Understanding the Interrelationships Between the PSM Elements For Effective Implementation

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Abstract

Every element of PSM has a role in controlling risk. These elements have an interrelationship – each depends on the implementation of one or more elements for effective implementation. Some elements have a greater influence than others. Understanding these relationships is critical for building and sustaining effective PSM programs. This paper will show through figures and discussions, these interrelationships, key attributes of each element that influence other elements and how poor implementation of each element adversely affects the implementation of the other elements.

1 Introduction

The elements of process safety work together to control risk, each providing a level of safety management. Some elements help to ensure processes are designed using Recognized and Generally Good Engineering Practices (RAGAGEP) for process safety, including the proper hazard reviews to ensure processes are safeguarded against human error and equipment failures that can lead to loss of containment and employee injuries and fatalities. Some elements set standards for day-to-day operations – operate within the design specifications, review changes prior to implementation, maintain the safeguards and equipment, investigate near misses and incidents to improve any design or operational shortcomings. Audits provide a periodic assessment to identify overall management system weaknesses and make recommendations to improve program shortcomings and effectiveness.

The governing PSM elements are Process Safety Information (PSI) and Management of Change (MOC). These two elements have the greatest influence on the development and execution of the other PSM elements. Discussions around these elements will show their core relationships with all other elements followed by identification of key relationships between some other elements.

2 Relationship Between Process Safety Information and Management of Change

2.1 MOC Protects PSI

The Process Safety Information element documents the process safety design. It is the foundation for process safety. Ninety-nine percent of changes are changes to PSI (others being organizational changes, some facility changes and stand-alone procedural changes). MOC is the umbrella, protecting the process safety design **(Figure 1)**. Not only is current PSI needed to evaluate the technical basis and evaluate the risk of the change, the PSI that is changing due to the process change must be identified and must be updated to reflect the change.

Figure 1. Relationship Between MOC, PSI and Other PSM Elements

2.2 MOC Protects Other PSM Elements

When a process change is proposed and evaluated, the quality and thoroughness of the MOC review extends beyond the change itself. The implementation of a change will require identifying other elements of PSM that must be changed/updated. For example, if a new instrument is added to a process:

- Operating procedures must be updated with instructions for operating, monitoring, and troubleshooting the instrument, and should have a description of its process safety function
- Mechanical Integrity program must be updated. The instrument data sheets must be filed properly, inspection, testing and preventive maintenance program established and entered into the Computerized Maintenance Management System (CMMS) and spare parts ordered

- Training guides must be updated to include the instrumentation, safe operating limits, consequences of deviations, and troubleshooting guidelines
- All related design and specifications of the instrument must be filed properly in the specific PSI documents such as loop sheets, P&IDs, etc.

2.3 Day-to-Day Use of PSI

On a day-to -day basis plant staff relies on the PSI documents to make decisions concerning process changes. Therefore, if documents are not updated to reflect changes as they occur, eventually the process safety design documents will be out of date and future process change decisions will be made on outdated information. PSI is the basis for implementing all elements of PSM. Some examples where PSI is used:

- Standard Operating Procedures (SOPs) content
- Training materials for operators
- Emergency Response Plans
- Training for Contractors and Mechanics
- Establishing ITPM for Equipment and Instrumentation
- Conducting Process Hazards Analyses (PHAs)
- Conducting Incident Investigations
- Evaluating MOCs

2.4 MOC Procedural Step to Protect PSI

To keep PSI updated and accurate, a critical step in the MOC process is to identify all the documents associated with elements of PSM that require updating, to reflect the process change with respect to the PSI. Many companies' MOC systems lack a mechanism to help the MOC owner identify all documents that contain PSI to be updated. **Table 1, "Documentation Checklist,"** is an example list that identifies all the documents related to PSM implementation that may need updating to reflect a process change. However, identifying the documents is only the first step. This trigger list consists of documents that define PSI, and documents that support the implementation of other PSM elements or proof documents of implementation. [1]

Table 1. Documentation Checklist Used to Identify All Documents Impacted by A Process Change

Processing
- ☐ Operating Manuals
- ☐ Training Material
- ☐ Standard Operating Procedure(SOP)
- ☐ Standard Job Procedure (SJP)
- ☐ Asset Operating Procedure (AOP)
- ☐ Operating Best Practice (OBP)
- ☐ Operating Instruction (OPI)
- ☐ Department Policies
- ☐ Quality Manual
- ☐ Training records
- ☐ Process Description
- ☐ Product Specifications
- ☐ Refinery Energy Model
- ☐ Refinery Utility Capacity Report
- ☐ Loss of Utility Emergency Procedures
- ☐ Shift Log / Turnover Log
- ☐ Shift Schedule for Plant
- ☐ Shift Personnel List

Piping
- ☐ Steam & Trap Docs
- ☐ Pipe Specs
- ☐ Pipe rack drawings
- ☐ LX drawings
- ☐ Piping isometrics

Organizational
- ☐ Corporate and Refining Phone List
- ☐ Organizational Charts
- ☐ Outlook Distribution lists
- ☐ On-Call Schedule
- ☐ Vacation Schedule
- ☐ Cintellate Hierarchy
- ☐ Oracle Hierarchy

Technical-PTS
- ☐ Process Flow Diagrams (PFDs)
- ☐ Piping and Instrument Diagrams (P&ID)
- ☐ Safe Upper and Lower Limits
- ☐ Maximum Intended Inventories
- ☐ Evaluation of the Consequence of Deviations
- ☐ Material and Energy Balances
- ☐ Description of the process materials and process chemistry
- ☐ Hazard Effects of mixing two chemicals
- ☐ Design basis
- ☐ Control Narratives

Technical-PCG
- ☐ Safety systems
- ☐ Cause and Effect Matrices
- ☐ DCS Configurations
- ☐ Process Historical Data (PHD)
- ☐ Event Analysis
- ☐ Process Control Instructions (PCI)
- ☐ Process Control Program
- ☐ Computer Graphics
- ☐ Safety Requirement Specifications (SRS)

Risk Identification
- ☐ Blast Study
- ☐ Toxic Release Study
- ☐ HAZOP
- ☐ LOPA
- ☐ FMEA (RELI-139)
- ☐ PPM Record
- ☐ Safety Integrity Level (SIL)

Health, Safety & Environment
- ☐ Evacuation Routes and Strategies
- ☐ Emergency Response Manual (ER)
- ☐ Health & Safety Instructions (HIS)
- ☐ Process Safety Instructions (PSMI)
- ☐ Environmental Instruction (EMSI)
- ☐ Training database
- ☐ OH Manual
- ☐ C. of A. records
- ☐ Waste Characterization
- ☐ Disposal Permit
- ☐ Process Hazard Analysis Report
- ☐ MSDS

Civil
- ☐ Equipment Plot Plans
- ☐ Underground drawings

Instrumentation
- ☐ SIS Instrument Check Procedures
- ☐ JX,PX drawings
- ☐ Loop diagrams
- ☐ Instrument Datasheets
- ☐ AMS Files

Reliability
- ☐ Materials of Construction Drawings and Datasheets
- ☐ Design Codes and Standards
- ☐ Equipment Datasheets
- ☐ Vessel Drawings
- ☐ Fire water system drawings
- ☐ Underground Drawings
- ☐ Lubrication records
- ☐ Vibration Database Records
- ☐ Spare Parts
- ☐ PD-18
- ☐ Equipment specification sheets
- ☐ CMMS records
- ☐ Vendor information
- ☐ Asset Criticality Assessment (RELI 138)
- ☐ Design Calculations
- ☐ EWO/TWO
- ☐ Reliability Instruction (RELI)

Electrical
- ☐ E-MENU data
- ☐ Single-line drawings
- ☐ Electrical Area Classification Docs
- ☐ Heat Tracing Dwg.
- ☐ Heat Tracing Controller Settings
- ☐ Panel Schedules
- ☐ MCC Schematics
- ☐ Wiring Drawings
- ☐ Protection Device Parameter Update (Multilin)

Mechanical Integrity
- ☐ Radiography Documents
- ☐ Pump Bench Records
- ☐ Notes to Equipment Files
- ☐ PSV Documentation
- ☐ Inspection Piping Isometrics
- ☐ Material Test Report (MTR)
- ☐ Non-Conformance Report (NCR)
- ☐ Mechanical Integrity Instructions (MII)
- ☐ Quality Assurance Manual
- ☐ Vessel (drawings, inspection reports)

Maintenance
- ☐ Repair Procedures
- ☐ Open Issue List
- ☐ Basic Equipment Maintenance Plan
- ☐ Materials Mgt. Instruction (MMI)
- ☐ Maintenance Instructions (MNTCI)
- ☐ Repair Procedures

Document Control/Management
- ☐ *All IOR Instructions, Policies & Standards*

Documentum:
- ☐ Bill of Material
- ☐ Breaker Testing Records
- ☐ Calculations
- ☐ Canadian Registration Number (CRN)
- ☐ Certificate of Compliance
- ☐ Data Sheets
- ☐ Drawing (Engineering Drawing, Isometric Loop, P&ID, PFD, Plot Plan, Sketch)
- ☐ Drawing (Above Grade Piping, Absorber, Boiler, Building, Column, Compressor, Concrete, Contractor, Cooling Tower, Design Data, Drum, Electrical, Exchanger, Fin Fan Coil, Foundation, Furnace, Grading, Insulation, Misc. Mechanical Equipment, Paving, Piping Isometric, Pump & Driver, Reactor, Stripper, Structural Steel, Tank, Vessel, Underground Piping
- ☐ eAM Equipment Data
- ☐ Emergency Procedures
- ☐ Engineering Equipment Summary
- ☐ Engineering Work Order (EWO)
- ☐ Feed Package
- ☐ Forms
- ☐ Inspection Record
- ☐ Inspection Test Plan
- ☐ Install Op Maintenance Manuals
- ☐ Instructions
- ☐ Instrument Index
- ☐ Isometric
- ☐ Line List
- ☐ Manufacturers Data Reports
- ☐ Material Testing Report (MTR)
- ☐ Parts List
- ☐ Performance Curves
- ☐ Principles & Philosophies
- ☐ Process Design Data
- ☐ Project PEP, PPM
- ☐ Quality Plan
- ☐ Refinery Application Manual
- ☐ Sketch
- ☐ Specifications
- ☐ Studies and Technical Reports
- ☐ System Turnover Books
- ☐ Technical Memorandum
- ☐ Unit Operating Procedures
- ☐ Vendor – Weld Procedures, Test Reports, Procedures and Drawings
- ☐ Catalogues, Vendor Data
- ☐ PSMI 201
- ☐ Datasheets – Equipment, Instrument, Material of Construction and Datasheets
- ☐ Drawings – Firewater, Loop, Piping & Instrument, Process Flow, Single Line Electrical, Underground, Vessel
- ☐ Electrical Area Classification
- ☐ Inspection Piping Isometrics
- ☐ MSDS
- ☐ Safety Systems/Cause and Effect Matrices
- ☐ Toxic Release and Blast Studies
- ☐ Vendor Data – Process Material, Process Chemistry, Hazardous Effects of Mixing Two Chemicals

3 Relationship Between Process Safety Information and Other Elements

As mentioned previously, MOC protect the process safety design based on PSI, PSI is the foundation of process safety. Defined as chemical, technology and equipment information, this information defines all aspects of the process design – including process safety. Each category of PSI is utilized in a variety of ways to meet PSM implementation. **Figure 2** shows PSI's strongest relationships.

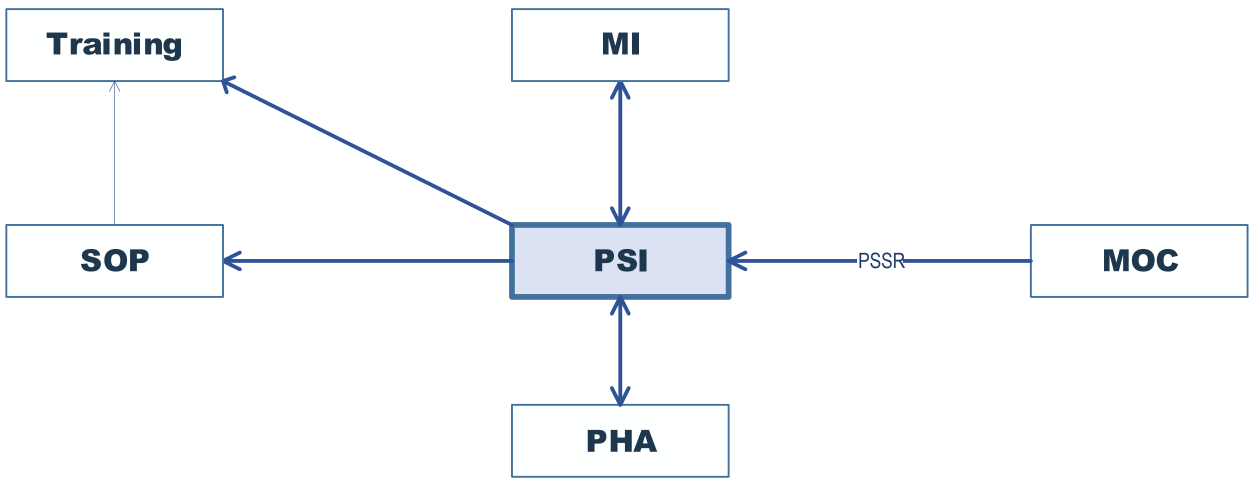

Figure 2. PSI's Strongest Relationships

3.1 Chemical Information

Chemical Information consists of physical properties and safety hazards of the chemicals, chemical reactivity and incompatibility hazards. Understanding the nature of the chemicals in storage or under process conditions (reactivity, corrosivity, thermal and chemical stability) is a critical component for equipment specifications, worker exposure hazards (toxicity, permissible exposure limits) and process safety hazards. The hazards of inadvertent mixing are necessary for managing process safety hazards of certain operational tasks where the incompatibles could possibly make contact. Some of these activities include:

- Raw material storage
- Raw material unloading
- Equipment cleaning
- Operation of multi-use equipment
- Maintenance
- Relief systems
- Berms/Sumps
- Chemical Sewers
- Waste Storage

- Product storage

3.1.1 Chemical Information Used in Implementation of Other Elements

PHAs – Inadvertent mixing is a potential cause of parametric deviations resulting in a process safety consequence of interest, requiring safeguard evaluation such as process design to minimize interactions along with evaluation of human error prevention, and detection and mitigation safeguards of inadvertent mixing. The continuous HAZOP deviation “high concentration of contaminants” typically identifies any incompatible chemicals and typical causes are equipment failures centered around the activities listed above including human errors with equipment operation (skipping steps and performing steps incorrectly). If inadvertent mixing data is missing or outdated, then these scenarios will be missed during the PHA. Incompatibilities may also be identified during parametric deviations such as “high temperature” and “high pressure” as incompatible materials may generate exothermic reactions and increased pressure.

Chemical information is also necessary during PHAs to estimate the severity and type of the consequence based on physical properties, toxicity and flammability.

SOPs and Training - Steps to avoid inadvertent mixing, if a concern, are incorporated into SOPs as warning statements and these steps are evaluated during the PHA of non-routine modes of operation for continuous processes and for batch procedures, to evaluate if steps skipped or performed incorrectly could possible lead to inadvertent mixing with process safety consequences. If so, then steps requiring human intervention are needed and information on how to avoid inadvertent mixing. During the PHA, evaluating how the operator would know they have made a mistake (such as how quickly the process responds to such errors and how the process is instrumented/alarmed to alert the operator of the deviation such as high temperature, high pressure, high level, etc.) is critical and this information must be incorporated into useable information in the SOP and in training guides.

MOCs - Chemical properties and inadvertent mixing information are used in the evaluation of MOCs from a technical basis and a process safety basis to ensure changes do not introduce incompatibility issues (for new or existing chemicals) with the existing or new process equipment, and that equipment configuration changes and SOP changes do not introduce inadvertent mixing potential. Materials of construction and other equipment design information must be reviewed along with the process operating conditions and chemical properties to ensure the process is designed for the interactions between chemicals, operating conditions and equipment specifications.

Mechanical Integrity – As mentioned under MOCs in the previous paragraph, a thorough MOC review will include understanding the impact of any chemical related changes, operating conditions and compatibilities with existing or proposed equipment. Of course, as part of the MOC process the impact of the change on other PSM management systems are identified. For

Mechanical Integrity (MI), evaluating whether increased inspections and testing or different testing protocols should be established based on anticipated corrosion rates, for example, and other mechanical issues that a new chemical or a new chemical in conjunction with process operating conditions can have on equipment must occur, and how the inspection testing and preventive maintenance will be impacted.

Safe Work Practices/Contractors – Contractors perform a variety of maintenance tasks on equipment containing highly hazardous chemicals. Chemical information is used when assessing the hazards associated with maintenance work such as performing Job Safety Analyses, completing work permits such as hot work, confined space entry and lock out/tag out. Maintenance procedures also contain information on chemicals.

Incident Investigations – With incident investigations all aspects of the work being performed when the accident occurred are analyzed. With many process safety incidents highly hazardous chemicals are released resulting in employee exposure, injuries and death, and equipment damage and environmental damage. Chemical information is one part of PSI that is needed to help determine the sequence of events and the potential impacts (in cases of near misses).

Emergency Planning and Response – Emergency responders use chemical information to determine PPE requirements, treatments for employee exposures who may be injured by the chemical release and for how to mitigate and clean up the release.

Audits – Auditing includes analyzing every element of PSM to ensure information and requirements for regulatory, industry and corporate standards are included in the management system governing the element. Auditing Chemical Information includes reviewing documents defining the chemical information such as summary of properties and hazards, SDS availability and hazards of inadvertent mixing documents.

Trade Secrets – Trade secrets can contain chemical information in the descriptions of the process technology, process chemistry descriptions and volumes.

3.2 Technology Information

Technology Information comprises the topics listed below:

Block Flow Diagram – Shows major process equipment, the inlet and outlets of process materials and how they interconnect throughout the process equipment. More complex diagrams, often called Process Flow Diagrams also show process operating conditions.

Process Chemistry – Defines raw materials, intermediates, products, byproducts, any purge gases, chemical equations, exothermic and endothermic conditions.

Maximum intended inventory – Is the maximum amount of PSM chemicals inventoried in storage tanks, feed tanks, in-process equipment and product storage vessels. This quantity is typically expressed in a usable, relative unit (such as pounds, kilograms, or volumes as opposed to a percentage of tank/vessel volume).

Safe Upper and Lower Process Parameter Limits – In PHAs the consequences of deviating from normal operating conditions is documented. The safe upper and lower limits are derived from the equipment design and from process chemistry. Safety systems set another tier of safety limits, establishing alarm set points and safety shutdown set points to keep the process from exceeding the equipment design limits. This information is related to safety systems, including relied system design and design basis, process chemistry and equipment design information.

Evaluation of Consequences of Deviations (CODs) – COD is a summary of quantities and materials released under specific conditions and the resulting impact of the release (health impact on employees and the size of the release (limited to release point area, impacts plant site, or off-site consequences). This information is documented in the PHA corresponding to specific process deviations, causes and safeguards. As part of the PHA, the team identifies how the consequence is detected (detection safeguards) and identifies the administrative and engineering controls to mitigate the potential severity of the consequence.

3.2.1 Technology Information Used in Implementation of Other Elements

PHAs – The PHA team collectively uses chemical, technology and equipment information to identify and evaluate the process hazards. Technology information and the other parts of PSI are needed to identify process deviations, causes, consequences and safeguards. This piece of PSI is dependent on the PHA process and other PSI necessary to conduct the PHA and specific to CODs, equipment design information, process chemistry, maximum intended inventory, operating conditions, safe operating limits, chemical hazards, and safeguards identifiable within safety systems documentation (cause and effect diagrams, firefighting equipment, emergency deluge systems, scrubbers), and P&IDs that show all equipment, instrumentation and the interconnectivity.

SOPs – SOPs contain all Technology Information to some degree. Chemistry Information, chemical amounts, safe operating limits and the consequences of exceeding those limits are collectively incorporated into the action steps to complete the process operations. Warning statements about CODs (exceeding safe operating limits), and additional information concerning safety systems (alarms, operator responses and safety shutdown systems) are important process safety information housed in SOPs, often in the troubleshooting guide section.

Training – Operators' understanding of process parameters, their limits, causes, resulting consequences, equipment design, operator response and automatic responses (safety shutdown systems) is imperative to an effective risk management system.

MOC – Many process changes involve process chemistry, chemical inventories, the resulting safe operating limit changes and the consequences of deviations. The MOC process evaluates these aspects of the process to ensure engineering and administrative controls are adequate or added and all aspects of other PSM elements are updated as a result of the change.

Mechanical Integrity - To establish inspection testing and preventive maintenance program to maintain the ongoing integrity of the equipment, the equipment design information is needed –

design limits, materials of construction; process chemistry and process operating conditions and the design and function of instrumentation and controls and shutdown systems.

Safe Work Practices / Contractors – Applicable Technology information is part of the contractor training program and in applicable procedures they may use on site to perform their work.

Incident Investigation – Incident investigators piece together the sequence of events that actually occurred. The team uses defined PSI to understand how the process deviated from normal to identify potential equipment failures and human errors, that if eliminated, would have stopped the chain of events. Understanding information from PFDs, process chemistry and safe operating limits is necessary for building the sequence.

Emergency Planning and Response - Emergency planners use all of the Technology Information in addition to PHA scenarios (which are developed in part from Technology Information) to develop emergency response scenarios – how to respond based on the chemical released under specific operating conditions and the amounts released. **Evaluation of Consequences of Deviations** information is needed to determine PPE requirements for workers in the area, necessity for escape PPE such as 5-minute escape respirators, shelter in place procedures, evacuation procedures for the plant and/or community and for emergency response procedures – how to respond and mitigate the release.

Auditing – Auditing includes analyzing every element of PSM to ensure information and requirements for regulatory, industry and corporate standards are included in the management system governing the element. Auditing Technology Information includes reviewing process chemistry documents, safe operating limit tables, CODs (often presented together due to their relationship), and chemical information including auditing numerous other PSM elements to ensure consistency, such as reviewing SOPs, where the PSI listed above is required content. Some companies, in their PSI manuals, point to the SOPs for this PSI to eliminate outdated discrepancies between copies of the same information located in two places. PSI auditors look for consistencies and inconsistencies across PSM implementation documents that share the same information. Skilled auditor knows the interrelationships between the PSM elements and uses that information for a thorough audit.

Trade Secrets – Trade secrets can contain Technology Information - the chemicals and volumes, process flows (PFDs), chemistry, and operating conditions.

3.3 Equipment Information

Equipment Information – Equipment information exists in specification sheets, U1As, data sheets for pumps, tanks, pressure vessels, instrumentation and includes materials of construction, thickness of materials, dimensions, volumes, nozzles and other connections, pressure and temperature ratings; for piping information such as schedule, diameter, connection information (flange information), materials of construction, piping support information and for pumps information such as pump type (positive displacement, centrifugal), inlet and outlet size, head pressure, etc. Instrumentation specifications are also part of equipment information.

**P&IDs - ** A piping and instrumentation diagram (P&ID) shows the interconnection of process equipment and the instrumentation used to control the process along with the following information: [2]

- Process piping, sizes and identification, including: pipe classes or piping line numbers, flow directions, interconnections references, permanent start-up, flush and bypass lines
- Mechanical equipment and process control instrumentation and designation (names, numbers, unique tag identifiers), including: valves and their identifications (e.g. isolation, shutoff, relief and safety valves), control inputs and outputs (sensors and final elements, interlocks), miscellaneous - vents, drains, flanges, special fittings, sampling lines, reducers and increasers
- Interfaces for class changes
- Computer control system
- Identification of components and subsystems delivered by others [3]

Electrical Classification - The National Electrical Code (NEC) defines hazardous area classification as those areas "where fire or explosion hazards may exist due to flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings." Electrical classification defines the design of electrical and other equipment necessary to prevent ignition sources where flammables or combustibles are present. [4]

Relief System Design and Basis - Describes the pressure relief system whose purpose is to control or relieve excess pressure. Relieving devices include rupture discs, relief valves, conservation vents, and others. The basis for the excess pressure is also documented such as the following scenarios - runaway reaction, blocked flow, external fire, and loss of power. Documents include the calculations defining set relieving pressure and capacity of the device, and orifice information. Design information also includes inlet size and outlet size of the relieving device, the inlet and outlet piping, whether the relief is to an open or closed system (involving knock out vessels and flares).

Ventilation System Design – Ventilation system information refers to ventilation related to process safety such as for buildings containing process equipment, fan sizes, exchange turnover rates, information on systems activated to maintain electrical classification in the event of a release, and also information for positive pressure control panels, etc. Other ventilation equipment includes shelter-in-place buildings and ventilation systems for toxic chemical storage and processing.

Codes and Standards – Refers to the design and construction industry codes and standards used for the process equipment and systems. These are found on equipment specification and data sheets, in design calculations and equipment fabrication drawings.

Safety Systems – Safety systems include for example, location of eye washes, safety showers, emergency stops, emergency scrubbers, deluge systems, emergency flares, relief devices and piping, process parameter alarms, interlocks and emergency shutdown systems, detection systems, and emergency isolation valves.

Material and Energy Balances (M&EB)– An understanding of material and energy balance information is needed to properly evaluate PHA scenarios, evaluate MOCs and is input for consequences of deviations with respect to amount of chemicals released in what phase at different points in the process. M&EB information is also needed for proper equipment sizing and design specifications.

3.3.1 Equipment Information Used in Implementation of Other Elements

PSI – Equipment Information is used to develop other pieces of PSI such as safety system information (cause and effect diagrams), PFDs, maximum intended inventory, for example.

PHAs – PHAs use P&IDs to divide the process into sections or nodes for hazard identification and analysis. Up to date P&IDs are critical for scenario development. Along with Chemical and Technology Information, process deviations (high temperature, high pressure, low level…) are defined and the **CODs** are developed based on the equipment, material and energy balances, properties of chemicals released, operating conditions, maximum intended inventory and other information. P&IDs summarize many parts of the above information. Causes are also identified by P&IDs and SOP information. **Table 2** summarizes the PSI used to identify and analyze parts of PHA scenarios. Safeguards are also determined in part based on instrumentation and controls shown on P&IDs, relief system information shown on P&IDs, relief system documentation and other safety system information. P&IDs provide physical sequences of process equipment and auxiliary equipment, instrumentation and control, and their interconnectivity, all necessary to complete a PHA analysis

Table 2. Examples of PSI Used to Identify and Analyze Parts of PHA Scenarios

Deviation	Cause	Consequence	Safeguards	Recommendations
P&IDs SOLs Equipment Information	P&IDs Equipment Information Chemical Information Chemistry	Chemical Information Equipment Information Operating Conditions Maximum Intended Inventory Material and Energy Balances	Safety Systems – Cause & Effects, Detection Systems, Mitigation Systems Relief Design Information P&IDs ITPMs	All PSI as applicable

SOPS - This information occurs in the SOP content as an overall description and as applicable in warning statements and troubleshooting guides. To write procedures an understanding of process flows, control equipment and safety information is needed, all information shown on P&IDs.

Training – Operators require an understanding of process flows, the size and other design specifications of equipment including safety systems (instrumentation, shutdown systems, relief systems and other mitigative equipment**).**

MOC – PSI is used to evaluate process changes for quality, cost and safety impacts. Additionally, the MOC process reviews proposed changes to PSI. If process safety information is not kept up to date, then future MOC evaluations will be based on PSI that does not reflect the current process resulting in possible safety, quality and operability issues. Depending on the change, a variety of PSI must be evaluated. However, P&IDs must be modified in the majority of equipment and process changes and are redlined to show the proposed change and once the change is approved, as with other PSI, P&IDs must be permanently modified as they summarize the design of the current process.

MI – Equipment design information including instrumentation and controls, P&IDs, and other Chemical and Technology information is needed to establish inspection testing and preventive maintenance plans and for maintenance procedures content.

Contractors/Safe Work Practices – Contractors perform work on equipment. Procedures and training, including safe work practices, inherently include equipment information.

Incident Investigations - Incident investigators piece together the sequence of events that occurred. The team uses defined PSI to understand how the process deviated from normal to identify potential equipment failures and human errors, that if eliminated, would have stopped the chain of events. Understanding information from equipment specifications, safety systems and material and energy balances is necessary for building the sequence of events, for identifying causal factors (equipment failures and human errors, negative events, that if prevented would have stopped the chain of events or lessened the severity of the outcome) and for identifying root causes (management system weaknesses).

Emergency Planning and Response - Emergency planners use Equipment Information, in addition to Chemical and Technology Information and PHA scenarios (which are developed in part from Equipment Information) to develop emergency response scenarios – how to respond based on the chemical released and size of the equipment (chemical amounts that could be released under specific operating conditions).

Audits – Auditing includes analyzing every element of PSM to ensure information and requirements for regulatory, industry and corporate standards are included in the management system governing the element. Auditing Equipment Information includes auditing numerous other PSM elements to ensure consistency, such as reviewing SOPs, where some PSI listed above will be in the content, reviewing other parts of PSI that are related to specific pieces of equipment – P&IDs, COD tables and Cause and Effect Matrices, etc. Some companies, in their PSI manuals, point to Mechanical Integrity files for this information to eliminate outdated discrepancies between copies of the same information located in two places. PSI auditors look for consistencies and inconsistencies across PSM implementation documents that share the same information. Skilled auditor knows the interrelationships between the PSM elements and uses that information for a thorough audit.

Trade Secrets - Trade secrets can contain Equipment Information - the equipment design, P&IDs, safety systems and material and energy balances.

4 Other Key Relationships Between the Elements and How to Use Your Understanding of the PSM Element Interrelationships to Strengthen PSM

As described in Section 2, MOC and PSI have the strongest interrelationships with all the elements. Section 3 provided examples of how specific PSI is used in implementing all PSM elements and within that discussion the role of the MOC system was highlighted:

- Up-to-date PSI is needed to evaluate technical basis and evaluate process safety risk for proposed process changes
- MOC process must ensure PSI gets updated as part of change management

The summary below highlights other interrelationships between elements beyond MOC and PSI.

Employee Participation – It is vital that operators and mechanics participate in the development and implementation of the PSM elements. This results in the staff taking ownership of the elements and provides a better understanding of their role in implementing each element.

PSI – Understanding that PSI is used to some degree in the implementation of all elements, provides the framework for ensuring PSI is managed properly. Incomplete and outdated PSI clearly results in weak overall PSM. MOC is the mechanism to ensure PSI is kept updated along with identifying the other elements of PSM that must be updated as a result of PSI changes. Failure to identify process changes will subsequently result in outdated PSI and impact the evaluation of process safety risks during the MOC review and approval process. Some PSI is built on other PSI. Chemistry and equipment information are needed for material and energy balances and this information is used to create P&IDs, establish SOLs and define safety systems, some of which are summarized on Cause and Effect Diagrams. **Figures 3 and 4** show how PSI impacts other parts of PSI, PHAs, MI, SOPs and Training.

PHAs – PHAs should not be performed unless complete, updated/current **PSI** is available. Expending the resources to conduct a PHA on a process that does not exist occurs when P&IDs are not up to date, safety system information, and material and energy balance information are unavailable or inaccurate. This results in scenarios that are poorly defined and risks that are under estimated, for example, taking credit for safeguards that do not exist or that are not designed to protect against the applicable hazard scenario. Using the results from PHAs is necessary to meet required **SOP** content requirements (consequences of deviations, supplements troubleshooting guide information on how to detect, avoid and correct process deviations) and to develop **Training** guides. Furthermore, CODs contain consequences identified and evaluated during the PHA and any updates to alarms and interlocks (human and system responses). Entries from the Cause and Safeguard columns are extracted for troubleshooting guide information. **Mechanical Integrity** program uses PHA results to prioritize maintenance activities, based on the importance of certain safeguards to detect, prevent, intervene and mitigate process safety scenarios. During revalidations **MOC**s and **incident reports** are reviewed. If these are poorly evaluated and/or poorly documented then the PHA revalidation team must spend more time to discuss each and the quality of these reviews will be negatively impacted given lapses in time since their occurrence and changes in staffing, meaning vital information to process safety may be forever lost.

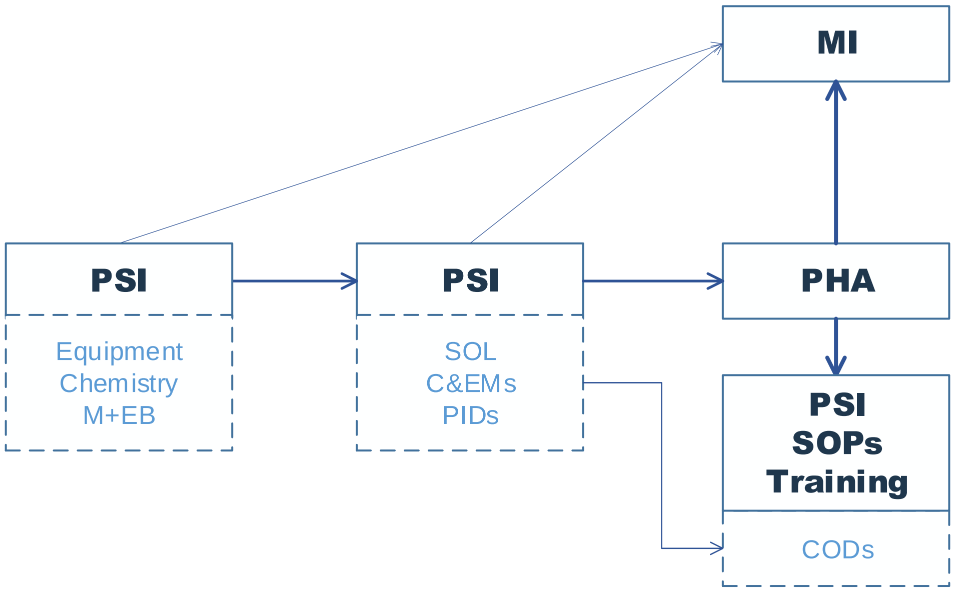

Figure 3. Relationship of Specific PSI to PHAs, MI, SOP and Training

SOPs and Training – As shown in **Figure 4,** SOPs rely on PSI and PHA results to be complete and accurate. SOPs and PSI are the building blocks for **Training.** Weak implementation of PSI, PHA and SOPs ultimately impact Training.

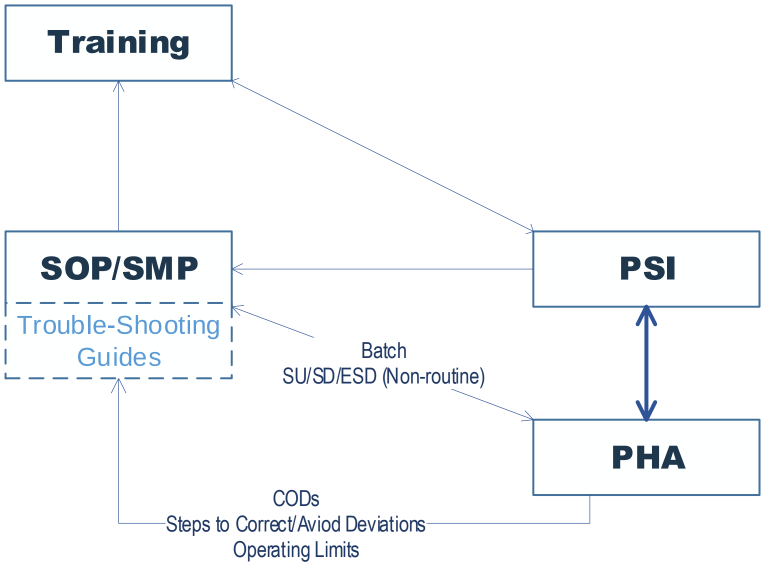

Figure 4. Relationships between PSI, PHA, SOPs and Training

Mechanical Integrity – Mechanical Integrity program exists to protect the design specifications and integrity of the process equipment. Up-to-date, well documented design information on equipment (part of **PSI**) is necessary for evaluating process changes, necessary for the hazard identification and analysis – how equipment can fail, to establish safe operating limits. If equipment is not maintained, then its operability and safety design can be compromised. Based on the equipment type, materials of construction, chemical service and operating conditions, inspections and testing and preventive maintenance plans (ITPMs) are developed. The other part to MI is quality assurance with respect to installing equipment that meets design specifications, and includes equipment designed for the service intended, procuring the correct equipment, fabrication of equipment, receiving the correct equipment, storage and retrieval systems, installation (instructions for maintenance techs, adequate procedures and training, tools and equipment), and operating within safe operating limits. ITPMs' test results and reporting near misses and incidents can identify mechanical integrity deficiencies. Deficiencies must be corrected or process changes (as a result of the deficiencies or continuing to operate with the deficiency) must be evaluated and approved. **Figure 5** summarizes the MI role.

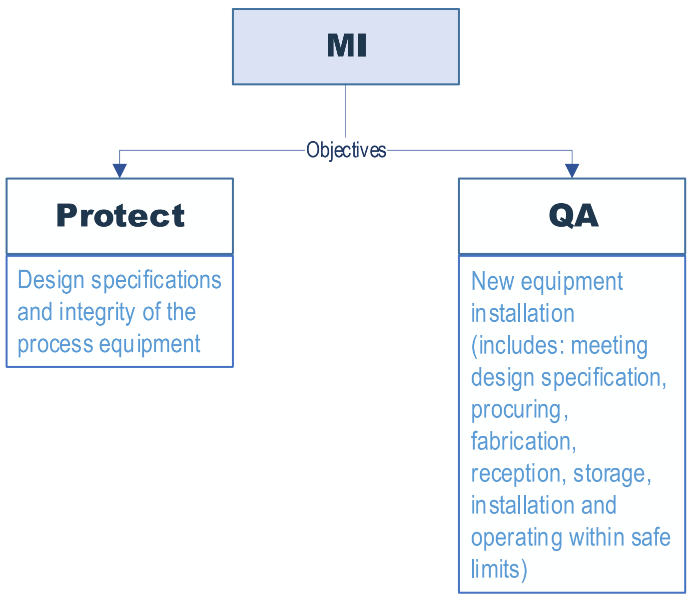

Figure 5. Role of Mechanical Integrity

5 Moving Forward

Figure 6 shows the overall relationships between the elements, and also shows some elements missing from OSHA's PSM program that are not discussed in this paper (leadership and accountability, key performance indicators and human factor optimization). Ensuring PSI is complete and accurate before start up, during the PHAs, and for use in MOC evaluations, and that subsequent changes to PSI and other PSM elements are updated to reflect process changes, are key to an effective PSM program. Understanding the interrelationships between the elements helps identify all information and documents impacted by a change (defining PSI and other implementation documents such as MI plans, SOPs, Training, Emergency response…) in the MOC process. Otherwise, the day-to-day implementation of all the elements will be weakened as all depend on PSI as their foundation. Some elements also strongly depend on other elements to be effective. Poor implementation of PSI, MOC and other inputs results in some degree of weakness in every element, leading to ineffective process safety risk management.

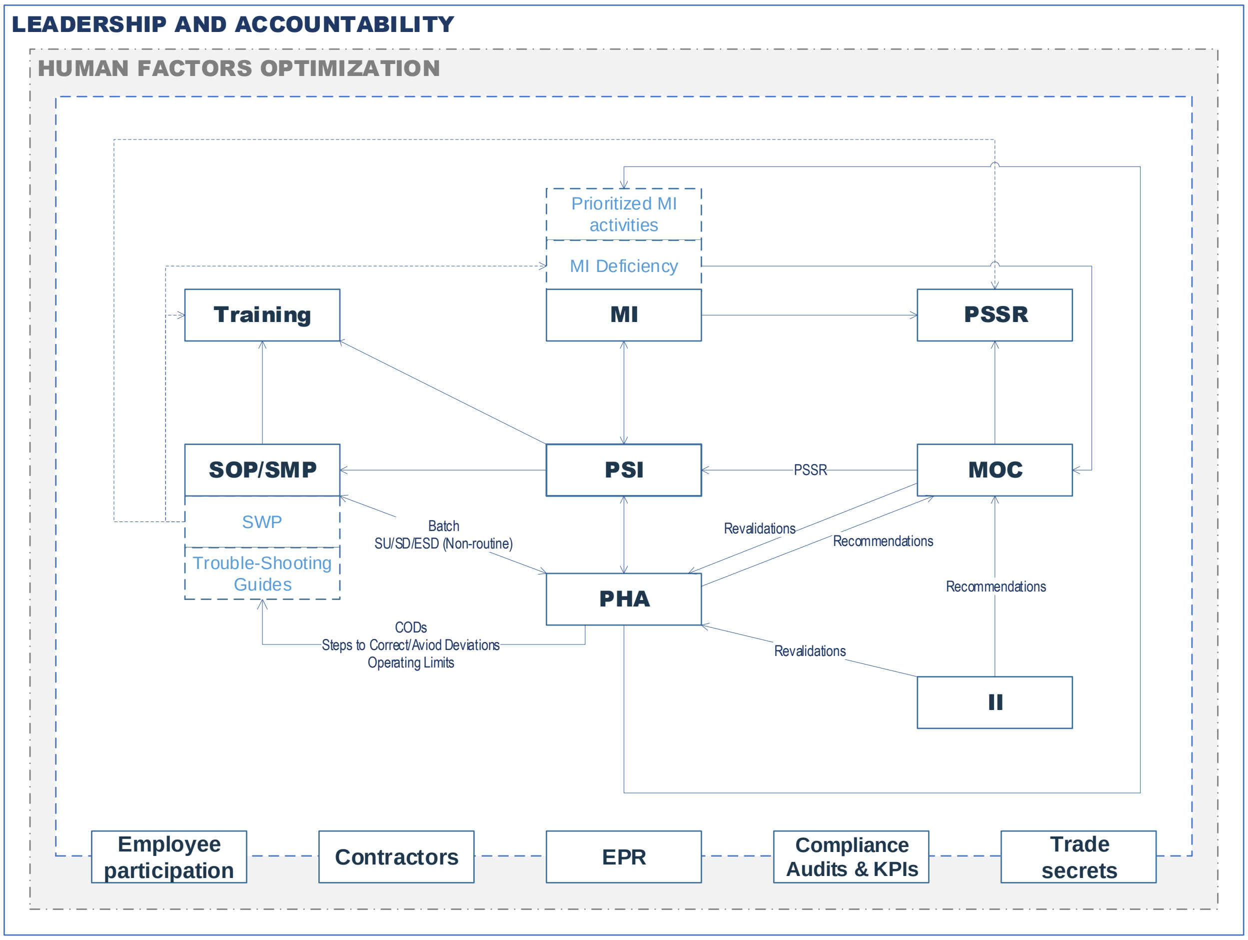

Figure 6. Interrelationships of PSM Elements

6 References

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