

Overpressure Protection Assurance through Management of Change

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Abstract

Pressure relief analysis and design basis integrity are paramount to the safe operation of any facility handling a highly hazardous chemical or operating a process system under potentially hazardous conditions. As one of the process safety information elements of the OSHA 1910.119 Process Safety Management mandate, facilities handling highly hazardous chemicals must establish and maintain their overpressure protection design basis. "Relief Systems" and "Blowdown Drums and Vent Stacks" are also on OSHA's National Emphasis Program Static List of Inspection Priority Items, which was implemented in June, 2007.

Data from numerous pressure relief analysis efforts provide evidence that deficiencies continue to exist in overpressure protection systems, including pressure relief devices and effluent handling systems. One of the primary reasons for these deficiencies is the shortage of technical personnel with sufficient experience to identify when the pressure relief analysis design basis must be reviewed and perhaps modified as changes to the process are made. The authors contend that comprehensive integration of pressure relief analysis expertise with a facility's management of change (MOC) program is necessary to establish and preserve overpressure protection integrity.

This paper shows how to achieve accelerated MOC program improvement when modifying existing processes and equipment by including key questions regarding pressure relief design aspects of the change under review. The focus is on developing an assessment checklist for the project design team. Responses to the checklist provide guidance regarding potential involvement of a pressure relief analysis subject matter expert as an integral element of the proposed modification.

Introduction

The consequences of industrial accidents may include loss of life or quality of life, financial injury, damage to assets, and potentially irreparable harm to public confidence in the company. Fires, toxic or hazardous releases, and explosions are possibilities; thus, it is imperative to develop an effective process safety management (PSM) program. In an effort to aid the industry in achieving a higher level of safety and regulatory compliance, OSHA developed Regulation 1910.119 “Process Safety Management of Highly Hazardous Chemicals” and Directive CPL 03-00-004 “Petroleum Refinery Process Safety Management National Emphasis Program” [1, 2].

Pressure relief analysis (PRA) has been a much emphasized part of PSM and the subject of many codes, regulations, and technical papers. Facilities handling hazardous chemicals must, therefore, establish and maintain their overpressure protection design basis to satisfy the PSM requirements. Overpressure protection integrity has three main constituents:

- Protection via physical assets, such as pressure relief devices and effluent handling systems;
- Protection via knowledge and expertise, which typically resides in PRA experts (both in-house or third-party); and
- Protection via work processes, which includes the application of guidance documents, flowcharts, and management of change protocol.

Since 1992, many chemical and refining companies have implemented and documented the required PSM elements. Two driving forces were responsible for this advance: OSHA’s PSM Regulation (1910.119) [1], and the quality initiatives developed by many companies. Overpressure protection is included within this scope; in OSHA’s Directive (CPL 03-00-004), the “Static List of Inspection Priority Items” requires documentation on relief devices, inlet and outlet lines, intervening block valves, flare systems, blowdown drums and vent stacks, including the original design and design basis, and mechanical integrity procedures for inspection [2].

The industry is now moving from the initial PSM element implementation and documentation phase into a maintenance phase. Consider, for example, an established facility intending to change a process flowrate. Every throughput change requires employers to conduct a management of change (MOC) procedure, including (when applicable), a review/analysis of any components to an overpressure protection system which may be impacted. This review should include not only an evaluation of the potential overpressure of process equipment and the pressure relief devices providing protection, but also the effluent handling system.

MOC procedures to manage changes that affect any covered process must be documented. If the facility’s MOC process and /or culture are deficient, the facility may

fail to maintain accurate pressure relief analysis and design basis information. Effective use of MOC procedures helps ensure an overpressure protection system's integrity.

Pressure Relief Analysis and Past Studies

Pressure relief analysis occurs when equipment and systems are in the design phase, later during baseline studies and revalidations, and as discussed above, any time changes are made to the plant. The applicable sources of overpressure as identified by a PRA expert need to be evaluated, and are well discussed in API 521[3]; an expert with specialization and training is required for a reactive system [4]. Unquestionably, this is a critical task; lacking the correct identification of potential overpressure, calculations will not be performed to protect against it [5].

The next elements of PRA include the calculations and subsequent verification of the relief device and the header it feeds into. Many computerized algorithms are available to perform these calculations quickly, but the required capacity and effective discharge area determined will be meaningless unless the correct conditions, compositions, and flow rates are input into the program [6]. An expert can ensure that the input is accurate.

One past study concluded that process hazard analyses (PHAs) were ineffective for evaluating pressure relief systems [7]. The study, performed in 1999, found that approximately 35% of equipment evaluated had at least one system deficiency, even though essentially all the systems studied had undergone a PHA. In addition, their study found that 12.5% of all equipment studied lacked any overpressure protection, even though the equipment had one or more credible overpressure scenarios. In an unrelated study, the Center for Chemical Process Safety (CCPS) in 1998 calculated that, of the 100 previous largest-loss incidents studied (at that time), one fourth were the result of a relief system inadequacy [8]. Both of these studies indicated a need for improvement that the PHA methodology was not providing.

Integrating PRA with Management of Change

Overpressure protection begins with a competent pressure relief team performing the initial process design. Even the best design and installation, however, will be of no use if the equipment fails due to neglect or lack of mechanical integrity (not the focus of this paper), or if the process changes. Changes can occur for a myriad of reasons, including:

- identical equipment unavailable when a replacement is needed;
- new raw material or product specifications;
- operating procedures modified;
- new administration;
- changes in regulations; and
- temporary equipment or process modifications.

Uncontrolled changes have directly caused or contributed to many major accidents within the chemical process industry and allied industries [6]. The rationale behind the MOC

process is to evaluate and control modifications prior to putting them into operation. Any potential change situation, as it goes through a comprehensive MOC process, will reach the point where the change must be reviewed by personnel with the appropriate expertise and tools [6]. The only way to ensure consistent, effective MOC practices is to involve that expertise in developing MOC practices, as well as in evaluating the impact of any change once identified. Employers are required by OSHA Regulation 1910.119 to establish and implement written procedures to manage all changes to process chemicals, technology, equipment and procedures [1]. Establishing and applying these MOC procedures consistently throughout the unit or plant is essential.

Most companies and engineers want to go beyond compliance and achieve a process safety culture (also called a safety climate) [9]. This “culture” is the sum of employee’s attitudes and perceptions of the importance their companies place on safety [10], and plays a critical role in how well those employees will commit to the programs in place [11]. Studies show a direct correlation from safety leadership (the CEO’s and the managers’ safety commitment and action) to safety performance (safety organization and management, safety equipment, emergency procedures, and accident rates) [11]. It has been suggested that the biggest challenge faced by a company may be the mindset and evolution of a safety culture necessary for a successful MOC system [6]. Obviously, the motivation for implementing a successful MOC system should exist, not only to achieve OSHA compliance, but also to earn a reputation for an operative process safety climate.

Data in This Present Study

The present study comprises over 3,000 systems in chemical plants, gas plants and refineries. The systems were analyzed by independent PRA experts as part of revalidation processes or audits at the plants. Analyses and calculations were based on process flow information provided by the companies, field verification of the relief devices and system equipment, and equipment files. This process verified which systems were adequately protected and summarized the concerns identified for the remaining systems.

The deficiencies included both improper installation as well as insufficient relief capacity; a listing of these deficiencies is given in Table 1 along with the percentage of systems with that deficiency. Of the 3,000 systems studied, only 48% had no concerns. This is of concern, as it represents a decrease over the aforementioned 1999 study, in which 65% of the systems had no concerns.

Table 1: Percentage of Systems Associated with Various Deficiencies. *Note:* Only those deficiency categories which exceed 5% are listed; total exceeds 100% as some systems had multiple deficiencies.

No Concerns	High Inlet Pressure Drop	High Back Pressure	Other Installation Concern	Toxic/Flammable Release	No Data/No Calcs	Fire	Blocked Outlet	Other Deficiencies
48.1	6.5	8.2	5.4	5.3	9.3	5.1	5.6	13.8

The data were further broken down based on equipment types, as shown in Table 2.

Table 2: Percentages of Various Equipment Types With Deficiencies

Equipment Type	Number of Systems	% Deficient	Notes of Interest
Columns	102	64.7	10% had relief systems which were inadequate for a power failure
Compressors	171	75.4	Companies were unable to provide sufficient data for calculations on 22% of compressor systems
Drums	151	49	
Filters	130	42.3	
Heat Exchangers, Fired Heaters, and Boilers	948	42.3	
Piping	266	17.7	82% had no concerns
Pump Discharges	647	57.3	
Reactors	50	66.0	Toxic/flammable releases were a concern for 34% of the systems
Tanks	127	68.5	42% had potential for toxic or flammable material to be released to the atmosphere
Turbines	56	64.3	48% had blocked outlet concerns
Vessels	514	68.3	
Other Equipment	54	38.9	

These data were also sorted by industry type: chemical plants, refineries, or gas plants. Of note, only 18% of the systems in chemical plants had no deficiencies, whereas refineries and gas plants systems were 59% and 75% deficiency-free, respectively. Almost 70% of the concerns in the chemical plants were data, inlet/outlet pressure drop, or other installation issues. The most commonly undersized scenarios can be summarized as:

- Blocked outlet (7.9%) and fire cases (6.2%) for refineries;
- Inadvertent valve operation (6.2%) and fire cases (3.6%) for chemical plants; and
- Blocked outlet (4.7%) and fire cases (4.8%) for gas plants.

Designs for these systems originated with reliable design firms and followed accepted engineering practices, including the design of the relief systems. In addition, most of these systems had previously undergone conventional PHAs. Thus the high percentages of deficient systems may at first appear surprising. It is the contention of this paper that many of the deficiencies uncovered in this study are a result of non-comprehensive management of change protocols.

PRA/MOC Checklist

Consider specifically the case where a Request for Change involves equipment with credible overpressure issues. The data presented previously indicates that many systems need audits, even before the proposed process changes occur. Does a relief system design team need to be involved during the evaluation phase? The MOC system design must include appropriate integration of PRA expertise.

The MOC review process starts with the identification of the pressurized system that may be affected by the change. It is important to note that this is not limited to the pressurized system that appears to be directly impacted by the change, but also those indirectly impacted. A list of the common input to various PRA evaluations and calculations is essential to translate the effects of the change into the consequences on the overpressure protection systems. Many engineers, operators and others involved in system operation do not realize the sheer number of potential input variables that are used in PRA, which may help explain why some current MOC processes fail to identify potential changes to the overpressure protection. The following examples describe modifications to an existing facility that may affect the overpressure protection, yet are often missed during an MOC process:

- Unit de-bottlenecking – Consider a modification made to increase the throughput of the unit simply by modifying tuning parameters on control loops. In many instances these changes are missed by the MOC process as no physical changes were made; however, the change in throughput can have a direct effect on the relief requirements for the overpressure protection and effluent handling systems.
- Liquid level – Consider a modification to the operating level of a vessel. The immediate effect of this increased operating level may be an increased relieving requirement due to additional wetted area for the external fire case or additional measures for overpressure protection due to reduced fill times. The cascading effects may include the following:
 1. If this vessel is feeding a fluid driver, the suction pressure of that fluid driver will be increased because of the increased liquid head, resulting in a higher maximum discharge pressure and possibly increased throughput. The systems downstream of the fluid driver need to be analyzed
 2. For systems downstream of a limiting element, such as a control valve, being fed by this vessel, the amount of liquid that may enter into the downstream system is increased. For credible vapor breakthrough cases, this may result in additional measures for overpressure protection due to an increased final liquid level downstream.
- Pump capacity – Consider a modification made to increase the capacity of a pump to provide a higher throughput. The immediate effect of this increased capacity may be to determine if a relief valve directly downstream can handle this increased capacity. The cascading effects may include the following:
 1. The modifications to the pump likely result in higher maximum discharge pressures, and downstream equipment should be analyzed to determine if new requirements for overpressure protection are needed.

2. The increased throughput may have caused control valves downstream to be modified as well to handle the increased throughput, and equipment downstream needs to be analyzed to determine if additional measures for overpressure protection are needed.
- Operating pressure – Consider a modification made to increase the operating pressure of a vessel. The immediate effect of this increased operating pressure may be to determine if the installed pressure relief device can handle the new operating margin. The cascading effects may include the following:
 1. For systems downstream of a control valve or other flow-limiting element, the maximum operating pressure of the vessel was likely used as the basis for the flow through that valve. Increasing pressure will likely result in an increased relief requirement for the downstream equipment, or may cause the failure of automatic controls to be a credible cause of overpressure when it was not previously.
 2. If this vessel is feeding a fluid driver, the suction pressure of that fluid driver will be increased, resulting in a higher maximum discharge pressure and possibly increased throughput. The systems downstream of the fluid driver need to be analyzed to determine if additional measures for overpressure protection are needed.
 - Flare System – Consider a modification made that has been found to increase required relief rates for a relief device. The immediate effect of this increased required relief rate may be the requirement for additional relieving capacity (note this does not necessarily mean a larger relief device is needed because the existing relief device may be adequately sized already). The cascading effects may include the following:
 1. For relief devices discharging to the atmosphere, the analysis performed to determine the acceptability of that release to atmosphere will need to be reviewed as there may be additional risks associated with increased relief rates.
 2. For relief devices discharging to a flare header, the hydraulic analysis for the pressures developed in the header for any case where the relief device is expected to participate will need to be re-evaluated as the hydraulic analysis is typically based on the required relief rate.

After an initial identification of the pressurized system that may be affected by a change, the design team needs to re-evaluate the potential causes of overpressure for the system. OSHA 1910.119 encourages employers to develop a form or clearance sheet to facilitate the processing of changes through MOC procedures [1]. As part of this clearance process, consider using the PRA/MOC Checklist given in Appendix A to determine if the design team needs to initiate the MOC procedure *for the overpressure protection system* for a proposed modification. Inclusion of Appendix A with an MOC system flow chart, such as that recommended by CCPS [6], should provide enhanced guidance.

A positive response to any item on the checklist requires PRA expertise to determine the impact of the change. The PRA/MOC Checklist addresses six categories for which to consider modifications, including both technical and mechanical changes:

- Physical assets – process equipment, piping, or auxiliary equipment;
- Operating issues – throughput, feed, operating conditions, process control;
- Pressure relief systems – relief devices and effluent handling systems;
- Regulatory or technical practice changes ;
- Near-misses – an abnormal event having the potential for a more serious consequence [13]; and
- Mechanical integrity – addressing results from maintenance and inspection.

Conclusions and Recommendations

Deficiencies in overpressure protections systems exist to a significant extent. One of the primary reasons for these deficiencies is the shortage of qualified personnel identifying when process changes require a PRA design basis review and perhaps an overpressure protection system modification. Incorporating pressure relief analysis expertise with a facility's management of change protocol will enhance a facility's likelihood of identifying when an overpressure protection system's design basis needs to be assessed against a change.

References

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Appendix A: PRA/MOC Checklist

A positive response to any item on the checklist requires pressure relief analysis expertise to determine the impact of the change.

1. Physical Assets:

- a. Are you installing, removing, or relocating/repositioning process equipment?
- b. Are you changing the process equipment temperature or pressure ratings (e.g. vessel re-rating)?
- c. Are you changing the internal or external heat transfer rates (e.g. heat transfer area, addition or removal of insulation, change in fire zone or changes that may alter sun exposure)?
- d. Are you changing pump or compressor capacity, including impeller changes?
- e. Are you installing, removing, or modifying fittings, instrumentation, valves or piping on process lines?
- f. Are you installing or removing block valves?
- g. Are you adding/removing any mechanical locking elements on valves, (e.g. chain-lock on a control valve bypass line)?

2. Operating Issues:

- a. Are you changing the process feedstock, intermediate or product composition, process chemical additives or concentrations or catalyst type or concentration?
- b. Is any alternative mode of operation not previously considered for the design of the overpressure protection being added?
- c. Are you changing the procedures for a specific mode of operation that affect pressure, temperature, level, flow, or composition within the equipment (e.g. changing the maximum level during start-up or the operator response to that level)?
- d. Are any changes being made to the maximum operating pressure within the equipment?
- e. Are any changes being made to the operating temperatures within the equipment?
- f. Are any changes being made to the operating level within the equipment?
- g. Are any changes being made to the flow rates through the equipment?
- h. Are any changes being made to the mixing, settling or reaction times?
- i. Are any changes being made to the operation of equipment which may affect the process fluid (e.g. voltage, power, current, rpm, or frequency/amplitude of vibrating equipment)?
- j. Are any changes being made to the composition, pH or density of the fluid within the equipment?
- k. Are you installing, removing, or modifying process control elements (e.g. alarms, trip points, programming of the DCS, a change from an analog transmitter to a digital one)?
- l. Are you changing orifice/trim sizes in valves or other flow devices?
- m. Are you changing the operating envelopes to conditions beyond the boundary conditions set by the design basis of the overpressure protection and effluent handling systems?

3. Pressure Relief Systems:

- a. Are you changing any aspect of the relief device installation (e.g. installing, removing, or modifying fittings, instrumentation, valves, piping on relief device inlet or outlet lines, or discharge location)?
- b. Are you changing relief device specification (e.g. manufacturer, model number, discharge area, materials of construction)?
- c. Are you changing any aspect of the effluent handling (e.g. flare) system, such as the piping, knockout drum, seal drum, flare?
- d. Have you removed a relief device from service (e.g. for maintenance), with no alternate means of protecting the system?
- e. Are you redirecting atmospheric discharge to an existing effluent handling (e.g. flare) system?
- f. Are you locating personnel closer to a relief device or effluent handling system discharging to atmosphere?
- g. Are you locating personnel closer to a flare or ignitable outlet (including any relief device or effluent handling system discharging flammables to atmosphere)?
- h. Are you locating personnel closer to a relief device subject to leaking to atmosphere (e.g. bellows type relief valve) and protecting a process system containing hazardous fluids?
- i. Are you changing separate processes that can affect shared or common relief headers?

4. Regulatory or Technical Practice Changes:

Have there been changes in regulations or technical practices which impact pressure relief design? These can cover a wide range of situations and applicability. In these cases, a review by an overpressure protection system expert may help establish the consequences of the changes in regulations, and how to identify what needs to be checked. This list of items to check can then be used in a gap analysis to determine the need for full review of the overpressure protection system design.

5. Near-Misses:

- a. Has your company's near-miss management system identified and disclosed a near-miss involving a process-related disturbance?
- b. Has your company's near-miss management system identified and disclosed a near-miss involving a spill?
- c. Has your company's near-miss management system identified and disclosed a near-miss which included a relief device release?

6. Mechanical Integrity:

- a. Are you changing any process equipment temperature or pressure ratings (e.g. mechanical integrity finds lower wall thicknesses which result in a decrease of the allowable pressure within the vessel)?
- b. Do you observe leaking, simmering, or chattering of the relief valve?
- c. Is the CDTP or the set pressure of the relief valve set incorrectly?
- d. Has the inspection interval for the relief device been exceeded?
- e. Has the relief valve experienced premature opening?
- f. Has foreign matter been allowed to accumulate in the relief system?
- g. Are the materials of the relief valve construction inappropriate for the required service?