Practical Implementation of Safety Management Systems at Unregulated Upstream Oil & Gas Facilities

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Abstract

Upstream oil and gas facilities are typically exempt from the OSHA Process Safety Management (PSM) standard; however, in light of recent regulatory scrutiny on the safety of upstream operations, many operating companies have extended their safety management programs to their upstream facilities creating challenges for implementation. Many of these facilities have been operating without significant incidents for many years without proper Process Safety Information, Process Hazard Analyses, Management of Change programs, etc. making the challenge of accepting and implementing these programs difficult to embrace. This paper is focused on providing insights and practical tips for the implementation of safety programs at upstream facilities to enhance the commitment to implementing process safety with limited resources.

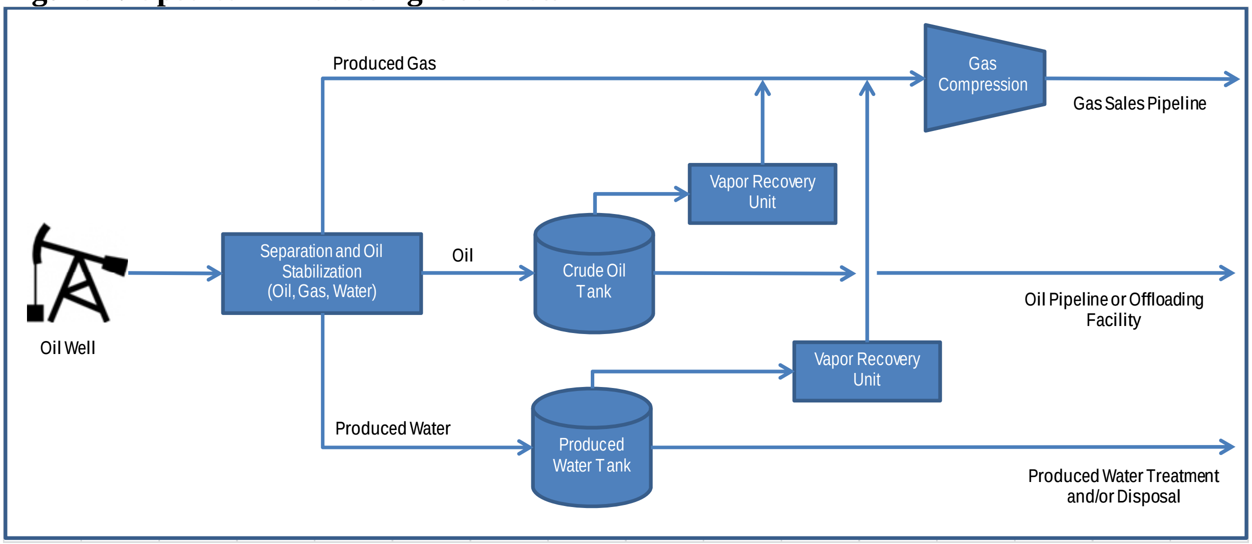
1. Introduction

Numerous facilities process and store highly hazardous materials, both toxic and flammable, below the PSM regulatory threshold. While these facilities are not required to comply with the rigorous requirements of PSM, because these facilities process highly hazardous materials they still have a responsibility to identify hazards associated with the process and ensure the facilities are designed, operated, and maintained to minimize hazards. In order to meet this objective, many facilities have elected to implement PSM elements at the unregulated facilities.

For example, upstream oil and gas facilities with over ten thousand pounds of hydrocarbons meeting the definition of flammable liquids or gases (e.g., with a flash point below 100 F) are subject to the OSHA PSM standard, with several exemptions; however, many upstream oil and gas facilities do not meet this requirement and are therefore not covered under the standard. These upstream facilities are typically geographically dispersed and include facilities within each area for collecting oil from one or more oil well and separating produced oil, gas, and water.

Additional processing may be completed within the area or the products may be exported for further treatment and/or processing. This results in numerous nearly identical facilities throughout the geographical area that have the same functional design. Figure 1 below provides a simplified overview of upstream oil production.

Figure 1. Upstream Processing Overview



This paper gathers insights from working with companies with upstream operations of various sizes and complexity to provide guidance for organizing and managing the safety management system (both organization and recommendation tracking), as well as specific tips for the following PSM elements:

- Process Safety Information
- Process Hazard Analysis
- Operating Procedures

2. Safety Management System Management

2.1 Organization

PSM program responsibilities extend to various disciplines at the facility, including operations, maintenance, engineering, instrumentation, safety, etc. With numerous stakeholders managing their respective portion of the program it can become difficult to ensure the program is properly implemented and requirements can slip through the cracks. Designating a specific individual or group to be responsible for the overall management of the PSM program provides centralized focus; however, it is also important to have coordination between all disciplines to support the implementation of the program. Some of the most successful PSM programs have support from management at the top and are implemented from the bottom-up, with process safety being embraced as part of the daily duties of all personnel. For example, the Operations Department utilizes the Operating Procedures on a daily basis and as Operations identifies opportunities for improvement and implements changes, the documentation is then updated and coordinated with the PSM Manager. The coordination between the specific departments and the PSM Manager is key to ensuring effective implementation of the program. Thus, it is imperative to have a clear structure in place with defined responsibilities and systems in place to foster coordination among different department.

2.2 Recommendation Tracking

Recommendations are the result of various safety management system studies, including Process Hazard Analyses, Incident Investigations, and Compliance Audits. However, due to the volume of data to process from numerous facilities and studies, recommendation tracking and closure presents one of the most difficult tasks for companies with limited manpower resources. The mechanism to track recommendation closure is left to the discretion of the company and varies a wide spectrum - from simple spreadsheets to customized software solutions. While the specific tool utilized to track the data can streamline the overall management process, the most significant means to streamline data management is to develop and prioritize recommendations based upon risk (e.g., limiting the recommendations to those that will close a risk gap).

A simple way to reduce the number of PSM recommendations precipitating from the studies is to develop specific criteria to drive the team to develop a study recommendation – typically based upon risk and regulatory requirements (including codes and standards). As a result, all suggestions that the team develops that are not risk or requirement driven, but are “nice-to-have”, can be tracked separately from the study recommendations, thus requiring less documentation when implemented. Having a separate mechanism to document the catch-all recommendations, such as a formalized “parking lot”, allows the team to identify potential operational improvements without having these suggested improvements fall through the cracks and also fosters creative solutions. Additionally, another benefit of designating implementation criteria is to supply management with a tool to prioritize the implementation of recommendations based upon the amount of risk reduction achieved by the respective recommendation.

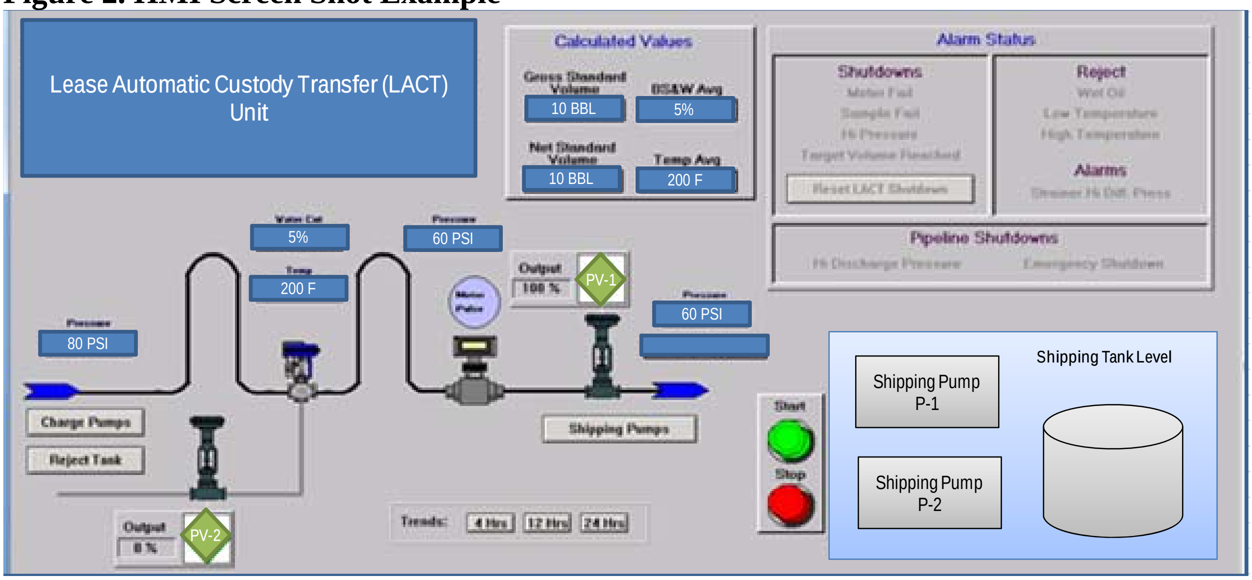
3. Process Safety Information

3.1 Piping & instrumentation Diagrams (P&IDs)

The successful implementation of PSM, even if not required, relies on accurate and complete Process Safety Information (PSI). An integral part of the PSI documentation is the P&IDs, which represents the process plant in a level such that it illustrates the process equipment, associated piping, basic process controls, and possibly safety instrumented systems. The P&IDs serve as a robust tool of understanding the facility. For legacy upstream facilities that may have switched owners several times, there is a significant gap in the availability of accurate P&IDs. Typically, either the P&IDs are very old and outdated or do not exist.

For facilities that do not have detailed P&IDs available it can be a significant undertaking to develop the P&IDs from scratch, requiring support from engineering and operations personnel via site walk-downs to work with the drafters to develop accurate P&IDs. This can be extremely time consuming and cost prohibitive for companies with limited engineering and operations support that are spread thin managing and operating numerous facilities. However, as mentioned previously, one characteristic of upstream facilities is that there are numerous facilities with the same functional design. While P&IDs are an efficient mechanism to document PSI and are considered best practices, there are other mechanisms a facility can utilize for documenting the technology of the process and the associated equipment. For simplified processes, such as those utilized for upstream operations, a process flow diagram can provide an overview of the technology of the process. Additionally, print-outs from the operations human machine interface (HMI) screen provide information regarding the normal pressures, temperatures, flow rates, shutdowns in place, etc. as well as the functional layout of the process. Figure 2 provides an example of a HMI screen shot for a Lease Automatic Custody Transfer (LACT) Unit that is utilized to accurately measure the amount of crude that is sold. These screen shots (if available) can be utilized as supporting PSI when conducting the Process Hazard Analysis, developing Operating Procedures, and implementing training programs.

Figure 2. HMI Screen Shot Example



Additionally, for facilities with developed P&IDs, without a drafting department or document control program there is a potential for facilities to postpone or sometimes even neglect P&ID changes. One of the best mechanisms for a P&ID review is the Process Hazard Analysis. During the study, the team systematically reviews the P&IDs in detail and typically finds errors and improvements during the study (and in some cases specific systems are field verified). It is in the facility's best interest to ensure that the PHA sessions document these P&ID errors and changes on a "red-line" copy, typically assigned to one process engineer in the study. This copy can serve as the master red-lined copy until the changes can be implemented by a drafter. This provides a direct means of controlling the required changes to the P&IDs and the responsibility for implementation of changes lies with the assigned process engineer.

4. Process Hazard Analysis

The PHA is another element of the PSM program that requires extensive resources and commitment from the company. Additionally, since upstream facilities are typically dispersed geographically and may be under different operational management, there can be additional challenges ensuring consistency among operating groups. The following sections provide tips to streamline the PHA study process to ensure consistency of the results and make efficient use of available resources.

4.1 Characterizing Hazards of the Process

When managing numerous facilities it can be difficult to ensure consistency in risk ranking for the PHAs, since the ranking is based upon the collective risk perception of each specific team. In order to provide a mechanism to calibrate the risk ranking, management can provide supporting information for the hazards of the process and what level of risk this presents to personnel safety, health and the environment. For example, providing dispersion modeling for various H_2S concentrations, with associated release sizes (e.g., leak vs. rupture) and heights (e.g., process failures vs. relief valves to atmosphere) helps to illustrate the potential for personnel exposure and define whether the associated event can result in a fatality or injury. This can be applied at each facility PHA to assist in ensuring that the risk ranking is applied consistently.

4.2 Checklist Development

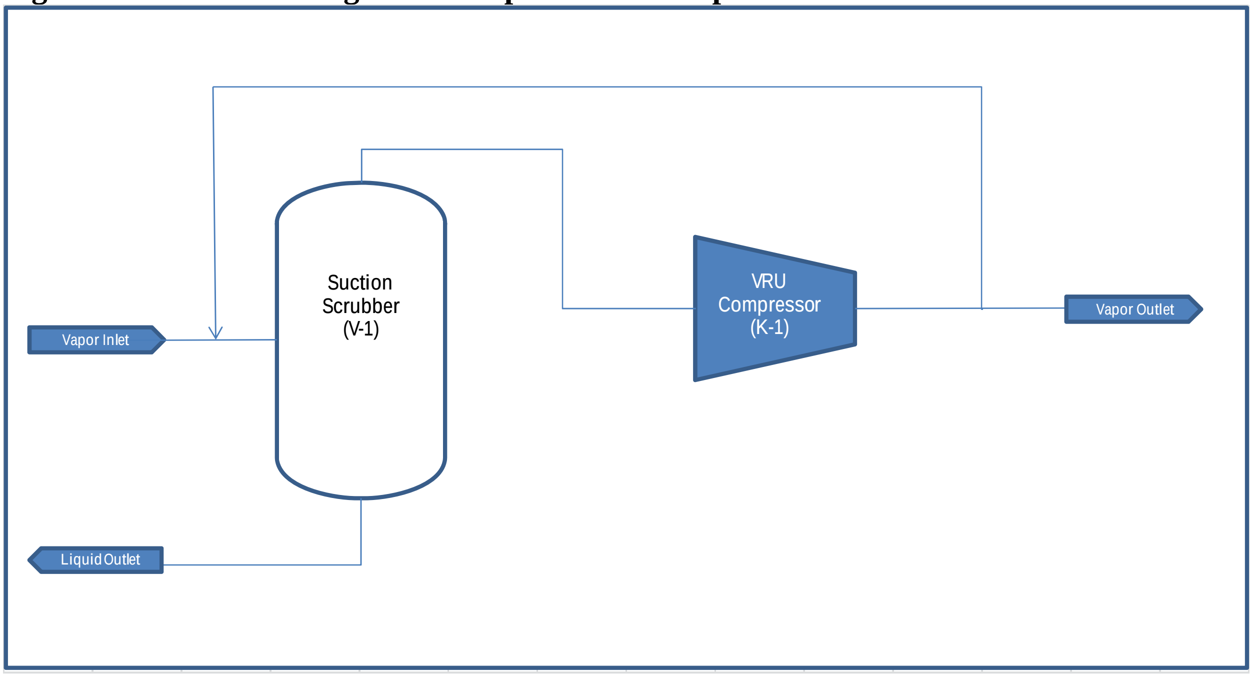
There are several PHA techniques that can be applied with various levels of detail, including What-If?, Checklists, and Hazard and Operability (HAZOP) studies. The HAZOP Study technique provides a comprehensive evaluation of the hazards of the process using a team-based, cause-by-cause methodology. While this provides a thorough evaluation, it also requires significant manpower resources when applied at numerous facilities. However, a typical characteristic of upstream operations is that while there are numerous widespread facilities, the facilities also tend to be patterned. By grouping similar facilities, such as tank batteries, compressor stations, vapor recovery units, gauge settings, automatic well test units, etc., we can evaluate each facility group systematically.

One effective approach to evaluate the facility groups is to conduct a baseline HAZOP Study for each facility type, then based upon the results of the study develop a checklist to evaluate the remaining facilities individually, while noting any differences in the evaluated facility from the baseline. These checklists are typically more detailed than the typical PHA checklists in that they are specific for each facility type, with a focus on mitigating specific consequences and safeguards.

4.2.1 Vapor Recovery Unit Checklist Development Example

The following section provides an example illustrating the checklist development for a Vapor Recovery Unit (VRU) Compressor (see Figure 3) based upon specific HAZOP scenarios. This example is not comprehensive, but provides an overview of the technique to transform HAZOP scenarios into checklist questions.

Figure 3. Block Flow Diagram Example –VRU Compressor



The following table provides an overview of several "No Flow" scenarios from the VRU Compressor baseline HAZOP Study:

Table 1. HAZOP Scenario Example – VRU Compressor: No Flow

HAZOP Scenarios					
Cause	Consequence	Safeguards	S	L	RR
1.1. Block valve on the suction of the VRU Compressor (K-1) inadvertently closed.	Potential loss of suction to the VRU Compressor resulting in increased temperature and bearing damage. This is an asset damage issue.	Operator Training and Procedures for valve operation. PALL-001 trips the VRU Compressor on low low suction pressure. TAH-001 alarms on high VRU Compressor bearing temperature. TAHH-001 trips the VRU Compressor on high high discharge temperature.	4	4	L
1.2. Block valve on the discharge of the VRU Compressor (K-1) inadvertently closed.	Potential increased VRU Compressor discharge pressure resulting in overpressurization of the discharge piping. Potential loss of containment with fire/explosion and personnel exposure.	Operator Training and Procedures for valve operation. PV-001 opens on low VRU Compressor suction pressure to provide recycle. PAHH-001 trips the VRU Compressor on high high discharge pressure. PSV-001 on the discharge of the VRU Compressor is designed to relieve pressure for the blocked discharge case.	1	4	M

In reviewing these examples, the following questions can be deduced from the consequences and safeguards:

Design Questions

- What are the operating suction and discharge pressures?
- What are the maximum suction and discharge design pressures?
- What are the operating suction and discharge temperatures?
- What are the maximum suction and discharge design temperatures?

Blocked Suction Questions

- Will a loss of suction flow result in increased temperature?
- If the temperature will increase, is there a potential for bearing damage?
- Is there any potential for loss of containment due to bearing damage?
- Are there alarms configured for high gas temperature? If so, will the Operator have sufficient time to respond?
- Are there alarms configured for high bearing temperature? If so, will the Operator have sufficient time to respond?
- Will the compressor trip on a loss of suction pressure?
- Is the suction piping or equipment designed for the maximum settle-out pressure for the compressor?

Blocked Discharge Questions

- Will a blocked discharge exceed the piping or equipment design pressure rating?
- If so, is overpressure protection (e.g., relief valve) provided to protect the piping and equipment?
- Will the compressor trip on high discharge pressure?
- Is there a minimum flow recycle to protect the compressor on a blocked discharge?
- Is the take-off for the minimum flow recycle upstream of the first block valve?
- Will a complete recycle of the flow result in increased temperature that could cause compressor damage?
- If so, are safeguards provided to mitigate increased gas temperature (e.g., cooler, high temperature alarm, high temperature trip)?

General Compressor Questions

- Area lock-out / tag-out procedures in place to minimize the potential for valve mis-operation?
- Is the compressor material selection appropriate for the expected vapor properties to minimize potential corrosion?
- For vibrating services, are pulsation dampeners included in the design?

- Is the discharge piping adequately supported for vibration?
- Is vibration monitoring provided for the compressor?
- Are emergency isolation valves provided in the design to safely isolate the compressor in an emergency?
- Are the emergency isolation valves (manual, automatic, remotely operated) appropriate for the specified service (location, fireproofing, fail position)?
- Are procedures in place for routine testing of the emergency isolation valves?
- Is fire water provided in the vicinity of the compressor?
- Can the fire water be safely operated in the event of a fire in the vicinity of the compressor?

After brainstorming potential questions for the scenarios, a checklist can be developed for these scenarios for the VRU Compressor. A sample abbreviated checklist format is provided on the following page:

Table 2. Checklist Example –VRU Compressor

VRU Compressor			
VRU Location:			
Checklist Team:			
Date of Completion:			
Design Parameters			
Design Pressure:		Operating Pressure:	
Design Temperature:		Operating Temperature:	
Checklist Questions	**Yes/No/NA**	**Comments / Recommendations**	
Will a loss of suction flow result in increased temperature? • If the temperature will increase, is there a potential for bearing damage? • Is there any potential for loss of containment due to bearing damage?			
Are there alarms configured for high gas temperature? • If so, will the Operator have sufficient time to respond?			
Are there alarms configured for high bearing temperature? • If so, will the Operator have sufficient time to respond?			
Will the compressor trip on a loss of suction pressure?			
Is the suction piping or equipment designed for the maximum settle-out pressure for the compressor?			

VRU Compressor		
Will a blocked discharge exceed the piping or equipment design pressure rating? • If so, is overpressure protection (e.g., relief valve) provided to protect the piping and equipment?		
Will the compressor trip on high discharge pressure?		
Is there a minimum flow recycle to protect the compressor on a blocked discharge? • Is the take-off for the minimum flow recycle upstream of the first block valve?		
Will a complete recycle of the flow result in increased temperature that could cause compressor damage? • If so, are safeguards provided to mitigate increased gas temperature (e.g., cooler, high temperature alarm, high temperature trip)?		
Are lock-out / tag-out procedures in place to minimize the potential for valve mis-operation?		
Is the compressor material selection appropriate for the expected vapor properties to minimize potential corrosion?		
For vibrating services, are pulsation dampeners included in the design? • Is the discharge piping adequately supported for vibration? • Is vibration monitoring provided for the compressor?		
Are emergency isolation valves provided in the design to safely isolate the compressor in an emergency? • Are the emergency isolation valves (manual, automatic, remotely operated) appropriate for the specified service (location, fireproofing, fail position)? • Are procedures in place for routine testing of the emergency isolation valves?		
Is fire water provided in the vicinity of the compressor? • Can the fire water be safely operated in the event of a fire in the vicinity of the compressor?		

5. Operating Procedures

Though not required by PSM, it is considered an industry best practice to develop and implement rigorous Operating Procedures. A well-developed Operating Procedures program can provide significant benefits to both the facility and its operators, including minimizing risk, documenting safe operating limits, capturing the knowledge of experienced operators, and providing valuable training tools.

Upstream facilities deal with a number of hazards, so from a safety perspective, strong Operating Procedures are an effective management tool to minimize the risk of potentially disastrous incidents from human error. They are most commonly applied to frequent, low-risk tasks though they are often applied to infrequent but high-risk tasks as well. Outside of process controls, administrative controls such as Operating Procedures are a crucial element in minimizing the occurrence of hazardous events.

In addition to reducing the risk of process safety incidents, Operating Procedures also provide operational benefits. By the Center for Chemical Process Safety's (CCPS) "Guidelines for Writing Effective Operating and Maintenance Procedures" [2] definition, Operating Procedures are designed to keep a process within its operating limits. Operating Procedures capture these operating limits and ensure the process is operating within its design intent. This ensures consistency of operations, which is also highly beneficial to facilities with multiple operators operating the same process. [1]

Additionally, one of the most significant challenges posed to upstream facilities is knowledge transfer. Many facilities have been operating for years without robust Operating Procedures, relying primarily on the knowledge of experienced Operators to safely operate the facility. However, as operators retire or switch positions, the knowledge of that particular facility or system is no longer available to those left behind to operate the facility. Developing Operating Procedures from scratch is a significant time investment; however, in the long-run developing a knowledge transfer program with comprehensive Operating Procedures will not only help to support operations, but will also provide a valuable training tool. An effective way of implementing a knowledge transfer program is to develop detailed Operating Procedures utilizing the operator shadowing method (i.e., documenting actions for specific procedures based upon observing the actions of the experienced operator). When operating a facility becomes second nature, it is easy to overlook all of the implicit actions associated with a simple task. For example, when discussing starting a pump with an experienced operator is typically documented as a single task (e.g., Start Feed Pump #1). However, this could be expanded to include the specific valve line-up (including recycle), monitoring of specific pressure or flow indicators, expected suction and discharge pressures, troubleshooting advice based upon operating experience, etc. One of the best ways to extract this information is by coupling less experienced operators or engineers with the experienced operators for the shadowing. This method also provides a valuable training tool for the less experienced operators.

5.2 Keeping the Operating Procedures Current

The implementation of successful Operating Procedures is reliant on the accuracy of the procedure. A key method of ensuring accuracy is to conduct an annual review of the operating procedures by key stakeholders from management and operations. Additionally, Operating Procedures should be reviewed following the completion or revalidation of the PHA to ensure the consequences of deviations from the normal operating limits are documented accurately. The resultant updated consequences of deviation can be used in the O&M procedures. Both the annual review and the PHA ensure that the O&M Procedures are current, thus continually minimizing risk and ensuring that the process is kept within its operating limits.

6. Conclusion

Effectively applying PSM at upstream facilities presents numerous challenges due to the geographic extent of facilities and limited available manpower resources. However, as evidenced in this paper there are systems available to streamline the implementation which requires pre-planning and setting up the systems as part of the overall management structure, including the following:

- Defining a management system and clearly assigning PSM responsibilities.
- Developing and maintaining PSI, including P&IDs, and implementing document control policies.
- Standardizing the PHA approach, including characterizing hazards to consistently apply risk ranking, setting risk criteria to define and prioritize recommendations, and organizing facilities such that resources can be systematically applied to baseline HAZOP Studies and subsequent checklists.
- Implementing a knowledge transfer program to develop robust Operating Procedures.

7. References

[1] Scholtz, Colin R. and Maher, Steven T. “Tips for the Creation and Application of Effective Operating Procedures”

[2] “Guidelines for Writing Effective Operating and Maintenance Procedures”, Center for Chemical Process Safety, American Institute of Chemical Engineers, 1996.