A Thesis report

On

PROCEDURE FOR PROCESS HAZARD ANALYSIS IN A PETROLEUM REFINERY

By

SATENDRA SINGH TOMAR

M.TECH. HSE

R070208009

College of Engineering

University of Petroleum & Energy Studies

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PROCEDURE FOR PROCESS HAZARD ANALYSIS IN A PETROLEUM REFINERY

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Master of Technology

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By

SATENDRA SINGH TOMAR

Under the guidance of

Mr. SANJAY KUMAR `

Asst. Professor

University of Petroleum & Energy Studies

Approved

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Dean

College of Engineering

University of Petroleum & Energy Studies

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CERTIFICATE

This is to certify that the work contained in this thesis titled **"PROCEDURE FOR PROCESS HAZARD ANALYSIS IN PETROLEUM REFINERY"** has been carried out by **Satendra Singh Tomar** under my/our supervision and has not been submitted elsewhere for a degree.

Mr. SANJAY KUMAR
Asst. Professor
Date 29/4/15

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ABSTRACT

Process hazard analysis is an important tool to identify the hazard involved in process in a petroleum refinery. So to select the method of performing of PHA is also very important because there are five six methods to do the PHA. A lot of factors are involved from quality to cost effectiveness.

In this project I have laid down a procedure to perform the PHA. It covers from object to human factor involved in a PHA.

Beyond this a new method of PHA is also given in this project that we can say a combined procedure of some existing methods. This method involves all the aspects of hazard analysis. It covers from operation to management and policy issues.

Later this method has been applied in one petrochemical process hexane food grade unit of CPCL. It has been testified that this method can easily performed on any process unit and later on it may be applied on whole refinery.

LIST OF FIGURES **PAGE NUMBER**

CHAPTER 1

INTRODUCTION

This procedure provides guidance for conducting Process Hazards Analyses (PHAs) at any refinery sites. It also describes how to document them in official reports.

Anyone who has responsibility for managing the PHA process, or who is asked to serve on a PHA team, especially the PHA Team Leader and PHA Team Resource, must become familiar with this procedure. In addition to describing how to conduct the PHA, this chapter contains clear lists of responsibilities for those who participate.

CHAPTER 2

LITERATURE REVIEW:

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CHAPTER 3

1. OBJECT:

This procedure provides guidance for conducting Process Hazards Analyses (PHAs) at any refinery sites. It also describes how to document them in official reports.

In this it has been shown that how to conduct PHA in a petroleum refinery and a new method of PHA has also given.

2. Purpose of PHA

PHAs are used to identify, evaluate, and control potential process hazards for all new facilities. They are also conducted regularly at scheduled intervals for existing processes and facilities and whenever there is a serious process incident. PHAs are also conducted on the facilities which are lying idle and require to be restarted as well as for the facilities which need to be dismantled.

Identify all potential hazards associated with the process, such as explosions, fires, release of toxic (or any reportable) material or serious injury.

Identify the causes of the hazards, such as uncontrolled reactions, failure of equipment, or human error.

Qualitatively evaluate the types of hazards and the probable area of involvement.

Where a large scale off-site event is indicated, use a quantitative analysis that predicts the area of involvement, the number of people in danger, financial risk, and frequency of occurrence.

Carry out human factor analysis and facility sitting studies, and check for using inherently safer processes

Recommend changes necessary to reduce, eliminate, or safely control the potential hazards of the process.

Document the PHA in a comprehensive report that is on permanent file and can be used as a reference when the process is reviewed at a later date

Determine that the process can be operated safely.

3. PHA APPLICATION

3.1 Timing and Frequency of PHAs

Consistent with the requirements of corporate standards on PSM, a series of PHA shall be conducted on all processes prior to start up of new facilities.

For existing processes, baseline PHA shall be conducted, as soon as possible, if it does not exist.

Throughout the life of processes, cyclical PHAs shall be conducted or revalidated at a frequency not exceed 05 (five) years.

4. Management Responsibilities

Line Management has the responsibility to implement this procedure.

4.1 Plant/Project Leadership (Plant HOD/Project Leader)

The Plant/Project Leadership are responsible for ensuring that all necessary PHAs are conducted in an appropriate and timely manner. Specifically, they ensure the following:

- PHA schedules are established.

- A qualified PHA resource is involved in all scheduled.

- The teams that conduct PHAs are properly balanced in expertise and experience and include appropriate operations, process engineering, and engineering personnel.

- Final PHA findings are communicated to all employees who work in a reviewed area or who are affected by a recommendation and must be documented.

- A final PHA report is issued when all accepted recommendations are closed.

- Charters are issued for all PHAs.

- PHA recommendations contained in PHA reports are acted on as promptly as possible.

- Control systems are established to monitor progress on completing open PHA recommendations.

- Has responsibility of receiving and addressing Improvement opportunities that are developed as part of the PHA.

4.2 Team Leader

The PHA team leader is selected by the Plant HOD/Project Leader and is usually a technically trained professional who is knowledgeable about the process. The PHA team leader has leadership and organization skills and training in and experience with PHA procedures and methodology. The team leader must have successfully completed Five days training on PHA.
The team leader ensures that the PHA is conducted effectively and efficiently and that recognized hazards are understood and controlled. Specifically, the PHA team leader has the following responsibilities:

• Organize conduct of PHA study using methods of analysis consistent with the Severity of the hazards or as suggested in the charter letter.

• Direct the team's efforts and activities.

• Ensure that the study is thorough and consistent with the charter and guidelines.

• Ensure that the analysis is completed within the specified time period.

• Keep plant manager informed on the study's progress, including identification of significant new findings or barriers to the timely completion of the effort.

• Ensure that meeting notes are regularly issued and the team's final report is completed on schedule.

Ensure that the permanent central PHA study file contains documentation of the team's work, including items that were evaluated and confirmed acceptable, as well as any found deficient.

4.3 PHA Team

The PHA team is selected by the Plant HOD/Project Leader in consultation with the PHA team leader. The team should include operations, CTS, CES, Maintenance, HSEF personnel who are experienced and knowledgeable in the process. The team may also include outside resources

such as consultants from process safety consultants and representatives from other business units or sites.

The responsibilities of the PHA team members include the following:

• Actively participate in the meetings, field tours, and the method of analysis.

• Give priority to completing PHA assignments according to the team's schedule.

• Tour the assigned facilities periodically to enhance understanding of the equipment, piping, controls, procedures, tasks, consequences of upsets and failure events, vulnerability to external challenges, and so on.

Identify all major hazards clearly and, where possible; make specific recommendations so that a clear basis and scope is available for establishing it.

Conclude and document whether or not the process studied is safe to operate.

4.4 PHA team member

The PHA team member is a person with specific training and experience in conducting PHAs. He/she ensures that the PHA is conducted efficiently and thoroughly and that all possible deviations are considered.

The PHA leader may also serve as a PHA team member provided the individual has the qualifications for both roles. PHA resources are available from members of PHA sub committee.

A PHA team member should have done the following:

- Attended three to five days PHA training course.

- Conducted/Participated in PHA study.

The PHA team members are also to ensure the following:

- Appropriate review methodologies are selected.

- The review methodologies are used appropriately.

- All hazards are defined and the causes defined.

5. Types of process Hazard Analysis

5.1 NEW FACILITIES REVIEWS

5.1.1 Project level facilities

New facilities requiring project-level investment (typically needing off-site authorization) must have the following PHA activities:

Screening process hazards review, as early as possible during basic data development, to identify potential acute hazards and concerns and to develop broad recommended changes in scope to significantly reduce these hazards (including consideration of the use of inherently safer technology).

Preauthorization process hazards analysis, before project authorization, to review the screening process hazards review, review any changes in scope or design intent since the screening review, confirm all process hazards have been identified, and determine if current project scope is adequate to control all the hazards. This review must be completed, documented, and authorized prior to project authorization.

Detailed process hazards analysis (design review), as soon as possible after the design release drawings issue, to review the earlier PHAs, analyze the process systematically and in depth, identify all process hazards and hazardous events, and develop recommendations for process hazards elimination or control. These reviews must be completed, documented, and authorized prior to start-up.

Final project safety report as a compilation of all detailed process hazards analyses, preauthorization process hazards analysis, screening process hazards review and related documentation for all other process safety-related topics addressed during the project engineering phase should be prepared prior to the facility pre-start-up safety review,. A copy of the final project safety report shall be transmitted to the facility site and shall become part of the permanent PHA file for the facility. This will form a baseline PHA report for this project.

5.1.2 Small project via management of change

The basic principles, as outlined for project-level new facilities, apply to smaller jobs (authorized via management of change), but the process shall be simplified to apply to the level of hazard involved.

For these changes and modifications, the three-stage analytical process described for large projects should be used when appropriate, such as for early screening, preauthorization, and detailed design study. The depth of the study and application of project-level techniques should be determined by the severity of the potential hazards.

5.1.3 Existing Facilities Reviews

5.1.3.1 Baseline PHA

The baseline PHA is the initial review of a process, which is intended to serve as the foundation for future cyclic PHAs or revalidations. The baseline PHA must be very thorough, intensive, systematic, and complete. It must be based on an up-to-date process technology package,

For new facilities, the final project safety report may serve as the baseline PHA if it meets the requirements stated above. For new facilities with significant changes during start-up, which could affect process safety, a revalidation of the baseline PHA shall be done within one year of start-up.

5.2 Cyclic Review Frequency

Following the baseline PHA, a frequency must be established for future cyclic PHAs. The PHA should be revalidated at a frequency consistent with the inherent and demonstrated hazards potential of the process as well as with applicable regulations.

The cyclic review frequency shall be a maximum of every five (5) years. Consideration should be given to review the frequency to less than five years for processes that experience many process safety incidents, have extreme hazards, or are subject to frequent significant change. The schedule for cyclic PHAs must be up-to-date, listing the date of the last PHA, and the next scheduled update.

5.3 Revalidation Protocol for Cyclic PHAs

A cyclic PHA starts with a review of the baseline and subsequent PHAs. This review must include examination of all the elements in these PHAs:

A review of the list of hazards and hazardous events: Are all hazards included? Are all still appropriately defined and characterized?

Application of an approved PHA methodology: Was the prior methodology applied correctly? Were the conclusions correct?

Identification of any incidents since the previous review that will have potential for catastrophic consequences.

Engineering and administrative controls to prevent or mitigate catastrophic consequences: Are all controls still in place? Are there any revisions since the previous PHA?

5.4 Other Unscheduled PHAs

On occasion, other situations arise that call for unscheduled PHAs. Examples of such situations include unusual, safety or environmental incidents, and the need for equipment decontamination. The Plant HOD of the unit is responsible for deciding whether or not a PHA is necessary. In general, all of the requirements for scheduled PHAs apply.

6. OVERVIEW OF THE PHA PROCESS

A PHA is generally divided into following six parts.

1. Planning and preparing to conduct a PHA

a. Selection and training
b. Charter definition
c. Preparation
d. Process technology package review

2. Hazards identification activities

a. Hazards identification techniques
- General hazards identification checklist
- Chemical interaction matrix
b. Field tour

3. Consequence analysis activities

4. Hazard evaluation activities

a. Hazard evaluation methods
b. Lines of defence identification
- Generic lines of defence checklist
c. Evaluating human factors
- Human factors checklist
d. Evaluating facility sitting
e. Evaluating inherently safer technology

5. Developing and managing recommendations

a. Evaluating the risk of identified hazards

- Qualitative risk assessment protocol

b. Developing recommendations

c. Documenting recommendations

d. Management's response to recommendations

e. Recommendation follow-up

6. Documentation requirements

a. General format

- PHA report - example forms

- PHA closure forms

b. Communicating the results

c. PHA completion checklist

6.1 Planning and preparing to conduct a PHA

The Plant HOD/project leader will charter the PHA study team, select the team leader , provide any resources required by the team as well as the necessary training, and adjust the team leader's and members' priorities according to the aims of the study.

6.1.1 Selecting and training the team

The plant HOD/Project Leader will select the leader and PHA team leader shall select other members of the study team in consultation with the Plant leadership. The Plant leadership shall arrange for the training of the team members.

• Team selection

• PHA Team leader must have adequate hands-on operating experience, preferably Production Manager or equivalent.

• The selection of the team members must be based on the skills needed for the planned studies.

• The PHA study team must be multi-disciplined. Team membership must include individuals with the following skills:

Knowledge of the basic science and technology involved in the operation of the process and equipment as well as the equipment design basis.
Hands-on operating experience in the process or system (This experience Involves knowing how the facilities actually operate as opposed to how they are intended to operate.)
Hands-on maintenance experience in the process or system (This experience involves knowing how the facilities are actually maintained as opposed to how they are intended to be maintained.)
In-depth training in the selection and application of hazards evaluation methods or prior in-depth experience with the specific method(s) being used (This person may be a PHA resource or the team leader.)
Other appropriate knowledge or expertise needed to accomplish the aims of the study (for example, mechanical integrity and quality assurance skills [These individuals may participate on a part time or as-needed basis.])
Each team must have representatives from operations (including an operator), technology, engineering, and maintenance, as a minimum. Supervisors, specialists, consultants, HSEF personnel and PHA resources should be included as needed to meet the objectives of the study. Permanent (or full-time) members, who participate for the life of the study, as opposed to rotating (or part-time) members, are encouraged.

Prior to the selection of the team, sites should inform employees in the area to be reviewed to give them the opportunity to express their interest in being selected to serve as team members, or to provide input on any issues or safety concerns that they feel should be addressed by the PHA team.
The actual number of participants on the PHA team can vary according to the needs and objectives of the PHA. Preferred team size is generally five to six members. Some project PHAs can be slightly larger because of the increased number of special consultants involved. An individual team member can provide more than one of the skills required on the PHA team.

6.1.2 PHA team training

Adequate training of the PHA study Team leader and the team must be done to ensure a high quality analysis of process hazards. Training is most effective when provided shortly before the beginning of the study. Team training requirements typically include the following:

PHA leader training:

At a minimum, the 5 days PHA course supplemented with on-the-job training by identified PHA Expert around the methodology and PHA Standard.

It is recommended that the leader attending this training Programme has served as a team member on at least one PHA prior to leading.

Team members should receive overview training in the PHA procedure and application of the PHA methodologies selected for the study. This training can be provided to team members in a one-day PHA training session by the corporate PHA resource or by the PHA team resource who has had in-depth training.

6.1.3 Team charter or scope

The Plant/Project leadership must prepare and issue a charter that defines the study team's responsibilities, tasks, and objectives. The charter should include study timing requirements, process boundaries, expectations, and any special objectives.

6.1.4 Team preparations

Reviewing and accepting the charter

The PHA team leader will review the team charter with the team, so that all members clearly understand the expectations from the team. This discussion should include the boundaries of the study (i.e., the systems that are included and those that are not), the required timing for completion, special work included in the charter, whether the PHA team is responsible for communicating the results of the study to all affected parties and how this is to be done, what resources are available to the team, where to go for help, how to resolve priority conflicts, and so on.

The site or project leadership shall be present for this review to address and resolve any questions concerning the scope of the study.

6.1.5 Team assignments and study schedule

The PHA team shall develop a plan for conducting the study, including team member assignments, and set an overall timeline for completing the plan.

6.1.6 Team responsibilities

The team leader shall do the following:

1. Organize the PHA, and conduct the study using methods of analysis consistent with the severity of the hazards or as suggested in the charter letter.
2. Direct the team's efforts and activities.
3. Ensure that the study is thorough and consistent with the charter and applicable guidelines.
4. Ensure that the analysis is completed within the specified time period.
5. Keep management informed regarding the study's progress, including identification of significant new findings or barriers to the timely completion of the effort.
6. Ensure that meeting notes are regularly issued and the team's final report is completed on schedule.
7. Ensure that the permanent central PHA study file contains documentation of the team's work, including items that were evaluated and confirmed acceptable, as well as any found deficient.

Full-time team members shall do the following:

1. Actively participate in the meetings, field tours, and the chosen method of analysis.
2. Give priority to completing PHA assignments according to the team's schedule.
3. Tour the assigned facilities periodically to enhance understanding of the equipment, piping, controls, procedures, tasks, consequences of upsets and failure events, vulnerability to external challenges, and so on.
4. Identify all major hazards clearly and, where possible; make specific recommendations so that a clear basis and scope is available for establishing realistic completion dates.
5. Conclude and document whether or not the process studied is safe to operate.

Part-time team resources shall do the following:

1. Participate in segments of the PHA requiring their areas of expertise.
2. Provide input to the PHA as requested by the team leader.

6.1.7. Process technology information

The Plant leadership must maintain an up-to-date process technology package, which must be correct before the process hazards analysis review is begun.

The process technology package is defined in Corporate Standard (PSM). It essentially consists of documentation on the: Hazards of materials, Process design basis, and Equipment design basis (including arrangement drawings, piping and instrument diagrams, plot plan, instrument logic diagrams, electrical diagrams).

Other documents and information that should be collected for review and use in the PHA includes, but is not limited to, the following:

1. Operating procedures
2. Standard operating conditions (safe operating limits)
3. Management of change documents (since prior PHA)
4. Serious incident reports (since prior PHA)
5. Prior PHAs (within the same boundaries)
6. PHAs from similar processes, if applicable

The PHA team should review the process technology information for the process or system to be studied to be satisfied that the information is sufficiently accurate for conducting the review. The team should correct minor errors as they are found. If serious deficiencies exist, the PHA team must stop work, report the problem to the plant leadership and request that the information be updated and the PHA goal completion dates be revised as needed. The team should also review the quality and adequacy of the prior PHAs, noting the status of recommendations and determining whether or not all corrective actions are still in place.

The PHA team, if during the course of conducting its process study, determines or finds any inconsistency with the plant's designation of PSM critical components, equipment or systems , shall document that finding as a recommendation of the PHA.

6.2 Hazards identification

Process hazards must be identified and listed in the initial stages of the process hazards analysis. These hazards are inherent and unique to the specific chemicals and process conditions under review. They are generally hazards having the potential for explosion, fire, large toxic release, or irreversible human health effects. The list of hazards is used during the PHA to help focus the discussion and shall be included in the final PHA report and in communication of the hazards to the affected personnel.

6.2.1. Hazards identification techniques

1. Listed below are techniques that may be helpful in identifying and ranking process hazards. Details of these techniques are found in the referenced appendices.
2. Review of serious process incident reports for the process under review and for similar facilities.
3. Review of management of change documents (What was the effect of the changes on process safety? Are there any interactions among the changes that create new hazards?)
4. Review of previous PHA reports for the process under review and for similar facilities.
5. General hazards identification checklist.
6. Chemical interaction matrix.
7. Experience - consultants

   (Consulting with others with either process experience or PHA expertise can be helpful in identifying hazards.)

6.3 Field tour

The PHA team must conduct a field tour of the facilities being studied. The team member with hands-on operating experience should serve as the tour guide. One purpose of the field tour is to ensure the team has a clear picture of the process and the layout of the area being studied. A second purpose is for the team to look for hazards and begin to develop the list of hazards.
On the tour, the team should compare the facilities to the P&I drawings to be satisfied that the drawings are up-to-date.

6.4 Consequence analysis

6.4.1 Scope

Consequence analysis consists of evaluating the direct, undesirable impact of potentially hazardous events, such as fires, explosions, and toxic releases, resulting from loss of engineering and administrative controls for the process. This evaluation includes estimating release amounts and conditions, evaluating consequences and affected areas, and determining the resulting safety and health effects. The purpose of consequence analysis is to help the PHA team understand the type, severity, and number of potential injuries, possible property damage, and significant environmental effects, at both on-site and off-site locations. Qualitative review of these hazards is acceptable, though more quantitative analysis may be useful and must be done when off-site impact is possible. A consequence analysis is normally conducted as part of every PHA, although it may also be desirable to conduct a consequence analysis for a large process as a separate review to help develop an overall understanding of possible consequences. In this case, each subsequent PHA of the process should review and update the consequence analysis, as needed, to ensure that it is complete and current.

6.4.2 Requirements

The PHA team must identify and understand the consequences of a wide range of possible hazardous events associated with the process. Based on the characteristics of these events, the following information must be considered in the consequence analysis,.

1. The type of resulting event, such as fire, explosion, or toxic exposure.
2. An estimate of potential release quantities.
3. Consequences of the event, such as estimates of distances to different levels of concern, such as toxic concentrations, thermal effects, over pressures, or significant environmental effects.
4. Safety and health effects on site and community personnel who could potentially be affected, including estimates of type and severity of potential injuries.
5. Quantitative estimates of consequences must be made when injures, major property damage, or significant environmental effects are possible at off-site locations.

6.5 Procedure

It is useful to conduct an initial consequence analysis in the early stages of the PHA. This helps the PHA team obtain an overall understanding of possible injuries, property damage, and significant environmental effects before evaluating the process with a detailed hazards evaluation methodology.

Areas of concern can also be identified where additional information, data, or technical resources may be required to fully understand the consequences of a hazardous event. The consequence analysis may be revisited many times during the review to study new results in these areas or to determine if additional events have been identified using the hazards evaluation methodology.

If a consequence analysis has been previously developed as part of a separate review, the PHA team should consider if additional hazardous events have been identified or if better estimates are needed to ensure an up-to-date understanding of consequences.

The following sequence is useful for conducting the consequence analysis:

Review the facilities, activities, process technology, previous process incidents, and the hazards identification findings to identify hazardous materials used in the process and to help identify potentially hazardous events.

Estimate consequences, including type of event, potential release quantities, affected areas, and possible safety, health, and environmental effects.

Consider major lines of defence that may prevent or mitigate these consequences.

At this point, the PHA team should have a good understanding of the hazard potential of the process being studied and how the process is protected against these hazards by major lines of defence. These results are used to help the PHA team evaluate the risks associated with potential hazardous events in conducting other parts of the PHA.

6.5.1 Identify credible event scenarios

The PHA team should consider scenarios involving hazardous events, as total loss of all engineering and administration controls that can lead to toxic releases, explosions, fires, spills, and similar hazards. Generally, a wide range of hazardous events should be considered, from small holes in pipes to larger, worst case events, to help bracket the range of possible consequences. If the process involves the storage of ammonia, for example, the PHA team would

consider small events such as small holes in pipes, pump leaks, or other types of events that can result in relatively small releases of ammonia.

The PHA team can then evaluate what locations could be affected by the release, the possible health effects related to exposure to ammonia, and the resulting type, severity, and number of injuries. Similarly, the PHA team would also consider events that could lead to larger releases of ammonia, such as large holes in pipes or vessel failure, and evaluate the possible consequences. As an initial review, bracketing the range of possible releases and their consequences in this way provides the PHA team a good understanding of the overall hazards of the process.
Often, the initial consequence analysis is led or resourced by a specialist, who has previously prepared many of these cases for the PHA team to consider.

6.6 Estimate consequences

Qualitative description of the consequences of hazardous event scenarios is acceptable, provided the consequences are well understood by the PHA team. Conservative, simplifying assumptions may be used to qualitatively estimate potential release quantities, affected areas, and possible consequences. Qualitative estimates based on past process incidents or simple calculations, for example, may be sufficient to help the PHA team understand possible consequences for many hazardous events.
Wherever required, some level of consequence modelling is needed to help the PHA team understand the consequences of hazardous events and make good estimates of possible injuries, property damage, or significant environmental harm. Many models are available to calculate the areas impacted by fires, explosions, toxic releases, etc. for events such as spills, holes in pipes, and stack releases. Typically, these models require inputs on physical properties, release conditions, meteorology, and levels of concern for various consequence thresholds.
The primary result from modelling is the area impacted by the release for the defined input conditions and levels of concern. This model result is then interpreted by the PHA team to evaluate the type, severity, and number of injuries, for example, in order to understand the consequences of the event.
This requires the PHA team to also consider how many people may be exposed to the release, how long they may be exposed, the warning properties of the material, ventilation, exits, and the effects the material may have on different people. For toxic materials, for example, it is

necessary to consider the acute toxicity of the material, how it enters the body, and whether or not it affects a person's ability to evacuate.

Consequence modelling can also be used to consider possible secondary effects resulting from the event, such as broken lines or damaged vessels in other parts of the facility that can lead to additional injuries or property damage.

Due to the complexity of modeling many different types of releases and the ease with which poor modeling results can be obtained with improper input, it is generally recommended that specialized resources be provided for completing consequence modeling activities. These people may be plant or central resources who have received training in consequence modeling, meteorology, toxicity, and other related topics.

Their role in the PHA is to prepare and help interpret model results for the PHA team so that consequences can be estimated and understood by the entire team. For toxic materials, for example, the resource typically models a range of releases, reviews the model results and the area impacted by the release, and interprets the possible toxic effects on people, based on event duration, to help the PHA team understand what injuries may occur.

6.8 Hazards evaluation

6.8.1 Scope

The PHA team conducts a systematic and comprehensive study of the process to:

Identify all of the ways that each hazardous event can occur and their consequences

Identify significant existing lines of defence against these events

Characterize the integrity of each significant line of defence

This section addresses the issues of hazards evaluation method selection, method application (i.e., the hazards evaluation or process hazards review), and the identification and characterization of existing lines of defence. The identification and characterization of all potential hazardous events and existing lines of defence are important. Consider the following examples to illustrate the difference between a process hazard and a potential hazardous event:

6.8.2 Requirements

The PHA team must select and apply appropriate hazard evaluation or Process Hazards Review (PHR) methods to the process under review to identify each specific hazardous event, identify

the significant existing lines of defence protecting against each event, and understand the availability and reliability of each significant line of defence.

6.9 Procedure

6.9.1 Methodology selection

In general, what if/checklist is the basic method for most portions of a process hazards analysis. However, more structured approaches, such as the Hazard Analysis and Operability study (HAZOP) or the Failure Mode and Effect Analysis (FMEA) method, Bow-tie Analysis should be used to study those segments, components, or unit operations in high hazard processes where failure of the automatic process control system will lead to rapid initiation or escalation of a hazardous event. Fault tree analysis is a useful tool to quantify the probability of the top event (occurring by multiple failures) identified by the other structured approaches such as What-if/check list, HAZOP, FMEA , FTA, Bow-tie Analysis to be used in other cases, to complement of the what if/checklist method, at the discretion of the PHA team.

More detailed information on PHA methodologies can be found in Guidelines for Hazard Evaluation Procedures, Sections 4 and 5, by the American Institute of Chemical Engineers' Centre for Chemical Process Safety. Brief descriptions of hazard evaluation methodologies and other methods are provided below:

What if/checklist

The what if/checklist method combines two basic hazards evaluation methods: the what if review and the checklist review. The most important aspect of the What if/checklist method is the order in which the two basic methods are conducted. The What if method should be applied first, without reference to any checklists, to help ensure the spontaneity and creativity of the What if questions. The checklist method should be used after the What if question period is completed.

Failure Mode and Effect Analysis (FMEA)

The FMEA method is a structured study of individual component failures and their effects on the whole system. The results of this study can be used to identify common mode and single component failures that lead to the same hazardous event. FMEA also helps identify lines of defense, as well as provide a method for beginning the study of probability and risk.

Hazards Analysis and Operability Study (HAZOP)

The HAZOP method is a structured study of specific deviations from system design intents and their effects on the rest of the system. The results of this study can be used to identify all the deviations from standard operating conditions that could cause specific hazardous events. HAZOP also helps identify lines of defence.

Fault tree analysis (FTA)

Fault tree analysis uses a logic diagram to describe all failure paths leading to a specified top event. The analyst begins with a pre-defined accident, then works backwards through the potentially multiple series of sub-events (or branches) needed to produce the top event, until each branch of the tree is driven to a small number of basic, initiating and enabling failures.
Logical mathematical operators (e.g., AND, OR, etc.) are used to connect events and branches. By applying known or estimated failure probabilities to each initiating and enabling event, the probability of the top event can be quantitatively estimated. This is the key advantage of the FTA. It also provides qualitative insight as to how multiple failures can combine to lead to an accident. Its disadvantages, however, are that
It is difficult to execute properly without detailed training (especially the probability calculations)
It is focused on a specific event, to the exclusion of all others (e.g., an FTA on the main engines of the space shuttle would not cover potential problems with the solid boosters)
Refer detailed procedure

Bow-Tie Analysis

This is structured Hazard analysis methodology relating the hazards to the top event indicating the mechanism of the hazard being realized to result into event and the consequences through mitigation measures. The bow-tie diagram method is a combination of fault tree on the preventive side and the event tree on the recovery side, to utilize advantage of both the tools for comprehensive process hazard analysis. A Bow-Tie diagram graphically represents the possible threats that can lead to the release of a hazard and the possible consequences that may result

from that release. The left side of the diagram shows the threats and the threat barriers (controls) in a form similar that of a fault tree. The right hand side shows the consequences and the recovery preparedness barriers (mitigation controls) similar to an event tree.

6.9.2 Methodology application

One can think of hazards evaluation methodologies as a set of tools. The What if/checklist is the "Swiss Army knife" - appropriate for almost all situations, but not necessarily ideal. FMEA and HAZOP are like screwdrivers and wrenches - better when the situation calls for them. Finally, the fault tree analysis is analogous to a torque wrench - inappropriate in most cases, but invaluable in specific instances. Some examples of how and when these "higher order" PHA methods should be used follow:

Example 1:

The consequence and lines of defence analysis has identified an accident scenario with potentially major off-site consequences. An electromechanical, hardwired, safety interlock is a critical line of defence. The What if/checklist study questioned the reliability of the interlock, but that methodology provided little insight into the adequacy of the interlock design.

Solution: The PHA methodology expert suggests a Failure Mode and Effect Analysis to identify each electrical and mechanical component of the interlock and to semi-quantitatively analyze the likelihood of failure. Since electrical components tend to fail in a "go/no go" manner, FMEA is a reasonable approach to study the interlock design in detail. Alternatively, if more rigor is needed, fault tree analysis might be considered; the scope of the job is small enough for an FTA to be manageable.

Example 2:

A PHA team is studying a process which includes a continuously stirred tank reactor as a key part. The reaction system has multiple feed streams and both the ratio and absolute flow rates into and out of the unit have to be maintained within certain bounds. There are also some non-routine operations involving manual actions by the operator.

Solution: A HAZOP study of the reactor would be quite appropriate here. The HAZOP forces rigor into the analysis of possible deviations in ingredient flows. It may also be used to identify human-factors problems that might arise, through the use of appropriate guide words. The other parts of the analysis scope may be adequately served by the What if/checklist alone.

Example 3:

As a part of the PHA scope, the unloading of a raw material, from truck or rail car into a large storage tank, needs to consider. From the hazards identification, consequence analysis, and facility sitting efforts, it is known that unloading of the wrong substance would cause a runaway reaction with little warning and potentially catastrophic impact.

The what if/checklist has flagged such an event as a possibility, because an adjacent area uses a material that is highly reactive with the one in question. The team knows there are multiple checks and balances, but they are all administrative in nature and the team is uncomfortable with the level of risk.

Solution: Consider the use of a fault tree to diagram the sequences of errors that must occur simultaneously to result in an unloading mistake. Even if the tree is done in a qualitative fashion (i.e., no event probabilities are developed), it is useful in understanding the number and types of errors that need to occur and in identifying any common-mode (i.e., single event which causes multiple failures) paths that might exist. The other parts of the analysis scope may be adequately served by the What if/checklist alone.

7. Human factors

7.1. Scope

An analysis of human factors includes all aspects of how humans interact with their work environment, in both routine and emergency situations. Within the context of process hazards analysis, human factors primarily concern the interactions between people and the equipment, systems, and information in their work environment. The PHA deals with the physical aspects of these interactions (human size and strength relative to the workplace and equipment design and layout), as well as the cognitive aspects (human intellectual capabilities for gathering, processing, and acting on information). The focus in the PHA is to identify and avoid situations where human error is likely, both in the process and in the maintenance of the equipment and systems associated with the process.

7.2. Requirements

To minimize the likelihood of future incidents, the PHA team shall specifically address human factors throughout the process hazards analysis. Human factors should be explicitly considered during the field tour of the facilities under review, when applying the hazards evaluation methodology to identify hazardous events, and while considering the lines of defense.

7.3 Procedure

For most facilities, the emphasis in the PHA should be on using the expertise of the team, including operator and mechanic experience, to help identify and highlight those situations where human interaction with the process has significant potential for initiating a process upset, permitting the escalation of a process incident, or detracting from the performance of process safeguards.

Such human error-likely situations may involve one or more of the following:

1. Deficient procedures or procedural violations.
2. Inadequate, inoperative, or misleading instrumentation Poor layout or design of controls
3. Poor task design (e.g., excessive mental tasks or extended periods of uneventful diligence)
4. Poor communications Conflicting priorities
5. In addition, a human factors checklist is available (see appendix) to supplement
6. various portions of the PHA in identifying and evaluating human factors issues.
7. Alternatively, the checklist may be used as part of a focused human factors review using the What if/checklist methodology.

8. In some rare instances, a probabilistic analysis of human factors issues may be required or desirable. An expert in the area of human reliability analysis should be consulted.

7.4 Field tour

The field tour provides an excellent opportunity to identify human factors issues, drawing especially upon the experience of the operators and mechanics in the area. During the field tour, the team should observe areas where man-machine interfaces occur and highlight those that are important for maintaining process safety.

The field tour should include the control room. The team should review the display of critical information, location and labelling of interlock buttons, instrument labelling, the alarm array, and so on.

Other key factors to be examined include the control room environment (e.g., lighting, communications capabilities, noise, layout) and the availability of protective systems or personal protective equipment that enable operators to carry out their duties in the event of an incident, such as a toxic fume release.

7.5 Hazardous event characterization

Dependent upon the PHA methodology used, a number of human factors issues may surface in the course of the review. In applying the PHA methodologies, flag those situations where the operator appears as an initiator of an action or event sequence. In such cases, does the operator have clear instructions on the correct action, or are instructions potentially ambiguous?

In processes that are heavily dependent upon operator action, a sequential review of the operating procedures, focusing on identification of human error-likely situations, may be warranted.

7.6 Lines of defence analysis

The PHA team should keep human factors in mind when reviewing the lines of defence for dealing with potentially hazardous conditions. For example, is an operator listed in the lines of defence as an intervener in a hazardous event sequence (e.g., as a backup to an automatic safety device), or is an alarm listed as an alert to an operator to take some corrective action? In either

case, the team should consider whether the operator has the capability to perform the required action satisfactorily, as well as the potential for other factors that could prevent the operator from completing the action.

7.7 Areas for consideration

Human factors come into play in a number of areas covered by the various elements of a comprehensive PSM system. The PHA team should be aware of these areas when attempting to identify human factors issues.

The PHA is not the time, however, for a complete human factors analysis of all the PSM elements. Some of the more significant areas are listed below:

Ergonomics

In this context, the term "ergonomics" does not refer to the likelihood of strain or cumulative-trauma injury. Instead, a key consideration is the accessibility of emergency controls and equipment. Physical issues (traditional ergonomics) can come into play if emergency controls require great strength, dexterity, or size to access and operate successfully.

Questions that the PHA team should consider include "Can emergency shutdown manual valves or emergency stop push buttons be accessed quickly in an emergency? Does a hazardous situation hinder or prevent access to key controls?

The man-machine interface

Another important human factors issue is the clarity of the design of panel boards and video display terminals. Are emergency controls clearly marked? Is emergency activation straightforward or complex?

• Can emergency or important controls be confused with others in close proximity? Keep in mind that both familiarity (boredom) and extreme anxiety (panic) vastly increase the chance of errors being made. Design of controls should take these factors into consideration.

• Distractions

• Consider what the work environment is like under routine conditions and what it might be like in an emergency. Are there many nuisance alarms or other chronic distractions? Are trivial or nuisance alarms in close proximity to critical ones, so they are likely to be ignored? In an

emergency, can information overload take place? Consider the number of required tasks, the work schedule, and likely response time.

- Training, skill, and performance
- The PHA team should consider the effectiveness of personnel training to deal with unusual and emergency situations. How effective is the program, and what actions are taken to remediate sub-par performance? If critical emergency procedures exist, are there drills to gauge how well they work in practice?
- The rate and management of personnel turnover is key in determining human reliability. The PHA team should consider the rate of turnover in key operating and supervisory levels and the quality and timeliness of training new people.
- Operating procedures
- The accuracy of operating procedures is generally related to human performance. Operating procedures linked to hazardous event situations should be reviewed for procedure accuracy and evaluated for user friendliness. Emergency procedures should be clear, explicit, and capable of being located quickly and efficiently.
- Maintenance procedures
- Inaccurate or unclear maintenance procedures can be a source of human error-likely situations. Maintenance procedures, involving PSM-Critical equipment linked to hazardous event scenarios, should be reviewed for adequacy.

8. Inherently safer processes

8.1 Scope

The hazards associated with any process typically result from either the fundamental chemical characteristics of the process materials (e.g., toxicity, flammability, reactivity, explosivity), the physical conditions under which the materials are handled (e.g., temperature and pressure), the characteristics of the process equipment, or a combination of these factors.

Processes are made inherently safer through the elimination of hazards rather than their control. As a result, the use of inherently safer process technology is an approach to the safe design and operation of facilities.

This approach relies upon the intrinsic safety characteristics of the process and equipment to prevent injuries, environmental damage, and property damage (rather than on control systems, interlocks, or procedures that prevent, stop or mitigate incidents).

8.2 Requirements

For all baseline PHAs the PHA team shall give consideration to incorporating inherently safer process technology in the process under review.

Where a What if/checklist methodology is chosen as the hazard evaluation technique, the inherently safer process evaluation can be integrated into the What if/checklist methodology. The PHA team should address/ consider inherently safer technology approaches/ options in the development of What if questions and in the development of recommendations. The inherently safer process checklist should be one of the checklists used to stimulate thinking and questions.

Where a HAZOP or Failure Mode and Effect methodology is chosen as the hazard evaluation technique, a separate standalone What if/checklist review utilizing the inherently safer process checklist would be an appropriate approach to conducting the inherently safer processes analysis.

8.3 Procedure

The process safety literature describes a number of different approaches for making processes inherently safer. In the CCPS Guidelines for Engineering Design for Process Safety, five principal categories are cited:

• Intensification (or minimization) by using only small quantities of hazardous materials (e.g., make and immediately consume a toxic intermediate to limit the quantity in the process to a few pounds).

• Substitution/elimination by replacing hazardous materials with less hazardous ones

• Attenuation (moderate) by using less hazardous conditions (e.g., lower pressure) or a less hazardous form of the material.

• Limitation of effects by designing the facilities to minimize the impact of a release of hazardous material or energy (e.g., build vessels strong enough to withstand the highest pressure that could be generated within, eliminating both the possibility of failure due to over-pressurization and the need for pressure-relief devices).

• Simplification/error tolerance by designing the facilities so that operating errors are less likely and forgiving of errors that are made.

Opportunities for making a process inherently safer can be identified at any time during the life cycle of the process. Project and cyclic PHAs typically provide such opportunities, and they should be capitalized upon to the greatest extent possible. Sites and project groups should recognize, however, that the best time for considering inherent safety opportunities is during process development at the R&D bench. If inherently safer process concepts are applied at this stage, they can be implemented relatively easily and cost effectively.

The difficulty and cost of implementation increases dramatically further down the process development path. Experience shows that, even as early as the basic data stage, implementation of the most effective inherent safety concepts is, typically, difficult. At this point, the fundamental chemistry and flow sheet conditions have been specified, and significant changes may necessitate going back to the drawing board.

Once a facility is actually constructed and in operation, the range of feasible options becomes even more constrained. Nevertheless, a careful examination of the entire process (looking at feed-stocks, processing and reaction systems, in-process inventories, location of equipment and piping, etc.) may result in the identification of some inherently safer options that can be

implemented feasibly. If it is not realistically possible to apply the inherently safer options identified at this point, the concepts should be referred to the relevant corporate technology, process engineering & R&D functions for potential incorporation in future versions of the process.

9 Developing and managing recommendations

9.1 Risk analysis of PHA findings

PHA teams must consider the risk of the hazardous events identified by the team. The relative degree of risk ultimately determines if recommendations need to be made.

Risk is the product of the seriousness of an event (consequence) times its likelihood of occurrence (probability). Hazardous events that have lesser consequences, but are much more likely to occur, may pose a higher risk.

To evaluate risk, the team should look at all the identified hazardous events and the impact of these events as developed in the consequence analysis. Next, the team should apply probability analysis (experimental or historical data) to determine the relative likelihood of the remaining serious events. This application can be either qualitative or quantitative, using the tools listed below.

9.2 Qualitative risk assessment:

The team develops a qualitative sense of the probability of occurrence for each event by applying standard hazard evaluation methodologies (e.g., what if/checklist, HAZOP, FMEA, Bow-Tie analysis) through the stages of hazards identification, hazardous event definition, and analysis of lines of defence. This information, in combination with the results of the consequence analysis, permits the team to make a qualitative assessment of the risk associated with each event. The PHA team should decide whether this risk is acceptable or not as per the Reliance Risk Matrix .

An event may be uncovered where the team is unsure if the risk is acceptable or not. An example is multiple routes to the accidental event. A small fault tree, specific for the hazardous event in question (even a qualitative one without a formal probability analysis), may be helpful for the team to visualize the probability of occurrence as high or low.

Another approach is the use of the qualitative risk assessment protocol. In this approach, a matrix is set up with one axis as a consequence ranking and the other axis as a probability ranking. The product of consequence and probability gives an overall ranking that is used to determine if a recommendation should be made.

9.3 Quantitative risk analysis (optional)

In some cases, particularly very high consequence events, the PHA team may feel the need to conduct a formal quantitative risk analysis. Usually, a fault tree analysis is required to develop the necessary frequency data. The results of the analysis provide the interval between incidents (IBI) in years. For events limited to on-site consequences, the IBI can be used to generate measures of risk, such as an Individual Hazard Index (IHI), which is the number of fatal injuries per 100MM exposure hours, or a Process Hazards index (PHI), which is the number of years per fatal injury.

Note: Typically, fault tree analysis and an quantitative risk analysis are time consuming and subject to error if not done carefully. In general, quantitative risk analysis should be reserved for only the most severe situations and when expert assistance is recommended.

Standard on Consequence Analysis Procedures for Identifying Hazardous Events provides additional guidance on analyzing events with off-site consequences.

10. Developing PHA recommendations and improvement opportunities

10.1 PHA recommendations

After risk has been evaluated, hazards requiring additional safeguards must be addressed. Recommendations must be made to provide additional safeguards where appropriate.

The following key factors should be considered in developing a PHA recommendation:

- Clear connection with the process hazard and the hazardous event
- Degree of risk.
- When the team considers risk and concludes that a PHA recommendation is appropriate, the recommendations shall be specific and accomplishable. In general, the team should avoid making open ended recommendation such as "check feasibility", "explore the possibility", 'study" and "investigate ". The team's job is to do/ or get done any investigation needed. Rarely would recommendation to study a situation be appropriate, except for something requiring a long-range study by an expert.

10.2 Documenting recommendations

In documenting recommendations, the PHA team should:

Address or reference specific findings in the hazard evaluation i.e., HAZOP work sheet, 'what if'/checklist, etc.

Use clear and concise wording.

For multi-part recommendations that would be done by different persons or groups, the recommendation should be broken into its parts, creating multiple recommendations that can be assigned individually. The goal is to have a single person, not a group of people, responsible for each recommendation.

10.3 Management's response to the recommendations

Recommendations from a PHA must be reviewed by the plant management. Management must document their response to each recommendation, either accepting the recommendation as is, accepting it as modified, or rejecting the recommendation. The response must assign follow-up responsibility and dates for completion of each recommendation.

For all recommendations, consider what interim actions or controls, if any, should be in place until the permanent solution is implemented. The plant unit management may justifiably decline to adopt a recommendation when it documents, in writing and based on adequate evidence, that one or more of the following conditions is true:

The analysis upon which the recommendation is based contains factual material errors.

The recommendation is not necessary to protect the health and safety of employees or contractors.

An alternative measure would provide a sufficient level of protection.

10.4 Recommendation follow-up

10.4.1 Tracking the recommendations

The tracking of recommendations shall be carried out vide an electronic system. Portal for entering and tracking status of recommendations will be developed and will be available to all personnel. Only plant managers and Team leaders will have access to enter or edit recommendations. While others will have only read access. Periodic reports listing open recommendations should be published at least quarterly and distributed to the site's management, all persons assigned to follow up a recommendation, and the supervisors of persons assigned the recommendation's follow-up.

Report should highlight recommendations that are past the due date. Recommendations must not be removed from the tracking system without closure documentation.

10.4.2 Closing or Modifying Recommendations

They are:

- Completing a recommendation (as originally stated)
- Modifying a recommendation
- Changing a recommendation's due date
- Cancelling a previously accepted recommendation
- Completing a Recommendation (as originally stated)
- In the tracking system, the notation for a completed PHA recommendation must clearly state who completed (or oversaw the completion) the recommendation, when the recommendation was completed (date), and a detailed description of what action was taken to complete the recommendation.
- Once management has responded to a recommendation, it may be modified or closed by the following actions:
- Completing a recommendation (as originally stated)
- The completion documentation must clearly state what action was taken to complete the recommendation.

10.4.3 Modifying a recommendation

In some cases, a PHA recommendation may need to be modified so that an alternate solution is implemented (rather than the solution specified in the original recommendation).

Reasons for modifying a recommendation may include process changes that invalidate the original recommendation, the discovery of a better solution, a lower-cost solution with equal safety results, or new data or information.

Carefully document the justification for the modification. The alternate solution shall be shown to address the hazard as effectively as the original recommendation.

The person responsible for completing the recommendation should discuss the proposed modification with the Plant HOD/Project leader and PHA Team Leader. If necessary, the PHA Team may be reconvened to discuss the proposal. It is line management's responsibility to insure that the modified recommendation addresses the hazard as effectively as the original recommendation.

10.5.4 Changing a recommendation's due date

Probably the most common situation that occurs is a change to a recommendation's due date. A recommendation may not be completed by the original due date for several reasons. Plant HOD/Project Leader must approve all extensions beyond the original due date.

The extension can be requested and granted in the tracking system. The modification to the tracking system entry to change the due date shall include,

Date on which request is made.

Reason why the original date cannot be met.

New completion date requested.

A summary of progress to date to complete the recommendation, and an evaluation of any interim actions that must be in place to help ensure safety until the recommendation is completed.

11 Documentation requirements

11.1 Report Objective

The purpose of a process hazards analysis final report is to formally document the review team's work. This document provides a report of the team's findings to management. This report format applies to baseline PHAs and detailed PHAs. It does not apply to project screening and preauthorization PHAs.

11.2. General

The report should be concise, but with sufficient detail and explanation to provide readers with a clear understanding of the hazards inherent to the process, the potential hazardous events, the lines of defence controlling the hazards, and the consequences of loss of the lines of defence.

The thinking and logic employed by the team to generate recommendations shall be well documented in the supporting detail section of the report. Detailed information is needed by those individuals assigned to finding a solution that corrects the conditions that led to a recommendation as well as by the members of subsequent reviews to avoid duplication of effort.

The copy of the final report sent to file must include all documentation of the team's work, including fault trees, calculations, a list of reference materials, and so forth. The file copy is a permanent record and shall be kept for the life of the facility.

Note: The central file may also include working documents and supporting information not included in the final report

11.3 Distribution

The distribution of the report may include the following:

1. Concerned plant HOD/Project leader of PHA activities who approve or authorize the PHA, manage the facilities being reviewed.
2. Site PHA element leader.
3. Each member of the PHA team.
4. Similar plant teams.
5. PHA competency leader and Corporate Process Engineering & Engineering functions.
6. Central file (a controlled file in a central location where the files can be securely retained for the life of the process) only the central file copy is mandatory.

Chapter 4

4.1 New methodology of process hazard analysis:

The existing methods of PHA have their own advantages and disadvantages. No method is completely perfect. Even HAZOP is not 100% perfect.

I have formulated a new method of PHA that we can say, covers all aspects of existing methods of PHA. The main advantage of this method is that it is ease to access the process information so it will take less time to perform the PHA.

The new method has given below:

1. Process:

1.1 material and flow sheet:

1.	What materials are the hazards(product Inter. By product)						
2.	Type (toxic, flammable combustible, etc)						
3.	Properties (Physical, combustible, reactive						
4.	Unwanted hazard reaction possibility due to improper storage, shock, abnormal process condition flow rate , blockage, mechanical failure etc						
5.	Provision for preventing runaway reaction.						

6.	Provision for rapid disposal if needed.						
7.	Compatibility with other material.						
8.	Storage facility Above BP, cryogenic, stored in large bins, inhibitors needed.						
9.	Effect by weather conditions						
10.	Reduction of hazardous material inventories.						
11.	Safety margin						
12.	Most severe credible accident						
13	Consequences of the accident						
14.	Root causes of the accident						
15.	Control measures						
16.	Potential for external fire						
17.	Experience of company with particular hazard						

1.2 Unit and layout:

1.	Hazards pose to the public or workers from the unit in control room, adjacent unit, nearby shop or office.				
2.	Nature of above Hazard.				
3.	Hazard to adjacent facility road, railway pose to personal and equipment				
4.	Nature of above hazard toxic, flammable noise radiation etc.				
5.	External forces that can affect the site high wind, earth movement, utility failure, terrorism, natural fire, extreme temperature flooding, lighting, drought, fog.				
6.	Provision made for reliving explosion in building.				
7.	Requirement of any barricade, concrete wall needed				
8.	Space between existing equipments and space for maintenance				

2. Equipments:

2.1 Pressure and vacuum relief

	Various relief devices				
1.	Withstand existing overpressure				
2.	Type of relief device eg. PRV rupture disc, liquid seal etc.				
3.	Basis for sizing eg. Utility failure, external fire, runaway reaction.				
4.	Relief set point and size.				
5.	Adequacy of inlet and outlet piping of relief device				
6.	Provision for sprayed liquid				
7.	Steam super heated needed				
8.	Impact of flare, incineration, or flameout				
9.	Action required if flare system is out of service.				
10.	Type of material of construction of relief device.				
11.	Worst case scenario for process discharging of the system.				
12.	Consequences if pressure increase beyond safety margin				
13.	If no pressure				

2.2Valve and piping:

1.	Piping specifications:				
2.	Compatibility				
3.	Normal temperature and pressure				
4.	Maximum and minimum holding temperature And pressure				
5.	Type of material carrying by piping system auto refrigerate, cryogenic.				
6.	Possibility of size reduction for reducing the hazard				
7.	Provision for draining				
8.	Content of lines				
9.	Grounded adequately to avoid static charge development				
10.	Pipe insulation if needed				
11.	Position of critical valves				
12.	Provision of indicating of the position of valves to control room				
13.	Double block valve needed.				
14.	Probability of failure of control valve				
15.	Consequences if				
16.	No flow in line				

17.	Less flow in line				
18.	High flow in line				
19.	Reverse flow				
20.	Causes of failure of these valve				
21.	Any parallel or series arrangement is in place in case of failure of one valve				
22.	Sensing alarm system				
23.	Accessibility for maintenance of control valve				

2.3 Pumps:

1.	Various pumps and their types				
2.	Design and running pressure				
3.	Safety signal nearby the pump				
4.	Maximum upstream temperature				
5.	Adequate protection against upset of pumps				
6.	Consequences if				
7.	Low pressure in pump				
8.	High pressure in pump				
9.	No flow of fluid				
10.	High flow in pump				
11.	Low flow in pump				
12.	Causes				

2.4 Reactors:

1.	Class and type of reactors				
2.	Probable cause of exothermic reaction for eg. Quench failure, excess or deficiency of reactant, cooling failure				
3.	Effect of an agitator (failure, too slow, too fast, reverse)				
4.	Monitoring of agitator motion				
5.	Adequacy of relief valve				
6.	Design temperature of reactor				
7.	Hazard associated with reactor				
8.	Hazard associated with regeneration				

2.5Vessels (drum, tank, tower):

1.	Various drums or tanks				
2.	Inspection and inspection methods				
3.	Adequacy of relief system.				
4.	Hazards due to loss of gas in case of purging, blanketing, inerting				
5.	Possibility of static electricity development				

6.	Other safety precautions if needed				
7.	Provision for isolation in case of emergency				
8.	Importance of vessel in operation				
9.	Vessel Content and its specifications				

2.6 Heat exchangers:

1.	Various heat exchangers				
2.	Consequences of tube failure				
3.	If no flow in tubes				
4.	Cause				
5.	Control measure				
6.	Consequences of low flow in tubes				
7.	Cause				
8.	Control measure				
9.	High flow in tubes				
10.	Cause				
11.	Control measure				
12.	Reverse flow in tubes of H.E.				
13.	Causes of tube failure like flashing, reacting, leakage etc.				
14.	Adequacy of pressure relief for both side of exchanger				
15.	Maximum upstream				

	pressure and temperature				
16.	Reliability of cooling water supply				

2.7 Furnace and boilers:

1.	Various furnaces and boilers				
2.	Firebox protection against explosion				
3.	Furnace protection against liquid in fuel gas system				
4.	Furnace protection against liquid fuel system failure				
5.	Adequacy of furnace against tube failure				
6.					

2. Instrumentation:

1.	Critical instruments indentified				
2.	Effect of faulty sensor transmitter, indicator, alarm or recorder				
3.	Effect of collective failure				
4.	Backup provision of all hardware components				
5.	Consequence of brief loss of instrument power				
6.	Procedure for testing and				

	proving instrument function				
7.	Provision of process safety when instrument taken for maintenance				
8.	Effect of atmospheric humidity and extreme temperature				
9.	Provision of grounding of instrument with catholic protection				
10.					
11.					

4. **Electrical power:**

1.	Location of all auxiliary electrical gears				
2.	Electrical area classification				
3.	Effect of failure of electrical interlocks and shutdown devices				
4.	Overload and short circuit protection devices				
5.	Provision of bonding and grounding				
6.	Grounding provision of truck and rail wagon during loading and unloading				
7.	Electrical equip. That can taken for P.M. without interruption production				

5. OPERATIONS:

1.	Human errors which may have catastrophic consequence				
2.	Maintaining up to date procedure				
3.	Availability of written working procedure				
4.	Training to new operating procedure				

6. Maintenance:

1.	Availability of written procedure for each facility		
2.	Necessity of shut down the process completely to safely repair a equipment		
3.	Cleaning and maintenance equipment required		
4.	Preventive maintenance schedule and realiability		
5.	Type of preventive maintenance		
6.	Hazards introduced during schedule maintenance		

7. **Personal safety:**

7.1 Building and structure:

1.	Standard followed in the design of ladder, platform, ramps etc.			
2.	Sufficiency safe route and exit			
3.	Steel ground structure			
4.	Enough SCBA			
5.				

7.2 Operating area:

1.	Fire and explosion hazards exposed to workers			
2.	Nature of chemicals			
3.	Where is possibility of exposed of chemicals			
4.	Requirement of PPE			
5.	Provision of shower and eyewash			
6.	Pressure hazards			
7.	Temperature hazards			
8.	Mechanical hazards			
9.	Provision of emergency stop switch			
10.	Provision of alarm system for medical emergency			
11.	Electrical hazards			
12.	Vibration hazards			
13.	Radiation hazards			
14.	Adequacy of lighting			

	system			

7.3 Fire protection:

1.	Combustible materials			
2.	Cause of occurrence of combustible mixture			
3.	Presence of ignition source			
4.	Provision of insulation for all hot system/equipments			
5.	Addition of odorant in all flammable gases			
6.	Presence of flame and detonation arrestor			
7.	Provision of smoke, gas, water, heat sensor			
8.	Fire fighting techniques			
9.	Adequacy of fire fighting system			
10.	Procedure in event of fire			
11.	Capability of fire brigade			
12.	Capability of fire water supply			
13.	Location of fire protection recourses			
14.	Adequacy of drainage to carry spilled flammable liquid			
15.	Adequacy of control room protection against external fire			

16.	Are fire protection system periodically tested			

7.4Environment protection:

1.	Chemicals sensitive for environment			
2.	Effluent stream description			
3.	Scrubber required			
4.	Sampling of effluent			
5.	Precautions for environment protection			
6.	Hazard during normal and abnormal operation			
7.	Dike provision for storage area			
8.	Toxic gas monitor alarm or detector			
9.	Updated emergency shutdown and evacuation plan			
10.	Nearest and largest onsite or offsite population			
11.	Capability of spill response team			
12.	Surface water runoff require and special treatment			
12.	Potential of release in process area			
13.	Can waste be safely handled			

8. Management and policy issues:

1.	Managements commitment toward health and safety of employees			
2.	Authority to stop the work if safety requirement not meet			
3.	Company's safety first approach			
	Discussion of health and safety in management meeting at all levels			
	Availability of written training policy			
	Provision of periodic testing of safety related equipments			
	Existing of auditing programme			

4.2. Application of this new technique in food grade hexane unit:

1. FOOD GRADE HEXANE UNIT

4.1.1 General description

The Food Grade Hexane unit of CPCL is to produce 25000 Tons of Food Grade Hexane. The plant is designed to produce 63-70 ^{o}C cut from Light straight run gasoline from plant-2 unit.

Dearomatisation of raw Hexane (63-70 ^{o}C cut) is done using EIL/IIP licensed sulfolane technology.

Food grade hexane is used to extract the oil present in oil cakes, bottom seedcakes, groundnut cake, rapeseed cake, Soya beans and rice husk. Totally 95 % of the hexane produced are consumed by this sector.

The balance 5 % is consumed in the following industries:

a. Drug & Pharmaceuticals

b. Rubber industry

c. Paint resin industry

Essence production from flowers and spices

4.2PROCESS DESCRIPTION

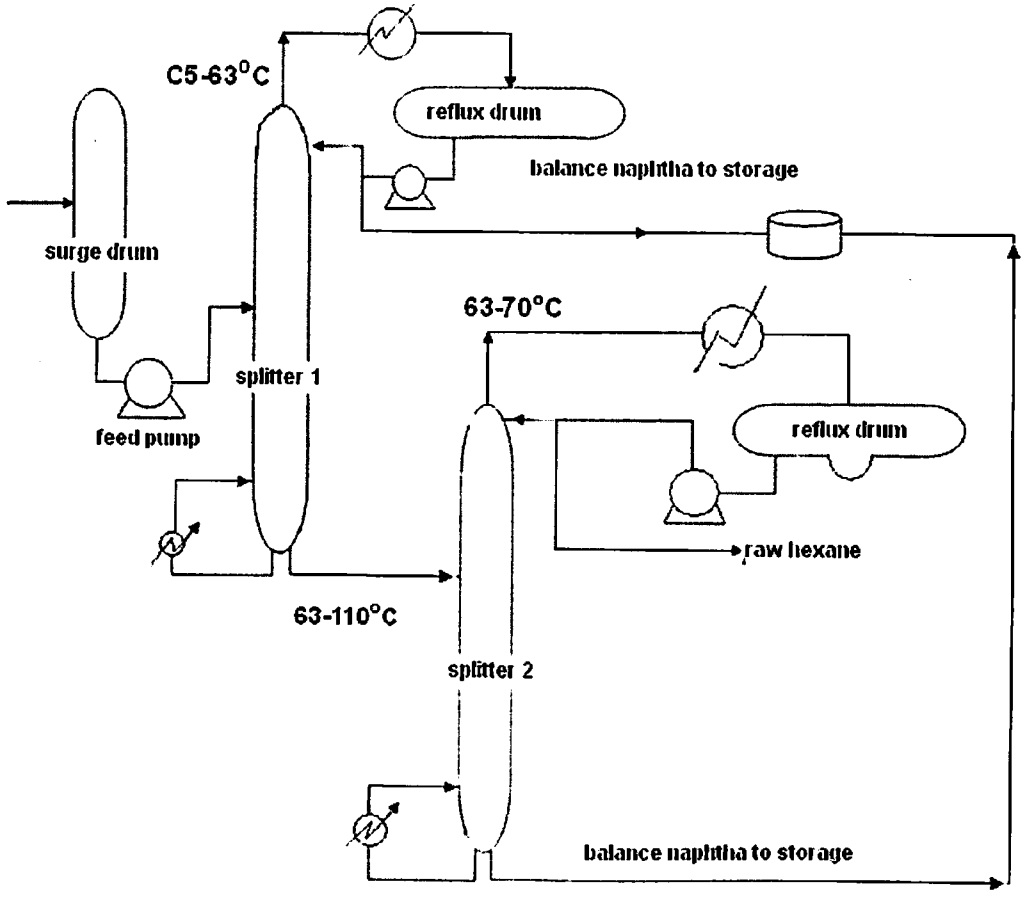
The food grade Hexane plant has two sections, which are Feed Naphtha Splitting, and Raw Hexane Dearomatization Section. This general description is described with the help of Process Flow Diagram. There are two sections.

- Production of raw Hexane in fractionation sections
- Extraction section.

4.2.1 Splitter section (fractionating section):

The feed to the plant is light straight run gasoline; C5-110 ^{o}C cut from plant-2 is the feed to hexane unit. The LSRG is treated for sulfur removal first in a caustic scrubber and then in a Merox extractor in a conventional murex system. The murex treated LSRG is the feed to the Hexane plant.

The feed is pumped into a feed surge drum from where it is sent to a splitter-I. The splitter-I has a re-boiler with MP steam as heating medium. In this splitter-I IBP-63 °C cut is removed as an overhead product and is sent to storage into Naphtha/gasoline pool as necessary. The bottom from splitter-I that is a 63-110 °C cut is routed to splitter-II that has a re-boiler with MP steam as heating medium. Here the 63-70 °C cut, which is called raw hexane, is removed to as a top product. The bottom product which is 70-110 °C cut is routed to Naphtha/gasoline pool as necessary. Raw-Hexane is sent to Raw-hexane surge drum.



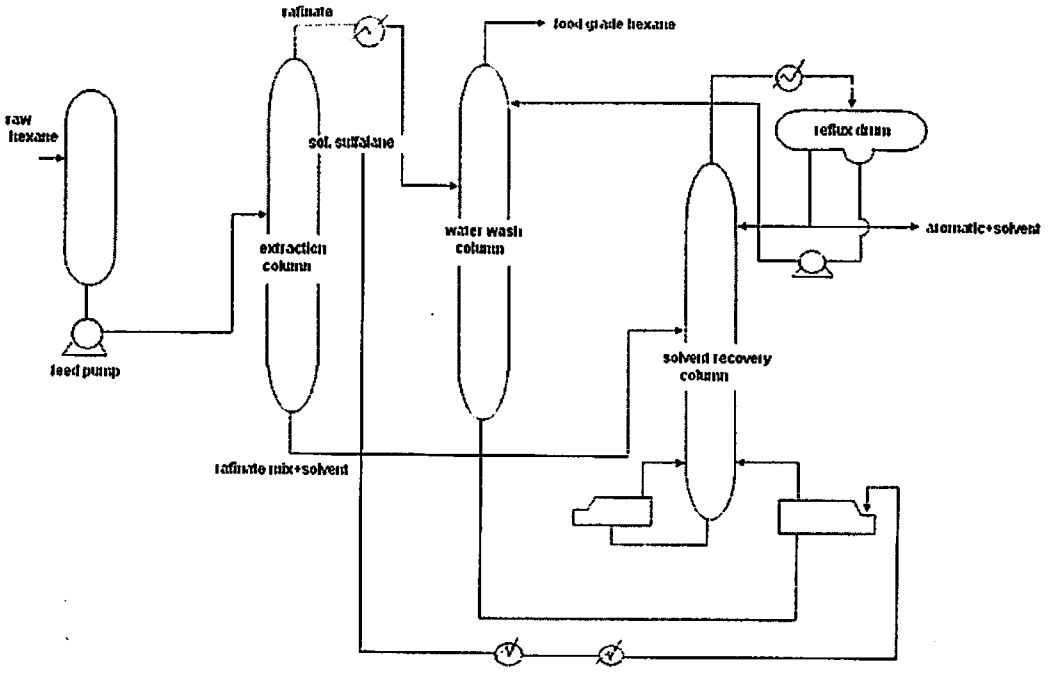
4.2.2 Extraction section:

The 63-70 °C, which is raw hexane, is sent to extraction section where aromatics are extracted with "sulfolane" as solvent.

The second section of the plant is called "Extraction Section". The raw hexane is pumped to the bottom of the extraction column and meets the descending solvent Sulfolane. The column

contains 40 nos. of Sieve trays, which provide contact surface for liquid extraction. The Sulfolane, which has affinity or solubility towards aromatics. So, the solvent extracts aromatics from Raw Hexane and exits the tower at bottom. The top stream from the extraction column, which is hexane (lean in aromatics), is removed as raffinate. The raffinate is routed to a water wash column where traces of Sulfolane is removed by water washing and is pumped to storage as Food Grade Hexane. The aromatic rich Sulfolane is flashed in a solvent recovery column under Vacuum after heat exchange. The aromatics in the solvent recovery column flash off and is condensed in the condenser and routed to storage into Gasoline pool. The bottom from solvent recovery column, which is Sulfolane, lean in aromatics is recycled back to the extraction column. Water from water wash column is going to bottom of the solvent recovery column after heating in an exchange and fed to the top of the columns as reflux.

A small slipstream of recovered Sulfolane from the bottom of solvent recovery column is routed to a solvent regenerator where amine is added to remove degraded solvent periodically. Here degraded solvent is removed from the bottom of the regenerator and purified solvent from top of the regenerator, is routed to solvent recovery col. bottom. To make up for Sulfolane solvent losses, solvent is periodically pumped into the solvent recovery column from storage. In order to minimize the solvent losses from the system in the event of safety valve discharge, a vent drum is provided to knockout-entrained solvent. This solvent along with drains of solvent from other equipment is routed to the solvent sump from where it is pumped into the solvent system.


raffinate
food grade hexane
raw hexane
sol. sulfolane
reflux drum
extraction column
water wash column
aromatic+solvent
solvent recovery column
feed pump
raffinate mix+solvent

4.3. DETAILED PROCESS DESCRIPTION

4.3.1 Introduction

The food grade hexane can be produced by the following processing schemes.

1. Conventional distillation followed by two stage oleium treating.
2. Conventional distillation followed by liquid-liquid extraction using Sulfolane as solvent.

The former scheme involves handling of olieum, which is highly hazardous and toxic. It also creates corrosion and pollution problems and hazardous effluents. Hence the process has operational problems, and is unsafe.

The latter scheme involves extraction of aromatics with a solvent "Sulfolane" which can be recycled back after flashing in a column. The concentration of aromatics in the hexane product is also considerably less in the latter scheme. Indigenous technology developed by M/s. EIL in collaboration with M/s. IIP is available for aromatics extraction using Sulfolane solvent.

Further alternate schemes look absorption process with activated carbon or silica gel after conventional distillation are also found to be unattractive due to economic consideration like higher quantitative requirement of activated carbon and silica gel. (Also monitoring of aromatic content in Food Grade Hexane will pose problems.)

The food grade hexane plant has two sections viz. Feed naphtha splitting and raw hexane dramatization.

Feed Naphtha Splitting:

Light straight run gasoline (LSRG) of C-5 to 110 ^{o}C TBP cut range is split into two stages in splitters-I and splitter-II to obtain raw hexane as distillate from splitter II.

Feed naphtha from plant 2 is received in hexane unit in feed naphtha surge drum under level controller. Split range controllers in nitrogen and flare header maintain the pressure in the feed naphtha surge drum. If low pressure in the drum will open the PV 10174B and let in N_2 to the

drum and high pressure in the drum will open the PV10174A and let out excess gas into the flare header. The pressure in the drum is measured by PT10174.

The drum is provided with a gauge glass LG10174 and level troll LT10174. There is a provision to announce high and low level in the drum. The drum is provided with a safety valve PSV10174 with bypass facility. Safety valve outlet is connected to the flare header.

The naphtha from feed naphtha surge drum is fed to splitter I (74 C 01) by feed naphtha pump 74 G 1 A/B under flow controller FV10174 after getting heat from splitter II bottom outlet stream in feed naphtha pre-heater 74E01. The temp of the naphtha entering the splitter is 65 ^{o}C. Splitter- I is operating at a top pressure of 1.65 Kg/cm^{2} g and top temperature of 65 ^{o}C. As the top pressure is measured by PT10274 and is controlled by split controller PIC 10274 through control valves PIC 10274 A/B provided in the overhead condenser 74E02 bypass line and to flare line respectively. The top temperature is measured by TI10674.

The light materials having the boiling point up to 63 ^{o}C are removed at the top. The top products are condensed in the condenser 74E02 and collected in the splitter I reflux drum 74C12. The outlet temperature of the stream from 74E02 is 42 ^{o}C.

The reflux drum 74C12 is provided with a safety valve PSV 10374 along with bypass facility. The drum is also provided with a gauge glass LG10374, a level troll LT 10374 and high and lower alarms. There is a facility to drain water from the drum.

The splitter I top product collected in the reflux drum is pumped by the splitter I overhead pump 74-G-02 A/B. One part of the top product is used as reflux to maintain the top temperature and the other part is going to balance naphtha under flow controller FV 10474 reset with level controller LIC 10374. The reflux flow is based on tray 33 temperature TI 10874 of splitter I and is controlled by TIC 10874 reset with FV 10374, reflux flow.

The bottom stream from splitter I at 118 ^{o}C is pumped by splitter I bottom pump 74G03A/B, under flow controller FV 10274 reset by column level controller LIC 10274 of 74 C 01, to splitter II 74-C-02.

The bottom of 74-C-01 (Splitter-I) is provided with a level troll LT10274 a gauge glass LG 102754 to indicate the column bottom level. It is also provided with a high and low level alarm.

The column is provided with two safety valves namely PSV70274A & PSV 10274B along with a by-pass facility.

Necessary heat to splitter I is provided by the thermosyphon re-boiler, 74E03, M.P. steam is used for heating under flow control FV 105 74 reset by column, tray 4 temperature control TIC 109

74. Splitter I bottom material are pumped by its bottom pumps 74G03 A/B to splitter II under flow control FV 10274 reset by level controller LIC 10274. The temperature of the naphtha entering the splitter II is 114°C.

Splitter II operates at a top pressure of 1.5Kg/cm^{2}g and top temperature of 99°C. The top pressure is measured and controlled by the split controller PIC 20174 through control valves of PV 20174 A/B. The light materials (63°C - 70°C) are recovered at the top of column.

The top products are cooled in the 74E04 and collected in the splitter II reflux-drum 74C-13. The outlet temperature of the stream from 74E04 is 87°C.

The drum 74C13 is provided with a safety valve PSV 20274 along with bypass facility. The drum is also provided with a gauge glass LG20274 a level troll LT 20274 and high and low levels alarms. There is facility to drain out water from the drum.

The top product of splitter II from reflux drum is pumped by 74 G 04 A/B. One part of the top product provides reflux to the column and the other part, under flow control FV 20274 reset by level controller LIC 20274, is cooled in raw hexane cooler, 74E06, and routed to raw hexane surge drum 74-C-74.

Reflux flow to the column is based on tray 33 temperature of splitter II measured and controlled by TIC 21074 reset with, FV 20174, reflux flow.

Splitter II bottom at 126°C preheats the feed naphtha in feed naphtha pre heater 74-E-01 under flow control FV20374 reset by column level controller LIC 20174 and mixed with splitter I top product.

This stream is called balance naphtha stream and is cooled to 43°C in balance naphtha cooler 74-E-07 and routed naphtha storage.

The column is provided with two safety valves namely PSV 20174 A/B along with by-pass facility. Column bottom is provided with a level troll LT 20174 and gauge glass LG 20174 to indicate the bottom level.

Thermosyphon type re-boiler, 74-E-05, provides necessary heat to splitter II. M.P. steam is used as heating medium under flow control FV 20474 reset by column tray 4 temperature controller TIC 21174. The re-boiler outer temperature is 129°C.

LIST OF P & ID,

Sl. no,	Equipment tag no	Service
1	74 C 01	splitter 1
2	74 C 02	Splitter 2
3	74 C 11	feed naphtha surge drum
4	74 C 12	Splitter 1 reflux drum
5	74 C 13	Splitter 2 reflux drum
6	74 C 14	Raw hexane surge drum
7	74 E 01	Feed naphtha pre heater
8	74 E 02	Splitter 1 over head condenser
9	74 E 03	Splitter 1 reboiler
10	74 E 04	Splitter 2 over head condenser
11	74 E 05	Splitter 2 reboiler
12	74 G 01 A/B	Feed naphtha pump
13	74 G 02 A/B	Splitter 1 over head pump
14	74 G 03 A/B	Splitter 1 bottom pump
15	74 G 04 A/B	Splitter 2 over head pump
16	74 G 05 A/B	Splitter 2 bottom pump

4.4. Application of hexane food grade unit in new technique of PHA:

1. **Process:**

1.1 material and flow sheet:

1.	What materials are the hazards(product Inter. By product)	Feed (Naptha) C5/110^{0}C	Hexane	oleum	sulpholean
2.	Type (toxic, flammable combustible, etc)	Flammable and combustible	Highly Flammable	Not combustible, but Toxic	Non flammable and Reactive, but toxic
3.	Properties (Physical, combustible, reactive	BP: 160^{0}C-220°C VP: >5mm Hg LEL: 1% FP: 37.78^{0}C	Flash point: -22°C c.c. Auto-ignition temperature: 225°C Explosive limits, vol% in air: 1.1-7.5	BP:116°C (30%)	Flashpoint: 166°C (330.8°F) (Cleveland Open Cup)
4.	Unwanted hazard reaction possibility due to improper storage, shock, abnormal process condition flow rate , blockage, mechanical failure etc	Improper storage, mechanical failure	Improper storage, mechanical failure	Improper storage	Improper storage
5.	Provision for preventing runaway reaction.	N/A	yes	yes	Yes
6.	Provision for rapid disposal if needed.	Yes	Yes	Yes	Yes

7.	Compatibility with other material.	Not with Strong oxidiser	Not with Strong oxidiser	Not with base and water	Not with Strong oxidiser
8.	Storage facility Above BP, cryogenic, stored in large bins, inhibitors needed.	Floating Roof	Underground storage	Dry, cool and ventilated	N/A
9.	Effect by weather conditions	N/A	N/A	N/A	N/A
10.	Reduction of hazardous material inventories.	Further reduction is not possible	polymerization	Reduction to acids, acid mists and vapours	Reduction to SO_x
11.	Safety margin	1.25	1.25	1.2	1.15
12.	Most severe credible accident	NA	NA	NA	NA
13	Consequences of the accident	Fire, Explosion, toxic impact, loss to life and property	Fire, Explosion, toxic impact, loss to life and property	Fire, Explosion, toxic impact, loss to life and property	Fire, Explosion, toxic impact, loss to life and property
14.	Root causes of the accident	leakage	-	-	-
15.	Control measures				
16.	Potential for external fire	Yes	Yes	Yes	Yes
17.	Experience of company with particular hazard	20 years	15 years	12 years	12 years

1.2 Unit and layout:

1.	Hazards pose to the public or workers from the unit in control room, adjacent unit, nearby shop or office.	Adjacent unit	Adjacent unit	No	No
2.	Nature of above Hazard.	Flammable	Flammable	Reactive	Reactive
3.	Hazard to adjacent facility road, railway pose to personal and equipment	No	No	No	No
4.	Nature of above hazard toxic, flammable noise radiation etc.	Flammable	Flammable	Reactive	Reactive
5.	External forces that can affect the site high wind, earth movement, utility failure, terrorism, natural fire, extreme temperature flooding, lighting, drought, fog.	High wind, Utility failure, Earth movement, tsunami	High wind, Utility failure, Earth movement, tsunami	High wind, Utility failure, Earth movement, Tsunami	High wind, Utility failure, Earth movement, Tsunami
6.	Provision made for reliving explosion in building.	Yes	Yes	Yes	Yes
7.	Requirement of any barricade, concrete wall needed	Yes	Yes	No	No
8.	Space between existing equipments and space for maintenance	Inadequate	Inadequate	Adequate	Adequate

Equipments:

Pressure and vacuum relief:

	Various relief devices	Splitter 1	Splitter 2
1.	Withstand existing overpressure	Yes	Yes
2.	Type of relief device eg. PRV rupture disc, liquid seal etc.	PRV	Rupture disk and PRV
3.	Basis for sizing eg. Utility failure, external fire, runaway reaction.	Utility failure and external fire	Utility Failure
4.	Relief set point and size.	1.25 MAP	1.25 MAP
5.	Adequacy of inlet and outlet piping of relief device	Not adequate	Adequate
6.	Provision for sprayed liquid	Adequate	NO
7.	Steam super heated needed	No	No
8.	Impact of flare, incineration, or flameout	No	No
9.	Action required if flare system is out of service.	Storage of vapours	Scrubbing
10.	Type of material of construction of relief device.	Carbon steel	Carbon steel
11.	Worst case scenario for process discharging of the system.	10 min	10 min
12.	Consequences if pressure increase beyond safety margin	Vessel burst, Spillage	Vessel Burst, and Spillage
13	If no pressure	NA	NA

.			

Valve and piping:

1.	Piping specifications:	7.981 in	10.02
2.	Compatibility		
3.	Normal temperature and pressure	93°C and 1.67 kg/cm^2	85°C and 1.67 kg/cm^2
4.	Maximum and minimum holding temperature And pressure	62°C and 128°C & 1.5 kg/cm^2 and 1.72 kg/cm^2	62°C and 128°C & 1.5 kg/cm^2 and 1.72 kg/cm^2
5.	Type of material carrying by piping system auto refrigerate, cryogenic.	BP= 63^{0}C	BP= 63^{0}C
6.	Possibility of size reduction for reducing the hazard	Yes	Yes
7.	Provision for draining	Provided	Provided
8.	Content of lines		
9.	Grounded adequately to avoid static charge development	Yes	Yes
10.	Pipe insulation if needed	Yes, to conserve energy	Yes, to conserve energy
11.	Position of critical valves	After the vessel	After the vessel
12.	Provision of indicating of the position of valves to control room	Yes	Yes
13.	Double block valve needed.	Yes	Yes

14.	Probability of failure of control valve	0.08/ year	0.08/ year
15.	Consequences if		
16.	No flow in line	Less level in splitter	Less level in splitter
17.	Less flow in line	Pump failure	Pump failure
18.	High flow in line	High pressure in the splitter	High pressure in the splitter
19.	Reverse flow	High back pressure	High back pressure
20.	Causes of failure of these valve	Imporper maintenance	Imporper maintenance
21.	Any parallel or series arrangement is in place in case of failure of one valve	Yes	Yes
22.	Sensing alarm system	Yes	Yes
23.	Accessibility for maintenance of control valve	Yes	Yes

Pumps:

1.	Various pumps and their types	Centrifugal	Vertical horizontal	Plunger	Reciprocating
2.	Design and running pressure	100 bar	100 bar	200 bar	150 bar
3.	Safety signal nearby the pump	Yes	yes	No	Yes
4.	Maximum upstream temperature	60^0C	60^0C	90^0C	85^0C
5.	Adequate protection against upset of pumps	Yes	Yes	Yes	Yes
6.	Consequences if	Low pressure	High pressure & Seal Failure	Flow rate	Leakage
7.	Low pressure in pump	Low head	Low flow rate		
8.	High pressure in pump	High head	High flow rate		
9.	No flow of fluid	Cavitation	Motor Failure	Production & Energy loss	Emergency stop
10.	High flow in pump	Pressure build up	Leakage	High suction head	
11.	Low flow in pump	Isolate pump	Redundant pump		

Reactors: N/A (No reactor is there in the unit)

1.	Class and type of reactors				
2.	Probable cause of exothermic reaction for eg. Quench failure, excess or deficiency of reactant, cooling failure				
3.	Effect of an agitator (failure, too slow, too fast, reverse)				
4.	Monitoring of agitator motion				
5.	Adequacy of relief valve				
6.	Design temperature of reactor				
7.	Hazard associated with reactor				
8.	Hazard associated with regeneration				

Vessels (drum, tank, tower):

1.	Various drums or tanks	Splitter 1	Splitter 2	Surge drum	Reflux drum
2.	Inspection and inspection methods	Operator and managerial	Operator and managerial	Operator	Operator
3.	Adequacy of relief system.	Adequate	Adequate	Adequate	Adequate
4.	Hazards due to loss of gas in case of purging, blanketing, inerting	Jet fire and Vapor cloud explosion	Jet fire and Vapor cloud explosion	Jet fire and Vapor cloud explosion	Jet fire and Vapor cloud explosion
5.	Possibility of static electricity development	All the units, piping are properly grounded	All the units, piping are properly grounded	All the units, piping are properly grounded	All the units, piping are properly grounded
6.	Other safety precautions if needed	QRA is needed	QRA is needed	QRA is needed	QRA is needed
7.	Provision for isolation in case of emergency	Yes	Yes	Yes	Yes
9.	Vessel Content and its specifications	Naphtha C5/110^{0}C, Hexane, Oleum and sulpholane	Naphtha C5/110^{0}C, Hexane, Oleum and sulpholane	Naphtha C5/110^{0}C, Hexane, Oleum and sulpholane	Naphtha C5/110^{0}C, Hexane, Oleum and sulpholane

Heat exchangers: only shell & tube multi-pass type of heat exchangers are used in food grade unit

1.	Various heat exchangers	Shell & tube Multi-pass
2.	Consequences of tube failure	Inner Leakage Mixing, May be reaction
3.	If no flow in tubes	Water losses
4.	Cause	Water losses, Equipment failure Temp., Difference
5.	Control measure	Temperature Flow rate Pressure
6.	Consequences of low flow in tubes	Low heat transfer Scaling
7.	Cause	Equipment failure, Water losses, Pressure losses
8.	Control measure	Temperature
9.	High flow in tubes	
10.	Cause	instrument error Mechanical error Human Error
11.	Control measure	Temperature, flow rate Pressure
12.	Reverse flow in tubes of H.E.	Choking
13.	Causes of tube failure like flashing, reacting, leakage etc.	Heat Exchanger out of control, Shut down, Tube change & restart
14.	Adequacy of pressure relief for both side of exchanger	Yes
15.	Maximum upstream pressure and temperature	40 bar, 325^0C
16.	Reliability of cooling water supply	0.99

Furnace and boilers: N/A

No furnace and boiler is used in this unit.

1.	Various furnaces and boilers	
2.	Firebox protection against explosion	
3.	Furnace protection against liquid in fuel gas system	
4.	Furnace protection against liquid fuel system failure	
5.	Adequacy of furnace against tube failure	

Instrumentation:

1.	Critical instruments indentified	Pneumatic pressure control valve	Hydraulic valve
2.	Effect of faulty sensor transmitter, indicator, alarm or recorder	Production loss	
3.	Effect of collective failure	Accident	Accident
4.	Backup provision of all hardware components	Only for some components	yes
5.	Consequence of brief loss of instrument power	Interlock pump trip-off and vapour is flared	
6.	Procedure for testing and proving instrument function	Yes	
7.	Provision of process safety when instrument taken for	Redundant	

	maintenance		
8.	Effect of atmospheric humidity and extreme temperature	Water proofing is done	
9.	Provision of grounding of instrument with catholic protection	All the vessel's, piping's and equipments are properly grounded	

Electrical power:

1.	Location of all auxiliary electrical gears	Yes
2.	Electrical area classification	Classified
3.	Effect of failure of electrical interlocks and shutdown devices	Emergency stoppage
4.	Overload and short circuit protection devices	Yes
5.	Provision of bonding and grounding	Yes
6.	Grounding provision of truck and rail wagon during loading and unloading	Yes
7.	Electrical equip. That can taken for P.M. without interruption production	Yes

OPERATIONS:

1.	Human errors which may have catastrophic consequence	Yes
2.	Maintaining up to date procedure	Yes
3.	Availability of written working procedure	Yes
4.	Training to new operating procedure	Trained

Maintenance:

1.	Availability of written procedure for each facility	Yes
2.	Necessity of shut down the process completely to safely repair a equipment	No
3.	Cleaning and maintenance equipment required	Yes
4.	Preventive maintenance schedule and realiability	Yes
5.	Type of preventive maintenance	Mechanical, Electrical and Instrumental
6.	Hazards introduced during schedule maintenance	Yes but SOP is Followed

Personal safety:

Building and structure:

1.	Standard followed in the design of ladder, platform, ramps etc.	Yes
2.	Sufficiency of safe route and exit	Sufficient
3.	Steel ground structure	No
4.	Enough SCBA	Yes

Operating area:

1.	Fire and explosion hazards exposed to workers	Yes
2.	Nature of chemicals	Flammable Toxic Reactive
3.	Where is possibility of exposed of chemicals	Sampling points Drainage Flare system
4.	Requirement of PPE	Yes
5.	Provision of shower and eyewash	Fixed at the required the locations

6.	Pressure hazards	Yes
7.	Temperature hazards	Yes
8.	Mechanical hazards	Yes
9.	Provision of emergency stop switch	At Control Room Inside the plant Peripheral area
10.	Provision of alarm system for medical emergency	Established
11.	Electrical hazards	Yes
12.	Vibration hazards	Yes
13.	Radiation hazards	Yes
14.	Adequacy of lighting system	Adequate

Fire protection:

1.	Combustible materials	Naptha	Hexane
2.	Cause of occurrence of combustible mixture	Leakage, Oxygen mixing,	Oxygen mixing, Runaway reaction
3.	Presence of ignition source	Yes, But Fire proof Intrinsically safe	Do
4.	Provision of insulation for all hot system/equipments	Provided	Do
5.	Addition of odorant in all flammable gases	Only for LPG	
6.	Presence of flame and detonation arrestor	Yes	Yes
7.	Provision of smoke, gas, water, heat sensor	Yes	Yes
8.	Fire fighting techniques	Followed	Followed
9.	Adequacy of fire fighting system	Adequate	Followed
10.	Procedure in event of fire	Documented	N/A
11.	Capability of fire brigade	Well Trained and Capable	adequate
12.	Capability of fire water	Adequate	Do

	supply		
13.	Location of fire protection resources	Well Designed	Do
14.	Adequacy of drainage to carry spilled flammable liquid	Well designed	-
15.	Adequacy of control room protection against external fire	Highly Protected	Adequate
16.	Are fire protection system periodically tested	Yes	Yes

Environment protection:

1.	Chemicals sensitive for environment	N/A
2.	Effluent stream description	N/A
3.	Scrubber required	Yes
4.	Sampling of effluent	Done
5.	Precautions for environment protection	ETP, scrubber and flare
6.	Hazard during normal and abnormal operation	Material release
7.	Dike provision for storage area	Yes
8.	Toxic gas monitor alarm or detector	Present
9.	Updated emergency shutdown and evacuation plan	Yes
10.	Nearest and largest onsite or offsite population	478 personnel
11.	Capability of spill response team to control	15 min for minor leak 25 min for major leak
12.	Surface water runoff require and special treatment	No
12.	Potential of release in process area	Yes

13.	Can waste be safely handled	Yes

Management and policy issues:

1.	Management commitment toward health and safety of employees	Yes
2.	Authority to stop the work if safety requirement not meet	Yes
3.	Company's safety first approach	Yes
	Discussion of health and safety in management meeting at all levels	No
	Availability of written training policy	Yes
	Provision of periodic testing of safety related equipments	Yes
	Existing of auditing programme	Yes, but not adequate

Chapter 5

Result and discussion:

The proposed new methodology of PHA covers a wide range of process, process hazard information, design basics, safety management principles, process safety management, check list, what- if analysis.

By this new methodology the PHA team will quickly get access to the process hazards and risk involved in the process. This PHA methodology will be a time saving for safety auditors and safety personnel.

Chapter 6

Conclusion:

One of the key components of Effective Process Safety Management (PSM) is Process Hazard Analysis (PHA). The proposed new methodology of PHA if implemented in the food Grade Hexane Unit, we can control the hazards in the unit quickly with fewer efforts. Later we can successfully implement this new methodology for the entire refinery.

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3. Loss prevention in process industry volume 1&2. F.P.Lee's
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5. Documents from Essar oil limited, Vadinar