400 Series:
Process Safety

Process Hazard Analysis

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Global Environmental, Health and Safety
Indorama Ventures

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1. Purpose

This standard establishes Indorama Ventures minimum requirements for when and how to carry out various Process Hazard Analysis (PHA) studies for new designs (projects), existing sites, and for modifications of new and existing sites, including requirements for PHA revalidations.

2. Scope

This standard applies to all applicable Indorama Ventures owned/operated sites as defined in IVL EHS-417 Process Safety Management Applicability Standard. This standard does not apply to joint ventures (JVs) in which Indorama Ventures is a minority owner, nor to third-party warehouses and tollers, unless specifically requested by the related Segment EHS Leader.

For the purpose of this standard, the term 'EHS' includes process safety, transportation, and security, as well as environmental, health and safety.

This standard may apply, but is not limited, to the following type of activities:

- Chemical processing (including formulations and blending);
- Chemical storage and warehousing;
- Chemical unloading and loading facilities (including docks);
- Utilities and Distribution activities that interface with chemical processes;
- Process safety and mitigation systems (i.e., scrubbers, fire protection systems, containment systems, etc.);
- Offsite infrastructure (e.g., valve sites, pipelines, waste recovery systems);
- Chemical research and development sites;
- Chemical packaging and distribution plants (including drum filling, etc.); and
- Research facilities and laboratories.

The effects that potential hazards may have on occupied buildings are addressed in the IVL EHS-407 Facility Siting Standard.

This standard must be implemented by each site. Until implementation of this standard is complete, each site must at a minimum be in compliance with the local applicable regulations.

3. Responsibilities

Following is an overview of key responsibilities for this standard. Additional responsibilities, as applicable, are included in Section 4, Requirements.

3.1. Corporate EHS

3.1.1. Provide ongoing technical assistance related to this standard.

3.1.2. Periodically audit sites to determine compliance with this standard.

3.1.3. Review, update and communicate to all Indorama Ventures sites any updates or changes to this standard and associated documents and tools.

3.1.4. Periodically review this standard to ensure its continuing adequacy and suitability to Indorama Ventures' operations.

3.1.5. Ensure this standard is consistently implemented from site-to-site within Indorama Ventures.

3.1.6. Communicate, as applicable, any lessons learned as a result of best practices identified or any non-compliances associated with implementation of this standard.

3.2. Site Head or Designee

3.2.1. Ensure implementation of and compliance with this standard including that it is adhered to and a site-specific program is developed so all employees receive the proper training, resources, and communications.

3.2.2. Assist with the implementation of the site-specific program; in particular:

- Be thoroughly familiar with the requirements of this standard, the site-specific program, and any associated procedures and work practices.
- Provide support, resources and training needed to carry out the requirements of this standard and the site-specific program.
- Ensure required records are maintained on file.
- Ensure compliance with site-specific program by employees and contractors (as applicable).

3.2.3. Ensure compliance with this standard for newly acquired and existing sites, including modifications and revalidations.

3.2.4. For newly acquired or existing sites, appoint competent PHA Study Leader(s) to perform the studies required.

3.3. Segment EHS

3.3.1. Ensure that any site or local standard or procedure related to the same topic follows the corporate requirements at minimum.

3.3.2. Support the sites on any technical point related to the standard, including implementation.

3.3.3. Periodically evaluate sites' level of compliance with this standard

3.4. Acquiring Business Lead

3.4.1. In the case of newly acquired sites, if a Site Head has not been named, the acquiring business lead is responsible for assigning a PHA Study Leader to conduct an independent review of existing PHA studies and determine compliance with this standard.

3.5. Project Manager

3.5.1. Ensure compliance with this standard for new sites and capital projects.

3.5.2. For new facilities or capital projects, appoint a competent PHA Study Leader(s).

3.6. Program Owner

3.6.1. Be thoroughly familiar with the requirements of this standard and local regulatory requirements.

3.6.2. Develop and implement a site-specific program that meets the requirements of this standard and any local/regional regulatory requirements.

3.6.3. Periodically review and monitor for compliance with the requirements of this standard, and per local regulatory requirements, at least every five (5) years.

3.6.4. Develop an action plan to correct any non-conformance with local regulatory or Indorama Ventures requirements.

3.7. PHA Study Leader

3.7.1. Facilitate and document the PHA in accordance with this standard.

3.7.2. Ensure that the PHA Study Team is comprised of competent persons that fill identified roles required under specific methodologies and inform the Site Head or Project Manager if there are any concerns with team composition.

3.7.3. Verify that the PSI, required in the IVL EHS-402 Process Safety Information Standard, is available and up to date for reference as needed.

3.7.4. Identify suggestions for design changes, procedural changes, or areas for further study related to weaknesses in the design and operation that could lead to accidents and assign recommendations/actions to address the suggestions.

3.7.5. Conduct an independent review of existing PHA studies as to compliance with this standard for newly acquired sites.

3.8. Employees and Contractors

3.8.1. All personnel must understand and follow the requirements of the site-specific program including:

- Being aware of and trained on, as applicable, the legal, regulatory and other associated requirements.
- Immediately reporting any situations that may cause or have a potential to cause a non-compliance.
- Completing any assigned regulatory tasks or actions.
- Being aware of and trained on the process safety information relevant to the process(es) they operate and/or maintain.

3.8.2. Individuals experienced in the process under evaluation (e.g., operations specialist, maintenance associate, process engineer) shall be involved in PHAs as requested, such as:

- Participating in PHAs as technical resources when requested.
- Being aware of the PHAs for the areas where they work and where to locate them if needed.
- Completing PHA recommendations as assigned.

3.9. In addition to the roles and responsibilities detailed above, the site-specific program must define and document the roles and responsibilities for all personnel who play a role in implementing the site-specific program, at a minimum:

- Supervisors
- Engineering and Maintenance
- EHS Personnel
- Other applicable functions, as staffed at individual site level

4. Requirements

The site shall develop and implement a written site-specific program for performing PHA studies which meets local regulatory requirements, and, at a minimum, fulfills the requirements in accordance with this standard. This standard addresses multiple possible PHA study methods, such as a Conceptual PHA, a Preliminary PHA, and a Detailed PHA, and identifies when additional Process Safety assessments are required.

4.1. The appropriate Process Hazard Analysis studies shall be performed on all applicable existing sites, acquired sites, and when significant changes are made to existing sites.

4.1.1. All PHAs shall evaluate risk and recommend improvements in accordance with the IVL EHS-208 Risk Management Standard and Matrix.

4.1.2. For all PHA credible scenarios assigned a potential Severity Category of F or worse event, per the IVL EHS-208 Risk Matrix, an Independent Protection Layer (IPL)/Safety Integrity Level (SIL) Assessment is required to be done for each of these scenarios per the IVL EHS-406 IPL/SIL Assessment Methodology standard to assign risk reduction credit to each identified IPL.

4.1.3. In addition, Procedure PHAs shall be performed when the PHA study, performed on a continuous or batch process, identifies a Severity F or worse event with a procedural step listed as the Initiating Cause or as an Independent Protection Layer (IPL). The Procedure PHA, per the requirements of IVL EHSG-403-08, is to evaluate the applicable steps within the associated operating procedures, which includes the normal operating procedures, start-up, shutdown, and emergency procedures.

4.1.4. For new plant design projects, inherently safe design concepts shall be utilized where possible.

4.1.5. See the IVL EHS-204 Management of Change standard for evaluating when a PHA is required due to a proposed change.

4.1.6. In addition, a PHA may be required:

- For new projects;
- After a major incident, as determined by Incident Investigation, IVL EHS-106; or
- To fulfil local or national legislative or regulatory requirements.

4.2. The PHA methodology selected and other process safety assessments required shall be determined and documented by the PHA Study Leader as early as possible in the review process. It is suggested that this be done early during the Conceptual PHA, especially for an existing or newly acquired site with no existing PHA or when there is a significant project modification to an existing site, but the PHA Study Leader may elect to move directly to a Detailed PHA (HS3) without performing a Conceptual (HS1) or Preliminary PHA (HS2) first, as long as the requirements of the Conceptual (HS1) and Preliminary PHA (HS2) are covered.

4.2.1. During the PHA performance, it may be determined that other studies and assessments are required. These may include, but are not limited to, a Facility Siting study (see IVL EHS-407), an IPL/SIL assessment (see IVL EHS-406), and an area classification study.

4.2.2. See section 4.7 and Figure 1 for the suggested timing of PHA studies for new designs and modifications.

4.2.3. Refer to Attachment B for the PHA Overview Process to review the purpose, general requirements, and typical sequence of the PHA process.

4.2.4. Refer to IVL EHSG-403-01 for the Conceptual PHA (HS1) process.

4.2.5. Refer to IVL EHSG-403-02 for the Preliminary PHA (HS2) process.

4.2.6. Refer to IVL EHSG-403-05, IVL EHSG-403-06, and IVL EHSG-403-07 for the Detailed PHA (HS3) methodologies available.

4.3. Preparation

4.3.1. The appropriate level of Process Safety Information (PSI) shall be compiled as defined in accordance with the PHA methodology of choice.

- PSI compiled in support of a study should be made available to team members for review prior to the study.
- The team members shall familiarize themselves with PSI for the study and participate in their described roles.

4.4. Team:

4.4.1. PHAs shall be conducted by a team of competent persons led by a PHA Study Leader. The competency of the PHA Study Leader shall be assessed and determined by the person responsible for the site's PHA program. See 4.8.1 below for clarification.

4.4.2. The team composition should be agreed to by the PHA Study Leader before beginning the study. In no case shall a PHA be completed by one person working alone. It is strongly recommended that the PHA team include the following personnel, as applicable:

- Process operations personnel with experience with the process being studied.
- Personnel familiar with health, safety, and environmental issues specific to the process being studied.
- Specialty personnel as needed for designated areas of concern, to provide knowledge of specific issues, such as process chemistry and kinetics, metallurgy, corrosion, etc.
- Maintenance personnel, an Occupational Hygienist, an Environmental Specialist, and others, including non-Indorama Ventures personnel, may be requested to join the team when appropriate.
- For all PHAs, at least one Indorama Ventures representative is required on the PHA Study Team.

4.4.3. The appointed PHA Study Leader shall have no direct responsibilities for the operations of the plant / unit under review.

4.5. Results

4.5.1. PHAs shall be documented and maintained for the life of asset and in accordance with Indorama Ventures and local agency record retention policies.

4.5.2. Results of the PHA shall be stored appropriately and readily available to site personnel.

4.5.3. PHA recommendations shall be managed in accordance with Management of Recommendations / Actions Standard, IVL EHS-107.

4.5.4. PHA Study recommendations shall only be rejected by a Site Head / Project Manager, or his/her designee if the rejection meets one or more of the criteria shown below. The rationale and justification for rejection of recommendations shall be documented:

- The analysis upon which the recommendation / action is based can be shown to be flawed;
- The recommendation / action can be shown to be non-EHS related (operational consequences only);
- An agreed, alternative recommendation / action would provide an acceptable solution to the identified risk with a sufficient level of protection; or
- The recommendation / action is technically infeasible. In such cases, alternative approaches to address the identified risk shall be explored, agreed, and documented.

4.6. Revalidations

4.6.1. PHAs must be revalidated on a periodic basis in accordance with the process outlined in Attachment C.

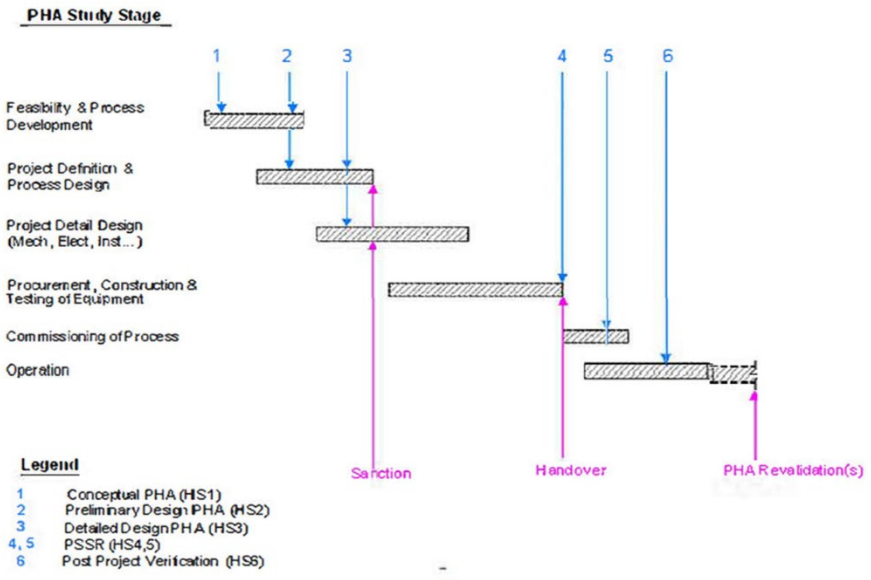
4.7. Timing

4.7.1. The typical relational timing of PHAs for new designs or modifications is shown in Figure 1.

4.7.2. For newly acquired PSM covered sites with no existing PHA(s) or with an unacceptable PHA(s), a suitable PHA which complies with this standard shall be in place as soon as possible, but no later than 12 months after the purchase.

4.7.3. A PHA Revalidation (including Procedural PHAs) shall be carried out for each PSM Covered process/unit within a site at least every 5 years. The timing for PHA Revalidations of a Non- PSM Covered process/unit within a site that is identified as a High Hazard Process System (HHPS) per the IVL EHS-417 Process Safety Management Applicability Standard may be set as desired but must not exceed 10

Figure 1 - Timing of PHAs for New Designs and Modifications



years between revalidations.

4.8. Clarifications

4.8.1. Site's may appoint someone responsible for the administration of the site's PHA Program but lacking in the competencies to lead certain PHA studies. In such cases, the PHA Program Leader should consult with an experienced PHA Study Leader, internal or external to Indorama Ventures, to determine the level of competency required when selecting a PHA Study Leader to facilitate a specific study.

4.8.2. PHA Study Leader must be trained in leading PHAs and in the specific process hazard methodology being used. Documentation of the PHA team leader training should be included in the PHA Report or with the PHA Program Leader.

4.8.3. The period between successive PHA revalidations on a site can be shortened at the discretion of the Site Head following a process related incident or changes such as a new development, change in technical standards or regulatory requirements.

4.8.4. PHA revalidation studies for processes/units at a site may be scheduled along a rolling timeline.

4.8.5. The main benefits of the PHA revalidation process are to:

- Refresh team awareness of the major hazards of the process and the basis of safety.
- Identify and assess significant changes in the process or new knowledge that may influence the need for improvements.

- Validate the administrative and engineered controls credited to reduce risk associated with the process/unit.
- Provide a mechanism for demonstration of continuous improvement in process safety and integration of developments in inherently safer design concepts since the last PHA.

5. Training

Training requirements must be defined in the site-specific program. At a minimum, all training must be documented with the training date, the names of personnel trained, the names of the trainer(s), the content of the training (or reference to content) and other site-specific/business segment requirements, when applicable.

5.1. Initial

Training on the requirements of this standard and the site-specific program must be provided to Indorama Ventures personnel based on their relevant responsibilities and shall be provided in the local language. At a minimum, personnel and/or management with direct responsibilities for this standard and site-specific program must be trained prior to conducting activities associated with the site-specific program.

The PHA Study Lead must be trained in leading PHAs and in the specific process hazard methodology being used.

5.2. Refresher

Refresher training shall be provided periodically according to the requirements of this standard, the site-specific program, and any local legal requirements, at appropriate intervals (e.g., changes to regulatory requirements), or at least once every three (3) years.

6. Recordkeeping

Records associated with the site-specific program and PHAs must be controlled and retained in accordance with regulatory or site business segment record retention requirements, whichever is more stringent. PHA and PHA Revalidation reports relevant to the site shall be maintained for the life of the asset. Examples of records to be maintained, include but may not be limited to, completed PHA reports and any associated information/documentation referenced.

7. References

7.1. IVL EHS-106 Incident Investigation

7.2. IVL EHS-107 Management of Recommendations / Actions

7.3. IVL EHS-204 Management of Change

7.4. IVL EHS-208 Risk Management Standard and Matrix

7.5. IVL EHS-402 Process Safety Information

7.6. IVL EHS-405 EHS Criticality Assessment

7.7. IVL EHS-406 IPL/SIL Assessment Methodology

7.8. IVL EHS-407 Facility Siting

7.9. IVL EHS-413 Pre-Startup Safety Review (PSSR)

7.10. IVL EHS-417 Process Safety Management Applicability

7.11. IVL EHSG-403-01 Conceptual PHA (HS1)

7.12. IVL EHSG-403-02 Preliminary PHA (HS2)

7.13. IVL EHSG-403-03 PHA Guidewords

7.14. IVL EHSG-403-04 Chemical and Thermal Risk Assessment

7.15. IVL EHSG-403-05 Detailed PHA (HS3): What-if and What-if Checklist Methodology

7.16. IVL EHSG-403-06 Detailed PHA (HS3): HAZOP Methodology

7.17. IVL EHSG-403-07 Detailed PHA (HS3): Failure Modes and Effects Analysis

7.18. IVL EHSG-403-08 Procedural PHA (P-PHA)

7.19. IVL EHSG-403-09 Dust Explosion Hazard Assessment

7.20. IVL EHSG-403-10 Post Project Verification

7.21. US Federal Legislation on Major Hazard Plants, OSHA 29 CFR Part 1910

7.22. AIChE, Centre for Chemical Process Safety “Guidelines for Hazard Evaluation Procedures”

8. Terms and Definitions

See IVL EHS Glossary and Attachment A

9. Revision History

Version	Date	Summary of Update	Owner	Approver	Next Review Date
Original	18 April 2022	Initial Release	Chad Wyble, Global Process Safety Program Director	Todd Hogue, VP, Global Head of EH&S	18 April 2025
1.0	09 August 2024	Updated implementation timeframe (Section 2) and Responsibilities (Section 3); made minor editorial updates.	Chad Wyble, Global Process Safety Program Director	Todd Hogue, VP, Global Head of EH&S	09 August 2029

Attachment A: Definitions and Glossary

A.1 ACS – Advanced Control Systems
High level process control using predictive models to anticipate the process behavior.

A.2 Action Control
Throughout the whole PHA standard, numerous actions/recommendations will be raised, some very minor and some with major implications. It is essential that these are all recorded in a clear and concise manner and that the actions are resolved to the satisfaction of the Project Manager/Site Head before the plant is started up or in accordance with a target schedule. The control of actions to completion is described in detail in the Management of Recommendations / Actions Standard, IVL EHS-107.

A.3 AIChE – American Institute of Chemical Engineers

A.4 ALARP – As Low as Reasonably Practicable

A.5 API – American Petroleum Institute

A.6 AQS – Air Quality Standard
A concentration of a substance in air deemed to be acceptable to the environment being considered. The AQS may apply at local, national or international level.

A.7 Basis for Safe Operation
The basis for safe operation should make clear why the design is safe to operate. For example, explosions may be avoided by preventing flammable mixtures, by control and/or trip systems, eliminating, as far as possible, ignition sources, providing explosion relief or designing to contain explosions.

A.8 BAT – Best Available Techniques
The most effective, procurable, proven techniques (including technology, methodologies, management systems, etc.) that can be justified having regard to costs.

A.9 Checklist
A method for hazard identification by comparison with experience in the form of a list of failure modes and hazardous situations

A.10 Chemical (Reactive) Hazard Assessment
Experimental assessment of propensity to give runaway or self-detonation properties using Dewar or similar laboratory equipment.

A.11 CIA – Chemical Industries Association
A leading trade and employer association in the United Kingdom

A.12 Competent
A competent person is one who meets the requirements for the job role concerned.

A.13 Conceptual PHA (HS1)
This is a PHA Study which is an early review of a project's process, materials and EHS impact so as to ensure that management of EHS is provided.

Performed during the project feasibility study, it takes input from early stage Inherent EHS studies and identifies the basic hazards of the materials involved and of the operation (it includes the results of Chemical Hazards Assessment if reaction hazards exist). Establishes safety, health and environmental criteria and ensures the necessary contacts with functional groups and external authorities.

This study also investigates the viability of the project and ensures that all team members understand the project scope.

For projects with no inherent hazards, the PHA Study standard may be curtailed following Conceptual PHA (HS1) at the discretion of the PHA Study Team. In these cases, the reasons for not following the full standard should be fully documented.

A.14 Consequence (Severity) Assessment
Consequence modelling evaluates effects of accidents and the impact on personnel, equipment, structures and the environment. Estimation of the consequences of each possible event often requires some form of computer modelling. Reference Risk Management Standard and Matrix, IVL EHS-208.

A.15 Contaminated Land Assessment
Inspection and identification of pollutant sources, their pathways and receptors and assessment of potential linkages that may harm human health, the environment or property.

A.16 Criterion
A standard of performance with which assessed performance may be compared.

A.17 DCS – Distributed Control System

A.18 Deflagration
A deflagration is a relatively slow explosion, generating only subsonic pressure waves. This sort of explosion is usually produced by rapid chemical combustion reactions, for instance of gunpowder in a firearm, or fuel in an internal combustion engine.

A.19 Detailed PHA (HS3)
This is a PHA Study of a design or procedure to identify hazards and operability problems. This study can be completed using one or more of several recognized methods, namely:

- Hazard and Operability study (HAZOP)
- "What-If"
- Failure Modes and Effects analysis
- Procedural PHA.

The most common method is HAZOP which is performed at the end of the project design stage using fully developed Piping and Instrumentation Diagrams (Engineering Line Diagrams) and procedures, which have been subjected to design review, to identify hazards and operability problems, which could arise through deviations from the design intent, using guidewords to stimulate creative thinking about possible deviations and their effects.

A.20 Detonation
A detonation is a rapid explosion that generates supersonic pressure waves (shock waves) in the surrounding medium. In addition to their possibility in a chemical site, detonations are commonly produced by high explosives, nuclear weapons, etc.

A.21 EHS – Environmental, Health and Safety

A.22 EIA – Environmental Impact Assessment
The process of considering and justifying the impact of a new plant or significant change on the immediate and general environment.

A.23 Electrical/Instrumentation (E/I) Synonym for Control/Electrical.

A.24 ELD – Engineering Line Diagram
A drawing showing the process piping, instrumentation and equipment. Also known as Piping and Instrument Diagram, Process and Instrument Diagram, PID or P&ID.

A.25 EQS – Environmental Quality Standard
A concentration of a substance deemed to be acceptable to the aquatic environment being considered. The EQS may apply at local, national or international level.

A.26 Existing PHA
This is a combination of hazard studies forming the basis for safe operation for a process plant. It is typically comprised of a Conceptual PHA (HS1), Preliminary PHA (HS2) and, if defined by a PHA Study Leader or in accord with local/national regulatory requirements, a Detailed PHA

(HS3); all of which must be based on an accurate and complete set of Process Safety Information.

A.27 Fault Tree
A logic model that graphically portrays the combinations of failures that can lead to a specific main failure or accident of interest.

A.28 Guide Diagram
A set of guidewords used to stimulate thinking about potential hazards. There are different guide diagrams for different stages of Hazard Studies and for different types of processes or operations.

A.29 Guidewords
Guidewords are used to prompt thoughts. A listing of suggested PHA guidewords are provided in IVL EHSG-403-03.

A.30 HAZCON
A 'What if / Check list' based study for construction and demolition activities.

A.31 Hazardous Event
The occurrence of an incident with a potential for human injury, damage to property, damage to the environment or some combination of these.

A.32 Highly Reactive
Intended to apply to those processes or chemicals with the potential for highly exothermic uncontrolled or unstable reactions.

Specific applicability includes ethylene oxide, propylene oxide, and alkoxylation reactions. These materials are considered highly reactive, may be unstable, and present the greatest energy potential per unit weight of common industrial chemicals known or suspected to create explosion hazards.

Several particularly sensitive, critical-to-control, or moderate exothermic reactions of concern include: nitrations, halogenations, alkylations, condensation, polymerization, oxidation, esterification, and addition reactions between inorganic acids and unsaturated hydrocarbons.

This includes any highly reactive mixtures of chemicals with a heat of reaction which, by convention, is expressed as a negative value for an exothermic reaction that has an absolute value greater than or equal to 1000 BTU/lb (or 555 calories per gram), and an NFPA instability rating of 4 (1000 W/mL instantaneous power density). See Reactives Hazard Investigation, Table 5, NFPA-Defined Degrees of Instability Hazards, 10-17-02, page 50.

A.33 HSE – Health and Safety Executive

A.34 I/O – Input/output

A.35 Individual Risk
The frequency at which an individual may be expected to sustain a given level of harm from the realization of specified hazards.

A.36 Inherent EHS
Concerned with the removal or reduction of a hazard at source. Examples of inherently safe techniques include substitution of a less hazardous process, use of corrosion resistant materials of construction, reduction or elimination of hazardous materials, design for maximum foreseeable operating conditions, fail- safe design principles, and appropriate plant layout etc.

A.37 LOC – Loss of Containment.

A.38 Numerical Hazard Analysis
The identification of undesired events that lead to the materialization of a hazard, the analysis of the mechanisms by which these undesired events could occur and usually the

estimation of the extent, magnitude and likelihood of any harmful effects. Also known as Hazard Analysis (Hazan) or Fault Tree Analysis.

A.39 OHS – Occupational Health Statement
Project statement indicating how occupational health issues will be managed and controlled, e.g., ergonomic and industrial hygiene assessments.

A.40 OSHA
Occupational Safety and Health Administration of the US Department of Labor. Mention of OSHA in context of PHA often refers to USA Regulation 29 CFR (OSHA) 1910.119. Guidance is available in brochures OSHA 3132 “Process Safety Management” and OSHA 3133 “Process Safety Management - Guidance”.

A.41 PCB – Poly Chlorinated Bi Phenyls

A.42 PES – Programmable Electronic System
Usually, a computer or PLC. Any electronic device that can be programmed. These may also be found in measuring elements and analyzers.

A.43 PHA – Process Hazard Analysis
A Process Hazard Analysis (PHA), in the context of the process safety procedures, is defined as a systematic approach for identifying, evaluating, and controlling the hazards of chemical processes (e.g. Conceptual, Preliminary, Detailed, Pre-Start-up, and Post Verification related to modifications and existing processes, as well as the other related studies such as Facility Siting, Procedural PHA, Area Classifications, etc.).

The Hazard and Operability (HAZOP) study is the most commonly used PHA method, but there are many other methods available which may be more suitable depending on the circumstances. These methods include but are not limited to the Checklist, What-if and What-if Checklist, Failure Modes and Effects Analysis (FMEA), Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Cause-Consequence Analysis (CCA), and Bow-Tie Analysis (BTA).

A.44 PLC – Programmable Logic Controller

A.45 Preliminary PHA (HS2)
This is a PHA Study for the identification of significant hazards and the appropriate safeguards, which together will form the basis for safe operation.

Performed at the project definition stage, using guidewords to stimulate creative thinking to identify significant hazards. Inherent EHS principles continue to be applied where possible and practicable, or assessment may be used to determine appropriate design features, including the identification of trip/alarm systems.

A.46 Preliminary PHA (HS2) of a PES
This is an extension of Preliminary PHA (HS2) to review the possible failures and their effects arising from a programmable electronic system (PES). This is used where a PES, such as a Distributed Control System (DCS), has a significant role in the project.

A.47 Process Safety
Process safety is the prevention of unexpected releases of harmful substances.

A.48 Project Specification
The project specification is developed from the process specification and provides the formal basis for the cost estimate leading to sanction and detailed design.

A.49 PSM – Process Safety Management

A.50 Pyrophoric
Pyrophoric materials ignite spontaneously in air. Since a wide variety of chemicals will burn if heated sufficiently, it is usual to define a pyrophoric material as one that will ignite spontaneously at temperatures below about 45˚C.

A.51 Reprotoxic
Effects of certain chemicals on the reproductive and neuroendocrine systems, and also the embryo, fetus, neonate and prepubertal mammal.

A.52 SEVESO III Directive
Refers to European Union EHS legislation 2012/18/EU enacted in response to the chemical disaster at Seveso, Italy. In UK embodied in CIMAH and, more recently, COMAH.

A.53 SIL – Safety Integrity Level

A.54 Societal Risk
The relationship between frequency and the number of people suffering from a specified level of harm in a given population from the realization of specified hazards. Now becoming known as Group Risk.

A.55 Störfallverordnung, StFV
Swiss regulations Verordnung vom 27. Februar 1991 über den Schutz vor Störfällen.

A.56 Tolerable Risk
Tolerable risk is discussed in Risk Management Standard and Matrix, IVL EHS-208.

A.57 URS – User Requirement Specification
General specification specifying performance requirements usually applied to control/electrical systems.

A.58 VCE – Vapor Cloud Explosion

A.59 VDU – Visual Display Unit

A.60 WEL – Workplace Exposure Limit

Attachment B: Process Hazard Analysis (PHA) Overview Process

B.1 Introduction

This attachment provides an overview of the Process Hazard Analysis (PHA) philosophy for Indorama Ventures and the use of the tools in this standard. Figure B-1 illustrates the sequential execution of PHAs in accordance with increasing levels of design or availability of comprehensive Process Safety Information (PSI).

B.1.1 Purpose

B.1.1.1 The purpose of the PHA is to systematically consider and analyze the environmental, health and safety (EHS) hazards, so that:

a. Hazards are eliminated where possible;

b. Adequate protection is provided;

c. Potential consequences are minimized;

d. Correct equipment is installed as intended;

e. Equipment meets legal requirements;

f. The operation meets design intent;

g. The means to bring process to a level of acceptable risk is identified; and

h. An opportunity is provided to challenge the project definition, assumptions, and business value, with a competent team.

B.1.2 General Requirements

B.1.2.1 All PHAs referenced in Figure B-1 below, shall always be completed by a competent team. Team composition shall be determined by the PHA Study Leader.

B.1.2.2 PHA Study Team

a. The Team must include personnel with hands on experience of the process being studied, personnel familiar with the health, safety, and environmental issues specific of the process being studied, and specialty personnel as needed to provide knowledge of specific issues, such as equipment, process chemistry, kinetics, metallurgy, etc. Most PHA Study Teams consist of individuals in the following roles:

- PHA Study Leader
- Project representative
- Site operations representative
- Process engineer
- Functional (design) engineer
- Process control engineer
- Safety Function Specialist/Engineer
- Specialists

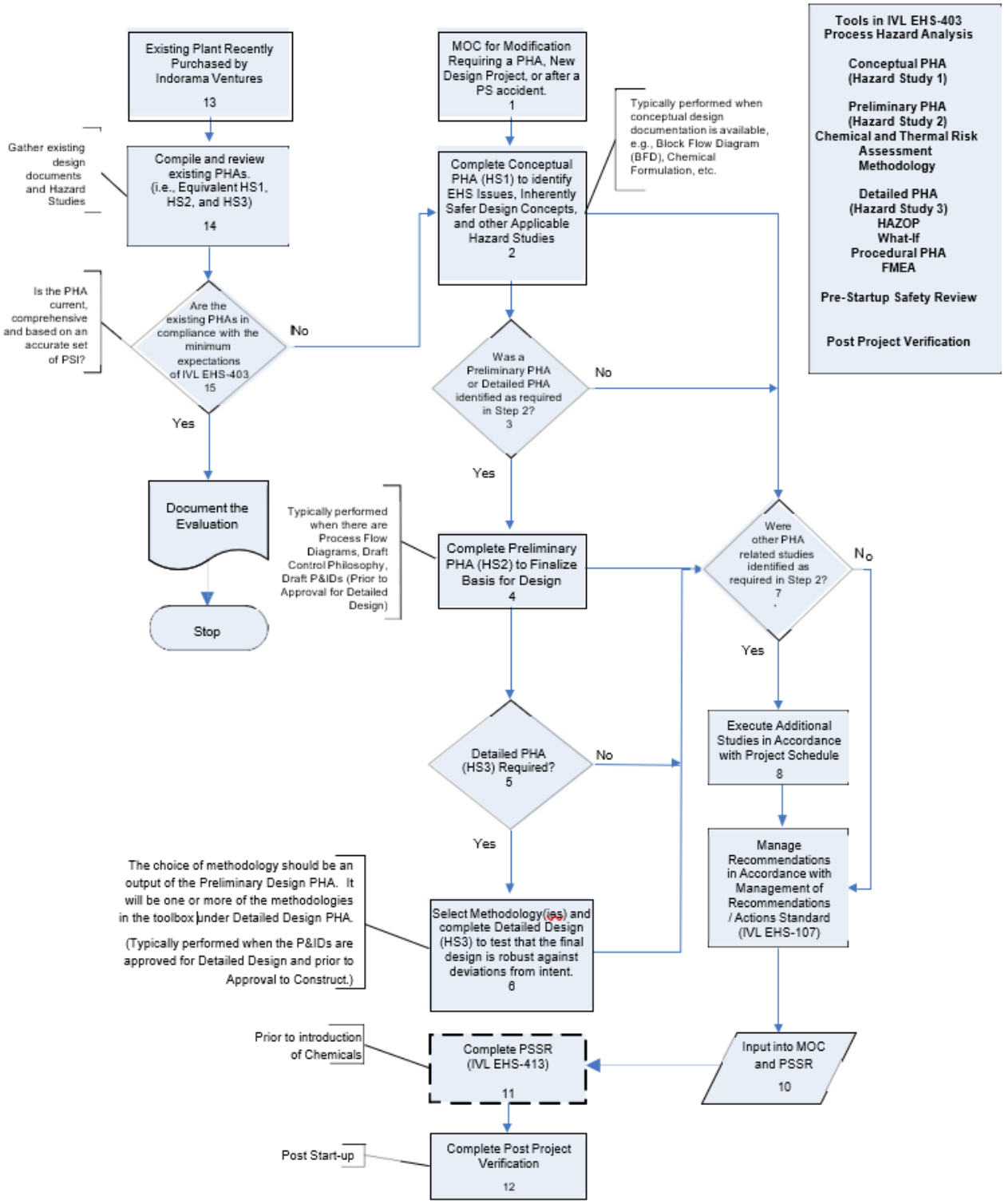
b. Experienced process and maintenance technicians should be involved whenever possible.

c. The ideal composition depends on the stage of the project.

d. In cases where operations are to be performed for Indorama Ventures by other parties under contract there may be a substantial involvement of non-Indorama Ventures personnel in the team. However, in all Indorama Ventures projects there should be at least one Indorama Ventures

representative on the PHA Study Team.

FIGURE B-1 TYPICAL SEQUENCE OF PROCESS HAZARD ANALYSIS STUDIES



B.2 PHA Process Steps

Referencing Figure B-1, the following is a stepwise description of Indorama Ventures' PHA philosophy for new and existing sites, as well as any modifications and acquisitions.

B.2.1 Step 1 – MOC for Modification or New Design Project

B.2.1.1 A PHA Study may be initiated as a result of:

a. A change as defined in the Management of Change (MOC) standard, IVL EHS-204.

b. A new design of a plant/unit or site.

c. A new or revised regulatory driver.

d. A PHA Revalidation Study (see Attachment C).

e. Following an accident which was unforeseen in prior PHAs.

B.2.2 Step 2 – Complete the Conceptual PHA (HS1)

B.2.2.1 The purpose of Conceptual PHA (HS1) is to ensure that the understanding of the project, the process and the materials involved is sufficient to enable EHS issues to be properly assessed. It also contributes to key policy decisions (e.g., on Facility Siting, see IVL EHS-407) and ensures that delays or constraints on the development of the project are identified at the earliest possible time by means of discussion with functional groups, site management and authorities.

B.2.2.2 The Conceptual PHA (HS1) shall be performed as early as possible in the life of a project when there is a basic business concept.

B.2.2.3 For an existing Indorama Ventures site where a PHA is required but none exists, a Conceptual PHA (HS1) is a good starting point to establish the basis for the identification of EHS issues and other required studies.

B.2.2.4 The Project Manager/Site Head shall consult with the site's PHA Study Leader to define the path forward to complete the PHA requirements.

B.2.2.5 The Conceptual PHA (HS1) shall be performed in accordance with the requirements in IVL EHSG-403-01.

B.2.3 Step 3 – Was a Preliminary PHA (HS2) or Detailed PHA (HS3) identified as required in Step 2?

B.2.3.1 For changes or new plant design projects, the Conceptual PHA (HS1) team shall stipulate which other PHA studies or PHA related hazard studies are required. (Reference IVL EHSG-403-01)

B.2.3.2 Yes – Proceed to Step 4, complete a Preliminary PHA (HS2) (Reference IVL EHSG-403- 02).

B.2.3.3 No – Proceed to Step 7 to complete other PHA related studies identified in Step 2. For sites subject to this standard, it is unusual for a plant/unit or design to stop prior to completing at least a Preliminary PHA (HS2).

B.2.4 Step 4 – Complete the Preliminary PHA (HS2) (Reference IVL EHSG-403-02)

B.2.4.1 The Preliminary PHA (HS2) is intended to identify significant hazards and ensure that there are appropriate measures to eliminate the risk or reduce the risk to tolerable levels. This is also the study intended to document the initial basis for safe operation and document the final design basis.

B.2.4.2 The Preliminary PHA (HS2) is typically performed:

a. During a design project when the process flow diagrams have been finalized and/or there are preliminary P&IDs. The expectation is that it will be performed prior to the sanctioning of capital funds.

b. Upon acquisition of a new site where the Existing PHA is not compliant with Indorama Ventures' minimum requirements and there is insufficient PSI to support a Detailed PHA (HS3).

c. For an existing site where it was determined to be required after completion of the initial Conceptual PHA (HS1).

B.2.4.3 The Preliminary PHA (HS2) shall be performed in accordance with the requirements in IVL EHSG-403-02.

B.2.4.4 A Preliminary PHA (HS2) must always be conducted by a PHA Study Leader, of agreed competency level, and all actions shall be managed to closure, according to IVL EHS- 107.

B.2.4.5 The PHA Study Leader shall identify the methodology to be used for the Preliminary PHA.

B.2.4.6 The requirement for a Detailed PHA (HS3) shall be affirmed during the Preliminary PHA (HS2) typically based on the complexity of the process, severity of the hazards, or regulatory requirements for existing sites.

B.2.5 Step 5 – Is there still a requirement for a Detailed PHA (HS3)?

B.2.5.1 Yes – Proceed to Step 6 and perform a Detailed PHA (HS3).

B.2.5.2 No – Proceed to Step 7 for consideration of any other process safety related studies.

B.2.6 Step 6 – Select the Detailed PHA (HS3) Methodology and Perform the Study

B.2.6.1 The purpose of a Detailed PHA (HS3) is to review the design and/or procedures to identify any hazards or obstacles to operability that could arise, particularly through deviations from the design intent.

The Detailed PHA (HS3) shall be performed using the Indorama Ventures recognized method which is most appropriate. The Indorama Ventures recognized methods for Detailed PHAs (HS3) are:

a. "What-If" (see IVL EHSG-403-05)

b. Hazard and Operability study (HAZOP) (see IVL EHSG-403-06). This is the predominantly recognized and preferred methodology for complex continuous flow processes or those involving batch reactive chemistry.

HAZOP studies require an accurate set of Engineering Line Drawings. Studies of batch processes also require a set of detailed operating instructions or sequence logic narratives.

c. Failure Modes and Effects analysis (see IVL EHSG-403-07).

d. Procedural PHA (see IVL EHSG-403-08)

B.2.6.2 The methodologies listed above shall be performed in accordance with their respective guidance.

B.2.7 Step 7 – Were other PHA related studies identified as required in Step 3?

B.2.7.1 Yes – Proceed to Step 8 and perform additional studies in accordance with the project schedule.

B.2.7.2 No – Proceed to Step 9 to manage any existing recommendations.

B.2.8 Step 8 – Execute Additional Studies

B.2.8.1 Consider and agree which EHS, quality or financial related studies will be required during the design of the project, and whether these will be covered as part of the PHA process or carried out as independent studies. Record who will be responsible for arranging the studies.

B.2.8.2 Some examples include Procedural PHAs (IVL EHSG-403-08),

Ergonomics, Facility Siting (IVL EHS-407) and Area Classification studies.

B.2.9 Step 9 – Manage Recommendations

B.2.9.1 All recommendations shall be documented and managed in accordance with Management of Recommendation / Actions Standard IVL EHS-107.

B.2.10 Step 10 –Input to MOC or PSSR

B.2.10.1 PHA study reports and the status of related actions may be compiled for completion of PSSRs and closure of MOCs in accordance with IVL EHS-413 and IVL EHS-204, respectively.

B.2.11 Step 11 – Complete Pre-Start Up Safety Review (PSSR)

B.2.11.1 A PSSR shall be carried out when stipulated during the PHA review or if required per the IVL EHS-204 MOC process to ensure all the actions identified during the change or new plant design project have been completed in accordance with the design intent.

B.2.11.2 A detailed description of the PSSR process is given in IVL EHS-413.

B.2.12 Step 12 – Complete Post Project Verification (See IVL EHSG-403-10)

B.2.12.1 A Post Project Verification shall be carried out when stipulated for the purpose of ensuring that the project met the EHS objectives and, as applicable, the physical systems and documentation has been fully integrated into the site EHS management systems.

B.2.12.2 The Post Project Verification shall review learnings from near misses, commissioning, changes and construction events.

B.2.12.3 A detailed description of the Post Project Verification process is given in IVL EHSG-403- 10.

B.2.13 Step 13 – Existing Site Purchased by Indorama Ventures

B.2.13.1 The purchase or acquisition by Indorama Ventures of a new site or activity may be the initiating event for a PHA.

B.2.14 Step 14 – Compile and Review existing PHAs from the purchased site.

B.2.14.1 Compile all existing PHAs at the acquired site for review by an experienced PHA Study Leader.

B.2.15 Step 15 – Are existing PHAs from the purchased site in compliance with IVL EHS-403.

B.2.15.1 An experienced PHA Study Leader, assigned by the acquiring business, shall conduct an independent review of existing PHA studies to determine compliance with this standard for newly acquired sites.

B.2.15.2 Yes – Document and Stop PHA process.

B.2.15.3 No – Proceed to Step 2 to complete a Conceptual PHA (HS1).

Attachment C: Evaluating the Existing Baseline PHA

C.1 Overview

Process Hazard Analysis (PHA) Revalidations are intended to review and validate the adequacy of the existing PHA as representative of the current configuration of the process/unit, process operating conditions, and administrative and engineered controls in place.

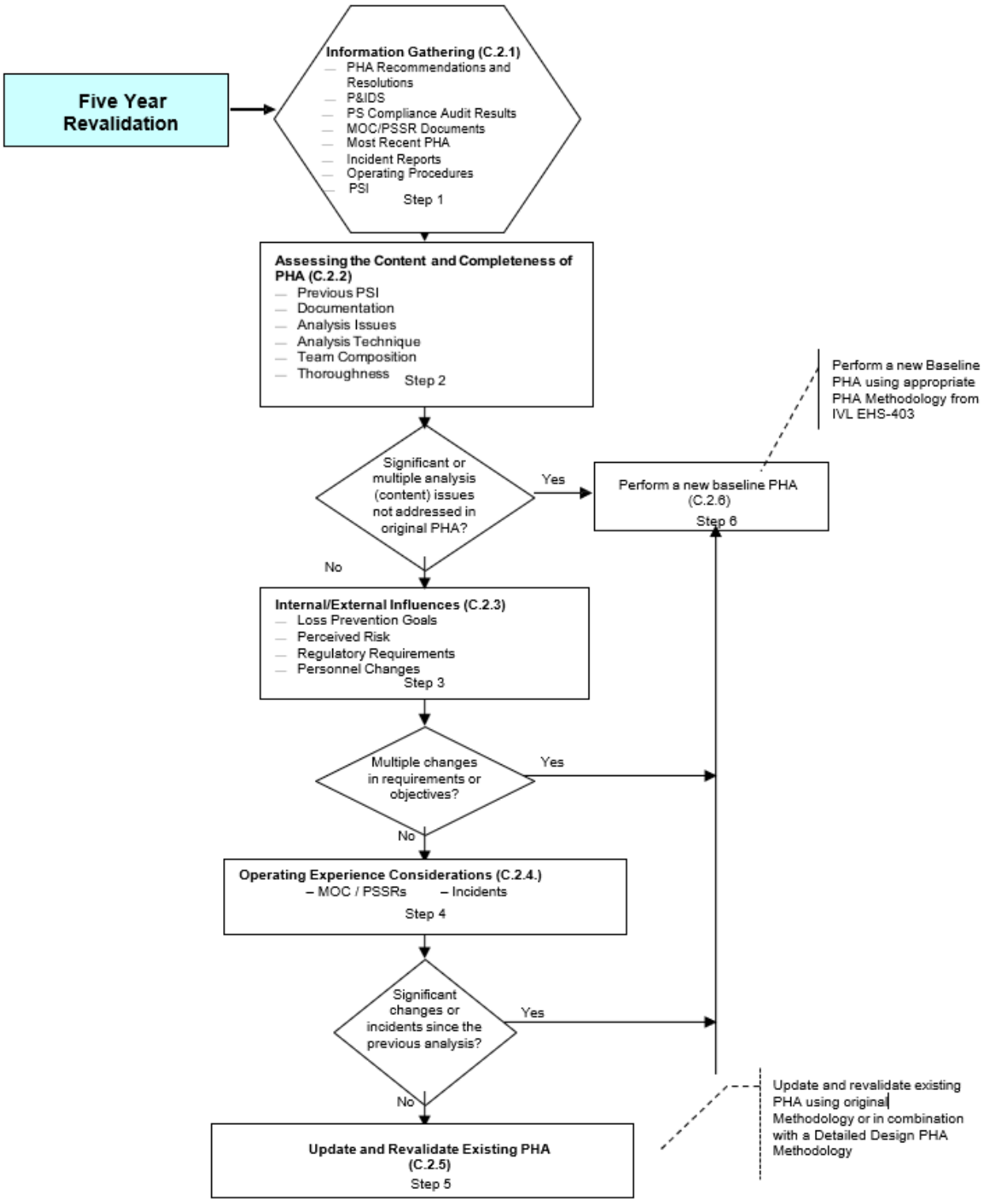
The PHA Revalidation shall be executed using the PHA methodology presented in this standard by a PHA Study Leader. The PHA Study Leader shall be competent in executing the PHA Study process.

The PHA Revalidation Study Report shall include documentation of any new or modified hazard event scenarios, associated consequences and safeguards, risk ranking of the event, and a prioritized list of recommendations, as developed by the team.

The PHA Study Leader shall be responsible for qualifying the baseline PHA and selecting the methodology to be used for the revalidation.

The flowchart in Figure C-1 illustrates a stepwise assessment of the baseline PHA to determine if it should be completely redone or updated and revalidated. It guides the PHA Study Leader through an evaluation of the “Completeness of the PHA”, the “Impact of Internal/External Influences”, and the “Operating Experience” since the last PHA.

Figure C-1 - PHA Revalidation Process Flowchart



C.2 Description of the Standard Steps

The following is a description of each step of the flowchart in Figure C-1.

C.2.1 Step 1: Information Gathering

C.2.1.1 The PHA Study Leader should gather the required input for the revalidation. This includes:

a. Previous PHA Report and supporting documentation used in PHA (PSI).

b. PHA Recommendation Tracking Report with documented closure or resolution.

c. PHA Closure Report.

d. Updated Process Safety Information, including current P&IDs and Safe Upper and Lower operating limits.

e. Relevant Incident Investigation reports (from study location or from other sites) since the previous PHA.

f. Relevant Management of Change (MOC), including organizational MOC, documentation since the previous PHA.

g. Applicable written operating instructions (operating procedures, manufacturing procedures, emergency procedures, etc.).

h. Audit findings that apply to the process, area, or PHA program.

i. Review LOPA and IPLS for possible gaps in the previous PHA.

j. Review P&IDS and nodes

k. Hazard Assessment Report(s), if applicable.

l. Facility Siting Report.

m. SIL Target Assessment Report.

n. Procedural PHA Reports.

o. Register of EHS Critical equipment.

p. Regulatory requirements, interpretations or changes to regulations relating to PHA and MOC.

q. Best industry practices for similar process facilities, e.g., inherently safer design concepts.

r. Current staffing levels.

C.2.1.2 The PHA Study Leader shall also assess the Process Safety Information (PSI) to ensure it is available, current, and up to date. Any gap discovered in the PSI should either result in a PHA recommendation to address the gap, or be closed prior to conducting the PHA Revalidation. The appropriateness of the resulting action should be at the discretion of the PHA Study Leader.

C.2.2 Step 2: Assessing the Content, or Completeness, of PHAs

C.2.2.1 Based on a review of the previous PHA, the PHA Study Leader, in consultation with individual(s) familiar with the process, shall determine if there were significant content, or completeness, issues related to the previous PHA meeting the requirements of this standard. This decision will determine which step in the flowchart is followed next.

There are 2 possible outcomes of this decision:

- ‘yes’ (there are significant issues), or
- ‘no’ (there are no significant issues)

If the decision is 'yes' – there are significant content or completeness issues – a complete new Conceptual PHA, baseline PHA and/or Procedural PHA shall be performed. Refer to Section C.2.6, Step 6 for further direction.

The PHA Study Leader should reach this decision if there is agreement with any of the following statements:

a. There are significant hazards of the process not addressed in the previous PHA that have been identified in the intervening period.

b. The PHA analysis technique was not appropriate for the nature of the process reviewed, i.e., a What-if/Checklist or Design PHA (Hazard Study 3) or company policy.

c. There is improved information and expertise now available to:

- Identify hazards that are specific to the unit.
- Provide insight into how the unit responds to upset conditions.
- Reflect on actual operating, maintenance, and training practices.
- Determine reasonable worst-case effects from upsets when considering no safeguards are present to protect the scenario.
- Question the adequacy of existing safeguards.
- Question the severity of each scenario.
- Question the safeguards credited in a scenario. For example: If there only administrative safeguards, such as SOPs protecting a scenario, consider finding other safeguards that may provide better protection.
- Question the initiating cause frequency of each scenario.

d. Non-routine operating modes were not included in the scope of the PHA.

e. The makeup of the previous PHA team did not include any of the following: individual(s) knowledgeable in engineering and process operation; at least one individual with experience and knowledge specific to the process under evaluation; and a team leader knowledgeable in the study methodology.

f. The previous PHA did not address incident investigation history or MOC history relevant at the time of the study.

g. The previous PHA did not address facility siting and human factor issues.

h. The supporting study documentation, i.e., PSI, procedures, etc. was not retained for record purposes.

C.2.2.2 If the decision is 'no' – there are no significant content or completeness issues with meeting the intent of IVL EHS-403 – proceed to Step 3, Evaluation of Internal/External Influences.

C.2.3 Step 3: Assessing Significant Changes in Internal or External Influences

C.2.3.1 Based on the information gathered, the PHA Study Leader in consultation with individual(s) familiar with the process shall determine if there have been any significant changes regarding internal or external influences. This decision will determine which step in the flowchart is followed next.

There are 2 possible outcomes of this decision:

- 'yes' (there are significant issues), or
- 'no' (there are no significant issues)

If the decision is 'yes' – there are significant changes regarding internal or external influences – a complete new Conceptual PHA, baseline PHA

and/or Procedural PHA shall be performed. Refer to Section C.2.6, Step 6 for further direction.

The PHA Study Leader should reach this decision if there is agreement with any of the following statements:

a. There are significant new applicable regulatory requirements imposed by regulatory agencies or by law.

b. There has been a response to settlement agreements with regulatory or local community/citizen groups.

c. There have been significant staff turnover in key roles such as Plant Manager, Operations Manager, Technical Manager, Maintenance Manager, or Lead Process Engineers such that there is no original PHA participant in key decision making roles.

d. There have been significant changes in Loss Prevention Goals or applicable company standards.

e. There have been significant changes in perceived risk or risk tolerance (i.e., risk ranking matrix as defined in Risk Management Standard and Matrix, IVL EHS-208.)

C.2.3.2 If the decision is 'no' – there are no significant internal or external issues – proceed to Step 4, Evaluation of Operating Experience Considerations.

C.2.4 Step 4: Significant Changes to Operating Experience Considerations

C.2.4.1 Based on the information gathered, the PHA Study Leader in consultation with individual(s) familiar with the process shall determine if there have been any significant process changes or incidents over the past 5 years, or since the last PHA. This decision will determine which step in the flowchart is followed next.

There are 2 possible outcomes of this decision:

- 'yes' (there are significant issues), or
- 'no' (there are no significant issues)

If the decision is 'yes' – there have been significant process changes or incidents since the last PHA – a complete new Conceptual PHA, baseline PHA and/or Procedural PHA shall be performed. Refer to Section N.2.6, Step 6 for further direction.

The PHA Study Leader should reach this decision if there is agreement with any of the following statements:

a. Initial PHA missed hazards now understood or since identified.

b. A comparison of PSI used for the previous PHA to current PSI identifies major or numerous modifications.

c. Numerous process related incidents have occurred in the process unit (this is an indication that the hazards of the process have not been sufficiently identified and mitigated or controlled).

d. Number of MOCs and/or significant changes have been implemented since previous PHA (numerous significant changes is an indication that the process has changed as a whole. Also, a combination of unrelated changes may have created new hazard scenarios).

e. Major process modifications, including process chemistry changes have been made.

f. Significant changes to the content of Operating Procedures have been made.

g. Significant changes to administrative or engineered safeguards have been

made.

C.2.4.2 If the answer is 'no' – there have not been significant process changes or numerous or major incidents since the last PHA – proceed to Step 5, Update and Revalidate the Existing PHA.

C.2.5 Step 5: Update and Revalidate the Existing PHA

C.2.5.1 The PHA Study Leader completes the pre-work necessary to confirm the following with the PHA Team:

- All Process Safety Information listed is current and up to date.
- All recommendations from closed MOCs are completed to resolution and the resolution is documented.
- All closed audit findings related to the process being evaluated are completed to resolution and the resolution is documented.
- All completed incidents including near misses have been investigated and recommendations have been completed to resolution and the resolution is documented.

C.2.5.2 The PHA Study Leader should visit the operating unit before the review to assess the scale of hazards and observe the operating standards and location in relation to other operating units and the surrounding environment.

C.2.5.3 The PHA Study Leader should revalidate the Conceptual PHA as the basis for assessing hazards related to changes since the last PHA.

C.2.5.4 The PHA Study Leader assembles a competent PHA Team, referencing the selected PHA methodology requirements in IVL EHS-403. The number of team members could be less than a "full" PHA would need, however they must have adequate expertise to review any changes since the previous PHA.

As a minimum, the team must include the PHA Study Leader, operator and process engineer. There must be at least one individual with experience and knowledge specific to the process being evaluated.

C.2.5.5 The PHA Team must modify the initial PHA to address changes that have been made to the process or gaps in the content of the original PHA. The team must determine if any changes made have introduced new hazards to the process. The team must consider, using an appropriate PHA methodology, the effect of any new hazards that have been introduced as a result of the change.

C.2.5.6 Review and, if required, update risk levels for previously identified scenarios based on more up-to-date incident history information, current safeguards, or remove them if process changes have eliminated the scenario.

C.2.5.7 Identify new scenarios that have resulted from process changes implemented during the last 5 years, or since the last PHA.

At this point, the purpose of the PHA Revalidation is to review the entire process area to identify concerns that could be missed by focusing on the detailed reviews that take place when dealing with specific changes addressed through the MOC process.

The PHA Study Leader must facilitate discussions regarding the process conditions that may give rise to the following risks:

- Fire.
- Explosion.
- Equipment damage

- (Exposure to) Hazardous Airborne Materials.
- (Exposure to) Hazardous Liquids and Solids.
- Material Spills.
- Inadvertent mixing hazards.
- Reactive hazards.
- (Exposure to) Mechanical or Electrical Energy.
- Abnormal operations' hazards
- Startup and shutdown hazards

C.2.5.8 The PHA Study Leader must facilitate a full evaluation of any new hazard scenarios applying the PHA methodology in use.

C.2.5.9 The PHA Study Leader must prepare a complete draft and final report of the study. The report must include a full compilation of reference PSI and recommendation action tracking summary.

C.2.6 Step 6: Perform a New PHA

C.2.6.1 The PHA Study Leader shall perform a complete new PHA in accordance with this standard. This process shall start with the performance of the Conceptual PHA (Hazard Study 1).