
Working Under Pressure

(How do you manage pressure hazards?)

**Angela E. Summers, Ph.D., P.E.,
SIS-TECH Solutions
12621 Featherwood Dr. Suite 120, Houston, TX
asummers@sis-tech.com**

Keywords: high integrity protective systems, protection systems, safety instrumented systems, overpressure protection, ASME, IEC 61511, UG-140, API 521

Abstract

Industry is increasingly moving towards utilizing HIPS to reduce flare loading and prevent the environmental impact of pressure venting. HIPS are becoming the option of choice to help alleviate the need to replace major portions of the flare system in existing facilities when adding new equipment or units. Another benefit is that a process unit protected by HIPS will relieve less frequently and perhaps with less quantity than a process unit designed for full flare loading. In some areas of the world this is becoming important as regulatory agencies place greater restrictions on release of greenhouse gases.

Any justification for HIPS must be thoroughly documented through a hazard analysis, which identifies all potential overpressure scenarios and demonstrates that the HIPS can adequately address each scenario. The ability of the HIPS to adequately address overpressure is limited by the knowledge and skill applied in the identification and definition of overpressure scenarios. Ultimately, it is the owner/operator that must verify that HIPS works from a process and holistic viewpoint and achieves the necessary safety integrity.

1. Introduction

In the process industry an important safety consideration is the prevention of losses due to vessel or pipeline overpressure events. The American Society of Mechanical Engineers (ASME) provides criteria for the protection of vessels from rupture or damage caused by excess pressure. The American Petroleum Institute (API) provides design and documentation requirements for pressure relief systems. In conventional designs, pressure relief devices (PRD), such as pressure relief or pressure safety valves, are used as the primary means of overpressure prevention and are designed to address all credible overpressure scenarios.

However, conventional design is not suitable for some processes, e.g., those where reactive chemicals polymerize and plug the relief system. Other methods of preventing overpressure must be utilized to achieve measurable risk reduction. Further, in many countries around the world, there is increased pressure from community and regulatory authorities to reduce release of

greenhouse gases. The need to balance safety requirements and environmental requirements has resulted in increased focus on using an alternative approach to overpressure prevention.

Fortunately, design practices have evolved over the last 15 years and now allow consideration of safety instrumented systems (SIS) for pressure protection. The overall likelihood of overpressure often results in the need for high SIS integrity; therefore, these systems are often called High Integrity Protection Systems (HIPS). The use of HIPS must be thoroughly documented through a hazard analysis, which identifies potential overpressure scenarios and identifies the combination of instrumented functions that prevents the overpressure.

HIPS are complex and require the successful functioning of multiple devices to achieve the performance of a single pressure relief device. The owner/operator must verify that HIPS will work from a process standpoint and that the HIPS design results in an installation as safe or safer than a conventional design. HIPS effectiveness is highly dependent on the field installation, device testing, and mechanical integrity program. When a PRD is not installed or is undersized based on conventional design, the HIPS becomes the “last line of defense,” whose failure potentially enables vessel rupture. Consequently, the HIPS designer must thoroughly understand the application-specific design and mechanical integrity constraints. Achieving the required effectiveness is more than simply designing and installing equipment in accordance with a single code. It requires information from and procedural support for multiple disciplines, including engineering, operations, and maintenance.

2. Code Requirements - ASME UG-140

The pressure vessel code [1], ASME UG-140, states that “a pressure vessel may be protected from overpressure by system design or by a combination of overpressure by (sic) system design and pressure relief devices.” The decision to limit the overpressure by system design is the choice of the owner/operator, but requires a documented rationale to support the system performance claims. The code allows the use of qualitative and quantitative techniques in assessing the likelihood and the magnitude of the overpressure of identified scenarios. The analysis should include descriptions of the overpressure scenarios from the cause, including fire, operator error, and instrumentation malfunctions, through final consequence.

At a minimum, assess the “Causes of Overpressure” described in ANSI/API 521 (ISO 23251) [2]. This analysis should demonstrate that there is “no credible scenario where the pressure exceeds 116% of the MAWP times the ratio of the allowable stress value at the temperature of the scenario to the allowable stress value at the design temperature.” Although the scenario analysis may use the 116% MAWP as a tolerable risk endpoint, the code is “not intended to allow for normal operation above the MAWP at the coincident temperature” and requires that the “scenario shall be readily apparent so that the operator or protective instrumentation can take corrective action”.

Extensive guidance on the credibility analysis can be found in the WRC Bulletin 498, “Guidance on the Application of the Code Case 2211 – Overpressure Protection by System Design” [3]. The guidance document warns that the justification for using system design or a combination of system design and pressure relief devices is based on likelihood alone and should not take

consequence severity into account. The guidance further suggests that the likelihood of overpressure should be reduced to less than 1 in 10,000 years.

ASME UG-140 has the following additional requirements:

- a) The vessel is not exclusively in air, water, or steam service unless these services are critical to preventing the release of fluids that may result in safety or environmental concerns.
- b) A detailed description of any safety critical instrumentation used to limit the system pressure, including the identification of all truly independent redundancies and a reliability evaluation (qualitative or quantitative) of the overall safety system.
- c) An analysis showing the maximum pressure that can result from each scenario.

3.0 International Standards

3.1 ANSI/API 521 (ISO 23251).

The standard, “Pressure-relieving and Depressuring Systems,” addresses HIPS in Clause 4.2.4 where it states “Fail-safe devices, automatic start-up equipment and other conventional instrumentation should not be a substitute for properly sized pressure-relieving devices as protection against single jeopardy overpressure scenarios.” This establishes that the use of HIPS or other instrumentation in reducing the calculated relief load should be justified and the standard provides the basis in the subsequent paragraphs. The standard also includes Annex E High Integrity Protection Systems (HIPS), which is an informative annex on the design and implementation of HIPS based on ISA 84.01-1996 [4]. The 1996 version of the standard has been updated as ANSI/ISA 84.00.01-2004 (IEC 61511 modified) [5,6].

The standard requires that the overall system design including instrumented safeguards:

- Comply with local regulations and the owner/operator’s risk tolerance criteria, whichever is more restrictive.
- Provide, as a minimum, safety integrity level 3 (SIL 3) performance when risk tolerance criteria is not available.

The standard states that “the favorable response of conventional instrumentation should not be assumed when sizing individual process-equipment pressure relief.” However, it is possible to consider the instrumentation in the design of some components of a relieving system (blowdown header, flare, and flare tip). The decision to exclude or reduce the size of specified loads should consider the number and reliability of the instrumented systems, as discussed in HIPS justification

3.2 IEC 61511.

The standard, “Functional Safety: Safety Instrumented Systems for the Process Sector,” establishes a framework for the design of instrumented systems that are used to address process safety risks [6]. This standard was accepted in the US as a national standard as ANSI/ISA

84.00.01-2004 [5]. The objective of this standard is to define the assessment, design, validation, and documentation requirements for SIS.

IEC 61511 is performance-based and uses the safety integrity level (SIL) as the primary performance measurement. The risk reduction provided by the HIPS is equivalent to the probability of failure on demand (PFD) attributable to all of the HIPS devices from the sensor through the logic solver and final elements. The relationship between the SIL and PFD is as follows:

Table 1 Relationship between SIL, PFDavg, and required risk reduction

DEMAND MODE OF OPERATION		
Safety integrity level (SIL)	PFDavg	Required risk reduction
4	$\geq 10^{-5}$ to $< 10^{-4}$	>10 000 to $\leq 100\ 000$
3	$\geq 10^{-4}$ to $< 10^{-3}$	>1 000 to $\leq 10\ 000$
2	$\geq 10^{-3}$ to $< 10^{-2}$	>100 to $\leq 1\ 000$
1	$\geq 10^{-2}$ to $< 10^{-1}$	>10 to ≤ 100

The SIL establishes a minimum required performance for the HIPS. The SIL is affected by the following:

1. Device integrity determined by documented and supportable failure rates;
2. Redundancy and voting using multiple devices to ensure fault tolerance;
3. Proof tests at specific intervals to determine that the device operates as specified;
4. Diagnostic coverage using automatic (on-line) methods to detect device failure; and
5. Other common causes including those related to the device, design, systematic faults, installation, and human error.

The SIL must be assigned by the owner/operator based on the risk reduction necessary to achieve the requirements of ASME UG-140 when the pressure relief device sizing is being impacted and ANSI/API 521 when the relief system design is being impacted. In either case, it is the owner/operator's responsibility to ensure that the system pressure is limited by design and that the overall safety system design is assessed for independence and common cause.

4.0 Applications

ANSI/API 521 (ISO 23251) Clause 4.2.4 acknowledges that there are applications where the use of pressure relief devices is impractical and reliance on instrumented safeguards is needed. The CCPS book, *Guidelines for Safe and Reliable Instrumented Protective Systems* [7], provides the following examples of HIPS applications:

- Vessel protection when PRD is routed to relief system (relief valves or header) that is not sized to mitigate a single or multiple relief scenario,

- Pipeline protection where piping is underspecified by design to reduce cost or due to physical limitations, and relief devices are not adequate or cannot be routed to a safe location,
- Pipeline protection where manifolds and piping connect to higher pressure wells and where submersible pumps raise the pipeline pressure to reach long distance collection points or to increase production rates,
- Pipeline protection where existing pipeline is de-rated due to corrosion or erosion,
- Vessel protection where exothermic reactions can “run away” at rates faster than the relief device is capable of reducing pressure,
- Vessel protection where polymerizing or depositing materials during normal operation can result in partial or complete relief device blockage, or
- Vessel protection where reactive process chemicals relieved into common headers interact with other materials in the header, causing header pluggage and rendering the relief device useless.

5.0 HIPS Justification

A HIPS may protect a network of vessels from a global hazardous event or a single vessel from abnormal operation. Many global events are caused by loss of utilities, which may affect the facility, process areas, or process units. Single vessel events may involve runaway reactions, hot spot formations, or de-rated vessels or pipelines.

The successful implementation of HIPS requires examination of applicable regulations and standards, including jurisdictional authority and insurer requirements. From ASME UG-140, the vessel cannot be exclusively in air, water, or steam service unless these services are critical to preventing the release of fluids that may result in safety or environmental concerns. ANSI/API 521 recommends the use of HIPS only when the use of a pressure relief device is impractical and reliance on instrumented safeguards is needed. It is the owner/operator’s responsibility to establish the definition of “impractical.”

Both standards allow the use of qualitative and quantitative techniques for the assessment of the identified overpressure scenarios. The hazards analysis should follow a structured, systematic approach, using a multidisciplinary team consisting of representatives from process engineering, research and development, operations, health and safety, instrumentation and electrical, and maintenance, as appropriate for the equipment or process under study.

Typical hazards analysis methods include “What-if” Analysis, “What-if”/Checklist Analysis, Hazard and Operability Study (HAZOP), Failure Modes, Effects, and Criticality Analysis (FMECA), Fault Tree Analysis (FTA), or Event Tree Analysis (ETA). Different methods may be employed across the lifecycle of a process or HIPS. Refer to CCPS *Guidelines for Hazard Evaluation Procedures* [8] for additional guidance on hazards analysis methods. Further, different levels of quantitative analysis can be used to support the likelihood analysis. In general, the quality of the results of any of these techniques (regardless of the quantitative analysis level) is limited by the knowledge and skill applied in the identification and definition of the overpressure events.

The hazard analysis should examine operating (e.g. start-up, shutdown, and normal operation) and upset conditions that result in overpressure. The “Causes of Overpressure” provided in ANSI/API 521 should be reviewed to ensure completeness of the hazard analysis. For example, the hazard analysis should examine the following initiating causes for overpressure events:

- loss of utilities, such as electric power, steam, water, etc.,
- runaway reactions,
- fire exposure,
- operating errors,
- maintenance errors,
- block outlet,
- equipment failures, and
- instrumentation malfunctions.

The need for HIPS may be identified during a unit hazard and risk assessment or in a focused study examining global hazardous events. Additional analysis is often performed for global events, such as process simulation, reactive calculations, dynamic simulation, and flare load calculations. Only those scenarios that can be successfully prevented by the HIPS can be considered for removal from the relief load calculations. For example, in hydrocarbon applications, the fire case scenario typically cannot be removed from the sizing calculations due to the inability of HIPS to mitigate the cause of overpressure.

Example – runaway reaction

The HIPS may consist of one or more functions - preventive and mitigative. For example, the HIPS may prevent a runaway reaction by closing the feed valves when the feed rate is above the safe operating limit. A separate function may mitigate a runaway by detecting high pressure and injecting a chemical that kills the reaction. The overall performance of functions should be assessed and determined to meet the risk tolerance criteria.

When multiple vessels simultaneously relieve, the system design and verification becomes more complex. The analysis should consider how each overpressure cause affects interconnected processes and their risk. A holistic view is necessary to fully understand the design basis for the HIPS, to identify the combinations of relief cases that potentially challenge the relief system design basis, and to ensure that overall risk meets the risk tolerance criteria. Guidance can be found in CCPS *Guidelines for Developing Quantitative Safety Risk Criteria* [9].

Example - flares or ground burners

Cooling water or power failure often yields the highest load due to multiple demands being placed across a facility when these failures occur. For a combined relief system, the HIPS consists of all of the individual functions used to protect the interconnected vessels from overpressure due to any cause. Consequently, the analysis should ensure adequate independence between the functions and the event causes and that the HIPS is effective in reducing the likelihood of overloading the relief system.

The overpressure risk of interconnected processes must be assessed to understand the overall risk reduction requirements. Achieving the risk reduction for the overall system often places high risk reduction requirements on individual HIPS functions. If many vessels are involved, it may be difficult to achieve the overall risk reduction unless independence and fault tolerance is implemented throughout the system design. The design basis should place special emphasis on independence and separation of the functions, equipment redundancy, and frequent proof testing.

It is preferable that the relief system be designed to relieve simultaneous vessel loads. These acceptable combinations of relief events determine the fault tolerance of the relief system. The relief system should be fault tolerant and include sufficient safety margin to account for uncertainty. When the relief system is capable of safely managing multiple vessel loads, the relief system design generally lowers the requirements on the individual HIPS functions. If the relief system cannot tolerate the relief of a specific vessel, the relief system cannot tolerate the failure of that vessel's HIPS function. If the relief system cannot handle any of the loads, the failure of any HIPS function results in the failure of the relief system. For example, if the relief system can tolerate the relief load of any one (1) of 5 vessels, but not 2 of 5, the relief system can tolerate the failure of only 1 of the 5 HIPS functions.

The maximum pressure, flow rate and back pressure should be determined for each scenario. ASME UG-140 requires that a PRD be installed if there are any scenarios where the maximum pressure exceeds 116% of the MAWP at the ratio of the allowable stress value at the temperature of the scenario to the allowable stress value at the design temperature.

6.0 Process requirements specification

The process requirements specification provides the functional specification of the HIPS from three aspects: 1) when to take action, 2) what action to take, and 3) how quickly to take it. When to take action and what action to take establishes the cause and effect relationship between the sensors and final elements. The process requirements also establish the rationale for the setpoint selection, which should consider the sequencing of any instrumented function response, measurement lag and error, shutdown lag and process lag. Refer to ISA TR84.00.04-2012 Annex Q for more information about process safety time (PST) and set point selection [10].

Just how quickly to take action is a critical decision in HIPS applications. A PRD opens in milliseconds in direct response to process pressure greater than its set pressure. In contrast, the HIPS must detect an abnormal process condition and take action on a process. HIPS response time is generally longer than the response time for a PRD. For example, if the HIPS initiates the closure of large valves, the response time can extend to tens of seconds unless special design practices are followed. Then, the process itself may take seconds, or even minutes, to respond to the HIPS action. For example, it may take minutes for heat input to stop after a reboiler is shutdown. Consequently, the process dynamics must be understood so that a maximum allowable response time (MART) can be defined for the HIPS – this is how fast the HIPS must act to prevent overpressure of the vessel.

The propagation of risk should also be considered when finalizing the functional specification. The HIPS takes action on the process to prevent overpressure, which results in isolation or

venting of a piece of process equipment or a process unit. Interconnected equipment are typically affected, potentially leading to process demands on other protective systems. For example, the shutdown of a reboiler results in a loss of fractionation (stripping), causing light components to pass to the next column, which may subsequently overpressure. The process requirements specification should ensure that these propagating risks are managed in a controlled and properly sequenced manner.

7.0 Safety Requirement Specification

A safety requirement specification (SRS) is used to document how and under what conditions the HIPS prevents the propagation of the overpressure scenarios, including a functional logic description with trip set-points and device safe state conditions. The SRS must also specify exactly how the HIPS is configured to achieve the target SIL. The high availability requirements for HIPS drive the choices made concerning device integrity, redundancy, fault tolerance, diagnostic requirements, and test interval.

7.1 Process Sensors.

The process variables (PV) commonly measured in HIPS are pressure, temperature and flow. Traditionally, these variables were monitored using discrete switches as the input sensor to the safety instrumented systems. Switches worked well for three reasons: 1) Most trip conditions are discrete events, i.e., a high pressure, high temperature, or low flow; 2) Relay systems and early programmable logic controllers (PLCs) processed discrete signal much easier than analog signals; and 3) Switches were usually less expensive than analog transmitters.

The evolution of PES technology has made it easy to use analog PV inputs. The use of transmitters to measure these variables is now preferred over the use of switches. Switches only give a change in output when they are activated and can “stick” or experience some other failure mode that is revealed only when the switch is tested or a demand is placed on it. Transmitters can be continuously monitored and the operability of the transmitters readily observed if the process condition varies over time. With transmitter redundancy employed, out-of-range or deviation alarming can be implemented to ensure a high level of availability.

Most HIPS applications require 1oo2 or 2oo3 transmitters on all field inputs. The use of redundant inputs enables the system designer to incorporate diagnostics into the HIPS, which significantly reduces the PFD for the field inputs. Separate process connections where practical to minimize common cause failures, such as closed isolation valves and plugged process taps. Utilizing diversity in the process variable measurement, where practical, is also recommended in order to reduce common cause failures.

7.2 Logic Solver.

IEC 61511 Clause 11.2.4 requires that the SIS be independent from the basic process control system (BPCS). The logic solver hardware must be designed to meet the assigned SIL. Since many HIPS are designated as SIL 3, the logic solver is typically specified to be compliant with SIL 3 according to IEC 61508. The logic solver can be relays, solid state, or programmable

electronic systems (PES). If a PES is used, the selected PES should provide a high level of self-diagnostics and fault tolerance. Redundancy of signal paths and logic processing is desirable and where practical the trip output function should be configured as de-energize to trip.

7.3 Final Elements.

The final elements are typically either 1) relays in the motor control circuit for shutdown of motor operated valves, compressors, or pumps or 2) fail-safe valves opened or closed using solenoids in the pressure supply to the valve actuator.

The valve specification must include acceptable leakage rates, since this affects downstream pressures and relief loading. The valve specification must also ensure that the actuator provides sufficient driving force to close the final element under the worse case, upset pressure condition.

For SIL 1 and 2, at least one of the valves must be a dedicated shutdown valve. The second valve can be a control valve, but it must be configured fail-safe; meet leakage and closure speed specification, have no minimum stops; and its actuation must be controlled by the HIPS logic solver. If SIL 3 is required, at least two independent block valves are required.

Solenoid operated valves (solenoids) configured as de-energize to trip are used to actuate the fail-safe valves. Solenoids can be configured 1oo1 or 1oo2, but spurious closure of the valves due to solenoid coil burnout can cause process disruptions, loss of production, and downtime. The solenoids can also be configured as 2oo2 to reduce spurious trips, as long as adequate testing is performed to uncover stuck valves or plugged vent ports. The solenoid should be mounted as close to the valve actuator as possible to decrease the required transfer volume for valve actuation. The exhaust ports should be as large as possible to increase speed of valve response.

7.4 Response Time.

The HIPS response time must be compared to the MART to ensure that it is fast enough to prevent vessel overpressure. The HIPS response time is evaluated by considering the time it takes to sense that there is an abnormal process condition; the scan rate and data processing time of the logic solver; and closure speed of the final element. ISA TR84.00.04-2012 Annex Q provides guidance on setpoint verification.

7.5 Diagnostics.

Diagnostic capability should be designed into HIPS. The ability to detect failures of devices on-line significantly improves the availability of the HIPS. For example, the use of signal comparison on analog inputs allows annunciation of transmitter failures to the control room. To support the claimed risk reduction associated with diagnostics, operation procedures must require that these alarms be responded to promptly with compensating measures for continued safe operation while the device is out of service. Maintenance procedures should also place high priority on repair of HIPS devices.

7.6 Test Interval.

If all failures were self-revealing, there would be no need to test safety system devices. Shut down valves that do not close completely, solenoid valves that are stuck in position, and pressure switches with stuck closed contacts are all examples of covert, dangerous failures. If safety system devices are not tested, dangerous failures reveal themselves when identified causes of overpressure occur. Testing is performed to uncover hidden failure before overpressure occurs.

The appropriate testing of HIPS is key to ensure that the availability requirements are satisfied. Architecture, redundancy, and device integrity have a significant effect on the PFD and therefore the required test interval. A quantitative verification of the PFD associated with random hardware failures is required by IEC 61511 Clause 11.9. Further, on-line and off-line testing provisions should be provided to permit each device to be completely proof tested. Any bypasses required for on-line testing must be controlled and subjected to access security constraints. Bypass time should be tracked to ensure that the out of service time does not exceed acceptable limits and is minimized to the extent possible.

8.0 HIPS Performance Requirements

The failure modes of PRDs are well-known and predictable. Their specification is covered by prescriptive standards and they are installed for a single purpose – to open at a specified setpoint to allow the release of pressure. Each isolatable piece of equipment that can be overpressured is protected by a dedicated PRD. In contrast, HIPS are more complex, requiring the successful functioning of multiple devices to stop overpressure. Yet, the HIPS is expected to protect the vessel from overpressure with at least the reliability of a dedicated PRD.

Further, when a spring-operated PRD opens in response to a high-pressure condition, the impact on the process is typically a process disruption and is self-correcting when the pressure is reduced below the PRD set pressure. In contrast, the HIPS acts to take the process to a safe state and keeps it there until the operator resets the HIPS and restarts the process. Taking action when required is acceptable under every scenario, but spurious operation of a PRD causes a disruption, while a HIPS causes shutdown. Consequently, HIPS reliability is equally important to integrity (or PFD) in most applications.

8.1 Probability of Failure on Demand.

The HIPS includes all devices required to reach the desired safe state; it is the entire instrument loop from the field sensor through the logic solver to the final elements, along with other devices required for successful SIS functioning, such as SIS owner/operator interfaces, communications, and power supplies. For example, if the final elements are air-to-move valves and the safe action requires valve closure, instrument air availability must be considered when determining the overall HIPS availability. Since any device used in HIPS can potentially contribute to the PFD_{avg} , the structure of the instrumented loop must be defined and evaluated as a system so the entire loop is demonstrated to meet the PFD_{avg} for the random hardware failures.

HIPS are generally expected to achieve SIL 3. This was considered by Lawley and Kletz [11] who suggest that if an SIS is used instead of a relief valve, it should be designed to provide a

reliability which is 10 times that of the latter. The reason for this is the uncertainty in the relief device failure rate data and the difference in the modes of failure; a relief device that fails to operate at the set pressure may nevertheless operate at higher pressure, whereas an SIS is more likely to fail completely.

This agrees with ANSI/API 521, which states that the instrumented safeguards should provide safety integrity level 3 performance, unless the owner/operator performs an analysis based on risk tolerance criteria. Annex E describes this risk analysis and concludes that the “large majority of cases for HIPS” are either SIL 2 or 3.

8.2 Reliability.

Due to the significant impact of HIPS on the process operation the HIPS should also be highly reliable. Redundant equipment, fault tolerance, diagnostics, and frequent inspection and proof testing are generally necessary for the HIPS to achieve reliability similar to a PRD. HIPS complexity requires careful consideration for common cause, common mode, and systematic failures. This complexity increases when networks of vessels are involved, risk propagates due to trips, and fast response times are required.

8.3 Common Cause.

A common cause failure (CCF) occurs when a single failure results in the failure of multiple devices or systems. ASME UG-140 requires the identification of “truly independent redundancies” and system evaluation using reliability analysis.

Considering independent redundancies in the safety system design is supported by IEC 61511, which requires that the HIPS be independent of the basic process control system (Clause 11.2.4) and the initiating cause (Clause 8.2.1). Requiring redundancies is further supported in the necessity to provide hardware fault tolerance for the field devices at SIL 3 (Clause 11.4). Reliability analysis of the HIPS results in an understanding of the PFD achievable by the HIPS based on random hardware failures (Clause 11.9). The standard requires that systemic failures associated with human errors be addressed through the functional safety management plan that requires quality assurance processes, such as verifications, assessment and audits, to identify and correct work performance gaps.

Therefore, the susceptibility of the overall system of HIPS functions to common cause, common mode, and systematic errors should be assessed and means implemented to reduce their occurrence when practical. Consider implementation of independent HIPS for each overpressure event where possible. When multiple HIPS functions are placed in the same logic solver, the logic solver becomes a single point of failure for the spurious shutdown of multiple vessels and for the dangerous failure of the relief system.

9.0 Advantages and Disadvantages of HIPS

It is poor practice to rely on pressure relief devices in services where there is a history (or reasonable expectation) of relief issues, such as runaway chemical reactions, multi-phase fluids,

or polymerizing materials. In these applications, alternatives such as HIPS should be examined to ensure mitigation of overpressure events.

Industry is increasingly moving towards utilizing HIPS to reduce flare loading and prevent the environmental impact of pressure venting. HIPS are becoming the option of choice to help alleviate the need to replace major portions of the flare system in existing facilities when adding new equipment or units. If the header and flare system must be enlarged, significant downtime is incurred for all of the units that discharge to that header. The capital and installation cost associated with HIPS is attractive when compared to the downtime or equipment cost of flare modification. Another benefit is that a process unit protected by HIPS relieves less frequently and potentially with less quantity than a process unit designed for full flare loading. In some areas of the world this is becoming important as regulatory agencies place greater restrictions on release of greenhouse gases.

The main disadvantage of HIPS is the careful documentation, design, operation, maintenance, and testing to ensure that the HIPS achieves the required safety integrity. Specific regulatory and enforcement jurisdiction requirements must also be determined. In some instances, approval of local authorities is required. Regulatory and standards requirements must be understood by all parties, including facility management and instrumentation and electrical, operations, and maintenance personnel.

Any justification for HIPS must be thoroughly documented through a hazard analysis, which identifies all potential overpressure scenarios and demonstrates that the HIPS can adequately address each scenario. The ability of the HIPS to adequately address overpressure is limited by the knowledge and skill applied in the identification and definition of overpressure scenarios. The owner/operator must verify that HIPS works from a process and holistic viewpoint and achieves the necessary safety integrity.

Most codes and standards focus solely on design. Once the piece of equipment is “certified” for compliance, the requirements for the code or standard are fulfilled. However, the HIPS integrity (or SIL) is not just a design parameter. It is also an operational parameter. The effectiveness of HIPS is highly dependent on the overpressure scenario identification and mechanical integrity program. Consequently, the owner/operator must understand the importance of application-specific design aspects, as well as the associated costs of the required testing and preventive maintenance. When a PRD is not installed or a relief system is undersized, the HIPS becomes the “last line of defense,” whose failure enables the vessel to overpressure and losses to occur.

10. References

- [1] American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code, Section VIII –Pressure Vessels, United Engineer Center, New York, NY.
- [2] American Petroleum Institute (API), RP 521, Guide for Pressure Relieving and Depressuring Systems, Washington, DC.

- [3] ASME, Welding Research Council Bulletin, Guidance on the Application of Code Case 2211 – Overpressure Protection by Systems Design, Bulletin 498, ISSN 0043-2326 (2005).
- [4] International Society of Automation (ISA), ANSI/ISA S84.01-1996, “Application of Safety Instrumented Systems (SIS) for the Process Industry,” Research Triangle Park, NC (1996).
- [5] ISA, ANSI/ISA 84.00.01-2004 (IEC 61511 modified) Part 1, Functional Safety: Safety Instrumented Systems for the Process Industry Sector - Part 1: Framework, Definitions, System, Hardware and Software Requirements, Research Triangle Park, NC (2004).
- [6] International Electrotechnical Commission (IEC), IEC 61511, “Functional Safety: Safety Instrumented Systems for the Process Sector,” Geneva, Switzerland.
- [7] CCPS/AIChE, Guidelines for Safe and Reliable Instrumented Protective Systems, Wiley-Interscience, New York (2007).
- [8] CCPS/AIChE, Guidelines for Hazard Evaluation Procedures, Third Edition, Wiley-Interscience, New York (2008).
- [9] CCPS/AIChE, Guidelines for Developing Quantitative Safety Risk Criteria, New York (2009).
- [10] ISA, ISA TR84.00.04, Guidelines on the Implementation Of ANSI/ISA 84.00.01-2004 (ISA 61511 Modified), Research Triangle Park, NC (2006).
- [11] Kletz, TA and HG Lawley, High Pressure-Trip Systems for Vessel Protection, Chemical Engineering, pp 81-88 (May 1975).
- [12] “High Integrity Protection Systems for New and Existing Vessels,” International Mechanical Engineering Conference, American Society of Mechanical Engineers, La Jolla, California, June 2004.
- [13] “Flare Reduction with High Integrity Protection Systems (HIPS),” ISA EXPO 2003, Research Triangle Park, NC: Instrumentation, Systems, and Automation Society, Houston, Texas, October 20-23, 2003.
- [14] “High Integrity Protective Systems for Reactive Processes,” Center for Chemical Safety Symposium, New York: American Institute of Chemical Engineers, Scottsdale, Arizona, September 23-25, 2003.
- [15] Chapter, “High Integrity Pressure Protection Systems (HIPPS),” Instrument Engineers Handbook, Volume 3, Chapter 2.6, 2003.