and flare systems design bases to ensure compliance with corporate, industry, and/or government standards, hereafter referred to as RAGAGEP (Recognized And Generally Accepted Good Engineering Practices). Prior to implementing any projects to mitigate concerns, it is advisable for a Plant Engineer to consider the following items when reviewing a concerns list.

1. Relief systems review methodology
2. Relief systems review priorities (are rear-ends being covered or exposed)
3. The Process Designer's familiarity with the process and/or plant when concerns are being reviewed
4. The Plant Engineer's understanding of the differences between compliance and best-in-class

A paper published in the year 2000 concluded that up to 40% of the installations evaluated had unidentified concerns. [1] Since the publication of this cited paper, many of the concerns have undergone a more detailed review that found many of these concerns did not require modifications to the facility. The purpose of this paper is to help the Plant Engineer review the concerns developed by the design engineer. Implementing field modifications without performing such a review is costly and exposes a facility to risks that are not justified.

For the purposes of clarity, the following terms used throughout this paper are defined as such:

Plant Engineer – The facility or owner's engineer that is responsible to review the concerns and determine if facility modifications should be implemented

Process Designer – The individual that is responsible for analyzing the relief device and overpressure protection system and develops the concerns

Concerns –Items that are listed as deviations from industry or company standards, but prior to being fully reviewed and accepted

At the end of the relief systems design basis project, many concerns are typically identified by the Process Designer. As most facilities want to comply with RAGAGEP, there is a mandate to resolve these identified concerns; the resolution of these concerns can be costly. Generally, most facilities want to comply with regulations for existing facilities and want to potentially build new equipment/facilities to a higher standard. This paper includes examples of how to review existing systems to determine if concerns justify the requirement of field modifications.

2. Relief Systems Review Methodology

Relief systems design basis reviews are typically performed by contractors that assist in developing project guidelines and then collect the necessary information. After these initial actions, the contractors analyze the system's design basis per the project guidelines and present a list of identified concerns to the plants' engineers and management. A listing of the concerns is presented, followed by the Plant Engineers and facility management initially thinking that the Process Designer standing in front of them is mistaken or that the one that designed the facility was less than effective. At this point in the process, prior to spending money to upgrade the relief systems, a Plant Engineer familiar with the process unit should review the concerns list to ensure the following:

- The details of the study are reasonable
- The assumptions of the study are reasonable
- Facility upgrades, not based on minimum compliance, have been thoroughly reviewed

By reviewing the concerns list with these suggestions, a Plant Engineer can ensure that the costly changes have a basis in sound engineering and that the expense is justified. Note that no hierarchical order is implied in this list.

Typically, when a relief systems design basis project is undertaken, the goal is to produce compliant documentation efficiently and consistently. In order to do so, Process Designers base the analysis in a framework to minimize effort and to ensure consistency. This is a practical method for performing a large scale relief systems analysis; however, for any particular concern the framework may break down and suggest that items are concerns which are not. In a recent review project, ~40% of the listed concerns were later found to be acceptable based on a detailed review, such as suggested in this paper. The following sections help walk a Plant Engineer through a systematic process and give insight into how to review the listing of concerns.

2.1 Reviewing the Relief System Study Details

The following sections provide information to help the Plant Engineer understand the details used to generate the relief systems design basis documentation. When the concerns are reviewed from the perspective of the Process Designer, the Plant Engineer can understand how the framework may have generated potential concerns. Understanding this process can help the Plant Engineer identify the concern which can be resolved by reviewing the design basis instead of cutting steel.

2.1.1 Process Designers Understanding of the Process

When completing large-scale relief systems design basis documentation and design processes, the Process Designer is generally very familiar with relief systems design, but may not be familiar with the particulars of the process/unit. The Process Designer, therefore, may make unrealistic judgments about process upsets. The following are some examples of these items:

- When process flows can be blocked, or if the normal rate is possible under upset conditions
- Use of the normal/design duty from a reboiler for relief rate estimation
- Equipment which is no longer in service is not properly protected

To ensure the best possible analysis, each study should be reviewed by personal familiar with the process operation to confirm that unique process characteristics are reviewed and captured in the relief systems documentation.

2.1.2 Credibility of the Scenario or Required Relief Rate

For each overpressure scenario that generates a concern, the Plant Engineer should give particular attention to ensure the credibility of the scenario or required relief rate. Many times, an overpressure scenario or the estimated rate may not be credible. The following are some examples:

- Pumps that can only pump to relief pressure if the upstream system is also upset, but a simultaneous upset would be considered double jeopardy.
- Systems where overpressure derives from heat input such that the relief temperature of the process fluid exceeds the relief temperature of the utility fluid.
- Control valve failure calculations that are based on the capacity of a control valve instead of another limitation (e.g., a long section of piping or a pump).

To ensure an accurate analysis, each concern should be reviewed to verify that consideration is given to the determination of the scenario applicability and that the relief rate estimation is reasonable for the particular process/unit.

2.1.3 Extent to which Facility Data was Gathered

The relief systems analysis process typically limits the amount of places and time that the Process Designer can look for process and equipment data. This limitation is usually defined as a project scope item and is used to ensure that the project has bounds. When reviewing concerns, the Plant Engineer needs to ensure that the Process Designer did not identify concerns that can be readily resolved by further searching for process and/or equipment data. Oftentimes this requires a call to an external supplier or technical body (e.g., the equipment manufacturer or national board).

2.1.4 Other Execution Issues

The relief systems process typically uses a consistent basis often times documented and referred to as site or project guidelines. These guidelines are beneficial, as they provide a means for efficient and consistent execution and help ensure that both the Process Designer and Plant Engineer are in agreement on the details of the analysis. When these generic and prescriptively conservative guidelines generate concerns, it is imperative that the team generating the documentation review the fundamentals of the analysis to confirm that the concern is a legitimate deviation from RAGAGEP and not just a result of the project execution process.

2.2 Reviewing the Relief System Study Assumptions

The typical execution method of a project tends to enforce consistent assumptions. For most of the project, this ensures that the relief systems design basis is conservative and compliant with RAGAGEP. To ensure that any field modifications are for items that really need to be addressed, these assumptions may need to be challenged when concerns are raised.

2.2.1 Standardization Assumptions

Standard and generally conservative assumptions are specified to ensure consistency and efficiency. These assumptions help the relief systems documentation process run efficiently; however, if generic assumptions result in concerns, they need to be re-visited and updated. The following are some examples of these items:

- Liquid levels for equipment
- Control valve flow coefficients and or trim sizes
- Utility pressures (e.g. steam, nitrogen, cooling water, etc.)
- Heat exchanger or pump capacities

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To ensure the best possible analysis, the assumptions associated with each concern should be reviewed and, if possible, refined to be specific for that system.

2.2.2 "Conservative" Assumptions (Generally Simplifying Assumptions)

The authors of this paper have been doing relief systems analysis for multiple decades, and at this point in our careers, we loathe the phrase "conservative assumption." It seems the so called "conservative assumption" is frequently a phrase for a simplifying assumption that the Process Designer invoked. Furthermore, this phrase typically has nothing to do with being conservative. The following are some examples of these "conservative assumptions:"

- Normal flow rate was used instead of a reduced estimate
- Column tray one or overhead flow rate was used instead of performing a simulation
- Multiple unrelated failures occur simultaneously

As previously stated, each "conservative assumption" should be reviewed and refined so it is specific for each system.

2.2.3 Other Assumptions

The design and analysis of relief systems is an art. Much of the analysis is based on the assumptions that form the overall basis. Mathematical errors are rarely the cause of an incorrect analysis; usually, the cause is almost always a problem with the basis. The basis for each system is one basis stacked on another. Usually once the assumptions are flushed out and determined to be correct, the mathematics are easy.

2.2.4 Example

In the past, the authors reviewed a Fractionator (Figure 1 on the following page) that had the normal feed vapor rate specified as the relief rate for a power failure relief load (conservatively assumed). When the capacity of the Feed Furnace was confirmed, the Feed Furnaces could barely vaporize the normal amount at the normal production rate and Fractionator pressure. This particular power failure scenario specified the loss of the pump-arounds, which resulted in the loss of ~80% of the crude preheat train duty. With the increase in pressure and cooler-than-normal feed temperature to Feed Furnace, the maximum vaporization would be around 50% of the normal vapor rate. The argument for keeping the feed preheat was it was conservative as the heat input may not be lost. If this was the case, then pump-arounds would have continued, leading to a significantly different outcome. Assumptions need to at least be internally consistent for each scenario. If the pump-around cooling is lost, then so is the feed pre-heat or visa-versa.

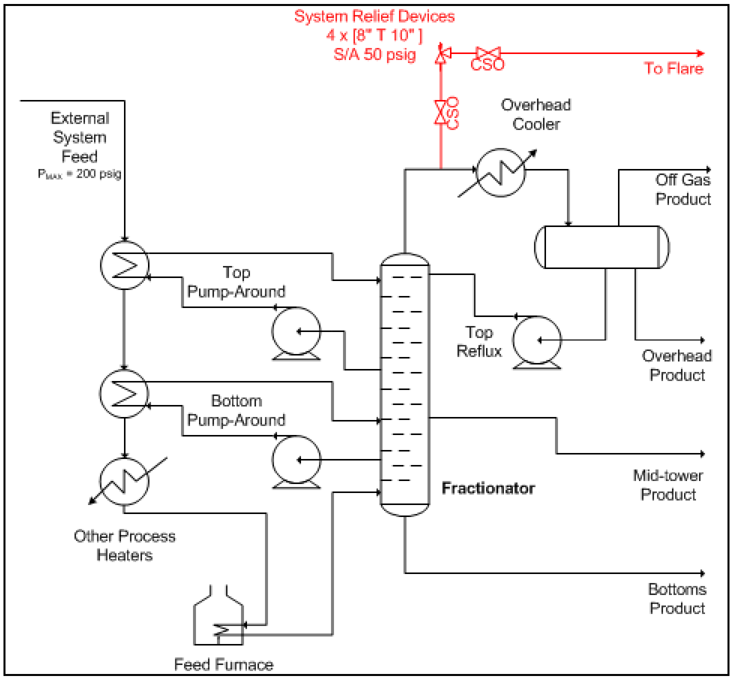

Figure 1: Example Fractionator

2.3 Determining the Difference Between Minimum Compliance and Best Practices

The final item that needs to be reviewed by the Plant Engineer is to ensure that any concerns are deviations from RAGAGEP and not just from best practices. Often, when completing relief systems projects, the team responsible for the design will, with the best of intentions, work into guidelines' requirements that go beyond RAGAGEP. While extra requirements may be justified based on the increased safety at nominal incremental costs in new construction, these requirements can be quite expensive for existing facilities. These additional requirements need to be reviewed and possibly excluded from items that need to be retrofitted. Regulatory requirements may require additional documentation to ensure that not making modifications present an acceptable risk. [2]

2.3.1 Grey Areas for Modifications

Often times there are items that may not be absolutely correct, but may also not rise to the level of requiring field modification. One example is when current corporate standards exceed the standards to which a unit was built. This situation is particularly relevant when a facility is acquired, thus creating a situation where a facility was built to one set of corporate standards, but is now operating with a new corporate standard in effect. In these cases, a Process Designer should investigate any deviations and document why these deviations are acceptable. For cases where past designs do not meet the current RAGAGEP standards but the deviations are deemed to be minor, the management of some facilities has choose to have more regulatory risks than safety risks.

2.3.2 Consideration of Risk to Make Changes

Consideration to fix issues with equipment design, especially when the facility is running or even during turnaround, needs to be taken with great care. In the past three or four years of literature searches, the authors have yet to find a single case of a relief device being slightly undersized resulting in an injury or loss of containment. There are, however, countless records of injuries sustained from refinery modifications which can easily be found via an Internet search of the subject.

To illustrate this point, in a 2009 CSB Video requesting that the City of Houston adopt the ASME Pressure Vessel Code, the CSB was unable to find instances resulting in loss of containment for pressure vessels for undersized relief devices. [3] The video cites three examples of vessel failures from undersized relief devices. The first example is a low pressure tank with an undersized relief device and the other two examples have plugged or isolated vent lines. [4, 5, 6] For a Plant Engineer responsible for increasing the overall facility safety, it may be possible to defer modifications for the resolution of minor deviations until other equipment changes are required. This would be at the discretion of the facility, require a reasonable level of risk, and may open the facility up to regulatory action.

3. Flare Systems Review Methodology

The previous section of this paper reviewed the typical methodology a Process Designer would use to generate a relief systems design basis. This section is to help the Plant Engineer understand how: the individual relief systems loads are developed, then used to create an overall set of global scenarios, which is then used to verify that the flare system and associated equipment are adequately designed. The following key topics will be further explored:

- Global Load Considerations
- Reasonable and Consistent Assumptions
- Advanced Flare Techniques

By reviewing the flare systems design concern list from these three angles, a Plant Engineer can ensure that the basis for costly changes is just.

3.1 Global Load Considerations

When a relief systems design project is undertaken, the individual relief device loads are typically gathered first. Once these loads are known, they are entered into a hydraulic analysis tool, and the flare system is analyzed. However, as with the individual load determinations, there are areas that a Plant Engineer needs to review.

3.1.1 Credibility of the Scenario

For global scenarios, the credibility of the scenario is much more of an art than a science. Typically, the Process Designer will review power failures (both a total loss of power and partial power failures), utility failures, and large-scale liquid pool fires. All of these scenarios affect multiple systems of equipment and should be considered. The Process Designer for each individual scenario looks at the underlying scenario to ensure that it is credible. For example:

- Is a large-scale liquid pool fire possible and to what extent?
- Is a total utility failure possible (or does the utility feed all the listed equipment systems)?
- Does one utility failure lead to another utility failure (e.g., loss of steam results in the loss of the turbine driven instrument air compressor)?

As previously stated, “conservative assumptions” for scenarios that are not controlling or do not have concerns may be acceptable. A Plant Engineer should review the scenario basis for any global scenarios that have concerns. Additionally, the “conservative assumptions” associated with the sizing of the relief device may not be consistent with or even possible given the specific global scenario being evaluated.

3.1.2 Credibility of the rates

Oftentimes the global overpressure scenarios are a compilation of relief rates specified as closely related individual relief device scenarios. While these scenarios may have been conservatively estimated and not have generated any concerns, summing multiple systems with conservative rates may result in problems. In a presentation to the 6th Global Conference on Process Safety, D. Smith reported on a refinery wide review that resulted in a 40% reduction in the design relief rate by reviewing the specified relief loads and eliminating overly conservative assumptions. [7] A Plant Engineer should ensure that the Process Designer does not simply create a global scenario on the basis of multiple conservative calculations, but reviews the system to ensure that rates are reasonable and defensible (not excessive due to assumptions).

3.2 Reasonable and Consistent Assumptions

As with the individual relief systems analysis, the scenario assumptions and those used to generate the relief rates make a tremendous impact on the adequacy of the flare system and associated equipment.

3.2.1 “Buried” Assumptions

When sizing individual relief devices, RAGAGEP require that the Process Designer assume that the worst case occurs and all related failures, pump line-ups, and control valve responses are either neutral of detrimental. For global scenarios, the Process Designer must assume that the global failure occurs, but the requirement for neutral or detrimental effects is more muted. The following are some examples of “buried” assumptions typically used:

- Heat exchanger duty based on service overall heat transfer coefficient and area (UA) instead of the clean and new UA
- Level control valves hold level in process vessels
- Airfin coolers retain some fractional cooling capacity
- Operations personal do not simultaneously open depressuring valves with utility failures unless directed to in operational procedures

The Plant Engineer and Process Designer should work with personal that operate the units and review scenario basis and loads for any global scenarios that have concerns.

3.2.2 Consistent Assumptions

In the definition of global overpressure scenarios and the associated rates, the need to ensure consistency is paramount. Many times the process engineer will assume for one equipment system that a pump was in operation and has failed and, in the next equipment system, the failure pump was spared and the alternative pump was in operation. For these analyses, consistency across the facility is required as the goal is to analyze the flare system (as compared to the individual relief devices). The following are some examples of assumptions that can result in system wide inconsistencies:

- When a pump is spared and used for multiple equipment systems, the scenario should specify which pump has failed for all systems
- Systems with heat integration need to consider the effects of the failures (as in the previous example illustrated by Figure 1)
- Utility failures that result in cascading losses need to consider those losses consistently

The Plant Engineer should review the controlling global scenarios to ensure that the assumptions used are internally consistent.

3.3 Advanced Flare Analysis Techniques

RAGAGEP, API Standard 521, allows for the consideration of positive action of instrumentation, operations, or other favorable items, as long as the failure of these items is considered. [8] Prior to making costly flare system modifications, the Plant Engineer should review more complex flare system analysis tools to ensure that any modifications are justified.

3.3.1 Flare Load Probability Analysis

In a presentation to the 6th Global Conference on Process Safety, D. Smith reported on a method to estimate the flare loading probability. [7] This method determines the likelihood of loads to the flare system and can be used to target instrumented responses and piping modifications. This method demonstrates that by analyzing the effects of safeguards and the Probability of Failure on Demand (PFD) of these safeguards can be used to develop the system loading as a function of probability/frequency. Using this information and given an acceptable time frame (e.g 1/100,000 years), the expected flare load is lower than the worst case scenario.

Recently the authors of this paper reviewed a refinery where the likelihood of a "worst case" load if a total power failure occurred was approximately 1/100,000,000. The design load for a 1/100,000 years was a fraction of the total load and more consistent with the complexity of the plant and the DCS programing and the safety instrumented functions and interlocks recently installed.

3.3.2 Flare Quantitative Risk Assessment

Flare quantitative risk assessment is a way to review each scenario and the perturbations of these scenarios to determine the likelihood of vessel overpressure as a function of frequency. [9] This varies from the Flare Probability Loading in that the statistical analysis and hydraulic analysis are coupled; whereas in the Flare Loading Probability the flare loading statistical analysis is separate from the hydraulic analyses. In both cases, the Plant Engineer needs to ensure that the scenario initiating event frequencies and the PFD of safeguards are reasonable and defensible.

3.3.3 Flare Load Dynamic Simulations

Offering and requesting dynamic flare system designs is becoming increasingly common. Like the other advanced flare analysis techniques, this one increases the complexity of the analysis; thus, requiring the facility to increase their understanding of the effects of assumptions on the final answer. [10] The basic premise of dynamic simulation is that by combining the effects of staged timing of releases and the dynamic pressurization of the flare system, the peak loads and backpressures on system components are reduced. In this method, the Plant Engineer needs to ensure that the fundamental assumptions affecting the timing of each system/release are reasonable and defensible to ensure that system is properly modeled.

3.3.2 Other Techniques

There are other methods to analyze flare systems that are proprietary to operating companies. All of these methods are designed to account for the probability that either operator intervention or instrumentation will operate or fail to operate as desired. Any method of flare header analysis that is not a worst case analysis will therefore need to establish some reasonable means of accounting for the positive action of instrumentation or operator intervention to mitigate the worst case load. The delicate balance between realism and conservativism in flare header design is paramount in creating a safely designed flare header at a reasonable cost. [11]

4 Conclusion

When reviewing concerns generated from either the relief system or flare design and documentation process, the Plant Engineer must ensure that each concern is valid and any resolution requiring physical changes are a proper investment of a facilities capital. To properly perform this task, it is recommended that a Plant Engineer understand how a Process Designer performs the study and review the concerns prior to making physical changes in the facility.

When properly reviewed upgrades to the flare and relief system from a relief systems analysis can improve the safety of an operating facility.

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