A short course on Process Hazard Analysis (PHA) for Chemical Engineers

Process Hazard Analysis (PHA) provides a means of systematically reviewing the design and operation of a facility to identify occurrence of hazardous events with potential consequences on people, property and production, environment and reputation (a more new issue to be considered in a PHA). PHA studies can be conducted not only on continuous and batch chemical processes, but also on storage, transportation and other operating, manufacturing or support systems. This paper describes the main elements to be considered when conducting such an analysis.

KEYWORDS
Process Hazard Analysis

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INTRODUCTION

Process Hazard Analysis (PHA) provides a means of systematically reviewing the design and operation of a facility to identify occurrence of hazardous events with potential consequences on:

- People.
- Property and production.
- Environment.
- Reputation (a more new issue to be considered in a PHA).

PHA studies are usually conducted by a team of individuals led by a person knowledgeable in the PHA technique (the PHA Leader, Team Leader, Facilitator o Director). When the team identifies possible hazard scenarios and consequences for the facility, the team may then evaluate whether existing safeguards are adequate to protect against the scenario. Safeguards may be either in the form of hardware or administrative procedures. In some cases, the team may make recommendations for corrective action, for further study to determine an optimal solution, or for additional investigation to determine whether a problem exists that warrants action. The team session are registered in form of table/worksheet by a technical secretary or scribe.

The primary objective of PHA is the identification of hazard scenarios. The generation of recommendations or corrective actions, is a secondary objective (but also important). The PHA team should avoid delaying the study sessions trying to engineer solutions to every potential problem identified. If a solution is not obvious, note in the worksheet that a potential problem exists and recommend that someone review it later for potential solutions.

Facility management may need more information to make decisions on what should be done. It is useful if a simple risk estimate can be assigned for each hazard scenario in order to provide a basis for deciding on the best allocation of resources to address the problems identified. Consequently, means must be provided for qualitatively estimating the severity and likelihood of each scenario identified during the study, in order to develop a risk estimate.

PHA studies can be conducted not only on continuous and batch chemical processes, but also on storage, transportation and other operating, manufacturing or support systems. The following specific PHA techniques are acceptable to OSHA and EPA under the PSM and RMP regulations (OSHA 1990, EPA 1996):

- Checklist.
- What-if.
- What-if/Checklist.
- HAZOP (HAZard and OPerability studies).
- FMEA (Failure Modes Effects Analysis).

These techniques are also identified by the American Institute of Chemical Engineers(AIChE) as recognized hazard analysis techniques for process facilities such as chemical, petroleum and petrochemical plants (CCPS 1985, 1992 and 2008).

The application of similar specific techniques are required by the European Commission (EC) major-accident directives (so-called Seveso directives I, II and III).

New or updated techniques and variations, similar to those presented above, can be used also used for hazard identification:

- FMEDA (Failure Modes Effects and Diagnostic Analysis).
- HAZID (HAZard IDentification study).
- SWIFT (Structured What-IF Technique).

Important note: while PHA can provide a comprehensive and systematic analysis of the hazards in a facility, it cannot provide complete assurance that all hazards have been identified. Also, no analysis method can compensate for a team that lacks knowledge of the process or operation under study, applicable codes and standards, regulations and accepted industry safe design practices.

THE PHA TEAM

A process hazard analyses is usually performed by a team. The interaction of the team members results in a more thorough and complete review than would be accomplished by each individual working separately on the same project. A team typically consists of 5-7 individuals. One member is a person trained and knowledgeable in the PHA technique. The other members are usually selected for their knowledge of the process and/or technical contribution to the team.

The team leader is responsible for study preparation, guiding and managing the team, and supervising the study documentation and report generation. Team members provide information about the system to the team and identify hazard scenarios under the direction of the team leader. In general a technical secretary or scribe is employed to record results and prepare reports. Alternatively, the team leader can assume this responsibility in small PHA studies.

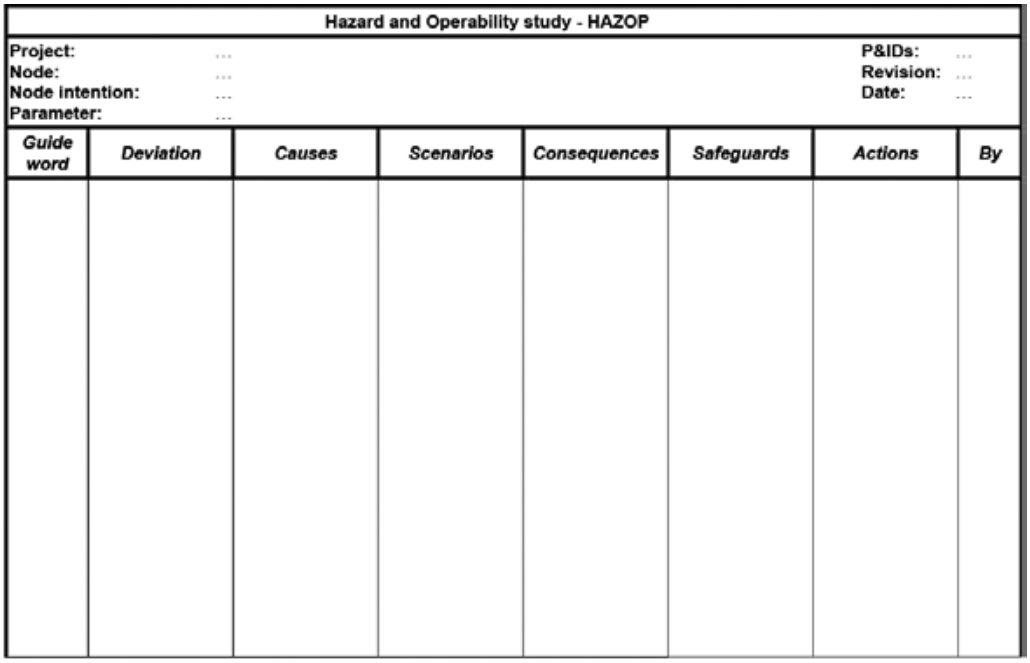
There is no one perfect combination of team members. However, since the team members need to be knowledgeable of the process and its operation, at least some of the team should come from the operating facility. A typical team may consist of the following members:

1. Team Leader or PHA Director.
2 Secretary or Scribe.
3. Process/Engineering representative.
4. Operations representative (essential member!).
5. Safety representative.
6. Maintenance/Inspection representative.
7. Instrumentation/Electrical representative.

The members 1 to 5 are essential and should be present during all the PHA meetings.

The actual composition of a specific team will depend upon the objectives of the study, the type of facility being

Figure 1. Typical PHA worksheet



Hazard and Operability study - HAZOP							
Project: ... Node: ... Node intention: ... Parameter: ...					P&IDs: ... Revision: ... Date: ...		
Guide word	*Deviation*	*Causes*	*Scenarios*	*Consequences*	*Safeguards*	*Actions*	*By*

studied, and other considerations. Other individuals may be used as resources for the team and brought into only those meeting sessions where their particular knowledge is needed. This approach keeps the core team to an efficient size.

THE PHA SESSIONS

A PHA team will require a number of hours to complete a study for a typical process. The team will therefore usually hold several meetings, or working sessions, spread over several days to perform the study. Since PHA is tiring, the sessions are usually scheduled for the morning when the team members are most fresh. The sessions are normally scheduled to last for periods of 4-6 effective hours. Longer sessions or afternoon sessions tend to tire the members, reducing the effectiveness of the analysis and the quality of the study.

During each session, the PHA team records their work in a worksheet. The basic purpose of the PHA study is to identify potential hazard scenarios. Therefore, the team should not spend any significant amount of time trying to engineer a solution when a potential problem is uncovered. If a solution to the problem is obvious, the team should document their recommended solution. If a solution is not obvious, they should recommend that someone follow up and resolve the problem outside the PHA study. Also, if there is insufficient information available at the time to decide if a potential problem exists, the team should note it, assign someone to collect additional information, and continue with the study. The issue should be revisited later by the team, when additional information is available, to determine if a potential problem exists.

THE PHA WOKSHEET

PHA is intended to identify hazards. It is not intended to be a problem-solving technique. The essential results of a PHA study are recorded in a worksheet containing:

- Selected question, root cause or failure origin of trouble.
- A description of each hazard scenario identified. The best way it is to use 2 two column approach in the worksheet: the scenario column (hazard) and the consequence column (damage).
- List of safeguards or measures available to protect against the scenario.
- A risk ranking of each hazard scenario based on severity, likelihood and/or risk, which may provide for more targeted analysis, planning and resource allocation. Risk ranking can be done in several ways:

  - Unmitagated risk (not considering the effect of the safewards on the risk ranking).
  - Mitigated risk (considering the effect of the safewards on the risk ranking).

- Recommended actions to improve safety such as:

  - Recommendations for changes in design, procedures, etc. to correct a problem where it is obvious to the PHA team.
  - Recommendations for follow up

where no conclusion was possible due to lack of information.

- Recommendations for additional study to determine if a situation actually represents a hazard of concern.

Typical columns in a PHA worksheet are:

- Question/cause/failure (origin of trouble).
- Scenario (evolution to a hazardous situation).
- Consequence (type and level of damage).
- Safeguard (to protect against scenario).
- Mitigated Risk Ranking (considering safeguards).
- Actions (proposed safety improvements in order to reduce the risk).

SUCCESS FACTORS

Discussion by the team may also reveal a lack of information or lead to a question. The study leader should ensure that any such issues are resolved before the study is completed so that the final report contains only warranted recommendations. There are several factors that can influence the success of a PHA study. These include:

- Clearly understood statement of the study purpose, scope and objectives.
- Degree of preparation by the team leader.
- Experience of the team leader in leading PHAs.
- Experience and breadth of knowledge of the team.
- Accuracy of the process drawings and other reference information.
- Adequacy of the study documentation.
- Adequacy of follow up activities after the study is completed. Usually a database o software tool is recommended for this follow up.
- Adequacy of meeting facilities.

DEFINING A STUDY

The first step in conducting a PHA is to explicitly state the purpose, scope and objectives of the study. They directly influence the content and emphasis of the study and the time that will be required to complete the study. Also be sure that the expected results of the study are clear to those who have requested the study. Sometimes, management has a perception of what the PHA study will achieve which may be different from that of the team.

Purpose

The purpose of the study is the underlying reason that the study was requested. Examples are:

- Comply with regulations.
- Meet company policy requirements.
- Address facility sitting.

Scope

It is also important to define the scope of the study. This includes specifying:

- Physical boundaries of the system to be studied.
- Modes of operation to be included.
- Whether domino effects (effects on and from adjacent systems) are to be included.
- What external events are to be treated.
- Extent to which recommendations for corrective actions will be developed.
- Whether severity and likelihood rankings will be used.
- Whether procedures will be treated implicitly or explicitly.

Objectives

Objectives are usually set by the person requesting the hazard analysis, but could be assisted by the PHA team leader. The objectives provide a clear focus for the study. Examples are:

- Types of hazards to be treated:
  - Toxic releases.
  - Fires and explosions.
- Consequences to be considered:
  - Public safety.
  - Public property damage.
  - Employee safety.
  - Liability.
  - Loss of plant or equipment.
  - Insurability.
  - Loss of production.
  - Environmental impact.
- Identify the major contributors to risk at the facility.
- Determine possible accident sequences for emergency planning.

SELECTING A TEAM

PHA is a team process. It relies on the principle that a team of people, working in a brainstorming session, will more thoroughly review the process than would be accomplished by each person working individually. The PHA team should consist of persons with differing backgrounds to bring a variety of viewpoints to the team. Previous PHA experience is desirable but not essential for team members.

A PHA team usually consists of 5-7 people, although a smaller team may be sufficient for a small facility. If the team is too large, the group approach fails because too many people are trying to communicate with one another and are inhibited from working closely. If the group is too small, it may lack the breadth of knowledge needed to help assure completeness and the creativity generated by multiple interactions.

The team is led by a person who should be knowledgeable and experienced in the PHA technique being used. The team leader does not necessarily need to know the process being reviewed. Duties of the team leader include:

- Preparation for the study (ensure needed information is available,

identify resources needed, plan study).

- Ensure participants understand the process and their roles.
- Guide team members through the review.
- Provide technical input to supplement the team.
- Manage the team.
- Supervise the recording of the meetings.
- Ensure the PHA reports are complete and accurate.

The team leader is usually assisted by a technical secretary, or scribe, whose responsibilities include:

- Record the results of the PHA team meetings.
- Prepare the meeting reports.
- Assist in the collection of needed information.

The scribe is the individual who will most likely use a software package for registration of the meeting notes in the PHA worksheet (using a word processor, a spreadsheet or a specially designed software product). It is also common for this software package to be used by the team leader.

Other team members are selected based on the technical expertise and/or operating experience they bring to the team. For example, a team may include:

- Design engineer.
- Instrument design engineer.
- Process engineer.
- Chemist.
- Safety engineer.
- Maintenance engineer.
- Operations supervisor.
- Operator.

Note that titles of job positions may vary with facilities and companies. The actual composition of the team depends on the particular study. The composition may also vary from meeting to meeting within a PHA study as various experts, or technical specialists, are utilized on an as needed basis. Some specially designed software products provide the capability to record team participants by session.

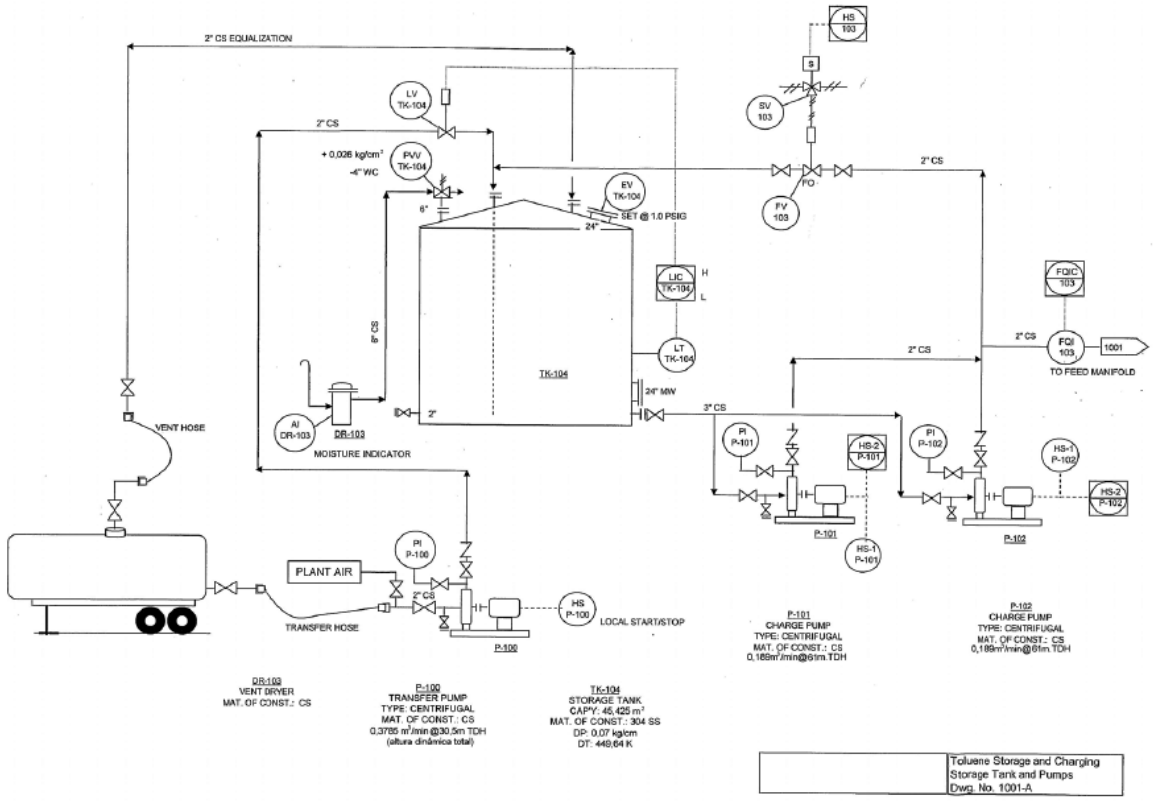
Team members provide information about the process, brainstorm hazard scenarios, identify existing safeguards, estimate severities and likelihoods of hazard scenarios, and identify any obvious initial recommendations.

It is also useful to have a designated local on-site coordinator when performing a PHA study in order to provide a liaison between local facility management and the team, and to help ensure adequate facilities are provided for the team.

PREPARING FOR A STUDY

The amount of preparation needed for a study will depend upon the size and complexity of the facility and whether a continuous or batch process is to be

Figure 2. Typical PFD/P&ID before node selection



studied. Study preparation involves several phases:

Obtaining needed information

The basic information needed will usually consist of:

- Process description and process chemistry details.
- Operating and emergency procedures (from a process point of view).
- Process Flow Diagrams (PFD's).
- Piping and Instrument Diagrams (P&ID's).
- Plot plan or layout.
- Material Safety Data Sheets (MSDS).

Information will also be needed on safeguards, instrumentation, interlocks and controls. Other documentation that may be needed includes utility drawings, mechanical drawings, isometrics and equipment data sheets. Additionally, instrument sequence control charts or descriptions, logic diagrams, cause-consequence matrices, plant manuals and equipment manufacturers' manuals may be needed.

Interlock definitions, logic diagrams and cause-consequence matrices are vital information when a PHA is integrated in a SIS life cycle analysis as defined in EIC 61511. In this case all SIF must appear in the safeguard column associated to the hazard scenarios may require protection.

Documents must be inspected to ensure they are appropriate, complete and accurate. Knowledge of the process including its operation is also required. This is usually provided by the team members.

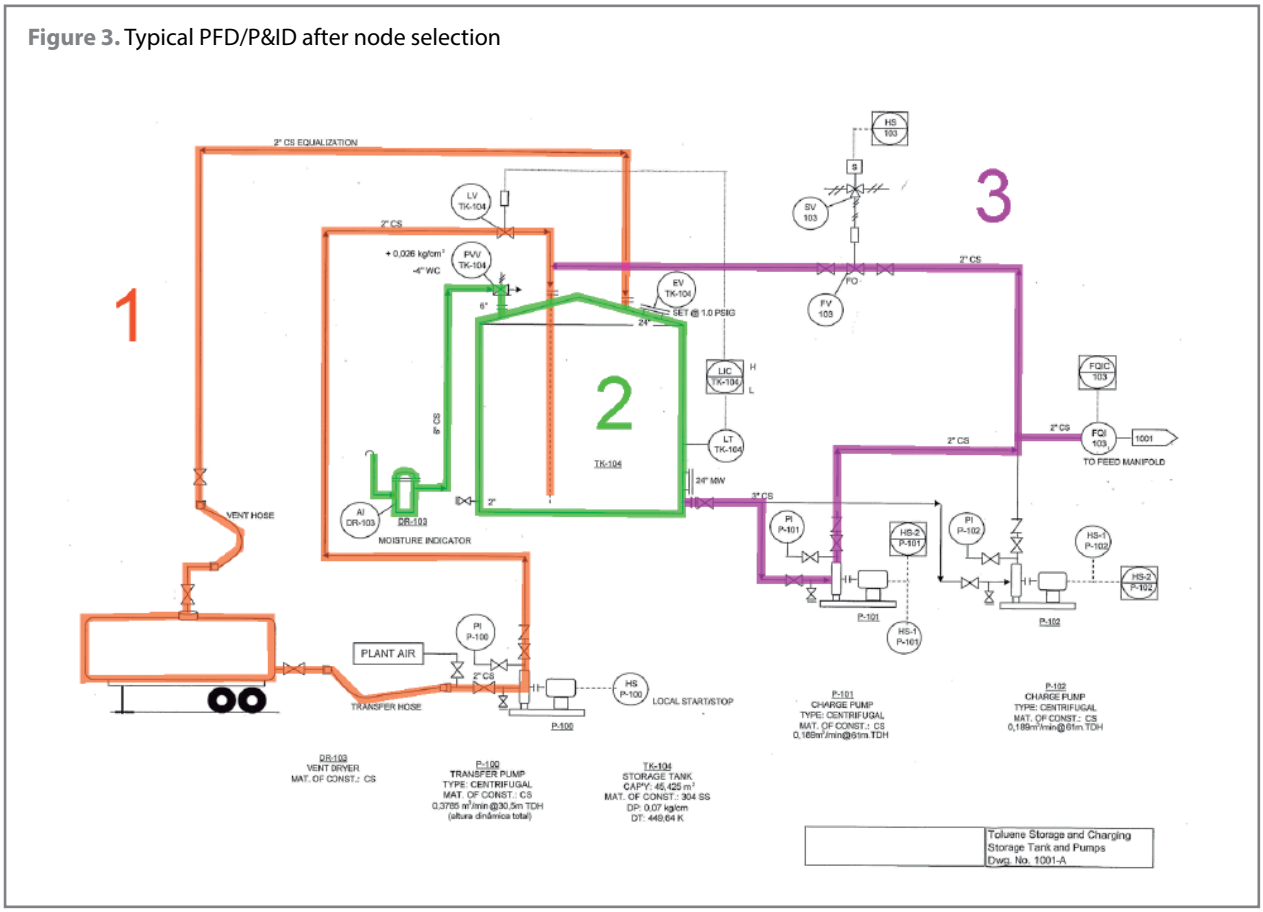
Converting the information to a suitable form

- For **continuous processes**, the preparative work is minimal. The existing process flow sheets, P&ID's and other documentation usually contain enough information for the study. For these cases the principal effort is to ensure they are accurate. This may entail walking the principal lines to compare the drawings with the actual installation.
- For **batch processes**, however, the preparative work is usually more extensive because the status of the process must be described at each step in the process. This information can be obtained from operating instructions but it is not usually readily available. It may be useful to prepare a display indicating the status of each piece of equipment on a time basis. If operators are physically involved in the process (e.g. in charging vessels), rather than simply controlling the process, their activities should be represented by means of flow charts or a list of sequential or parallel tasks describing the recipe.

Planning the study

- The team leader will usually

Figure 3. Typical PFD/P&ID after node selection



plan the sequence of work prior to beginning the PHA study. This will help to ensure that the team approaches the process and its operation systematically. The study plan is based on how the process is operated:

- For continuous processes the sequence of study is straightforward. The study team starts at the beginning of the process and progressively works downstream.
- For batch processes, the sequence of study should follow the steps in the batch.

• Planning the study sequence usually includes the initial selection of study nodes or systems/subsystems. This information can be entered into a list prior to starting the study sessions or as the meetings are held:

- The division of a process into nodes may be made on the basis the process conditions (P, T) between main valves, presence of main vessel, isolation capabilities or some other criterion. It is a good idea identify each node on a P&ID using colour layout makers.

- The division of a process into systems and subsystems may be made on the basis of area within the facility, type of process, stage in the operation, or some other criterion.

• The precise breakdown depends on the facility being studied; how detailed a study is to be conducted; the purpose, scope and objectives of the study; and the preferences of the team members.

• The study plan should be discussed with the study team before starting the study.

Defining the risk ranking (optional)

• The team may assess the likelihood of a hazard scenario occurring, and the severity of its consequences, given that the scenario occurs. The likelihood and severity levels can then be used to estimate the relative risk. This allows prioritizing the scenarios to more effectively address the recommendations that may arise.

• If a risk ranking of hazard scenarios is used, levels and definitions should be established for severity, likelihood and risk. These should be established prior to starting the team sessions and should be agreed upon by management.

• In order to compare the potential hazards in various areas of the facility, several statistical comparisons can be made using these severity, likelihood and risk ranking estimates. The risk presented by any area of the plant depends on the number and types of hazards present, the number of ways they can be realized (causes), how likely they are to occur (likelihood) and the extent and magnitude of their consequences should they occur (number of consequences considered important and their severities).

• It should be noted that these prioritization factors should only be used to provide general guidance on ranking risks, since there is considerable subjectivity involved in the performance of a PHA and in the estimation of severity and likelihood values in particular. Moreover, the severity and likelihood values provide rankings rather than true numerical estimates, so the prioritization factors do not represent actual risk values.

• These prioritizations must be tempered by engineering judgment and a careful check of the original worksheets to see if any unusual conditions exist that could distort the area groupings derived by statistical means.

• Additional insight into the risks presented by each area of the plant is provides an indication of systems that have a high proportion of high risk hazard scenarios and consequently are potential candidates for further analysis.

Arranging the Meetings

There are a number of methods for estimating the time required for the PHA team meetings. These methods are based on the number of nodes or systems in the process. For example, in the case of the HAZOP technique, a rule of thumb is to allow approximately 2-3 hours/node. These values represent 2-3 nodes/day according the PHA session periods recommended for to maintain the team fresh. In any case, experience with the PHA technique is usually the best method of estimating the time. It should be noted that time for study preparation, documenting the study outside the study sessions, and follow up activities also needs to be estimated. A software tool greatly reduces the documentation time required.

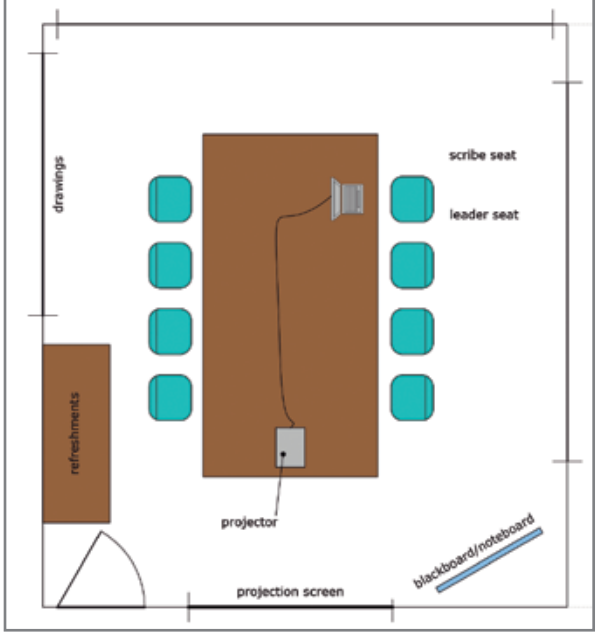
Individual PHA team sessions should last no more than 4-6 net hours. The work is intensive and the effectiveness of the team diminishes rapidly as the length of the session increases. Sessions are best scheduled for the morning when the participants will be most alert. For large projects, the process may need to be broken into separate units and each assigned to one of several teams in order to accomplish the work in the desired time frame. The proposed schedule should be discussed and agreed upon with management and team members prior to beginning the study sessions. Management should be kept informed if significant changes to the schedule become necessary.

Adequate facilities should be scheduled for the study sessions. Ample room is required to spread out drawings and other information. The meeting room should also be located where interruptions are less likely to occur.

CARRYING OUT THE STUDY

The team uses the chosen PHA technique to identify hazard scenarios. Different PHA techniques vary in how they do this. Details are provided in independent lectures for each specific technique.

Figure 5. Typical PHA meeting room layout



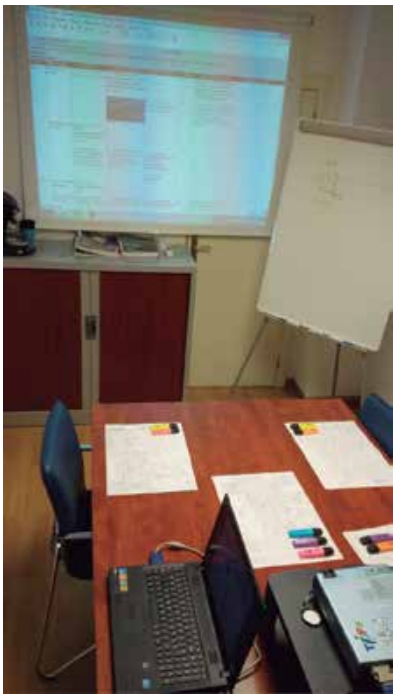


Figure 6. PHA meeting room (P&IDs on the table, PHA worksheet projected and blackboard for notes)

Figure 7. PHA meeting room (with P&IDs on wall)

When evaluating the possible causes of a scenario, the PHA team should keep in mind the three basic types of causes:

- Equipment failure (includes instrumentation failures).
- Human error.
- External events.

A scenario is determined to be realistic, and is therefore subject to further review, if in the judgment of the team, there are sufficient credible causes to believe it can occur. In determining whether seemingly low probability events can occur, the relative probability of occurrence of the three basic types of causes should be kept in mind.

The order of probability of occurrence generally is:

Human errors > Equipment failures > External events

But the order of frequency of occurrence for instrumented processes with minimal human intervention generally is:

Equipment failures > Human errors > External events

Once realistic hazard scenarios are identified, any existing safeguards should be noted. If a risk ranking is being used, values of severity and likelihood are estimated. It is important that values are assigned consistently throughout the study.

If it is considered that a potentially significant hazard exists, and the existing safeguards are not adequate given the severity and/or likelihood of the event, a recommendation for corrective action may be made. An assignment of responsibility should be made to an individual or department for follow up on the recommendation.

Even though the team leader prepares in advance for the study, in many cases the team may not have sufficient information, or knowledge, to determine whether a significant hazard potentially exists. In these cases, someone should be assigned to follow up and obtain additional information. This person can then report back to the PHA team at a subsequent meeting. The team can then assess whether or not a potential hazard exists and whether a recommendation is needed. If the problem is a lack of knowledge on the team's part, other specialists may be called in.

It is useful to track the progress of the study by marking on the P&ID those sections that have been studied. This can be done using a highlighter or by annotating the drawing. This procedure helps ensure complete coverage.

GENERATING REPORTS

Recording the results is a vital part of a PHA study. It is impossible to record manually all that is said, yet it

is important to document what the team reviews and the background of any recommendations made. It is also important that the documentation allow for, and facilitate, following up any action items and information needs. The basic documentation produced to facilitate these needs includes a PHA worksheet, some form of action items report, and a final study report.

The PHA worksheet is the key to recording the essential information. It is completed by the scribe during the team sessions. The worksheets should represent a complete record of what the team considered during the study. From the worksheets, the action items and information needs are extracted. These are usually summarized in a separate report. This facilitates follow up on the items without having to search through the worksheets to find them.

A software tool facilitates the documentation process by allowing the worksheet to be completed on a personal computer as the study progresses. The use of a computer allows more information to be documented than would be likely if the worksheets were completed by hand. This is particularly important when the report may be reviewed by someone outside the team, such as a regulatory authority. The use of a software tool is particularly effective when combined with a computer data projection device. This allows the PHA team to view what is entered in the worksheet as it is entered. The team can provide immediate feedback thus minimizing the need for post-session review and editing of the worksheets.

A software tool also facilitates the follow up activities by providing the ability to automatically generate action items and information needs lists.

RESPONSIBILITIES OF THE TEAM LEADER

The team leader is responsible for the overall satisfactory completion of the study. The team leader's role and responsibilities can be categorized by the stage of the study as follows:

- Preparatory stage.
- Study stage.
- Follow up stage.

The team leader is responsible for:

- Guiding the process.
- Managing the team.
- Recording the results of the study.

QUALITY CONTROL OF A PHA STUDY

Quality control of a PHA study involves consideration of several items. These include:

- Ensuring the study meets the purpose, scope, and objectives established at the beginning of the study.
- Ensuring the study is thorough, complete, and done correctly.
- Ensuring the study is adequately documented and transmitted to the appropriate persons.

Often a study is perceived as being "poor" because of misconceptions by management as to the actual results of a PHA study. For this reason, it is important to ensure that everyone clearly understands the nature of the PHA process and the expected results of the study. Other reasons for a "poor" study include:

- Inadequate study time.
- Inadequate documentation.
- Inadequate team efforts.
- Incomplete study.
- Inadequate team guidance
- Inadequate facilities.
- Inadequate follow up.

DOCUMENTING THE STUDY

A study report should be prepared at the completion of the study. The report should clearly explain to a reader the purpose, scope and objectives of the study, what was accomplished, and any significant recommendations. The study session worksheets should be included, possibly as an appendix item.

Proper documentation of a PHA study will address the following items:

- Documentation of the team sessions.
- Follow up reports.
- Study report.

A typical study report may include the following sections:

EXECUTIVE SUMMARY

Ideally, the executive summary provides brief overview of what, when, where, why, who, how and findings, and is:

- Targeted for management review.
- Usually one to three pages in length.
- Best written after complete report is drafted.

INTRODUCTION TO THE EXECUTIVE SUMMARY

The introduction for the executive summary includes a brief process description describing how the unit(s) studied fit into the overall site, lists the highly hazardous chemical included in the study and includes a reference block flow diagram (BFD) or process flow diagram (PFD), if available. The introduction also describes the contents of the report by presenting the title of each section of the report.

PURPOSE, SCOPE AND OBJECTIVES

This section provides a summary discussion of both the scope and objectives of the study. this is particularly important if the study analyzed only a portion of a process. The scope should identify the boundaries of the study and critical interfaces to other systems. The objectives should specify the hazards treated and the classes of consequences considered.

STUDY APPROACH

This section provides a summary discussion of how the study was conducted.

STUDY RESULTS/FINDINGS

This section provides a summary discussion on the types of hazard scenarios, safeguards and recommendations identified. Also provided is a summary of the results by risk ranking, if applicable, a description of how recommendations are categorized, a description of the purpose and intent of the recommendations, and a categorical listing of study recommendations, if manageable.

CONCLUSIONS

This is an optional section. It highlights the fact that all study recommendations are preliminary and will require further consideration before implementation. Planned follow up activities are sometimes described.

APPENDIXES

A. Description of Hazard Analysis Study Technique

A detailed description of the PHA technique used to complete the study must be provided. This is typically a boilerplate description.

B. Study Nodes or Systems/ Subsystems and Drawings

A listing and description of the study nodes or systems/subsystems is provided. Also, a list of the process drawings used in the study is included. Drawing references should include the drawing number, revision and date. Key equipment and lines should be identified on the drawings.

C. Action Items

An Action Items Report can be generated by the software in an automatic way for inclusion in this appendix and it must provide a complete description of all recommendations.

D. Hazard Analysis Study Worksheets

A Worksheet Report can be generated also by a software tool for inclusion in this appendix and it contains the complete contents of the study worksheets.

DOCUMENTING TEAM SESSIONS

Documentation of the team sessions should be completed in the form of a worksheet. The worksheet should contain areas to record the part of the process being reviewed, information describing the hazard scenario, safeguards, the scenario severity and likelihood, and any recommendations. A software tool facilitates the recording of the team sessions by the use of an electronic worksheet.

FOLLOW UP ACTIONS

The PHA study will generate action items which can be classified as one of two basic types:

- Information needs.
- Recommendations.

Information needs often happens during the team sessions, because insufficient information is available to determine if a problem exists. In such cases, rather than belabor the team when no resolution will result, the item should be documented as a need for information. It should be assigned to one of the team members to investigate and report back at a subsequent team meeting. Follow up assignments should be documented in an information needs report (if necessary) and distributed promptly to the assigned individuals. As the individuals report back on specific items, the revised status of these items should be documented. All follow up items should be resolved before the study is completed. The team leader should ensure that information need action items are investigated and resolved during the course of the study when the team is available to review the item.

Recommendations are those items which may result in a change in the design and/or operation of the facility. These items may take time to complete

and will therefore be documented in the final report as open action items.

PRIORITIZATION OF ACTIONS

The PHA study may result in a large number of action items. The number of action items may be greater than the facility could reasonably be expected to handle at one time. To properly manage the action items, a method of prioritization of the action items is desirable to allow the facility to focus its resources. Several schemes are available to help prioritize the action items, including:

- **Risk ranking:** an estimate is made of the likelihood of the event and the severity if it were to occur. Risk is a combination of the likelihood and severity of an incident. A risk matrix, with likelihood and severity as the axes, is then used to determine the risk.
- **Simple prioritization:** a scale (e.g. 1 to 5, A to E, etc.) is used to subjectively prioritize the action items.
- **Categorization:** action items are categorized as either safety or procedural items. Higher priority is given to the safety items. Sub-categorization of the items in each category may also be done, such as into hardware (equipment) and procedural items. Procedural items are considered no (or low) cost items and easily accomplished.

COMMUNICATING PHA RESULTS

The benefit of the PHA study may be diminished if the results are poorly communicated to those responsible for following up on the action items. A key aspect of this communication is a complete study report. Since the PHA study may generate a large number of worksheets, in which the important items are buried, a summary report is necessary. The summary report should be able to stand alone, inform readers of the purpose, scope and objectives of the study, describe what was accomplished, and identify the most significant findings. For completeness, the worksheets may be included as an appendix item or as a supplemental report.

Assignments for follow up of the PHA findings will most likely be distributed among a number of individuals and/or departments. The most effective communication of the results is one which comes from top management. The study team should prepare a report for the top management of the facility. The report should then be distributed from management to the responsible individuals/departments to highlight management's commitment to resolving any action items resulting from the study.

MANAGEMENT OF CHANGE

Resolution of the PHA study action items may result in proposed changes to the facility design and/or operation. The proposed changes should be reviewed to ensure the resolution of a problem does not introduce new hazards. Often this can be done quickly by an individual reviewing the original PHA report and evaluating potential effects of the proposed change. At other times it may be necessary to reconvene the PHA team to evaluate the potential effect of a proposed change.

ACRONYMS

PHA: Process Hazard Analysis
OSHA: US Occupational Safety and Health Administration
EPA: US Environmental Protection Agency
PSM: Process Safety Management of highly hazardous chemicals (OSHA requirement)
RMP: Risk Management Plan (EPA requirement)
HAZOP: HAZard And OPerability study
FMEA: Failure Mode and Effects Analysis study
AIChE: American Institute of Chemical Engineers
CCPS: Center for Chemical Process Safety
HAZID: HAZard IDentification study

REFERENCES

1. CCPS, " Guidelines for Hazard Evaluation Procedures with Worked Examples", AIChE (1992)
2. CCPS, " Guidelines for Hazard Evaluation Procedures with Worked Examples", AIChE (2008)
3. IEC 61882:2001 Hazard and operability studies (HAZOP studies) - Application guide