GUIDANCE FOR IMPLEMENTING PROGRAMS FOR OSHA 29 CFR 1910.119

PROCESS SAFETY MANAGEMENT OF HIGHLY HAZARDOUS CHEMICALS

PART TWO

PROCESS HAZARD ANALYSIS

by

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GUIDANCE FOR IMPLEMENTING PROGRAMS FOR OSHA PSM

PROCESS HAZARD ANALYSIS

This document contains information that may assist a company in establishing, or reviewing and updating, the process hazard analysis (PHA) element of their process safety management (PSM) program. The information in this document is based upon the U.S. Occupational Safety and Health Administration's regulation, 29 CFR 1910.119, *Process Safety Management of Highly Hazardous Chemicals*. However, this information may be of use to anyone developing or updating a PSM program for any purpose.

In 1993 the U.S. Department of Labor Occupational Safety and Health Administration (OSHA) commissioned Primatech Inc. to develop a "training material reference manual" related to 1910.119. The purpose of the manual is to provide OSHA's Office of Training and Education with a resource for training federal and state OSHA field officers on enforcing the PSM regulation.

The training material reference manual features an annotated form of the Program-Quality-Verification (PQV) inspection checklist originally presented in Appendix A of OSHA Instruction CPL 2-2.45A. Example programs are provided to illustrate the positive and negative indicators of the checklist questions. OSHA has agreed to allow Primatech to make this information available to interested parties. This should in no way be construed as acceptance by OSHA of the suitability of the information or examples provided herein.

The format of this document follows the PQV inspection checklist presented in Appendix A of OSHA Instruction CPL 2-2.45A, often referred to as the "compliance directive". For each question in the PQV inspection checklist, clarification is provided on the checklist item along with positive program indicators and negative program indicators for each question. The positive and negative program indicators are intended to provide ideas for the user to help them in assessing their existing or planned program.

The example programs provided in this document illustrate approaches taken by companies seeking to address the requirements of 1910.119. These examples have not been reviewed and/or endorsed by OSHA and should not be construed as model programs.

The example programs provided herein were developed for specific processes, and are not generic in nature. Since the OSHA PSM regulation is performance-based, readers are strongly encouraged to develop programs tailored to their own covered processes.

This document is offered for the user's general guidance only. This document does not attempt to provide any interpretation of the OSHA regulations.

Primatech makes no claims regarding the acceptability to OSHA of the information contained herein to OSHA. Consequently, Primatech can accept no liability for any use which the user may make of the information contained herein. Note that the information contained in this manual does not necessarily represent the opinion of Primatech.

OVERVIEW

This guidance document is arranged in a tabular format. The following is a description of each of the column headings used in the table:

PQV Question

The PQV question is derived from the checklist in Appendix A of the OSHA Compliance Directive (CPL 2-2.45A), which is based on the specific regulatory requirements for the element. Note that the verification portion of the checklist includes questions for records review, on-site conditions, and interviews. In order to avoid unnecessary duplication of information, this guidance document references the checklist questions from the records review section only. Specific questions or concerns from the on-site conditions and interviews sections that are not addressed in the records review section are accounted for in the positive and/or negative program indicators column.

Explanation

The explanation clarifies or provides additional insight into the PQV question. In some cases, the explanation provides an interpretation of the PSM requirement. In no cases should the information contained in this column be viewed as a substitute for the actual regulatory requirement.

Positive Program Indicators

The information included in the positive program indicators column is intended to provide guidance and examples on what to look for in a well developed program. This column also includes guidance on what to look for when evaluating PSM programs. This column is not intended to contain all conceivable attributes of a good program for all industry types. Rather, it is intended to provide suggestions and ideas on what a good program might include.

Negative Program Indicators

The information in the negative program indicators column is intended to provide guidance on possible signs of a poor or incomplete program. This information could be of assistance for identifying potential problem areas when conducting PSM program evaluations. A PSM program that contains one or more of these attributes does not necessarily constitute a poor program. Rather, this information is intended to serve as a guide on what to look for in a less developed program.

It is important for the user of this manual to understand that over 25,000 employers may be covered under the PSM standard. Covered facilities range from large complex chemical, petrochemical, or petroleum facilities, to relatively simple ammonia refrigeration or chlorination systems. This guidance document cannot cover all of the possible ranges regarding the content of PSM program elements in the various industry groups. Additionally, since the PSM standard is a performance based regulation, this guidance document can not address the specific approaches different companies or facilities may choose to implement in complying with the requirements.

In addition to the table, this guidance document contains several helpful appendices, including:

Appendix A - List of Acronyms	Contains description of key acronyms used in the guidance document.
Appendix B - Glossary of Terms	Contains definitions of key terms used in the guidance document.
Appendix C - Technical References	Contains a list of helpful technical references to support the information presented in the table.
Appendix D - Example Program(s)	Contains example(s) of how this PSM element has been adopted. Most of the examples are actual programs provided by industrial companies.

PSM TRAINING MATERIAL REFERENCE MANUAL

PROCESS HAZARD ANALYSIS [29 CFR 1910.119 (e)]

PQV Question	Explanation	Positive Program Indicators	Negative Program Indicators
1. Has the employer determined and documented a priority order for conducting initial PHAs based on a rationale that includes at least these factors: • the extent of process hazards • number of potentially affected employees • age of process • operating history?	The initial PHAs scheduled to be conducted should be prioritized and this prioritization is based on at least the extent of process hazards, the number of potentially affected employees, the age of the process and the operating history of the process. Priorities are made on different processes, not process components within the same process. If the employer has only one process, the prioritization is not required. The extent of process hazards refers to the severity and likelihood of potential hazards. Severity is used to describe the extent of the consequences of the potential hazard. Likelihood is used to describe the estimated frequency of occurrence of the hazard. The facilities with potential exposure to larger concentrations of employees should receive higher priority. Special issues concerning older units, including older technology needs to be considered. The operating history should be considered, with priority to those processes with more frequent incidents or near misses. The employer should accept input from the employees when establishing the priority order for scheduling and conducting the PHA studies.	Documentation exists describing the rationale and scheduling of PHAs including an estimate of necessary time and resources to complete the studies. The employer has accepted input and suggestions from employees in determining the priority order for conducting the PHA studies. Interviews with a representative number of PHA team members shows that the priority order for conducting PHAs is based on the extent of the process, the number of potentially affected employees, the age of the process, and the operating history of the process. The facility has established an approach for conducting the PHAs, including training for the team leaders. A preliminary hazard analysis, decision tree, or "truth" tables could be used to conduct the prioritization.	No PHA schedule exists (unless there is only one process at the site). The PHA schedule is based on analyzing process components and not individual processes. The priority order and plan for conducting PHAs did not take into account the extent of the hazards, number of affected employees, age of the process and operating history. Employees were not given an opportunity to provide input into establishing the priority order for scheduling and conducting the PHA studies.

PROCESS HAZARD ANALYSIS [29 CFR 1910.119 (e)]

POV Question	Explanation	Positive Program Indicators	Negative Program Indicators
2. Are the initial PHAs for processes covered by the PSM standard being performed as soon as possible?	The employer should plan to conduct initial PHAs for covered processes within a reasonable period of time. Employers should not wait until 5/26/94 to complete their first (or only) PHA study. Initial PHAs should be conducted as soon as possible, but not later than 5/26/94, or the schedule requiring 50% completion by 5/26/95, 75% completion by 5/26/96 and 100% completion by 5/26/97. Employers should establish a schedule for completing the initial PHA studies. The schedule could be dependent on the availability of the necessary PSI, availability of a trained team leader and the availability of an appropriate team. If it is reasonable, based on these and other factors, to complete the initial PHA prior to 5/26/94, it should be done.	Employer has a schedule for conducting initial PHAs whose time frame is reasonable in accordance with the scope and complexity of the process, availability of a trained team leader, availability of an appropriate team, and availability of the necessary PSI. Initial PHAs are schedule to be completed as soon as possible, but no later than 25% completion by 5/26/94, 50% completion by 5/26/95, 75% completion by 5/26/96 and 100% completion by 5/26/97. An employer with a single covered process has an established schedule which calls for the completion of the initial PHA by 5/26/94. Employers with multiple covered processes have a reasonable plan for completing the initial PHAs which accounts for the total level of effort required, availability of the necessary PSI, the availability of a trained team leader, and the availability of appropriate team members.	Initial PHAs are not being conducted as soon as possible. No schedule exists requiring initial PHAs to be completed as soon as possible, and not later than 25% completion by 5/26/94, 50% completion by 5/26/95, 75% completion by 5/26/96 and 100% completion by 5/26/97. An employer with a single covered process schedules the PHA to be completed according to the four year schedule, or 25% of the process completed by 5/26/94, 50% of the process completed by 5/26/95, etc. The four year schedule should not be applied in this fashion. It applies to employers with multiple covered processes located at a single site. Employers with multiple covered processes located at different sites in different states, schedule initial PHAs for these covered processes according to the four year schedule. The four year schedule should not be applied in this fashion. It applies for multiple covered processes located at a single site.

PSM TRAINING MATERIAL REFERENCE MANUAL

PROCESS HAZARD ANALYSIS [29 CFR 1910.119 (e)]

PQV Question	Explanation	Positive Program Indicators	Negative Program Indicators
3. Does the priority schedule for PHAs assure that all initial PHAs will be performed by 5/26/97 and that: • No less than 25% of the PHAs shall be completed by 5/26/94? • No less than 50% of the PHAs shall be completed by 5/26/95? • No less than 75% of the PHAs shall be completed by 5/26/96? (PHAs completed after 5/26/87 which meet the requirements of this paragraph are acceptable as initial PHAs; they must be updated and revalidated at least every 5 years.)	The priority schedule for conducting initial PHAs should be established so that no less than 25% of the covered processes at a single site are completed by 5/26/94, another 25% by 5/26/95, another 25% by 5/26/96 and the final 25% by 5/26/97. The PHA schedule may be based on the total number of covered processes to be completed, where there are multiple processes on a single site, or based on the total number of work hours estimated to complete all of the PHAs. For example, the schedule for an employer with four covered processes on site may schedule one process to be completed by 5/26/94, the second process to be completed by 5/26/95, the third process to be completed by 5/26/96 and the fourth process to be completed by 5/26/97. Employers who have completed PHAs on covered processes after 5/26/87 should review those PHAs in order to determine that they meet the requirements of a completed PHA. PHAs conducted after 5/26/87, that meet the requirements of 1910.119(e), are acceptable as initial PHAs. Employers with multiple covered processes on site, some for which appropriate PHAs have been completed and are acceptable as initial PHAs, may count those PHAs as part of the initial 25% to be completed by 5/26/94.	The employer has determined that multiple covered processes are operated on site. The employer has established a schedule for completing the initial PHAs as soon as possible, but not later than 25% completion by 5/26/94, 50% completion by 5/26/95, 75% completion by 5/26/96 and 100% completion by 5/26/97. The schedule for conducting initial PHAs calls for completion of at least 25% per year from 1994 through 1997. The employer is on-time or ahead of the established PHA schedule for completing the initial PHAs. The facility has established a system to track progress towards completing the PHAs. The employer has reviewed PHAs conducted after 5/26/87 to determine that they meet the requirements of 1910.119(e) in order to be accepted as the initial PHA. To be accepted as initial PHAs, the employer has verified, in writing, that the PHA addresses all of the requirements of 1910.119(e) (i.e. team approach, team composition, consideration for human error, previous incidents, facility siting issues, failure of safeguards)	An employer with multiple covered processes on site has not established a schedule for conducting the initial PHAs. An employer's established schedule does not require completion of the initial PHAs according to the requirement (i.e. 25% completed by 5/26/94, 50% completed by 5/26/95, etc.) The PHA schedule is based on analyzing process components and not individual processes. The employer has an established schedule but is not tracking progress towards completion of the schedule or can not determine the percentage completed and yet to be conducted. PHAs conducted after 5/26/87 are accepted as the initial PHAs, but do not contain all of the requirements of 1910.119(e) (i.e. team approach, team composition, consideration for human error, previous incidents, facility siting issues, failure of safeguards) PHAs conducted prior to May 26, 1987 are credited as initial PHAs.

PROCESS HAZARD ANALYSIS [29 CFR 1910.119 (e)]

PQV Question	Explanation	Positive Program Indicators	Negative Program Indicators
4. Does the hazard *evaluation use one or more* of the following PHA methodologies: • What-if? • Checklist? • What-if/Checklist? • Hazard & Operability Study (HAZOP)? • Failure Mode and Effects Analysis (FMEA)? • Fault Tree Analysis (FTA)? • Other appropriate methodology?	The PHA should use one of the OSHA accepted *hazard analysis methodologies*, recognized by the American Institute of Chemical Engineers (AIChE), Center for Chemical Process Safety (CCPS). "Other appropriate methodologies" should be at a minimum, consistent with the thoroughness and effectiveness of the explicitly listed methods. It should involve a team approach to hazard identification. The simpler PHA methodologies could be appropriate for the simpler, less complex, more stable (i.e. little or no process changes), lower volume of highly hazardous chemicals processes. The simpler PHA methods include the Checklist, the What-if? and the What-if/Checklist?. More complex processes with greater potential hazards, process, or undergoing more frequent change may require one of the more advanced methods. The more advanced methods include the HAZOP, FMEA, and FTA.	The PHA report describes the methodology used. If more than one methodology was used for different parts of the process, the rationale for such a decision should also be included. The methodology used is appropriate for the size and complexity of the process. For example, a simple Checklist study would not be appropriate for a large, complex, and highly automated process. Criteria for selecting appropriate hazard analysis methodologies may include: scope and objective for the study; the type of results needed; the type of information available to perform the study; extent of process hazards; skill and experience level of team leader, scribe and study team; and, resource availability. The employer has established a procedure for accepting input and suggestions from employees on the appropriate PHA methodology to be used for the study. An employer may use a generic hazard analysis approach for similar processes (i.e., similar technology, equipment, and volumes). For example, non-unique operations such as ammonia refrigeration facilities or *chlorination systems may utilize a generic PHA study*, possibly developed by a trade association or by the employer, as the basis for the study. When using a generic PHA, the employer must account for variations (i.e. differences in siting, incident histories, technology, equipment, operations, etc.) for each process covered by this generic approach. The employer uses "another appropriate method" that is at least as consistent and thorough as one of the six listed methods. The employer describes the rationale for selecting one of the non-listed methods and describes why it is at least as thorough as one of the listed methods, including a description of why it is used in the particular application.	Inappropriate application of an acceptable methodology. For example, the study documentation fails to describe how causes of hazards occur in the equipment being studied; how those causes create consequences of concern; no acknowledgement of the equipment and procedures in place to detect or prevent the causes and mitigate the consequences; or, *listings of recommendations is not included* in the study report. Use of a methodology or a hybrid methodology which does not properly address the extent of process hazards. For example, hazard analysis "by action items only", where the PHA would include only those deviations for which recommendations are made for safety improvements; or hazard analysis "by exception", where the PHA would include only those deviations for which the team felt there were significant consequences (e.g., explosions, toxic releases). PHAs "by *exception" may overlook subtle hazards.*

PROCESS HAZARD ANALYSIS [29 CFR 1910.119 (e)]

PQV Question	Explanation	Positive Program Indicators	Negative Program Indicators
4. Does the hazard evaluation use one or more of the following PHA methodologies: (contd.)	(See above)	(See above)	A non-listed method is used that is not at least as consistent and thorough as one of the six listed methods. The non-listed method must be able to address the hazards of the process, previous incidents with likely potential for catastrophic consequences, the consequences of failure of existing engineering and administrative controls, the engineering and administrative controls applicable to the hazards and their interrelationships, facility siting, human factors, and an evaluation of the possible safety and health effects of each control failure on the employees. The method must enable the team to address both the possible causes of each hazard and the recommendations for correcting these causes and avoiding the potential consequences.

PROCESS HAZARD ANALYSIS [29 CFR 1910.119 (e)]

PQV Question	Explanation	Positive Program Indicators	Negative Program Indicators
5. Does the PHA address the following: a. The hazards of the process?	The PHA should identify all process hazards. Process hazards include scenarios which result in an unacceptable or undesirable consequence including employee injury through a release or exposure to highly hazardous chemicals. The PHA should include, at a minimum, hazard scenarios which can potentially cause a major uncontrolled emission, fire, or explosion of the covered highly hazardous chemical potentially causing serious danger to employees in the workplace.	The PHA report contains clear definitions of both credible scenarios (with plant specific examples) and credible safeguards (with plant specific examples). Credible scenarios and credible safeguards are determined based upon the discussion of the team facilitated by the team leader. The PHA study report shows that all credible scenarios have been identified. Credible scenarios include all hazards due to human error, equipment failure, and external events. The study team, as described in the PHA report, consistently applied the credibility definitions in identification of hazard scenarios and safeguards. Clear definition in the report of consequences that were considered to affect employee health and safety - as a minimum, release of toxic materials, flammable gases and liquids, and potential fires/explosions. The scope of the PHA study included all process equipment where a failure of safety controls could lead to a significant hazard to the employees. Observations of a representative sample of process-related equipment indicates that obvious hazards have been identified, evaluated, and controlled. For example, hydrocarbon or toxic gas monitors and alarms are present; electrical classifications are consistent with flammability hazards; destruct systems such as flares are in place and operating; control room siting is adequate or provisions have been made for blast resistant construction, pressurization, alarms, etc.; pressure relief valves and rupture disks are properly designed and discharge to a safe area; pipework is protected from impact.	The PHA study report does not clearly document the scenarios which may lead to catastrophic incidents. The PHA report does not include documentation for different categories of causes including human error, equipment failure, and external events. The PHA report indicates that hazard identification was biased unrealistically by installed safeguards. For example, a hazard should not be discarded or considered as non-credible due to an installed safeguard. Rather, the report should document the potential hazard, assuming that there is no safeguard, and then document the safeguard and its impact on the severity of the consequence or the likelihood of the event occurring. The scope of the PHA study did not include all process equipment whose failure could result in a significant hazard to an employee. The PHA study does not include hazards and incompatibilities listed in a MSDS of a chemical used in the process, potential hazards identified in other process safety information, or recognized hazards outlined in trade publications and consensus standards for the process. The PHA report only addresses chemical release type hazards and does not address cascading type hazard scenarios which could spread throughout the plant (i.e., an explosion which disrupts power which results in a loss of safety controls).

PROCESS HAZARD ANALYSIS [29 CFR 1910.119 (e)]

POV Question	Explanation	Positive Program Indicators	Negative Program Indicators
5. Does the PHA address the following (contd.) b. Previous incidents with likely potential for catastrophic consequences?	The PHA should take into account the operating history of the unit, specifically, the accident history of the process.	The PHA report or study worksheets show objective evidence of causes and/or consequences derived from previous operating history, including "near misses". The PHA study approach includes a requirement for the study team to review reports of previous incidents associated with the covered process. Interviews with a representative number of the PHA team members, operators and maintenance employees shows that previous incidents with likely potential for catastrophic consequences were addressed.	No clear evidence in the PHA report that any hazard scenario causes and/or consequences were derived from previous operating history.
5. Does the PHA address the following (cont'd.): c. Consequences of failure of engineering and administrative controls?	The PHA should describe the effects of the failure of existing controls as contributing factors to the hazard scenarios.	The PHA report or the study worksheets contains clear evidence that failures of existing engineering and administrative controls (i.e. safeguards) are considered as the causes of hazard scenarios. For example, PSVs are both safeguards against high pressure, and also the potential cause of leaks or low pressure if stuck open. Additionally, the PHA report documents the consequences of potential failures of safeguards, such as alarms, interlocks, and monitors. The study team did not assume that installed safeguards do not fail. Clear definition in the report of what constitutes an effective safeguard for the process. For example, a pressure safety valve could be a safeguard against overpressure of a vessel. Clear evidence in the study worksheets that credible scenarios were derived from the common cause failure of controls and utility systems. For example, failure of an electrical system could result in control and safeguard failures. Interviews with a representative number of the PHA team members shows that consequences of failure of engineering and administrative controls were addressed. For example, failure to follow confined space entry procedures would be failure of an administrative control.	No clear evidence in PHA report or the study worksheets that hazard scenario causes were derived from failure of existing engineering and administrative controls (i.e., safeguards). The PHA report indicates that safeguards were assumed by the team to be 100% reliable and infallible.

PROCESS HAZARD ANALYSIS [29 CFR 1910.119 (e)]

PQV Question	Explanation	Positive Program Indicators	Negative Program Indicators
5. Does the PHA address the following (cont'd.): d. Engineering and administrative controls applicable to the hazards and their inter-relationships?	The PHA should identify the management, operational, and engineering procedures and *policies specific to hazards they are intended to* manage. The interaction of these controls should be documented in the PHA. Engineering and administrative controls should include measures taken to mitigate or detect a hazard.	The PHA report includes a discussion of the installed engineering and administrative controls (i.e. safeguards). *Alternatively, the study worksheets include a safeguards* column which documents existing engineering and administrative controls that detect and prevent the causes and/or mitigate the consequences of hazard scenarios. Interviews with a representative number of the PHA team members show that engineering and administrative controls applicable to the hazards and their inter-relationships were addressed.	The PHA report and the study worksheet contains no description of, or an incomplete *description of installed engineering and* administrative controls. Inconsistent consideration of the effectiveness of installed safeguards. For example, level indication is a safeguard against overfilling in one instance and not another.
5. Does the PHA address the following (cont'd.): e. Facility siting?	The PHA should account for facility siting issues such as spacing between equipment, between equipment and employees, between equipment and potential ignition sources, and the potential for an incident to propagate from one process area to another, separate area.	Objective evidence in the PHA report or the study worksheets that facility siting issues were considered. The report or the worksheets show that particular attention to hazards which have the potential to affect locations in the plant/unit where personnel congregate were considered, for example: control rooms; local operating stations for equipment; utility operating stations; *guard houses and security stations; lunch/break* rooms and administrative spaces within the plant/unit. The PHA study addresses the causes or effects of spacing and the layout of the process equipment. Interviews with a representative number of the PHA team members should show that facility siting was addressed.	No objective evidence in PHA report or the study worksheets that facility siting issues were addressed. Concerns such as spacing and equipment layout are not addressed in the PHA, either as a cause nor a consequence. No consideration is made of cascading effects of an incident in separate process areas.

PROCESS HAZARD ANALYSIS [29 CFR 1910.119 (e)]

PQV Question	Explanation	Positive Program Indicators	Negative Program Indicators
5. Does the PHA address the following (cont'd.): f. Human factors?	The PHA should address human factors by considering human error as a cause in a hazard scenario, by assessing the environmental influences on employees by evaluating the clarity of procedures, by accounting for the human element in evaluating existing administrative and engineering controls (i.e., safeguards), and in identifying potential recommendations to prevent, mitigate, or detect a potential hazard.	The PHA report or the study worksheets clearly indicate that human error was included as a cause of hazard scenarios. This can be accomplished by appropriate wording of the causes indicating that the cause is an operator or human error or by other denotation. Alternatively, the PHA report could document how human factors were accounted for during the study. The PHA report or the study worksheets clearly identify that the adequacy of controls and instrumentation were examined during the study. Examples would include: vulnerability of controls to external events; accessibility of controls; instrument indicators adequate for tasks expected of operators; potential for alarm "overload"; confusion over indicators (e.g., using green lights for trouble alarms); control space lighting; and, control power supplies. Interviews with a representative number of the PHA team members should show that human factors were addressed. The PHA report or the study worksheets considers the demands on employees such as the number and frequency of tasks an operator is required to perform or the duration or peculiarity of a work schedule.	Missing or incomplete consideration of human factors in PHAs. PHA report and study worksheets show no evidence that human factors were accounted for in identifying causes of hazards, assessing environmental influences, evaluating the clarity of operation and maintenance procedures, describing installed engineering and administrative controls (i.e., safeguards), or in identifying potential recommendations.

PROCESS HAZARD ANALYSIS [29 CFR 1910.119 (e)]

PQV Question	Explanation	Positive Program Indicators	Negative Program Indicators
5. Does the PHA address the following (cont'd.): g. A qualitative evaluation of a range of possible safety and health effects of failure of controls on employees in the workplace?	The PHA study should include documentation of the range of consequences of potential hazards. The *consequences should consider* the failure of installed engineering and administrative controls (i.e., safeguards), and their effect on safety and health. The range should include minor effects to the worst credible case. Minor effects may include near misses, minor first aid cases, or exposure to fugitive emissions. Worst credible cases may include serious employee injury, fatalities, or potential off-site effects. A qualitative (i.e., non-calculational) ranking or prioritization scheme which offers an easy-to-apply method of distinguishing between the severity and/or likelihood of the hazard scenarios identified. This could include a written evaluation of the range of possible safety and health effects of control failure. The qualitative evaluation of the range of possible safety and health effects of identified hazards will assist the employer in establishing priorities for addressing and follow-up of study recommendations.	The PHA report or the study worksheets describe a range of potential safety and health effects of the failure of installed safeguards. The description is included in the PHA report by organizing the consequences identified in the PHA study into various categories, such as minor, medium, and major. Alternatively, the PHA worksheets include a description of the range of possible health effects, for example: no injury, minor first aid case, OSHA 200 reportable injury, hospitalization, or death. One possible method of qualitatively evaluating the range of health and safety effects is by the use of a risk ranking scheme to assess the hazard scenarios. This may take several forms. One typical method employed by many companies is to rank both the severity (S) and likelihood (L) of each scenario using a pre-determined number of levels. For example, using five levels of severity and likelihood, where the first level is the most severe and most likely ranking and the fifth level is the least severe and least likely ranking. Each combination of severity and likelihood is then assigned a risk ranking (R) using assignments that have meaning to the company in terms of prioritization of action to reduce the risks. The S, L, and R rankings should be clearly shown on the worksheets. The definitions of each level of severity and likelihood used are clearly listed in the report in terms of health impacts to employees, property damage, environmental effects, and other consequences which are important to the company. It is important that the qualitative ranking scheme be evenly and consistently applied throughout the PHA. Where a company-wide or site-wide scheme is used, it is consistently applied in all the PHAs performed.	The PHA report and study worksheets contain no qualitative evaluation of the range of possible safety and health effects of the failure of installed safeguards. The employer has no way to assess the range of potential consequences of identified hazard scenarios. The employer has no logical method of prioritizing the recommendations identified in the PHA study. There is evidence that the PHA study team inconsistently applied an evaluation or ranking. This could lead to inappropriate priorities being established to address study recommendations.

PROCESS HAZARD ANALYSIS [29 CFR 1910.119 (e)]

PQV Question	Explanation	Positive Program Indicators	Negative Program Indicators
6. Are the process hazard analyses performed by teams with expertise in engineering and process operations, including at least one employee with experience and knowledge specific to the process being evaluated and one member knowledgeable in the specific PHA methodology used?	The PHA study should be performed by a team. The team should include members with engineering and process operations expertise. The team should also include at least one employee with experience and knowledge in the process being studied. The employee with experience and knowledge in the process being studied could be an operator or hourly employee. The PHA team leader should be fully knowledgeable and experienced in applying the PHA methodology being used.	The PHA study team should understand the methodology to be used during the study. A PHA team may vary in size from two to seven or eight people. Some team members may only participate in a portion of the study, while others will participate in the entire study. The PHA study team should have expertise in the process technology, process design, operating procedures and practices, including how the work is actually performed, alarms, emergency procedures, instrumentation, maintenance procedures, and safety and health. The team should have knowledge of the standards, codes, specifications and regulations applicable to the process being studied. The PHA study should be performed by a team of individuals experienced and knowledgeable in the covered process or in areas that impact on the covered process. A study team may consist of a design engineer, process engineer, maintenance representetive, operations representative, and an operator. The team may also include a safety/health/environmental representative or an equipment manufacturer's representative. The PHA study report or the worksheets identify the team members and the technical expertise of each. The qualifications of the team leader are clearly documented by either resume evidence of other studies conducted or evidence of formal training in the applicable hazard analysis technique. A team leader's qualifications may include training course completion certificate or letter, other verification of formal training, or resume.	The PHA was performed by one individual, and not by a team. The PHA report and the worksheet show that the team did not consist of persons knowledgeable in the design, operation, and maintenance of the process being studied. The PHA study team did not include an employee knowledgeable in the specific process being studied. The PHA report and the study worksheets did not describe the technical expertise of the team members or hazard analysis technique qualification of the team members or team leader. There is insufficient technical representation based on the size and complexity of the process being studied and the materials handled. For example, the study team did not include an instrument specialist for a study on a process heavily equipped with new state-of-the-art instrumentation. Or, the study team did not include a process chemist for a study on a process with complicated reaction chemistry. PHA team leader had no formal training or documented previous experience.

PROCESS HAZARD ANALYSIS [29 CFR 1910.119 (e)]

POV Question	Explanation	Positive Program Indicators	Negative Program Indicators
6. Are the process hazard analyses performed by teams with expertise in engineering and process operations, including at least one employee with experience and knowledge specific to the process being evaluated and one member knowledgeable in the specific PHA methodology used? (cont'd.)	(See above)	Interviews with the PHA team members, show that the study team members had the appropriate expertise in engineering, process operations, and the process methodology used. At least one member of the team was an employee (i.e. operator or hourly worker) with experience and knowledge in the specific process. Where applicable, the employer consulted with contract employees on the conduct and development of PHAs in the same manner that it consulted with direct hire employees. Where appropriate, contract employers shared responsibility for ensuring that there is consultation with their employees. For example, if a covered process is normally maintained through the use of outside contractors, then a representative from that contractor knowledgeable in the maintenance activities should be a member of the PHA study team.	(See above)

PROCESS HAZARD ANALYSIS [29 CFR 1910.119 (e)]

PQV Question	Explanation	Positive Program Indicators	Negative Program Indicators
7. Has a system been established to promptly address the team's findings and recommendations? (Review a representative sample of the documentation.) Has the system been able to: • Assure that the recommendations are resolved and documented in a timely manner? • Document actions to be taken? • Complete actions as soon as possible? • Develop a written schedule of when actions are to be completed? • Communicate the actions to operating, maintenance and other employees whose work assignments are in the process and who may be affected by the recommendations or actions?	A management system should exist to review and resolve the recommendations generated during a PHA study. The management system should be written, include an implementation schedule, ensure timely resolution to action items as necessary, and ensure that those employees affected by the changes resulting from the implementation of the recommendations are aware of the change and its implications. Resolution of the PHA study recommendation could include implementation of the recommendation as identified by the study team, implementation of a revised recommendation, or a decision not to implement the recommendation. The rationale supporting the decision-making process should be included as part of the follow-up/tracking documentation.	The resolution of recommendations generated during the PHA are documented. The employer has a management system in place to track the status and implementation of the recommendations, including an implementation schedule with periodic status reports. For recommendations not implemented after further review or implemented in a revised format, reasoning is given as to why the recommendation was not implemented or revised, including the rationale used for selecting alternatives. Observations of a representative sample of process-related equipment indicate that PHA recommendations have been promptly resolved. Interviews with the PHA team members show that a system is established by the employer to resolve the team's findings and recommendations in a timely fashion. Interviews with operators, maintenance, and other employees who may be affected by PHA recommendations, show that actions taken to resolve PHA findings have been communicated to these employees. Where necessary, affected employees have been trained in operations/maintaining the modified equipment/procedures.	No management system exists to review and document the follow-up to PHA study recommendations. Recommendations made during a PHA are not resolved according to the established schedule. Recommendations are declared to be not feasible but no scheduled activities are substituted to resolve the hazard; this error usually happens with management systems that track recommendations rather than hazards. No rationale is given for resolving the recommendations or for the schedule of implementation. Long term resolutions are scheduled without one or more interim measures taken to mitigate the hazard in the interim period. The employer does not have a system or procedure in place to inform operating, maintenance, or other employees affected by a change resulting from implementation of a PHA recommendation, of the affects that change may have on them.

PROCESS HAZARD ANALYSIS [29 CFR 1910.119 (e)]

PQV Question	Explanation	Positive Program Indicators	Negative Program Indicators
8. Are the PHAs updated and revalidated at least every five years by a qualified team meeting the requirements in PQV question #6 (above) to assure that the process hazard analysis is consistent with the current process?	Initial PHAs should be reviewed and revalidated after five years by a qualified team to ensure that they are consistent with the design and operating procedures for the current process.	The employer documents any deviations from the previous PHA study (i.e. any changes to the process which have not been reviewed via a hazard analysis in the past five years). Where deviations exist between the previously analyzed and existing process, the employer conducts and documents a PHA on those deviations using appropriate methodologies. The PHA is updated and revalidated by a qualified team. The team members should be knowledgeable and experienced in the current design, operation, and maintenance activities for the covered process. Revalidation includes, but is not limited to, a complete review of all parts of the worksheet, correction of minor errors, including minor changes, and includes reconvening a hazard analysis team to review changes or review process safety incidents. Another PHA is performed as part of the update /revalidation process, if it is determined that there were significant process changes.	PHAs are not updated and revalidated at least every five years by a qualified team. The employer has no schedule or procedure for updating and revalidating previous PHA studies. The PHAs are not updated and revalidated by a team, but rather by one individual. The PHA revalidation team is not knowledgeable and experienced in the process being reviewed.
9. Are all initial PHAs, updates or revalidations, and documented resolutions or recommendations kept for the life of the process?	All necessary PHA documentation, including study results, study worksheets, and information on the resolution of the study recommendations, should be retained for the life of the process.	The employer maintains a file of the following information: reports of initial PHA studies, reports of updated/revalidated PHA reviews and recommendation resolution/tracking documentation. The initial PHA study report and worksheet is maintained as finalized by the study team, and not updated or modified over time as the process is modified. A separate copy of the PHA study report or worksheet could be made for updating and revising as the process changes.	PHA documentation is not complete or not retained for the life of the covered process. The employer did not maintain an original copy of the PHA documentation on file, but rather modified/updated the documentation as the process changed. A second copy of the documentation could be used for this purpose, while the original copy is maintained on file.

APPENDIX A

List of Acronyms

LIST OF ACRONYMS

AIChE *	American Institute of Chemical Engineers
ANSI *	American National Standards Institute
API *	American Petroleum Institute
ASHRAE *	American Society of Heating, Refrigeration and Air-Conditioning Engineers
ASME *	American Society of Mechanical Engineers
ASTM	American Society for Testing and Material
AWS *	American Welding Society
BFD	Block Flow Diagram
CCPS *	Center for Chemical Process Safety
CGA *	Compressed Gas Association
CMA *	Chemical Manufacturers Association
DIERS	Design Institute for Emergency Relief Systems
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FMEA	Failure Mode and Effects Analysis
FTA	Fault Tree Analysis
HAZOP	Hazard and Operability Study
HHC	Highly Hazardous Chemical
IDLH	Immediately Dangerous to Life and Health
IIAR *	International Institute of Ammonia Refrigeration

ISA	Instrument Society of America
LC	Lethal Concentration
LD	Lethal Dose
MSDS	Material Safety Data Sheet
NFPA *	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
P&ID	Piping and Instrument Diagram
PEL	Permissible Exposure Limit
PFD	Process Flow Diagram
PHA	Process Hazard Analysis
PSM	Process Safety Management
PQV	Program-Quality-Verification
SOCMA	Synthetic Organic Chemical Manufacturers Association
SOP	Standard Operating Procedure
STEL	Short Term Exposure Limit

* Mailing address and telephone numbers included

Referenced Agency Addresses and Phone Numbers

AIChE
American Institute of Chemical Engineers
345 East 47th Street
New York, New York 10017
Phone: 212-705-7338

ANSI
American National Standards Institute
11 West 42nd Street
New York, New York 10036
Phone: 212-642-4900

ASHRAE
American Society of Heating, Refrigerating and Air-Conditioning Engineers
1791 Tullie Circle, N.E.
Atlanta, Georgia 30329
Phone: 404-636-8400

ASME
American Society of Mechanical Engineers
22 Law Drive
P. O. Box 2300
Fairfield, New Jersey 07007-2300
Phone: 800-843-2763

AWS
American Welding Society
550 N.W. LeJeune Road
Miami, Florida 33126
Phone: 800-443-9353

CCPS
Center for Chemical Process Safety of the AIChE
345 East 47th Street
New York, New York 10017
Phone: 212-705-7319

Referenced Agency Addresses and Phone Numbers (Continued)

CGA
Compressed Gas Association
1725 Jefferson Davis Highway, Suite 1004
Arlington, Virginia 22202
Phone: 703-412-0900

CMA
Chemical Manufacturers Association
2501 M Street, N.W.
Washington, D.C. 20037
Phone: 202-887-1100

IIAR
International Institute of Ammonia Refrigeration
1101 Connecticut Avenue, N.W., Suite 700
Washington, D.C. 20036
Phone: 202-857-1110

ISA
Instrument Society of America
67 Alexander Drive
P.O. Box 12277
Research Triangle Park, North Carolina 27709
Phone: 919-549-8411

NFPA
National Fire Protection Association
1 Batterymarch Park
Quincy, Massachusetts 02169
Phone: 800-344-3555

GLOSSARY OF TERMS

BLOCK FLOW DIAGRAM or BFD[1]

A diagram used to show the major process equipment and interconnecting process flow lines as well as flow rates, stream composition, temperatures, and pressures. The BFD is intended as a simplified diagram.

CHECKLIST[2]

Detailed list of desired system attributes or steps for a system or operator to perform. Usually written from experience and used to assess the acceptability or status of the system or operation compared to established norms.

CONSEQUENCE[2]

The direct, undesirable result of an accident sequence usually involving a fire, explosion, or release of toxic material. Consequence descriptions may be qualitative or quantitative estimates of the effects of an accident in terms of factors such as health impacts, economic loss, and environmental damage.

DECISION TREES[4]

Decision trees are a special case of event tree models used to guide the user through multiple questions and provide a course of action based on the outcome of all of the questions. They provide no logical method of choosing the initiating event.

ELECTRICAL ONE-LINE DIAGRAM[1]

A diagram including legend of the electrical power distribution system that could contribute to a highly hazardous chemical release showing such items as power consumers, the chain of supply back through starters, distribution centers, substations to the main feeder, emergency power supply, and connections to various components. For complex systems, the one-line diagram may be a group of drawings.

FACILITY[3]

The buildings, containers and equipment that could reasonably participate in a catastrophic release as a result of being physically interconnected or of their proximity and in which dangerous substances are used, stored, manufactured, handled, or moved.

FAILURE MODE AND EFFECTS ANALYSIS or FMEA[1]

A specifically designed method to identify the conceivable ways that a highly hazardous chemical equipment or its components can fail and the effect of the failure on the system with respect to a release. The failure and effects are determined in a study of updated piping and instrument diagrams that describe the facility taking into consideration process chemistry, standard operating procedures, maintenance procedures, operator job descriptions, process flow diagrams, inventory tabulations, electrical one-line diagrams and other documents. The resulting qualitative analysis is translated into a quantitative FMEA when probabilities of the failure of components are assigned. The results of the FMEA are reported for a unit or system of a facility on an FMEA table. The results are entered on a FMEA table for each equipment item or component studied are as follows: the identification number of the item, the name of the item, the other equipment potentially affected with the equipment identification number and the effect of the failure on that equipment, a classification of the criticality ranking of the failure based on quantity or rate of the potential release, the probability of the failure and the suggested action in terms of equipment or procedure to prevent the failure or to mitigate the results of the failure.

FAULT TREE ANALYSIS or FTA[1]

The analysis of the logic diagram constructed from a study of the updated piping and instrument diagrams that describe the facility taking into consideration process chemistry, standard operating procedures, maintenance procedures, operator job descriptions, process flow diagrams, inventory tabulations, electrical one-line diagrams and other documents. The logic diagram is called a fault tree and represents a qualitative analysis of the hazards. Results of the FTA are reported for a unit or system on a table. Entered on the table are the descriptions of the various combinations of equipment or procedural failures that can lead to a release. The combinations are determined by solving the fault tree logic diagram for the minimal cut sets, that is, the smallest combination of equipment or procedural failures, which if all occur, will result in the "top event", that is the highly hazardous chemical release. The table is also entered with a criticality ranking based on the quantity or rate of the potential release, a probability for the respective failures and the suggested action in terms of equipment or procedure to prevent the failure or to mitigate the results of the failure. The analysis of the logic diagram includes the identification of "minimal cut sets." When probabilities are assigned to each element of the event sequence, a qualitative fault tree is obtained which gives the probability or frequency of occurrence of the release.

HAZARD[2]

An inherent physical or chemical characteristic that has the potential for causing harm to people, property, or the environment.

HAZARD ANALYSIS[1]

A systematic identification of the potential conditions that may result in an EHS accident.

HAZARD AND OPERABILITY STUDY or HAZOP[1]

A systematic study of updating piping and instrument diagrams that describe the highly hazardous chemical facility taking into consideration process chemistry, standard operating procedures, maintenance procedures, operator job descriptions, process flow diagrams, chemical inventory tabulations, electrical one-line diagrams and other documents. The study is performed by a multidisciplinary team to identify hazard or operability problems that would result in a highly hazardous chemical accident. Deviations from the design value of key parameters (flow, temperature, composition, time, quantity, etc.) of each segment of the highly hazardous chemical facility and its procedures are studied using guide words (such as, more of, less of, none of, part of, more than and other) to control the examination and evaluation. The study team shall consist of trained personnel knowledgeable in the technology and operations, such as process chemistry, the design of the system, the procedures of its operation and maintenance, and the related codes, standards and practices. In addition, the study team shall have technical expertise to answer most questions of the review without resorting to further expertise. The study team shall include a study leader specifically qualified for his or her leadership role by training or previous experience in HAZOP studies and a team secretary who shall record the results of the study. Persons who occupy these team study positions shall be technically trained and be available for the duration of the study. Results of the HAZOP study shall be reported by tabulation for a unit by key equipment, such as vessels or pipelines, and process parameter. The results are entered on the table as follows: guide word, causes of the deviation, consequences of the deviation in terms of a potential release, the criticality based on the quantity or rate of potential release and the suggested action in terms of equipment or procedure to mitigate the deviation.

HIGHLY HAZARDOUS CHEMICAL or HHC[3]

A substance possessing toxic, reactive, flammable, or explosive properties.

HUMAN ERROR[2]

Actions by or failures to act on the part of designers, operators, managers, or other individuals that may contribute to or result in accidents.

MATERIAL SAFETY DATA SHEET or MSDS[1]

A document which describes, at a minimum, the chemical and physical properties and the physical and health hazards of a substance.

MODIFICATION[1]

Any change in existing equipment or procedures that would require a change in process safety information and/or operating procedures. Modification does not include routine maintenance or replacement in kind.

OPERATOR[2]

An individual responsible for monitoring, controlling, and performing other tasks as necessary to accomplish the productive activities of a system. Often used in a generic sense to include people who perform various tasks (e.g.; reading, calibration, maintenance).

PIPING AND INSTRUMENT DIAGRAM or P&ID[1]

One or more detailed drawings including legends and citations of referenced documents showing: every item of highly hazardous chemical equipment and its identification number (including installed spare equipment); every pipe size, flow direction, identification number and identification of ANSI piping specification and break between piping specifications; symbols and identification of every instrument including instrument function to show trips and interlocks represented in accordance with Instrument Society of America standards or a standard adequate for the conduct of a safety review or hazard analysis with an appropriate symbol legend shown, every valve, the failsafe position of control valves or non-hand operated valves in the case of instrument air or power failure; steam traps; representation of insulation or heat tracing of piping, highly hazardous chemical equipment and instruments; sizes of all important equipment nozzles with location shown schematically to reflect function and elevation, such as, drains, vents, flushing connections and steam connections; references to inter-facing with other diagrams describing process, service, treatment, disposal, or utility systems; data on type, size, and set pressures of every relief valve and relieving device; instruments to monitor early detection of abnormal conditions or a highly hazardous chemical release; where critical, the relative elevations between equipment and of key piping; notes or symbols on such items as slope of critical piping to avoid pockets, or, where critical symmetrical piping; notes on each item of highly hazardous chemical equipment, such as, material of construction, design temperature, design pressure, design thermal duty of heat exchangers, design capacity and dynamic head of rotating equipment, etc.

PRELIMINARY HAZARD ANALYSIS[2]

A technique that is derived from the U.S. Military Standard System Safety Program Requirements. Focuses in a general way on the hazardous materials and major process areas of a plant, and is often used as a precursor to further hazard analyses.

PROCESS CHEMISTRY[1]

The chemical reactions which are relevant to possible scenarios of highly hazardous chemical releases, including information on raw materials, intermediates, products, and waste products.

PROCESS FLOW DIAGRAM or PFD[1]

A diagram including a legend of a facility which depicts the use, generation, storage or handling of a highly hazardous chemical showing items of equipment (groups of duplicate equipment may be represented by one symbol if desired), flow of material from item to item, simplified basic control loops or major control schemes, points of discharge to the environment, and showing or cross-referencing documents which give details of material balance, flows, raw materials, products, intermediates, treatment chemicals, operating conditions of temperature, pressure and steam characteristics, operating cycles and batch sizes where applicable. A process flow diagram includes, or references, a block flow diagram that depicts the receipt, handling and storage steps at the site of shipping containers of the highly hazardous chemical.

PROCESS SAFETY MANAGEMENT[2]

The application of management systems to the identification, understanding, and control of process hazards to prevent process-related incidents and injuries.

REPLACEMENT IN KIND[1]

The replacement of existing highly hazardous chemical equipment with identical or equivalent highly hazardous chemical equipment, and installation according to criteria for design and operation.

RISK[2]

Combination of the expected frequency (events/year) and the consequence (effects/event) of a single accident or a group of accidents.

STANDARD OPERATING PROCEDURE[1]

The document setting forth the operating procedures covering all details of the operation involving highly hazardous materials that are currently in effect at the facility.

TRUTH TABLES[4]

A listing of all combinations of the states of basic events, the resulting occurrence or non-occurrence of a top event, and the corresponding probabilities for the combinations.

WHAT-IF CHECKLIST[1]

A method of hazard analysis based on a systematic study of updated piping and instrument diagrams that describe the highly hazardous chemical facility taking into consideration process chemistry, standard operating procedures, maintenance procedures, operator job descriptions, process flow diagrams, inventory tabulations, electrical one-line diagrams and other documents. The study is performed by a multidisciplinary team to identify hazards or operability problems that could result in a highly hazardous chemical accident. The study is composed of a comprehensive list of questions prepared in advance from study of documents by team members either in conference or independently usually corresponding to their individual background. The study team shall consist of trained personnel knowledgeable in the technology and operations, such as process chemistry, the design of the equipment, the procedures of operation and maintenance and the related criteria for design and operation. In addition they shall have technical expertise to answer most of the questions of the review without recourse to further expertise. The team shall include a person assigned to lead the study and a person to record the results who are technically trained and will be available for the duration of the study. Results of the study shall be reported for a unit on a table. The results are entered on the table as follows: the "what if" question and its corresponding consequence/hazard, the criticality based on the quantity or rate of the potential release and the recommended action in terms of equipment or procedure to mitigate the consequence/hazard.

1. New Jersey Toxic Catastrophe Prevention Act, N.J.A.C. 7:31, New Jersey Department of Environmental Protection and Energy, June 18, 1993.

2. Guidelines for Hazard Evaluation Procedures, 2nd. ed., Center for Chemical Process Safety of the American Institute of Chemical Engineers, 1992.

3. Process Safety Management of Highly Hazardous Chemicals, 29 CFR Part 1910.119, Occupational Safety and Health Administration, February 24, 1992.

4. Reliability Engineering and Risk Assessment, Ernest J. Henley and Hiromitsu Kumamoto, Princeton-Hall, Inc., 1981.

APPENDIX C

Technical References

GENERAL REFERENCES

Ammonia Plant Safety (and related facilities), vol. 23, American Institute of Chemical Engineers, 1981.

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Ammonia Plant Safety (and related facilities), vol. 27, American Institute of Chemical Engineers, 1987.

Ammonia Plant Safety (and related facilities), vol. 28, American Institute of Chemical Engineers, 1988.

Ammonia Plant Safety (and related facilities), vol. 31, American Institute of Chemical Engineers, 1988.

"Guidelines for Safe Automation of Chemical Processes," American Institute of Chemical Engineers, 220p.

"Guidelines for Investigating Chemical Process Incidents," American Institute of Chemical Engineers, 347p.

"Guidelines for Auditing Process Safety Management Systems," American Institute of Chemical Engineers, 136p.

"Management of Process Hazards," American Petroleum Institute, Recommended Practice 750.

"Process Safety Management (Control of Acute Hazards)," CMA.

Chemical Manufacturers Association (CMA's Manager Guide), First Edition, September 1991.

"The Revised Field Operations Manual (FOM)," OSHA Instruction CPL 2.54B, June 15, 1989.

"State Plan Policies and Procedures Manual," OSHA Instructions STP 2.22A, Ch-2, January 29, 1990.

"Integrated Management Information Systems (IMIS) Forms Manual, Chapter V " OSHA Instruction ADM 1-1.12B, December 29, 1989.

"Systems Safety Evaluation of Operations with Catastrophic Potential," OSHA Instruction CPL 2-2.45, September 6, 1988.

"Process Safety Management Guidelines for Compliance," OSHA 3133; U.S. DOL, 1992.

"Process Safety Management," OSHA 3132; U.S. DOL, 1992.

"Safety and Health Program Management Guidelines," U.S. DOL, 1989.

"Review of Emergency Systems," June 1988; U.S. EPA, Office of Solid Waste and Emergency Response, Washington DC 20480.

"Chemical Exposure Index," Dow Chemical Co., May 1988.

"Accident Investigation * * * A New Approach," National Safety Council, 1983.

Process Safety Management Resources from the American Institute of Chemical Engineers for Use by Industrial Hygienists, James A. Gideon and Thomas W. Carmody, American Industrial Hygiene Association Journal (53), June 1992.

"Improving Construction Safety Performance," Report A-3, The Business Roundtable.

"Recommended Guidelines for Contractor Safety and Health," Texas Chemical Council.

"Loss Prevention in the Process Industries," Volumes I and II, Frank P. Lees, Butterworth, 1983.

"Guidelines for Engineering Design for Process Safety," 500p.

APPENDIX D

Example Programs

The following examples illustrate approaches taken by companies seeking to address the Process Hazard Analysis requirements of 29 CFR 1910.119. These examples have not been reviewed and/or endorsed by OSHA and should not be construed as model programs. Primatech makes no claims regarding the acceptability to OSHA of the information contained herein.

The example programs provided herein were developed for specific processes, and are not generic in nature. Since the OSHA PSM regulation is performance-based, readers are strongly encouraged to develop programs tailored to their own covered processes.

CONTENTS

D-1 Process Hazard Analysis

A Hazard and Operability (HAZOP) study was performed for a sulfur recovery unit, which is generally found in a petroleum refinery. The following is a portion of the worksheets, specifically the sulfur converter and condensers. The worksheets identify the causes and consequences of potential deviations in the system. Safeguards are then recognized, which may prevent the scenario from occurring or mitigate the consequences, should the scenario actually occur. Where a potential need for improvement was noted, a recommendation was made.

Session 1 . SRU

Company: Jones Refinery
Location: Princeton, NJ
Facility: Sulfur Recovery Unit

Session Date: 09-21-93 Drawing No.: P&ID 93-001

	Name	Phone number	Location
Leader:	Peter Jordan	Princ. Engr	Princeton, NJ
Scribe:	Peter Jordan		
Team:	Chris Tripoli	Process Oper.	Princeton, NJ
	Lisa Martel	Process Eng.	Princeton, NJ
	Sherry Lichtenwalner	Process Eng.	Princeton, NJ
	John Palmer	Oper. Supr.	Princeton, NJ

Comments: Completed Nodes # 1-3

Company: Jones Refinery
Facility: Sulfur Recovery Unit

Session: 1 09-21-93 Revision: 0 Dwg#: P&ID 93-001
Node: 1 Sulfur Converter (Bed 1)
Parameter: Flow Intention: Unobstructed flow thru Sulfur Converter

DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
No Flow	1. Catalyst pluggage	Potential overpressure of sulfur converter; potential sulfur converter rupture; Potential release of acid gas to atmosphere; Potential explosive atmosphere	Catalyst rakes to free pluggage Vessel inspection program for all process vessels. Inspection schedule based on service not to exceed five years Alarms on high pressure in reaction furnace High-high pressure alarm activates shutdown of SRU. Downstream is open to atmosphere Area H2S monitors Plant wide emergency response and evacuation procedures Fire monitors are present throughout the unit Appropriate response equipment, PPE and response teams are present on-site on a 24 hour basis	1	4	4	: No recommendations	
	2. Loss of flow from upstream	Operability issue						
	3. Downstream pluggage	Potential overpressure of sulfur converter; potential sulfur converter rupture; Potential release of acid gas to atmosphere; Potential explosive atmosphere	Vessel inspection program for all process vessels. Inspection schedule based on service not to exceed five years Alarms on high pressure in reaction furnace High-high pressure alarm activates shutdown of	1	4	4	: No recommendations	

Company: Jones Refinery
Facility: Sulfur Recovery Unit

Session: 1 09-21-93 Revision: 0 - - Dwg#: P&ID 93-001
Node: 1 Sulfur Converter (Bed 1)
Parameter: Flow Intention: Unobstructed flow thru Sulfur Converter

DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
			SRU. Area H2S monitors Plant wide emergency response and evacuation procedures Fire monitors are present throughout the unit Appropriate response equipment, PPE and response teams are present on-site on a 24 hour basis					

Session: 1 09-21-93 Revision: 0 - - Dwg#: P&ID 93-001
Node: 1 Sulfur Converter (Bed 1)
Parameter: Temperature
Intention: Maintain converter temperature outlet below approximately 600 deg F.

DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
Higher Temperature	1. High inlet temperature	Potential runaway reaction; Potential catalyst damage	Five temperature indicators on Sulfur Converter (Bed 1)	4	2	7	: No recommendations	
		Potential fire in transfer line to Condenser	Temperature indicator on outlet of converter Operator training	4	2	7	: No recommendations	
		Potential equipment damage; Potential release of acid gas to atmosphere; Potential explosive atmosphere	Nitrogen station in area and hoses available to inert the reaction	1	4	4	Consider installing permanent nitrogen connections on Sulfur Converter to eliminate the need for use of temporary hoses	ENG
	2. Excess air	Potential runaway reaction; Potential catalyst damage	Five temperature indicators on Sulfur Converter (Bed 1) Operator training	4	2	7	: No recommendations	

Company: Jones Refinery
Facility: Sulfur Recovery Unit

Session: 1 09-21-93 Revision: 0 Dwg#: P&ID 93-001
Node: 1 Sulfur Converter (Bed 1)
Parameter: Temperature
Intention: Maintain converter temperature outlet below approximately 600 deg F.

DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
		Potential equipment damage; Potential release of acid gas to atmosphere; Potential explosive atmosphere	Nitrogen station in area and hoses available to inert the reaction	1	4	4	: See above recommendation for installing permanent nitrogen connections on Sulfur Converter to eliminate the need for use of temporary hoses	
	3. Loss of auxiliary burner flame	Potential runaway reaction; Potential catalyst damage	Five temperature indicators on Sulfur Converter (Bed 1) Operator training	4	2	7	: No recommendations	
		Potential equipment damage; Potential release of acid gas to atmosphere; Potential explosive atmosphere	Nitrogen station in area and hoses available to inert the reaction	1	4	4	: See above recommendation for installing permanent nitrogen connections on Sulfur Converter to eliminate the need for use of temporary hoses	
Lower Temperature	4. Catalyst fouling	Operability issue						
	5. Lower inlet temperature	Operability issue						

Company: Jones Refinery
Facility: Sulfur Recovery Unit

Node: 2
Page: 1

Session: 1 09-21-93 Revision: 0 - - Dwg#: P&ID 93-001
Node: 2 Line from Sulfur Converter (Bed 1) to Sulfur Condenser
Parameter: Flow
Intention: To transfer acid gas flow from Sulfur Converter to Sulfur Condenser.

DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
No Flow	1. Line becomes blocked	Potential release of acid gas to flare; Operability issue Potential to blow seal leg; Potential release of acid gas and sulfur to atmosphere; Potential explosive atmosphere	Alarms on high pressure in reaction furnace High-high pressure alarm activates shutdown of SRU. Operator training Area H2S monitors Plant wide emergency response and evacuation procedures Fire monitors are present throughout the unit Appropriate response equipment, PPE and response teams are present on-site on a 24 hour basis	1	4	4	: No recommendations	
	2. Emergency valve inadvertently activates	Potential release of acid gas to flare; Operability issue						
	3. Loss of flow from upstream	Operability issue						
	4. Line rupture	Potential release of acid gas to atmosphere; Potential explosive atmosphere	Line inspection program with frequency of inspection determined by calculated and observed corrosion rates Area H2S monitors Plant wide emergency response and evacuation procedures Fire monitors are present throughout the unit	1	4	4	: No recommendations	

Company: Jones Refinery
Facility: Sulfur Recovery Unit

Node: 2
Page: 2

Session: 1 09-21-93 Revision: 0 - - Dwg#: P&ID 93-001
Node: 2 Line from Sulfur Converter (Bed 1) to Sulfur Condenser
Parameter: Flow
Intention: To transfer acid gas flow from Sulfur Converter to Sulfur Condenser.

DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
			Appropriate response equipment, PPE and response teams are present on-site on a 24 hour basis					
More Flow		No significant hazards or operability issues						
Less Flow	5. Significant line leak	Potential release of acid gas to atmosphere; Potential explosive atmosphere	Line inspection program with frequency of inspection determined by calculated and observed corrosion rates Area H2S monitors Plant wide emergency response and evacuation procedures Fire monitors are present throughout the unit Appropriate response equipment, PPE and response teams are present on-site on a 24 hour basis	2	4	7	: No recommendations	

Company: Jones Refinery
Facility: Sulfur Recovery Unit

Node: 3
Page: 1

Session: 1 09-21-93 Revision: 0 - - Dwg#: P&ID 93-001
Node: 3 Sulfur Condenser
Parameter: Temperature Intention: Cool gases and condense sulfur formed in first converter.

DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
Higher Outlet Temperature	1. Tubes fouling in Sulfur Condenser	Potential inability to condense all the elemental sulfur; Operability issue	Temperature indicator indicates condenser outlet temperature Operator training					
	2. Loss of boiler feed water	Potential equipment damage; Potential release of acid gas to flare; Operability issue	Low level soft alarm to board Emergency valve activates on low-low level indication					
	3. High inlet temperature	Potential inability to condense all the elemental sulfur; Operability issue	Temperature indicator indicates condenser outlet temperature Temperature indicator indicates condenser inlet temperature Operator training					
Lower Outlet Temperature		No significant hazards or operability issues						

Session: 1 09-21-93 Revision: 0 - - Dwg#: P&ID 93-001
Node: 3 Sulfur Condenser
Parameter: Pressure Intention: Maintain Sulfur Condenser pressure below MAWP.

DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
Higher Pressure	1. Sulfur condenser tube pluggage	Potential equipment damage to Sulfur Condenser; Potential release of acid gas to atmosphere; Potential explosive atmosphere	Exchanger inspection program for all process exchangers. Inspection schedule based on service not to exceed five years Alarms on high pressure in reaction furnace High-high pressure alarm activates shutdown of SRU. Temperature indicator indicates condenser	1	4	4	: No recommendations	

Company: Jones Refinery
Facility: Sulfur Recovery Unit

Session: 1 09-21-93 Revision: 0 - - Dwg#: P&ID 93-001
Node: 3 Sulfur Condenser
Parameter: Pressure Intention: Maintain Sulfur Condenser pressure below MAWP.

DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
			outlet temperature Downstream is open to atmosphere Area H2S monitors Plant wide emergency response and evacuation procedures Fire monitors are present throughout the unit Appropriate response equipment, PPE and response teams are present on-site on a 24 hour basis					
	2. Downstream pluggage	Potential equipment damage to Sulfur Condenser; Potential release of acid gas to atmosphere; Potential explosive atmosphere	Exchanger inspection program for all process exchangers. Inspection schedule based on service not to exceed five years Alarms on high pressure in reaction furnace High-high pressure alarm activates shutdown of SRU. Temperature indicator indicates condenser outlet temperature Downstream is open to atmosphere Area H2S monitors Plant wide emergency response and evacuation procedures Fire monitors are present throughout the unit	1	4	4	: No recommendations	

Company: Jones Refinery
Facility: Sulfur Recovery Unit

Session: 1 09-21-93 Revision: 0 - - Dwg#: P&ID 93-001
Node: 3 Sulfur Condenser
Parameter: Pressure Intention: Maintain Sulfur Condenser pressure below MAWP.

DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
			Appropriate response equipment, PPE and response teams are present on-site on a 24 hour basis					
	3. Seal leg pluggage	Potential equipment damage to Sulfur Condenser; Potential release of acid gas to atmosphere; Potential explosive atmosphere	Exchanger inspection program for all process exchangers. Inspection schedule based on service not to exceed five years Alarms on high pressure in reaction furnace Seal flow is monitored thru look box Seal is flushed three times daily per procedure. High-high pressure alarm activates shutdown of SRU. Temperature indicator indicates condenser outlet temperature Downstream is open to atmosphere Area H2S monitors Plant wide emergency response and evacuation procedures Fire monitors are present throughout the unit Appropriate response equipment, PPE and response teams are present on-site on a 24 hour basis	1	4	4	: No recommendations	

Company: Jones Refinery
Facility: Sulfur Recovery Unit

Session: 1 09-21-93 Revision: 0 - - Dwg#: P&ID 93-001
Node: 3 Sulfur Condenser
Parameter: Pressure Intention: Maintain Sulfur Condenser pressure below MAWP.

DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
Lower Pressure		No significant hazards or operability issues						

D-2 What-if Analysis - Ammonia Refrigeration System

A What-if analysis was conducted for an ammonia refrigeration facility. The following is a portion of the worksheets, specifically the ultra low vessel. The worksheets identify potential hazards and consequences of a system as well as recognize current safeguards in place to reduce the risk or likelihood of an incident. Recommendations were made where there was a potential need for improvements.

Session 1 for SAMPLE

Company: Smith's Company
Location: Princeton, NJ
Facility: Ammonia Refrigeration System

Session Date: 09-28-93

	Name	Phone number	Location
Leader:	Peter Jordan, Primatech	Prin. Eng.	Princeton, NJ
Scribe:	Peter Jordan		
Team:	Chris Tripoli	Refr. Supr.	Princeton, NJ
	Lisa Martel	Operator	Princeton, NJ
	Sherry Lichtenwalner	Operator	Princeton, NJ
	John Palmer	Engineer	Princeton, NJ

Comments:

Company: Smith's Company
Facility: Ammonia Refrigeration System

Session: 1 09-28-93 Revision: 0 - -
System: 1 Ammonia Refrigeration System
Subsystem: Ultra low Vessel Dwg#: 606A

WHAT IF...	HAZARD	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
1. Corrosion of vessel, piping, instrumentation	Potential release of ammonia from leak point	Potential release of ammonia into the engine room	Ultra low vessel operating parameters will be logged by operators every four hours; small leak should be detected during logging procedures Ammonia detector in engine room; detector will alarm in control room and start ventilation fans automatically *when setpoint (100* ppm) is reached	1	4	4	: No recommendations	
2. Drain valve open/leaking on ultra low vessel	Potential release of ammonia from leak point	Potential release of ammonia into the engine room	Drain valve contains a plug Ultra low vessel operating parameters will be logged by operators every four hours; leak should be detected during logging procedures Ammonia detector in engine room; detector will alarm in control room and start ventilation fans	2	3	6	Consider ensuring that the operating engineer regularly checks that caps and plugs are on placed on drain valves in the ammonia refrigeration system	CFT

Company: Smith's Company
Facility: Ammonia Refrigeration System

System: 1
Page: 2

Session: 1 09-28-93 Revision: 0
System: 1 Ammonia Refrigeration System
Subsystem: Ultra Low Vessel Dwg#: 606A

WHAT IF...	HAZARD	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
			automatically when setpoint (100 ppm) is reached					
3. Manual valve or hand expansion valve closed in liquid supply line to ultra low vessel	Low levels could develop in ultra low vessel	Potential damage to ultra low pump due to cavitation	Sight glass provided on ultra low vessel Ultra low vessel operating parameters (including level) will be logged by operators every four hours; microprocessor continuously logs and trends process variables Low level alarm/shutoff (LSL-100) alarm will automatically stop ultra low pumps	3	3	7	: No recommendations	
4. Failure of level control system (LCV-101) (for example, oil in level probe or instrument not properly calibrated)	Low levels could develop in ultra low vessel	Potentially damage to ultra low pump due to cavitation	Sight glass provided on ultra low vessel Ultra low vessel operating parameters (including level) will be logged by operators every four hours; microprocessor continuously logs	3	3	7	: No recommendations	

Company: Smith's Company
Facility: Ammonia Refrigeration System

Session: 1 09-28-93 Revision: 0 - -
System: 1 Ammonia Refrigeration System
Subsystem: Ultra Low Vessel Dwg#: 606A

WHAT IF...	HAZARD	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
			and trends process variables Low level alarm/shutoff (LSL-100) alarm will automatically stop ultra low pumps					
	High levels could develop in ultra low vessel	Slug of liquid could be sent to ultra low compressors, which could damage the compressors	Noise on compressor caused by slug of liquid would provide indication of liquid carryover - operators would respond to problem once noise is observed Low lube oil temperature cutout and alarm may detect problem before compressor damage results High level switch (LSH-102) will automatically shut down ultra low compressors if high levels develop in ultra low vessel (switch is independent of LCV-101)	2	3	6	: No recommendations	

Company: Smith's Company
Facility: Ammonia Refrigeration System

Session: 1 09-28-93 Revision: 0 - -
System: 1 Ammonia Refrigeration System
Subsystem: Ultra Low Vessel Dwg#: 606A

WHAT IF...	HAZARD	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
5. Manual valve open in level control system by-pass line	High levels could develop in ultra low vessel	Slug of liquid could be sent to ultra low compressors, which could damage the compressors	Noise on compressor caused by slug of liquid would provide indication of liquid carryover - operators would respond to problem once noise is observed Low lube oil temperature cutout and alarm may detect problem before compressor damage results High level switch (LSH-102) will automatically shut down ultra low compressors if high levels develop in ultra low vessel (switch is independent of LCV-101)	2	3	6	: No recommendations	
6. High compressor suction pressures	Higher pressure could develop in ultra low vessel	No safety or environmental consequences since unlikely to overpressure ultra low vessel (operability issue)	Pressure rating of ultra low vessel (150 psig) is above high pressure shutdown setpoint for ultra low compressors (100 psig)	4	3	8	: No recommendations	
7. Low compressor	None	No safety or	Ultra low vessel	4	3	8	: No recommendations	

Session: 1 09-28-93 Revision: 0 - -
System: 1 Ammonia Refrigeration System
Subsystem: Ultra Low Vessel Dwg#: 606A

WHAT IF...	HAZARD	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
suction pressures		environmental consequences (operability issue)	is rated for full vacuum					
8. Manual valve closed in pump suction line	Ultra low suction pump could cavitate	Potentially damage to ultra low pumps	Ultra low vessel operating parameters will be logged by operators every four hours; microprocessor continuously logs and trends process variables Pressure gauge in common pump discharge line Manual valves in pump suction lines are only closed for maintenance operations; maintenance operations are covered by lockout/tagout procedures	3	3	7	: No recommendations	
9. Manual valve closed in pump discharge line	Potentially develop high pump discharge pressures	Potentially overpressurize system, which could lead to an ammonia release in the engine room	Pressure regulator (vented back to ultra low vessel) provided in pump discharge line Pressure safety valve on discharge of pump P-1B which vents to the ultra	1	4	4	Consider providing a pressure relief valve on the discharge of pump P-1A	PJP

Session: 1 09-28-93 Revision: 0 - -
System: 1 Ammonia Refrigeration System
Subsystem: Ultra Low Vessel Dwg#: 606A

WHAT IF...	HAZARD	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
			low vessel Ultra low vessel operating parameters will be logged by operators every four hours (including pump pressure) Manual valves in pump discharge lines are only closed for maintenance operations; maintenance operations are covered by lockout/tagout procedures					
10. Malfunction of pressure regulator in pump discharge line	Potentially develop high pump discharge pressures (if regulator does not open on high pump discharge pressures)	Potentially overpressurize system which could lead to an ammonia release in the engine room	Ultra low vessel operating parameters will be logged by operators every four hours (including pump pressure) Pressure safety valve on discharge of pump P-1B which vents to the ultra low vessel	1	3	3	: See recommendation identified in previous scenario concerning installing a pressure safety valve for pump P-1A	
	Low pump discharge pressures could develop	No safety or environmental		4	3	8	: No recommendations	

Company: Smith's Company
Facility: Ammonia Refrigeration System

Session: 1 09-28-93 Revision: 0
System: 1 Ammonia Refrigeration System
Subsystem: Ultra Low Vessel Dwg#: 606A

WHAT IF...	HAZARD	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
	(if regulator opens prematurely)	consequences (operability issue)						
11. Manual valve closed in pump pressure regulator line	Potentially develop high pump discharge pressures	Potentially overpressurize system which could lead to an ammonia release in the engine room	Ultra low vessel operating parameters will be logged by operators every four hours (including pump pressure) Pressure safety valve on discharge of pump P-1B	1	3	3	Consider car sealing (open) the manual valves in the pump pressure regulator line	CFT
12. Pump stops (due to either mechanical failure or failure of low level switch (LSL-100))	Loss of flow to evaporators	No safety or environmental consequences (operability issue)		4	2	7	: No recommendations	
13. Leaking pressure safety valve on ultra low vessel (PSV-001A/B)	Potential release of ammonia from PSVs	Potential ammonia release to the atmosphere	PSV's covered by mechanical integrity program Ultra low vessel operating parameters will be logged by operators every four hours; release should be detected during rounds	2	3	6	: No recommendations	
14. Leaking pressure safety valve in pump discharge line (PSV-002)	Low pump discharge pressures could develop	No safety or environmental consequences (operability issue)	PSV's covered by mechanical integrity program	4	3	8	: No recommendations	

D-3 HAZOP Analysis - Ammonia Refrigeration System

A Hazard and Operability (HAZOP) study was performed for an ammonia refrigeration facility. The following is a portion of the worksheets, specifically the ultra low compressors. The worksheets identify the causes and consequences of potential deviations in the system. Safeguards are then recognized, which may prevent the scenario from occurring or mitigate the consequences, should the scenario actually occur. Where a potential need for improvement was noted, a recommendation was made.

Session 1 for OSHA

Company: Smith's Company
Location: Princeton, NJ
Facility: Ammonia Refrigeration Facility

Session Date: 09-29-93 Drawing No.: P&ID 606A/B

	Name	Phone number	Location
Leader:	Peter Jordan	Prin. Eng.	Princeton, NJ
Scribe:	Peter Jordan		
Team:	Chris Tripoli	Refr. Supr.	Princeton, NJ
	Lisa Martel	Operator	Princeton, NJ
	Sherry Lichtenwalner	Operator	Princeton, NJ
	John Palmer	Engineer	Princeton, NJ

Comments:

Company: Smith's Company
Facility: Ammonia Refrigeration Facility

Node: 1
Page: 1

Session: 1 09-29-93 Revision: 0 - - Dwg#: P&ID 606A/B
Node: 1 Ultra Low Compressors (UB-1 and UB-2)
Parameter: Flow
Intention: Ammonia flow of 5 to 80 lb/min per ultra low compressor at 18 in Hg to 25 in HG nominal suction pressure

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
No	No Flow	1. Valve closed in individual compressor suction line	Individual compressor will develop low suction pressures - No safety or environmental consequences (operability issue)	Compressors equipped with low suction pressure alarm and cutout	4	3	8	: No recommendations	
		2. Strainer plugged in compressor suction line	Individual compressor will develop low suction pressures -No safety or environmental consequences (operability issue)	Compressors equipped with low suction pressure alarm and cutout	4	2	7	Consider checking the strainers in the compressor suction lines on an annual basis	CFT
		3. Main valve closed in common suction line to both compressors	Both compressors will develop low suction pressures - No safety or environmental consequences (operability issue)	Compressors equipped with low suction pressure alarm and cutout	4	3	8	: No recommendations	
		4. Valve closed in individual compressor discharge line	Individual compressor will develop high dischnrge pressures which could lead to equipment damage or an ammonia release in the engine room	Compressors equipped with high discharge pressure alarm and cutout Compressors equipped with pressure relief valves (PSV- Compressor parameters will be logged every four hours; microprocessor continuously logs and trends process variables	1	4	4	: No recommendations	

Company: Smith's Company
Facility: Ammonia Refrigeration Facility

Session: 1 09-29-93 Revision: 0 - - Dwg#: P&ID 606A/B
Node: 1 Ultra Low Compressors (UB-1 and UB-2)
Parameter: Flow
Intention: Ammonia flow of 5 to 80 lb/min per ultra low compressor at 18 in Hg to 25 in HG nominal suction pressure

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
				Ammonia detector in engine room; detector will alarm in control room and start ventilation fans automatically when setpoint (100 ppm) is reached					
		5. Main valve closed in common discharge line from all compressors	Same consequences and safeguards as for cause #4		1	4	4	: No recommendations	
		6. Compressor stops (due to either mechanical failure or failure of one of the compressor cutouts)	Other compressor will attempt to compensate by ramping up; if compressors can't compensate, suction pressure will increase to a higher level (well below PSV setpoint) - No safety or environmental consequences (operability issue)	Refrigeration system equipped with high suction pressure alarm Compressor parameters will be logged every four hours; microprocessor continuously logs and trends process variables	4	2	7	: No recommendations	
		7. Slide valve on compressor permits no flow	Other compressor will attempt to compensate by ramping up; if compressors can't compensate, suction pressure will increase to a higher level (well	Refrigeration system equipped with high suction pressure alarm Compressor parameters will be logged every four hours; microprocessor continuously logs and trends process variables	4	2	7	: No recommendations	

Company: Smith's Company
Facility: Ammonia Refrigeration Facility

Session: 1 09-29-93 Revision: 0 - - Dwg#: P&ID 606A/B
Node: 1 Ultra Low Compressors (UB-1 and UB-2)
Parameter: Flow
Intention: Ammonia flow of 5 to 80 lb/min per ultra low compressor at 18 in Hg to 25 in HG nominal suction pressure

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
			below PSV setpoint) -No safety or environmental consequences (operability issue)						
More	More Flow	8. Higher suction pressures due to upset in system	Compressors will attempt to compensate for higher suction pressures - pressure may stabilize at a higher suction pressure, but this pressure will be well below PSV setpoint -No safety or environmental consequences (operability issue)	Refrigeration system equipped with high suction pressure alarm Compressor parameters will be logged every four hours; microprocessor continuously logs and trends process variables	4	1	4	: No recommendations	
		9. Lower discharge pressure	Compressors will attempt to compensate for lower discharge pressures - No safety or environmental consequences (operability issue)	Compressor parameters will be logged every four hours; microprocessor continuously logs and trends process variables	4	2	7	: No recommendations	
Reverse	Reverse Flow	10. Not credible, since compressor would have to stop and both suction and						: No recommendations	

Company: Smith's Company
Facility: Ammonia Refrigeration Facility

Node: 1
Page: 4

Session: 1 09-29-93 Revision: 0 - - Dwg#: P&ID 606A/B
Node: 1 Ultra Low Compressors (UB-1 and UB-2)
Parameter: Flow
Intention: Ammonia flow of 5 to 80 lb/min per ultra low compressor at 18 in Hg to 25 in HG nominal suction pressure

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
		discharge check valves would have to fail simultaneously							
Other Than	Other Than Flow	11. Leak from compressor seal	Release of ammonia into engine room	Ammonia detector in engine room; detector will alarm in control room and start ventilation fans automatically when setpoint (100 ppm) is reached Routine lubrication oil analysis and leak checking should prevent and/or readily detect seal problems	3	3	7	: No recommendations	
		12. Leak from compressor fittings, valves, flanges, oil separator manway, sight glasses and other instrumentation	Release of ammonia into engine room	Ammonia detector in engine room; detector will alarm in control room and start ventilation fans automatically when setpoint (100 ppm) is reached Compressor parameters will be logged every four hours; microprocessor continuously logs and trends process variables	2	3	6	: No recommendations	
		13. Excessive vibration on compressor	Damage to compressor could result, leading to an ammonia leak	Ammonia detector in engine room; detector will alarm in control room and start ventilation fans automatically when setpoint (100 ppm) is	2	3	6	Consider conducting regular vibration analyses of the compressors	CFT

Company: Smith's Company
Facility: Ammonia Refrigeration Facility

Session: 1 09-29-93 Revision: 0 - - Dwg#: P&ID 606A/B
Node: 1 Ultra Low Compressors (UB-1 and UB-2)
Parameter: Flow
Intention: Ammonia flow of 5 to 80 lb/min per ultra low compressor at 18 in Hg to 25 in HG nominal suction pressure

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
				reached Compressor parameters will be logged every four hours; microprocessor continuously logs and trends process variables					
		14. Leak from drain and purge points	Release of ammonia into engine room	Ammonia detector in engine room; detector will alarm in control room and start ventilation fans automatically when setpoint (100 ppm) is reached Oil drain lines contain two manual valves, and one of these valves is spring loaded (closed)	2	3	6	: No recommendations	

Company: Smith's Company
Facility: Ammonia Refrigeration Facility

Node: 1
Page: 6

Session: 1 09-29-93 Revision: 0 - - Dwg#: P&ID 606A/B
Node: 1 Ultra Low Compressors (U8-1 and U8-2)
Parameter: Temperature Intention: Discharge temperature: 120 to 200oF

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
More	Higher Discharge Temperature	1. Failure of oil lubrication system	Compressor bearings or seals could be damaged	Compressors equipped with low lube oil pressure alarm and cutout Differential pressure indicator associated with the lubrication oil filters Compressor parameters will be logged every four hours; microprocessor *continuously logs and* trends process variables	3	3	7	: No recommendations	
		2. High suction gas temperatures	Compressor discharge temperatures could increase, which could damage the compressor bearings and seals	Compressor is equipped with high discharge temperature alarms and cutouts Compressor parameters will be logged every four hours; microprocessor continuously logs and trends process variables	3	3	7	: No recommendations	
Less	Lower Temperature	3. Reduction in load from plant user points	Compressor system will compensate for reduced loads by shutting off compressors or reducing capacity on individual compressors -No safety or environmental consequences (operability issue)		4	1	4	: No recommendations	

Company: Smith's Company
Facility: Ammonia Refrigeration Facility

Node: 1
Page: 7

Session: 1 09-29-93 Revision: 0 - - Dwg#: P&ID 606A/B
Node: 1 Ultra Low Compressors (UB-1 and UB-2)
Parameter: Pressure
Intention: Suction side pressure: 18 in Hg to 25 in Hg; Discharge side pressure: 9 psig to 34 psig

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
More	Higher Pressure	1. Load increase in plant usage points	Compressors will attempt to compensate by ramping up; if compressors can't compensate, suction pressure will increase to a higher level (well below PSV setpoint) - No safety or environmental consequences (operability issue)	Compressor parameters will be logged every four hours; microprocessor continuously logs and trends process variables	4	1	4	: No recommendations	
		2. Overall loss in booster compressor capacity	Other compressor will attempt to compensate by ramping up; if compressors can't compensate, suction pressure will increase to a higher level (well below PSV setpoint) - No safety or environmental consequences (operability issue)	Compressor parameters will be logged every four hours; microprocessor continuously logs and trends process variables	4	3	8	: No recommendations	
		3. Wear in compressors over extended periods of time	Compressors will attempt to compensate by ramping up; if compressors can't compensate, suction pressure will increase to a higher level (well	Compressor parameters will be logged every four hours; microprocessor continuously logs and trends process variables	4	3	8	: No recommendations	

Company: Smith's Company
Facility: Ammonia Refrigeration Facility

Session: 1 09-29-93 Revision: 0 · · Dwg#: P&ID 606A/B
Node: 1 Ultra Low Compressors (UB-1 and UB-2)
Parameter: Pressure
Intention: Suction side pressure: 18 in Hg to 25 in Hg; Discharge side pressure: 9 psig to 34 psig

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
			below PSV setpoint) - No safety or environmental consequences (operability issue)						
		4. Manual valves closed in compressor discharge lines	See causes #4 and #5, no flow, this node, for consequences and safeguards					: No recommendations	
Less	Lower Pressure	5. Reduction in load from plant user points	Compressor system will compensate for reduced loads by shutting off compressors or reducing capacity on individual compressors -No safety or environmental consequences (operability issue)	Compressor parameters will be logged every four hours; microprocessor continuously logs and trends process variables	4	1	4	: No recommendations	
		6. Both compressors running (when only one compressor is needed)	Compressor system will compensate for reduced loads by reducing capacity on individual compressors -No safety or environmental consequences (operability issue)	Compressor parameters will be logged every four hours; microprocessor continuously logs and trends process variables	4	3	8	: No recommendations	
		7. Manual valves closed in	See causes #1 and #3, no flow, this					: No recommendations	

Company: Smith's Company
Facility: Ammonia Refrigeration Facility

Node: 1
Page: 9

Session: 1 09-29-93 Revision: 0 - - Dwg#: P&ID 606A/B
Node: 1 Ultra Low Compressors (UB-1 and UB-2)
Parameter: Pressure
Intention: Suction side pressure: 18 in Hg to 25 in Hg; Discharge side pressure: 9 psig to 34 psig

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
		compressor suction lines	node, for consequences and safeguards						
		8. Suction side blockage	See cause #2 no flow, this node, for consequences and safeguards					: No recommendations	
		9. Compressor capacity control malfunction	Compressor system will compensate for reduced loads by shutting off compressors or reducing capacity on individual compressors -No safety or environmental consequences (operability issue)	Compressor parameters will be logged every four hours; microprocessor continuously logs and trends process variables	4	3	8	: No recommendations	

Company: Smith's Company
Facility: Ammonia Refrigeration Facility

Node: 1
Page: 10

Session: 1 09-29-93 Revision: 0 - - Dwg#: P&ID 606A/B
Node: 1 Ultra Low Compressors (UB-1 and UB-2)
Parameter: Phase
Intention: Ammonia is handled as a gas in the compressor suction and dicharge lines

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	RECOMMENDATIONS	BY
More	More Phase	1. Liquid carryover from ultra low vessel	Small quantities of liquid will have no effect -No safety or environmental consequences (operability issue)		4	2	7	: No recommendations	
			Slug of liquid could cause potential compressor damage	Level control system (LCV-101) and high level switch (LSH-102) associated with ultra low vessel Noise on compressor caused by liquid will provide indication of liquid carryover - operators would respond to problem once noise is observed Low lube oil temperature cutout and alarm may detect problem before compressor damage results	1	4	4	: No recommendations	

D-4 Risk Ranking System - Process Hazard Analysis

The following is a summary of definitions used in a risk ranking system. Both potential severity and likelihood values are defined. The definitions of severity are broken down into categories for injuries, fires, releases and explosions.

SEVERITY AND LIKELIHOOD DEFINITIONS

DEFINITIONS OF SEVERITY

Potential Severity	For Injuries	For Fires	For Releases	For Explosions
High 1	Fatality or extended disabling injury	Conflagration or destruction of system	Causes complete shutdown of system and has off-site consequences	Any explosion or detonation
Moderate 2	Lost time injury (LTI)	Fire large enough to disrupt system operations	Causes partial shutdown of system and has on-site consequences	Overpressure or underpressure failure of equipment
Low 3	First aid case	Incipient fire only	Release can be handled by small spill procedure	Internal unplanned equipment pressure fluctuation without failure
None 4	No injuries	No fires	No release	No pressure fluctuations

DEFINITIONS OF LIKELIHOOD

Likelihood Potential	Description
High 1	Can potentially occur once or more per year.
Moderate 2	Can potentially occur once every several (two - three) years, but less than once a year.
Low 3	Can potentially occur once every ten years, but less than once every several years.
Extremely Low 4	Can potentially occur once in the lifetime of the system.

RANKING:

SEVERITY \ LIKELIHOOD	1	2	3	4
1	1	2	3	4
2	2	4	6	7
3	3	6	7	8
4	4	7	8	9

RANKING:

SEVERITY →

LIKELIHOOD ↓	1	2	3	4
1	1	2	3	4
2	2	4	6	7
3	3	6	7	8
4	4	7	8	9