Automation & Safety Solutions

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High-Integrity Pressure Protection System (HIPPS)

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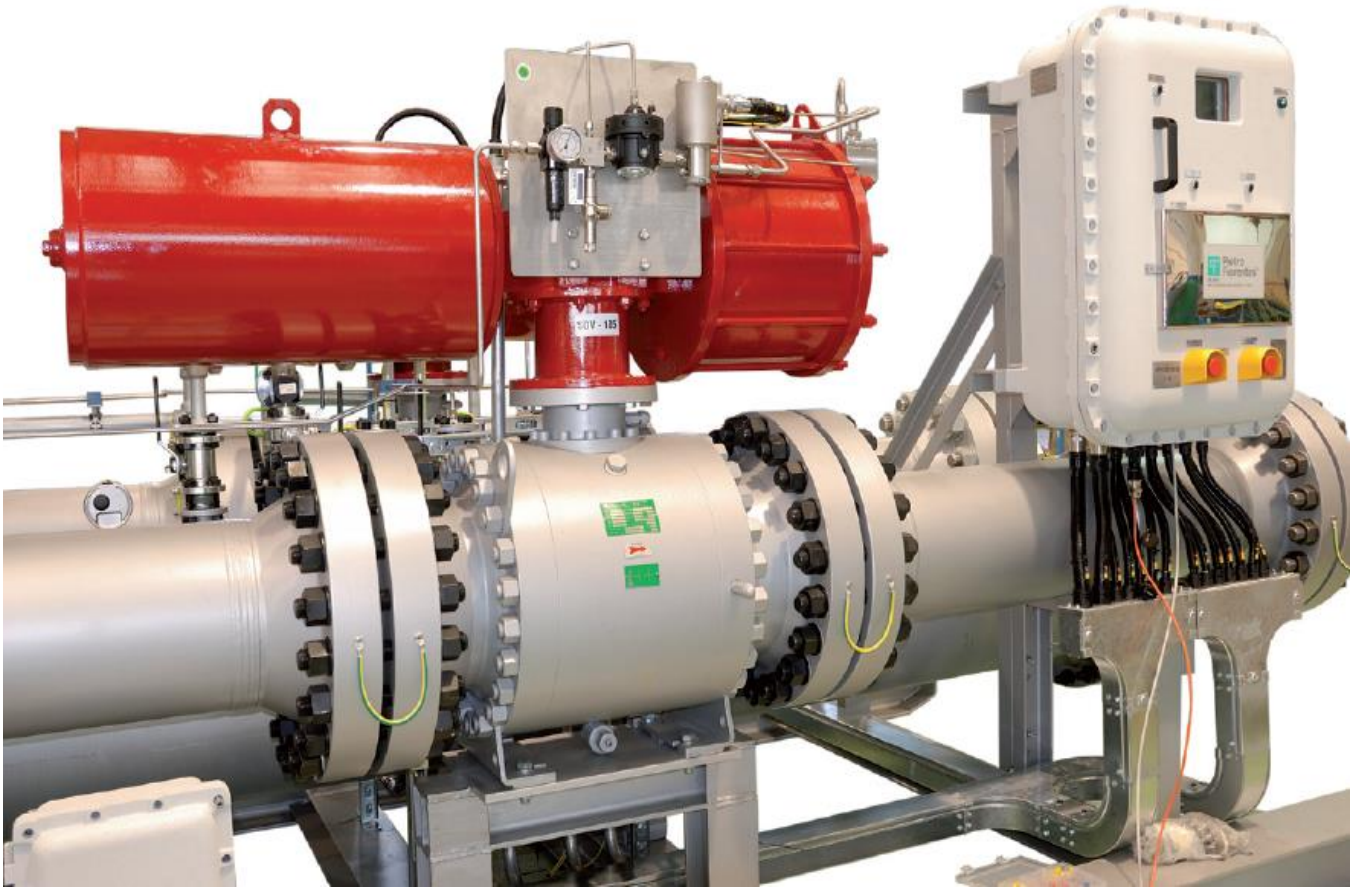
1. Introduction

A **high-integrity pressure protection system** (HIPPS) is a type of safety instrumented system (SIS) designed to prevent over-pressurization of a plant, such as a chemical plant or oil refinery. The HIPPS will shut off the source of the high pressure before the design pressure of the system is exceeded, thus preventing loss of containment through rupture (explosion) of a line or vessel. Therefore, a HIPPS is considered as a barrier between a high-pressure and a low-pressure section of an installation.

HIPPS is a mechanical and electrical system designed in order to reduce the chance that the system pressure will exceed the tolerable allowable pressure. The protection against over-pressure is obtained by quickly isolating the source causing the overpressure.

These systems are used in the oil & gas industries in order to provide pressure protection of pipelines, piping, vessels and process packages against over pressure, allowing the use of lower design pressure downstream the HIPPS.

Conventional design standards against overpressure are based on the use and the proper sizing of relief devices, such as relief valves.



The use of the HIPPS becomes the only feasible and practicable approach from a technical and commercial point of view, especially when:

- environmental restrictions and safety constraints limit the venting
- overpressure risk shall be reduced
- extremely high pressure and/or flow rate are involved
- sizing of relief device is difficult to define or inadequate due to chemical reactions, multiphase fluids or plugging
- on existing systems in order to avoid replacement of flare system when adding new units

2. Standards

With HIPPS the overpressure protection is achieved by reducing to a tolerable degree the risk that the pressure can exceed certain maximum levels. HIPPS design is governed by:

- IEC 61508: "Functional Safety of Electrical / Electronic / Programmable Electronic Safety Related Systems"
- IEC 61511: "Functional Safety: Safety Instrumented Systems for the Process Sector,"
- ANSI/ISA S84.01-1996, "Application of Safety Instrumented Systems (SIS) for the Process Industry,"

The objective of these standards is to define the assessment, design, validation, and documentation requirements for SISs. While these design standards are not prescriptive in nature, the design processes mandated by these standards cover all aspects of design including: Risk assessment, conceptual design, detailed design, operation, maintenance, and testing. Since HIPPS is a type of SIS, the requirements of these standards, as pertaining to each specific HIPPS application, must be investigated and applied thoroughly.

The SIS standards are performance-based with the Safety Integrity Level (SIL) as the primary performance measurement. The SIL must be assigned by the user based on the risk reduction necessary to achieve the user’s risk tolerance. It is the user’s responsibility to ensure consistent and appropriate SIL assignments by establishing a risk management philosophy and risk tolerance. The risk reduction provided by the HIPPS is equivalent to the probability of failure on demand attributable to all of the HIPPS devices from the sensor through the logic solver and final elements.

The SIL establishes a minimum required performance for the HIPPS. 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. Functional testing at specific intervals to determine that the device can achieve the fail safe condition;
4. Diagnostic coverage using automatic or 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.

Because the criteria used to establish the SIL affects the entire HIPPS's lifecycle, the SIL forms the cornerstone of the HIPPS design.

3. HIPPS vs Emergency Shut Down

HIPPS is an application-specific safety system to prevent over-pressurisation of a pipeline, and resultant damage to plant and equipment. It is the last line of defense in the event of an over pressurisation incident and should not be confused with an Emergency Shut Down (ESD) system. An ESD system provides a safe and orderly shutdown of a process. HIPPS is an emergency response to a pressure build-up rapidly closing the pipeline, the time of closure will be dependent on the protected volume. Once activated, the HIPPS will automatically shut off and isolate the source of the high pressure, before the design pressure of the system is exceeded, thus preventing an uncontrolled loss of containment. In effect HIPPS creates a barrier between a high-pressure and a low-pressure section of pipe.

4. Safety Requirement Specification

A Safety Requirement Specification (SRS) must be developed to address each overpressure scenario that will be addressed using HIPPS. The SRS describes how and under what conditions the SIS will mitigate each overpressure scenario, including a functional logic description with trip set points and device fail-safe state. Only those scenarios that can be successfully mitigated by the SIS can be considered for removal from the pressure relief and flare loading calculations. For example, in hydrocarbon applications, the fire case scenario often can not be removed from the sizing calculations due to the inability of HIPPS to mitigate

the cause of overpressure. When specifying the process performance of HIPPS, the process dynamics must be evaluated to ensure that the HIPPS response time is fast enough to prevent overpressure of the vessel. The response time must be evaluated by considering the time it takes to sense that there is an unacceptable process condition; the scan rate and data processing time of the logic solver; and initiation of the final element. For general process industry applications, HIPPS valves are typically specified to have closure times of less than five seconds. However, the actual required closure must be determined for each installation. The valve specification must include acceptable leakage rate, 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.

In addition to the safety functional requirements, the SRS also includes documentation of the safety integrity requirements, including the SIL and anticipated testing frequency. At a minimum, the target SIL for the HIPPS should be equivalent to the performance of a pressure relief device. Reliability information for a single-valve relief system is provided in “Guidelines for Process Equipment Reliability Data” by the Center for Chemical Process Safety.

The SRS must also specify exactly how the HIPPS will be configured to achieve the target SIL. The high availability requirements for HIPPS drive the choices made concerning device integrity, diversity, redundancy, voting, common cause concerns, diagnostic requirements, and testing frequency.

5. Device Integrity and Architecture

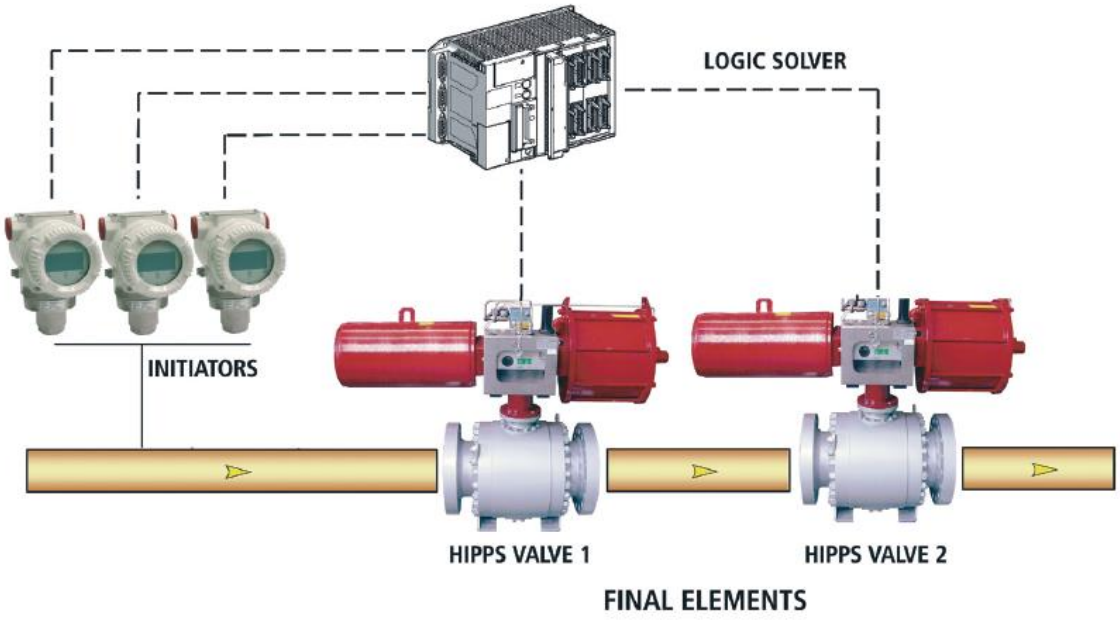
It is important to recognize that the HIPPS includes all devices required to reach the desired fail-safe condition for the process. The HIPPS includes the entire instrument loop from the field sensor through the logic solver to the final elements, along with other devices required for successful SIS functioning, such as SIS user 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 HIPPS availability. Since all devices used in HIPPS contribute to the potential probability of failure on demand for the HIPPS, the structure of the instrumented loop must be defined and

evaluated as a system so the entire loop meets SIL requirements. A brief discussion of SIS devices follows.

6. Components of HIPPS

A HIPPS is a complete functional loop consisting of:

- The initiators that detect the high pressure. These initiators may be electronic or mechanical.
- For electronic HIPPS, a logic solver, which processes the input from the initiators to an output to the final element.
- The final elements, that actually perform the corrective action in the field by bringing the process to a safe state. The final element consists of a valve and actuator and possibly solenoids or mechanical initiators.



The above schematic is a typical HIPPS architecture. The solver will decide based on 2-out-of-3 (2oo3) voting whether or not to activate the final element. The final elements consist here of two block valves that stop flow to the downstream facilities to prevent them from exceeding a maximum pressure. The components in the loop can vary according to customer specification and requirement.

7. Diagnostic

Diagnostic capability should be designed into HIPPS. The ability to detect failures of devices on-line significantly improves the availability of the HIPPS. 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 a work order for repair within the mean time to repair specified in the safety requirements specification. Maintenance procedures must also place high priority on repair of HIPPS devices.

8. Testing Frequency

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 a process demand occurs, often resulting in the unsafe event that the safety system was designed to prevent. Testing is performed for one reason, and one reason only, to uncover failures.

The appropriate testing of HIPPS is key to ensure that the availability requirements are satisfied. Architecture, redundancy, and device integrity have a significant effect on the probability to fail on demand and therefore testing frequency requirements. To determine the required testing frequency, quantitative risk assessment is the accepted approach by most Users. In general, all HIPPS components require a testing frequency in the range of 3 to 12 months. On-line and offline testing provisions should be provided to permit each device to be completely function tested. Any required bypasses must be managed through a change management process with appropriate access security.

Whatever the testing frequency, it is essential that the testing is performed throughout the safety system life. Any changes in the testing frequency must be validated by quantitative methods to ensure that the availability is not lowered to an unacceptable level.

9. Common Cause Failures

A common cause failure (CCF) occurs when a single failure results in the failure of multiple devices. To minimize common cause failures, the initiating causes of each scenario identified during the hazard analysis should be examined. Then, the HIPPS hardware and software should be designed to function independently from these initiating causes. For example, if a control transmitter is listed as an initiating cause to the scenario, the control transmitter cannot be the sole means for detecting the potential incident.

At least one additional transmitter will be required for the HIPPS.

Once independence of the HIPPS devices is demonstrated, common cause failures (CCF) related to the design must be examined. The following are often cited as examples of common cause faults:

- Miscalibration of sensors
- Fabrication flaws
- Clogging of common process taps for redundant sensors
- Incorrect maintenance
- Improper bypassing
- Environmental stress on the field device
- Process fluid or contaminant prevents valve closure

The most critical failure is that the SRS is incorrect at the beginning of the design process and the HIPPS cannot effectively detect or prevent the potential incident. Improper system specification can compromise the entire HIPPS.

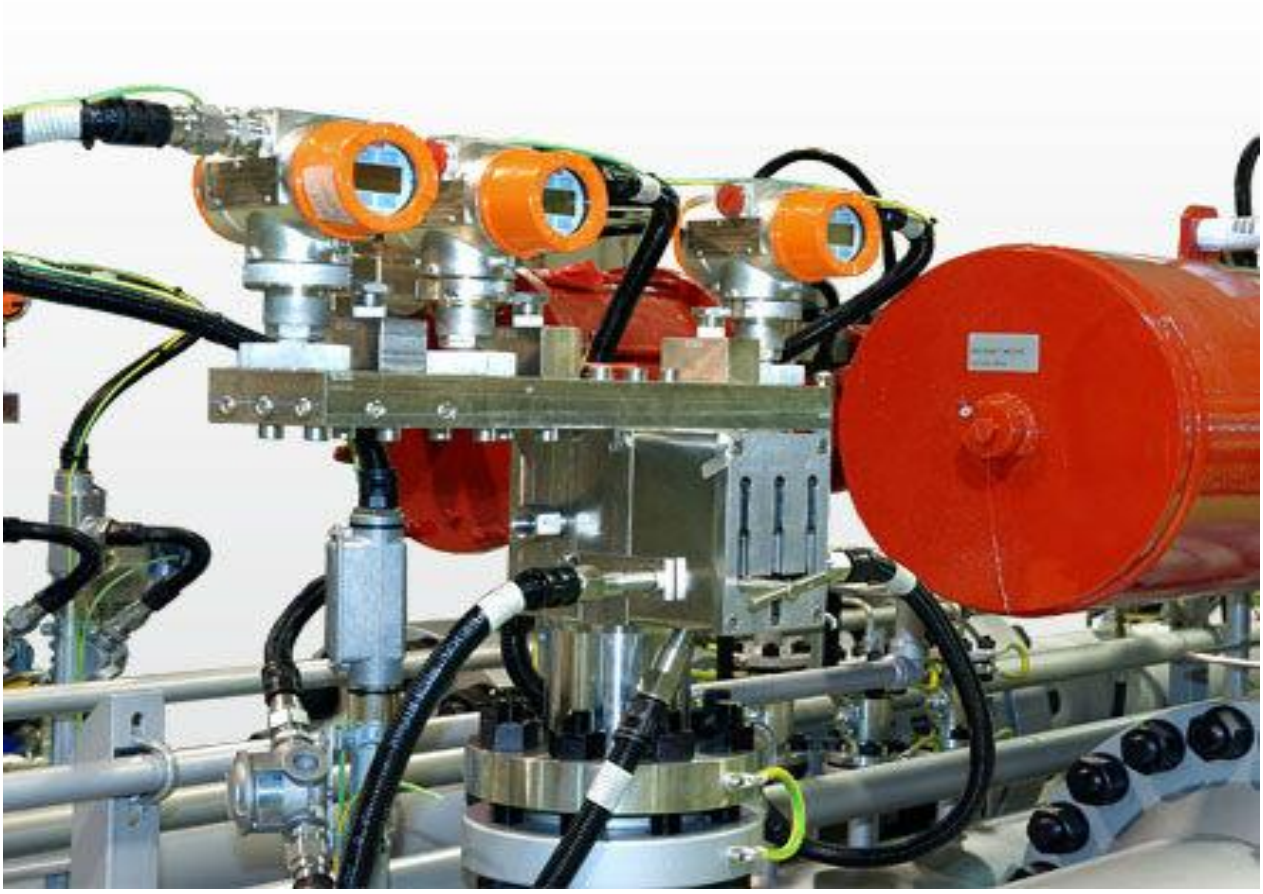
Industrial standards and corporate engineering guidelines and standards can be utilized to reduce the potential for CCF. The proposed or installed HIPPS design can be compared to these standards. Deviation from the standards can be corrected through design revision or documented to justify why this specific application has different requirements.

Checklists can also be used to reduce potential CCFs. A checklist analysis will identify specific hazards, deviations from standards, design deficiencies and potential incidents through comparison of the design to known expectations, which have been expressed as checklist questions.

In some cases, it may be necessary to consider the impact of potential common cause failures when verifying whether the HIPPS can achieve the target SIL. In such cases, the potential common cause failures will need to be considered in the quantitative performance evaluation.

10. Implementation and Commissioning

Implementation/commissioning activities must be performed within the bounds of the safety requirements specification and detailed design. Any deviations from these documents must be evaluated for impact on the safety integrity level and on any assumptions made with regard to performance.



11. Operate and Maintain

The HIPPS must be operated, maintained and tested throughout the life of the plant. The high integrity of HIPPS is often achieved through the use of frequent testing. Once the required testing frequency is determined for a particular HIPPS design, the testing must be performed at that frequency. If the SIL verification calculation states that the testing is to occur at a 6 month interval, it must be done at 6 months, not one year.

12. Advantages and Disadvantages of HIPPS

It is poor safety practice to install and rely on pressure relief devices in services where the sizing of the device is poorly understood or known to be inadequate due to chemical reactions, multiphase fluids, or plugging. In these applications, alternatives, such as HIPPS, should be examined to ensure mitigation of overpressure events.

Industry is increasingly moving towards utilizing HIPPS to reduce flare loading and prevent the environmental impact of pressure venting. They 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 HIPPS is attractive when compared to the downtime or equipment cost of flare modification. Another benefit is that the process unit will not flare as much as 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 flaring of process gases.

The main disadvantage of HIPPS is the careful documentation, design, operation, maintenance, and testing to ensure standard's compliance. Specific regulatory and enforcement jurisdiction requirements must 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 HIPPS must be thoroughly documented through a hazard analysis, which identifies all potential overpressure scenarios and demonstrates that the HIPPS can adequately address each scenario. The ability of the HIPPS to adequately address overpressure is limited by the knowledge and skill applied in the identification and definition of overpressure scenarios.

HIPPS systems are more complex, requiring the successful functioning of multiple devices to achieve the performance of a single pressure relief device. The user must verify that HIPPS will work from a process standpoint and that the HIPPS design results in an installation as safe or safer than a conventional design. The effectiveness of the system is highly dependent on the field design, device testing, and maintenance program. Consequently, the user must understand the importance of application-specific design aspects, as well as the associated costs of the intensive testing and maintenance program whenever a HIPPS is utilized. When a

pressure relief device is not installed or is undersized based on conventional design, the HIPPS becomes the “last line of defense,” whose failure potentially results in vessel rupture. Finally, there is no “approved” rubber stamp in any regulation or standard for the use of HIPPS for reduction in the size of relief devices and associated flare system for pressure vessels or pipelines. Substantial cautionary statements are made in the standards and recommended practices, concerning the use of HIPPS. No matter what documentation is created, the user still has the responsibility to provide a safe and environmentally friendly operation.

References

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