Preparing for a Successful HAZOP/LOPA (Making or Breaking Quality & Efficiency)

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Abstract

Although many factors can affect the quality and efficiency of a Hazard and Operability (HAZOP) Study or Layer of Protection Analysis (LOPA), one of the most important influences on the outcome is preparation. Contemporary HAZOP/LOPA guidebooks, such as the ones published by the Center for Chemical Process Safety (CCPS), have long dispelled the notion that a facilitator merely needs to show up and ask "blind" questions. Beyond facilitator preparation, given that each team and each evaluation is unique, thought must be given to ensuring that preparation is focused and tailored to the needs of the particular effort. Failure to properly prepare for the HAZOP/LOPA is one of the easiest ways to compromise results. The objective of this paper is to encapsulate experiences of the authors in facilitating HAZOP/LOPA over a wide-spectrum of industries, owner/operators, and facility-types, and provide the reader with some practical tips for transforming focused preparation activities into a successful HAZOP/LOPA outcome. Key paper topics include:

- Why quality and efficiency are both pivotal to a successful outcome
- Synchronization with organizational and regulatory objectives
- Guidance for ensuring process, operations, and the remainder of the core support team are properly prepared
- Advice for ensuring vendors are properly prepared
- Effective use of part-time "Subject Matter Experts"
- Making good use of a design review
- Master timeline in preparing for a successful HAZOP Study
- Pros and cons for pre-definition of causal events
- Nuisances of preparation for capital projects vs. operating facilities
- Differences in preparing for a new HAZOP/LOPA vs. a revalidation
- Ensuring the right tools are available

1. Focus on Objectives – Why is a Quality Process Hazard Analysis (PHA) Important

Most people attempt to avoid undesirable outcomes and organize their actions to minimize risk; however, very few apply a structured evaluation of potential undesired outcomes to avoid. Whereas this may be a personal decision for the individual, this is unacceptable for a complex process system, where the undesired events can have impacts well-beyond those directly involved. These events may be rare and involve a complex set of initiating events and failure of safety/mitigation systems; thus, it is necessary to perform thorough evaluations.

FIGURE 1.1 – Tragedies to Avoid

The December 2, 1984 Methyl Isocyanate (MIC) release from the Union Carbide Bhopal Facility is considered a pivotal event in catalyzing the application of Safety Management Systems (SMS) approaches to enhance process safety. The MIC release and the magnitude of the tragedy (3,928 fatalities and over 100,000 estimated permanent injuries) [1], drew the attention of industry, the public, and the regulatory community to the potential consequences associated with process safety events (Figure 1.1). Industry's response was swift and definitive. The American Institute of Chemical Engineers (AIChE) founded the Center for Chemical Process Safety (CCPS) in 1985, recognizing that the most effective mechanism for addressing process safety was not the application of additional prescriptive mechanisms, or by addressing any specific action, but by effecting changes in the way business is done (i.e., safety culture and management systems). CCPS Guidebooks are currently considered key references in conveying the technologies needed for process safety, and the very first guidebook ("Guidelines for Technical Management of Chemical Process Safety" [2]) published in 1987 was designed to address this pressing need.

A key part of managing process safety has always been the identification and understanding of potential hazards and their consequences. This need pushed practical techniques for hazard identification to the front lines in the effort to manage process safety (i.e., the Hazard and Operability (HAZOP) Study, developed in the decades prior to the Bhopal tragedy).

2. Brief History of Key PHA Techniques and Regulatory Requirements

Although there are quite a few tools in the PHA toolkit, the team-oriented, patterned-brainstorming sessions associated with HAZOP Studies [3] are generally considered the workhorse of the industry (Figure 2.1). Layer of Protection Analysis (LOPA) [4], frequently integral with the HAZOP Study, is a complimentary tool that is best patterned to integrate with the HAZOP Study. LOPA provides

additional insights, some of which can be directly used for identifying appropriate reliability targets for key safety features. Although HAZOP Studies have been a core part of an acceptable hazard evaluation process referenced in various industry guidelines [2,3], as well as regulatory requirements such as Process Safety Management (PSM)[5] and Risk Management Programs (RMP)[6] for onshore facilities in the United States, LOPA is a relatively new tool that simplifies Quantitative Risk Assessment (QRA) techniques to a manageable level to facilitate usage. LOPA applications are gradually becoming best practice for addressing higher consequence/risk events and are especially useful for an initial assessment of the reliability needed for key safety systems. As well as an industry accepted practice for important applications, for California Refineries, PSM [7] and the California Accidental Release Prevention (CalARP) Program [8] require the development of Safeguard Protection Analysis (SPA), with LOPA as an acceptable tool.

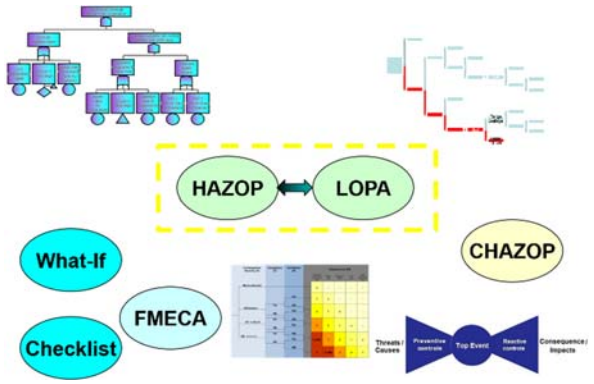

FIGURE 2.1 – HAZOP & LOPA are Core Elements of Hazard Evaluation

Although the core of the HAZOP approach hasn't changed, HAZOP and LOPA applications have been evolving to accommodate higher expectations of both regulators and industry practitioners with respect to quality and level-of-detail. HAZOP/LOPA must also address and integrate some of the evolving regulatory requirements, e.g., California's mandate for the application of SPA, Damage Mechanism Review (DMR), and Hierarchy of Hazard Control Analysis (HCA) to California Refineries.

To achieve this requires careful planning and preparation, but even before that, definition of clear objectives and defining the approach.

3. Defining Objectives and Approach

The core objectives of all hazard identification exercises (e.g., HAZOP/LOPA) are to uncover potential weaknesses/vulnerabilities in system design/operation that could result in an undesired outcome, e.g., injury, environmental impact, equipment damage, operational impact, or compromised company reputation. Additionally, the focus of the HAZOP/LOPA and the approach chosen can vary significantly for:

- Capital Projects (Early Stages)
- Capital Projects (Latter Stages)
- Operating Facility Initial HAZOP/LOPA
- Operating Facility HAZOP/LOPA Revalidation
- Addressing Specific Regulatory Requirements and Issues Associated with the Geographical Location

- Owner-Specific Priorities

When defining the objectives for all HAZOP/LOPA efforts, it is important to ensure that system boundaries are clearly defined. Table 3.1 outlines some general HAZOP/LOPA objectives.

TABLE 3.1
GENERAL HAZOP/LOPA OBJECTIVES

- **Identify causes that could lead to potential safety, environmental, or operability issues.**
- **Recommend changes, or further study, to overcome safety, environmental, or operability problems.**
- **Provide training to inexperienced personnel in the design intentions, expected operation, and potential hazards of the facility.**
- **Provide background and bases for the preparation of plant manuals and operating procedures, mechanical integrity programs, and understanding of facility hazards.**
- **Encapsulate background for recommended actions.**

3.1 Capital Project HAZOP/LOPA

Team dynamics and composition can be substantially different for capital projects compared to an operating process unit at a large industrial facility. [9,10] Capital projects typically:

- may have fundamental vulnerabilities or design options that HAZOP/LOPA can help resolve;
- involve large multi-disciplinary teams with numerous stakeholders who wish to participate in the HAZOP/LOPA – Preparation must accommodate a team that may be widely-separated geographically;
- have knowledge significantly compartmentalized, increasing the importance of the HAZOP/LOPA function to harmonize the design, while increasing the challenge;
- encounter financial pressures to accelerate project schedule;
- use package vendors to accelerate project schedule and compartmentalize design work;
- spread financial project risk over many companies; or
- have significant financial impacts associated with design mistakes that can result in re-work and start-up challenges.

Many large projects make increasing use of vendor packages to distribute costs and accelerate progress. This modularized approach can allow multiple elements of the project to proceed in parallel, theoretically streamlining completion and allowing the specialist companies to focus on their areas of expertise. It's important to note that this significantly increases the complexity of the project and increases the importance of planning and preparation for the HAZOP/LOPA. HAZOP/LOPA can be a crucial element for binding these activities and flushing out potential weaknesses in the design or its integration, and

TABLE 3.2
HAZOP/LOPA SUCCESS =
PLANNING & PREPARATION

- **Quality**
- **Team Utilization & Effectiveness**
- **Session Time**

previous papers have discussed the need for systematic application of HAZOP/LOPA during the design process.

In the early-stages of a capital project, the HAZOP/LOPA may focus on higher consequence scenarios to support decisions regarding fundamental design issues. Design details (e.g., instrumentation) are likely not readily available, but are generally not necessary to support these fundamental decisions or demonstrate a proof-of-concept for design acceptability. Significant value can be obtained from working out these issues early and ensuring that the various design participants are moving in the right direction. Starting the HAZOP/LOPA at these early stages, and later building on it, can support accelerated project progress. [9] In the latter-stages of a capital project, design details become readily available, and the focus of the HAZOP/LOPA shifts towards finalizing and vetting design details, design optimization, and neutralizing start-up challenges.

During capital project development, significant pressure is placed on the design team for maintaining project progress and doing things right the first time. Additionally, as the design progresses, changes to the design become more difficult and more expensive. Both of these challenges are typically best addressed by a phased approach to HAZOP/LOPA through the design process in an incremental fashion and with periodic sessions to keep pace with the design process. HAZOP/LOPA should synchronize with the availability of design information, and thus, the planning and preparation activities match the design details available, and objectives are adjusted to match the decision-making needs for that portion of the project. It should be noted that, properly structured, the HAZOP/LOPA can be readily updated as the design progresses.

FIGURE 3.1 – Use HAZOP/LOPA to Harmonize Subsystems

3.2 Operating Facility HAZOP/LOPA

Objectives for an Operating Facility HAZOP/LOPA are quite different. The key areas of focus are typically meeting regulatory requirements for the performance of HAZOP/LOPA and ensuring that company risk acceptance thresholds are maintained. There is no great impetus to optimize or simplify the design, as equipment has already been purchased and installed. It is important to treat continual improvement opportunities in a different manner than actions that may be necessary to meet regulatory requirements or the company's risk acceptance thresholds. Continual improvement opportunities include improvements suggested by the team for system configuration and/or operation, improvements to safety margins, and improved risk acceptance thresholds, even if current thresholds are already met.

Although this focus is somewhat simpler, there are other facets that may be required by regulation or company best practices that require additional planning/preparation for an Operating Facility HAZOP/LOPA, including the following.

- Simplification of high-maintenance-cost portions of the design
- Removal of dead-legs
- Incident Investigations
- Management of Change
- Facility Siting
- Damage Mechanism Review
- Safeguard Protection Analysis
- Hierarchy of Hazard Control Analysis
- External Events (e.g., seismic, storm loadings)

Operating Facility HAZOP/LOPA studies typically involve much smaller teams, with individuals typically having a wider-range of knowledge and experience of design and operation, greatly simplifying planning and preparation logistics. Various Subject Matter Experts, however, may be needed to support the above Operating Facility specific objective, along with the relevant documentation.

Defining the objectives for Operating Facility HAZOP/LOPA Revalidations may also involve addressing the perennial dilemma of deciding whether it is more fruitful to take a fresh look with the team or build on the results of the previous HAZOP/LOPA. A proper decision on objectives and approach is best made by accessing the previous HAZOP/LOPA and evaluating the following.

- Previous Technical Participants – If the previous team was highly capable and experienced, updating the previous effort may result in the best product, especially if the current team has limited experience.
- Previous Facilitator – Even with a good team, if the previous facilitator did not drive the team to excel, any use of the previous HAZOP/LOPA should be exercised with caution.
- Previous HAZOP/LOPA Documentation – Even if the team and facilitator were capable, if the document is sparse, its use has the potential for misleading the team into a false sense of comfort.

Researching these items and making good decisions regarding objective and approach in preparation for the HAZOP/LOPA Revalidation can have a huge impact on the quality of the results. To optimize the quality and validity of the revalidated HAZOP/LOPA, it is typical to build on the previous study and carefully drill down into the details. This also minimizes any potential liability associated with the Revalidation Team missing an important risk that may have been documented in the previous effort. If there were significant deficiencies in the facilitation or documentation quality of the previous study, recreating the study may still be beneficial. Proper and thorough documentation in a fresh study will lead to higher quality Revalidations in the future, as long as considerations made in the previous study are still addressed.

4. Planning Tips for the HAZOP/LOPA

A successful HAZOP/LOPA can be measured by its quality, completeness, and effectiveness, among other parameters. Planning and preparation are pivotal to a successful HAZOP/LOPA outcome. Planning activities such as ensuring the attendance of core personnel are essential and must be done well in-advance. The following paragraphs explain essential planning activities for a successful HAZOP/LOPA Session. Figure 4.1 presents a general timeline that is divided into two key types of activities, planning and other preparation activities. Planning and other preparation activities are also detailed in Sections 5 through 7 of this paper. It is important to note that planning may require significant lead time to establish the correct team and align schedules for a successful study, while other preparation tasks may be completed within a shorter timeframe before the session is scheduled to begin.

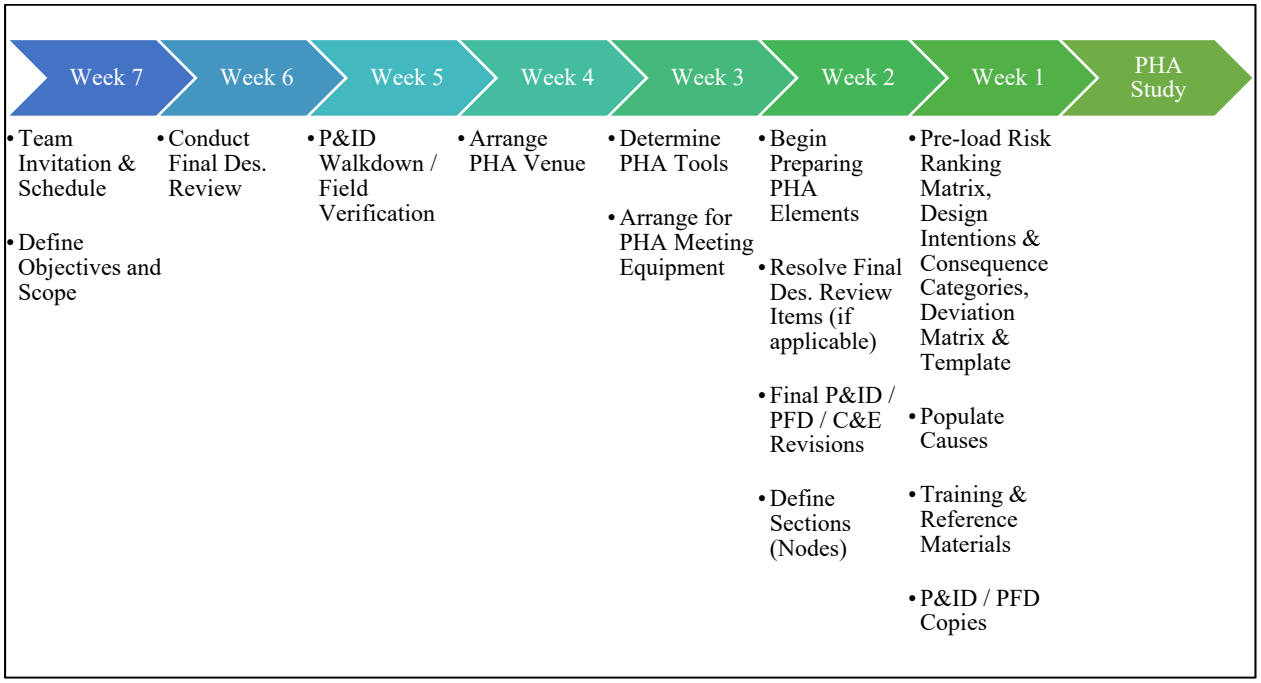

FIGURE 4.1 – Timeline for PHA Planning/Preparation

Whether for an Operating Facility or Capital Project, it is important to recognize that in addition to it being an independent safety evaluation, a HAZOP/LOPA is a technical problem-solving and decision-making exercise. As such, a critical element is the quality of the resources (i.e., design/safety information and personnel) available to the HAZOP/LOPA. Since unlimited attendance is not practical, it is important to understand the technical resources needed for technical problem-solving and decision-making. Table 4.1 below identifies the key disciplines useful for any HAZOP/LOPA Team.

The investment in resources aligned to a HAZOP/LOPA Team can be significant. Channeling these resources and energies can yield significant benefits, and rapid feedback can result in being able to utilize these insights much more quickly, either to progress a Capital Project or address potential risks associated with an Operating Facility. It is essential that the right people participate in the HAZOP/LOPA Study, and that they are motivated to objectively evaluate the design and to openly participate in technical problem-solving. Personnel involved must:

- be knowledgeable in the design of their portion of the system,
- be knowledgeable in the dynamics of system response, and
- have critically considered the response of their portion of the design to upset conditions.

Table 4.1
Key Disciplines Useful for a HAZOP/LOPA
(R = Required by PSM/RMP)

- Facilitation/Leadership (R)
- Team Scribe/Recorder
- Process/Project Engineering (R)
- Operations (R)
- Maintenance (R)
- Control/Protection Instrumentation Engineer
- HSE Engineering
- Rotating Equipment Specialists
- Specialists to Address Unique Requirements, e.g., DMR, SPA, HCA

Note that an optimal team size for an Operating Facility HAZOP/LOPA is 6-8 individuals.

4.1 HAZOP/LOPA Facilitator

Having a competent facilitator can make or break a HAZOP/LOPA study. Their main goal is to motivate the Team and ensure that they are being pushed enough to address all potential hazards. A facilitator should approach the study with a clear understanding of the process, and be prepared to ask the key questions that will inspire active discussion to ensure each scenario is being thoroughly considered. Additionally, it is the responsibility of the facilitator to keep the Team on track, and prevent them from wasting precious session time designing solutions to every scenario. This is a delicate balance between promoting creativity, and knowing when to re-focus the Team. An exceptional facilitator will likely have extensive industry experience and be able to work with a wide range of Team dynamics, and still be able to maintain control of the room.

4.2 Scribe Support

Scribing skills include typing, software usage, and computer interfaces with various types of equipment. The facilitator can be tasked with both facilitation and scribing duties depending on various parameters of the HAZOP/LOPA, such as system complexity and team composition. For a relatively small, manageable group, a facilitator might be able to also accommodate scribe duties. The pivotal decision-making parameter is whether the additional cost of a scribe outweighs the money saved by shortening the HAZOP/LOPA Sessions and the subsequent documentation time. Many professionals, especially in a large company, tend to underestimate the value of their time and that of their peers. The employee-time cost can be substantial and shortening the HAZOP/LOPA sessions could have a significant financial benefit for an individual facility. In

most cases, this financial threshold is reached once the team size (excluding facilitator and scribe) exceeds 3 to 4 individuals for local projects and possibly 4 to 5 individuals if travel costs for the facilitator and the lower-cost scribe are considered. As another benchmark, Reference 16 recommends to "use a dedicated Scribe, for meetings longer than 4-total hours" and "Use a well-trained scribe to take the documentation load off of the team. This rule can save 30-50% of meeting time and increases brainstorming (because the team is not daydreaming as they wait for Leader to complete the notes)." Along with tangible savings, the scribe can provide an improvement in the quality of the documentation, and the session itself, by allowing the facilitator to better focus on engineering issues and maintain an optimal pace of the HAZOP/LOPA.

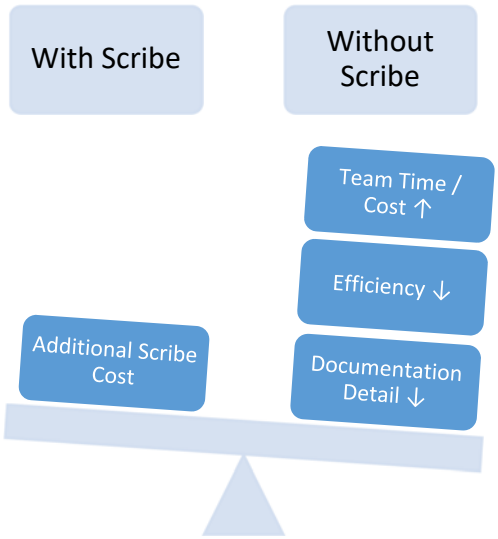

FIGURE 4.2 – Weighing Your Scribe Options

Of course, the decision to involve a scribe pivots on the scribe's capabilities. Some key characteristics to look for in a scribe include familiarity with HAZOP/LOPA techniques, reading engineering drawings, and the HAZOP/LOPA documentation software. For a HAZOP/LOPA, its advised that the facilitator avoid offers from the facility to provide a scribe. Unless properly trained and motivated, a poor scribe can compromise quality and team progress. Typically, a younger engineer that may be undergoing training to become a facilitator in the future is the ideal candidate.

4.3 Regulator

For some studies, it is appropriate to have the regulator's involvement in the HAZOP/LOPA study. This is particularly helpful in areas with more involved regulatory requirements, such as California. Including the regulator in the process will appease them knowing that you are taking regulatory requirements seriously and help develop a solid relationship between the facility and the regulators. Additionally, if the regulator chooses to participate, they can potentially instill some insight from their experiences attending a wide variety of HAZOP/LOPA studies, while also having the opportunity to express their concerns on design and operations at the facility.

5. Preparation Tips for the HAZOP/LOPA

5.1 Key Preparation Needs – Process Safety Information

Section 4 discusses many of the long-term planning requirements which pivot around personnel resources, which may need to be arranged months before the HAZOP/LOPA Sessions. The other

key part of a successful HAZOP/LOPA is the quality, completeness, accuracy, and availability of necessary Process Safety Information (PSI). The adage "garbage in, garbage out" applies to the PSI used for the HAZOP/LOPA. Not only can incomplete and inaccurate PSI result in erroneous HAZOP/LOPA conclusions, but the recovered time that would have been lost by the HAZOP/LOPA Team to resolve information discrepancies/inaccuracies or to re-work previously completed scenarios, as information materializes, can pay for accurate PSI. This is particularly important when considering accurate Piping and Instrumentation Diagrams (P&IDs). For operating facilities, it is helpful to have an operator do a walkdown of the system to document any mistakes in the drawings prior to the HAZOP Study.

Table 5.1 illustrates the general information requirements for the performance of a HAZOP/LOPA. HAZOP Studies have been in use since the 1970s, and there are many styles of application. Many Teams have not yet been exposed to a HAZOP/LOPA that thoroughly challenges key elements of the design, and that is imperative for achieving the desired level of safety and operability. Thus, providing clear expectations and helping the individuals responsible for preparing the PSI can be very helpful.

TABLE 5.1 – GENERAL INFORMATION REQUIREMENTS FOR A HAZOP/LOPA

- **Process Flow Diagrams**
- **Piping & Instrumentation Diagrams (with changes identifiable from any previous HAZOP Studies)**
- **Cause & Effect Diagrams**
- **Alarm & PSV Setpoints**
- **Site Layout / Platform Location Drawings**
- **Accident/Incident History & Reports**
- **Management of Change (MOC) & Pre-Startup Safety Review (PSSR) Documentation**
- **Previous HA/PHA Recommendation Status**
- Equipment Data Books
- Operating & Emergency Procedures
- Maintenance Records
- System Descriptions
- Previous HA/PHA Reports
- Toxic, Chemical, and Physical Properties
- Prevention Program Compliance Audits

Bold items in the list above are generally more important.

It is important to note that not all HAZOP/LOPA studies need to be treated with the same level of detail. Some systems that are lower risk, or are unregulated, can utilize less detailed PSI information and still address a majority of the significant hazards. For large Capital Projects, it is often helpful to take a phased approach to HAZOP/LOPA studies. As previously discussed in Section 3.0, incorporating HAZOP/LOPA studies earlier in the design process allows for the Team to correct potential design issues early on. The Team must be cognizant of the level of completeness and accuracy of the PSI information available and must ensure that the areas in the process with limited information is re-HAZOP'd at later phases of the design process, as additional design information becomes available. [9]

5.2 Preparation Timing to Support HAZOP/LOPA Objectives

Section 5.1 stressed the importance of PSI preparation before the HAZOP/LOPA. Especially in support of a capital project, if PSI is poor and/or the team is poorly prepared to support a

challenging HAZOP/LOPA, it can lead to an unfortunate waste of time and critical resources. This can result in a huge negative impact on a project. In addition to frequent and quality communications, a key part of a facilitator preparing their team includes verifying that their concept of accuracy, completeness, and detail is consistent with HAZOP/LOPA needs, confirming that the depth-of-challenge that the facilitator is planning for the HAZOP/LOPA is consistent with what they may have been exposed to previously, and emphasizing the need for pacing their preparation activities accordingly.

P&IDs should contain complete information and the key technical support members on the team should be prepped regarding the types of questions that materialize during the HAZOP/LOPA, otherwise the Team will struggle to identify and evaluate potential design/operations weaknesses, which may lead to more time and increased session costs associated with poorly focused resources.

TABLE 5.2
SCHEDULE FOR EFFECTIVE HAZOP/LOPA
DESIGN INFORMATION PREPARATION

- **3 Weeks Before HAZOP/LOPA Session (Facilitator Actions)**
  - Review complete Drawing Package (PFD, Material Balance, Process Description, P&ID, and Cause & Effect (C&E) Diagram) to ensure a clear understanding of the process.
  - Transmit to the Process Engineer any questions based on any perceived design information gaps (note that other background information may have been provided as part of the design package beyond the P&IDs).
  - Verify with the Control/Protection Systems Engineer that their design integrates with the rest of the plant and that common functions such as the Emergency Shutdown (ESD), Fire and Gas Detection System, and Power & Other Utilities have been addressed.

- **2 Weeks Before HAZOP Session (Facilitator Actions)**
  - Communicate with Process Engineer and Control/Protection Systems Engineer and ask a few questions to spot-check that they understood and are addressing any gaps.

- **1 Week Before HAZOP Session (Process Engineer Actions)**
  - Provide updated drawings and other design information, in a form suitable for reproduction.
  - Having the ultimate responsibility for the design, verify that gaps have been addressed and the drawings are complete and accurate. In general, Process Engineers are the only ones capable of taking on the role of ensuring that the design and control philosophy addresses the system functional requirements.

- **2 Days Before HAZOP Session (Process Engineer Actions)**
  - Ensure that copies of pertinent information are reproduced for the HAZOP Study Team Members.

Please note:
- If multiple design documents are provided (e.g., P&IDs, PFDs, C&Es), they should all be up-to-date, legible, and consistent.

5.3 Types of Information

Important general design information requirements were specified in Section 5.1. Any information provided should be in a form that is consistent with project specifications, up-to-date, legible, and consistent. Section 5.2 provides a schedule for working with the HAZOP/LOPA Team to ensure that key preparation activities are performed. Table 5.3 and Table 5.4 provide examples of common information gaps in design information, and key HAZOP/LOPA-related issues that the Team should be prepared to address. This is a critical part of preparation for a HAZOP Study.

TABLE 5.3 – COMMON DESIGN INFORMATION GAPS

General P&ID Information Content:

- Key Equipment Design Information Blocks (either top or bottom of P&ID) – Include at least design pressures (e.g., vessels, pumps, filters, strainers, and heat exchangers), design temperatures, material specifications.
- Equipment Tag Numbers
- Some Indication of Piping Specifications (e.g., size, material, design pressure)
- Piping specifications conform to facility standards

Control Valves:

- Valve Failure Positions (e.g., loss of air, loss of power, loss of hydraulic pressure, thermostatic control)
- Actuator Types
- Size
- Setpoints

Relief Valves:

- Setpoints
- Size/Sizing Basis

Pumps:

- Blocked-in Discharge Pressure
- If Stopped, is Flow Reversal possible?
- AutoStart Function - Flow/pressure/electrical fault? Setpoint?

Block Valves:

- "Normal" Position (unless clear from context)
- Hazardous Area Drawings, as required

TABLE 5.4 – ADDITIONAL QUESTIONS/INFORMATION DETAILS THAT THE TEAM SHOULD BE PREPARED TO ADDRESS

Heat Exchangers/Coolers:

- Impact of Loss of Heating/Cooling Medium Flow?
- Impact of Changes in Heating/Cooling Medium Temperature?
- Impact of Loss of Power (total or partial) to Cooler Fans?
- Impact of Fin-Fan Cooler Louver Malfunction Open/Closed (also, what is the "failure position")?

General Process Condition Changes:

- Consequences of loss of flow, excess flow?
- Consequences of temperature excursions high/low?
- Do these consequences violate a) safety limits resulting in near-term damage, b) safety limits resulting in long-term damage or equipment degradation, or c) compromising warrantee or stable operation?

Instrumentation:

- Protection System Setpoints?
- Protection System Actions? If complex, a C&E may be necessary.
- Alarm Setpoints?
- Alarm Annunciation Locations (i.e., local, DCS, remote center)?
- Alarm Effect (i.e., panel indicator, audible alarm, flashing lights)?
- Communication with the DCS and partitioning of instrumentation and control between the local panel and from the DCS?

Electric Immersion Heaters:

- Damaged if Uncovered (without activation of protection features)?
- Will Control/Protection Temperature Transmitters function as-intended, if uncovered?

Other (primarily applicable for lube oil systems):

- For three-way valves, is total isolation possible? Can flow go down both paths if the valve is mispositioned?
- Sensitivity to lube oil composition?

Tanks:

- Vent locations and potential hazards?
- Provisions for tank maintenance, e.g., draining?
- Accessibility / procedures for filling?
- Materials of construction?
- Secondary containment and draining requirements?

6. Venue Tips for the HAZOP/LOPA

There are many factors to consider when deciding on the most efficient venue to perform a HAZOP/LOPA study. It is vital to select an appropriate location, especially because more complex HAZOP/LOPA studies can last several weeks at a time. Additionally, while having shorter session times is desirable because it can result in more active Team participation and focus, this is often not very feasible because of project time constraints and team availability. Thus, session times can often drag out longer than preferable, resulting in long hours. Selecting a venue that is comfortable, convenient, and flexible can optimize the Team's morale and even streamline the study with the appropriate preparation.

6.1 Location

Choosing the right room for the HAZOP/LOPA sessions can help contribute to the success of study. The room should be large enough for all Team members to have plenty of space. Ideally, everyone will have their own set of P&IDs that they will want to spread out and review, so larger tables are preferable. The room should also have plenty of wall space to hang up large drawings as needed, and to project the session notes and electronic versions of the P&IDs to allow the Team to easily follow along. Ensure that the room selected also has extra chairs and table space to accommodate the part-time participants who may need to join the session to offer their expertise periodically.

The actual venue location should also be thoughtfully considered. While it is convenient to select a room that is right near the regular workplace for the majority of the team, this has several potential downsides, as the close proximity to normal work-place areas can lead to major distractions. This includes the potential for Team members' getting preoccupied with day-to-day matters, wandering off during breaks, or session time getting interrupted by coworkers asking for support from Team members for unrelated tasks. Selecting a room location that is slightly removed from the centrally located and highly trafficked areas can mitigate these distractions and will allow the Team to remain focused on the task at hand.

The room selected for the study should also consider proximity to the actual site. Often times, performing a walkdown of the system being assessed helps the Team get a better idea of potential hazards. For currently developed facilities, the Team should assess the need for a walkdown and select a venue accordingly. During design HAZOPs, the focus should be on locations that will maximize Team comfort and engagement. Make arrangements for site access and reserve meeting locations (e.g., conference rooms) well in-advance.

6.2 Team Member Distribution

Some strategy can be put into arranging the Team members to optimize participation. Try to evenly disperse individuals around the table so it is easy for every team member to speak and be heard. the best spot for the facilitator and scribe is at the front of the room next to the displays/screens. This is so that the facilitator can easily guide the scribe, get up to captivate people's attention, or point out important items in the session worksheets or drawings being projected onto the screens.

For more outgoing or key members of the HAZOP/LOPA Team that are bound to talk frequently, it is sometimes helpful to place them on the other side of the room to help draw the rest of the Team members into the discussion. For quieter individuals, do not allow them to sit in the corner answering emails on their phone. Ideally, move them to a more central location, possibly near the facilitator, to force them to engage with the rest of the Team. No one on the HAZOP Team should be there to just to observe. Everyone should have some input, share their insights and expertise, and be encouraged to contribute their viewpoints for each scenario. [11]

6.3 Venue Amenities

The Venue selected should be equipped with several helpful items that the Team may require. This includes large displays with so that the scribe can project the worksheets and relevant P&IDs. White boards should also be available so that individuals can quickly throw together rough drawings, calculations, diagrams, or quick summarizations of main points. Numerous highlighters of varying colors should also be available on the conference table, should the Team need to change up the nodes used for the study.

While it is easy to get caught up in the technicalities of HAZOP/LOPA studies, some consideration should also be put into the more basic preparations for a HAZOP/LOPA. Ensuring that snacks, coffee, and refreshments are available throughout the study will help HAZOP/LOPA Team members maintain focus and keep up Team morale. Additionally, simple arrangements such as ordering lunch to be delivered ahead of time can save the HAZOP/LOPA Team lots of precious study time spent digressing from relevant conversations to discussions about where to eat and when. The duration of lunch breaks can also be minimized by planning ahead. Table 6.1 the Venue Selection Tips to keep in mind.

TABLE 6.1
VENUE SELECTION TIPS

PHYSICAL ACCESS
- **Physical Site Access**
- **Conference Room Availability**
- **Location Removed from Daily Workplace Areas**

ROOM CONFIGURATION / RESOURCES
- **Adequate Table Space**
- **Strategically Distributed Team Members**
- **Sufficient Resources (e.g. computer displays, wall space, white boards, etc.)**

6.4 Including Remote HAZOP/LOPA Team Members

Although it would be ideal to schedule a perfect HAZOP where all key members can be physically present, this is highly unlikely to occur. It is smart to prepare for the inevitable scenario where at least a few individuals will have to attend the sessions remotely. Performing a HAZOP/LOPA remotely is not the right answer for many applications, but for some, it can be a very effective solution that can engage resources (e.g., Vendors or Subject Matter Experts) that wouldn't be available otherwise. All of this can accelerate the progress of efforts such as capital projects, aid in project control, enhance teamwork, and result in tangible savings to the Owner/Operator. [12]

To prepare for including remote Team members, the Venue selected should have internet access and the scribe should anticipate that they will need to share their screen so that the remote Team members can also follow along. This can easily be accomplished if the HAZOP Team shares relevant contact information in advance, and the Team utilizes remote meeting programs to connect with new members quickly. The conference room selected should also have a local phone accessible to contact remote Team members and not worry about spotty service concerns affiliated with cellphones.

Certain preparation efforts are more important for a successfully including remote HAZOP/LOPA Team members due to the potential technical problems associated with additional equipment. The following paragraphs explain essential preparation activities for a successful remote HAZOP/LOPA Session, and for convenience, these are summarized in the form of a checklist in Table 6.2.

Adequate Computers/Displays

To help ensure that remote team members are properly engaged, the scribe should ensure that they have both the HAZOP/LOPA notes and the P&IDs readily accessible on the screen they are sharing. The scribe should switch over to the P&IDs during more complex team discussions to ensure that the remote Team members follow along and can contribute effectively. Alternatively, it is often helpful for a process engineering representative or the "owner" of the P&IDs to also share their screen with remote member and "drive" the display to focus the Team's attention on the portions being evaluated. This additional communication link can also be used to share other information pertinent to the HAZOP/LOPA, e.g., photographs, other engineering information, etc.

TABLE 6.2
REMOTE HAZOP/LOPA PREPARATION CHECKLIST

EQUIPMENT
- **Adequate Computers/Displays**
- **Cameras**
- **Arrange Communications Access and IT Support**
- **Testing**

RESOURCES AND ACCESS
- **Check Power and Communications Connections for All Computer Equipment**
- **Ensure all rooms have adequate internet access, and phone service or landline phone access.**

TECHNICAL PREPARATION
- **Send all necessary documentation to remote Team members ahead of time (e.g., highlighted P&IDs, risk ranking matrix, relevant PSI, etc.)**

Cameras

Some companies have interactive video conferencing between their sites. This can help the Facilitator verify that the remote Team members are present and engaged. Even if a dedicated video system is not available, screens with a video feed of team members can be setup if the Team feels it is necessary.

Pre-Arrange Communications Access and IT Support

If bringing computers with specialized software, make arrangements for any necessary login or network permissions, plan on setting up early, and make arrangements for contingency IT support ahead of time. Also, verify that power connections are sufficient and accessible for all equipment, and if wireless Internet access is insufficient, ensure data communications cables can reach.

7. Final Readiness Tips

When it comes to a successful HAZOP/LOPA, there are few activities more important than planning and preparation. Just as the HAZOP/LOPA is used to identify what can go wrong with the chemical process being evaluated, teams should postulate potential problems that can arise with the HAZOP/LOPA Sessions and how the problems might be addressed. An essential way to mitigate the problems addressed is by sufficiently reviewing the process being studied and formulating a framework for the anticipated study. The following paragraphs explain essential preparation activities for a successful HAZOP/LOPA Session.

7.1 Pre-Define Causes

Pre-defining causes by the facilitator is a contentious issue for some professionals. Although some individuals express concerns of putting boundaries on the team's imagination, for an in-person HAZOP/LOPA there can be a number of benefits that include the following.

- **Completeness** – For a cause-by-cause HAZOP Study, pre-defining causes can help avoid missing an important initiating event. By the facilitator defining the prominant causal events up-front, it frees the team to brainstorm the less-obvious causes and subtle process issues.
- **Future Use** – Rather than random brainstorming, careful patterning of causal events before the interactive chaos of a HAZOP Study can facilitate future use.
- **Quickly Locating Equipment During the Session** – Careful patterning up-front, and including tag numbers and P&ID references, streamlines locating the equipment during the HAZOP/LOPA Session.
- **Grouping Causes** – If carefully patterned, a natural grouping of the initiating events can minimize multiple detailed discussions of the consequences, adding clarity, consistency, and accuracy to the HAZOP/LOPA.

The team can be tasked with reviewing the causes and being prepared to explain the associated process dynamics and credible ultimate consequences. From experience, defining the process dynamics and associated ultimate consequences can represent the single largest segment of session time, so if the team can be aided in converging on these issues team focus is improved and the overall HAZOP/LOPA effort streamlined.

7.2 Pre-Define Questions

In the same way that pre-defining causes can focus the team's efforts, for many industries and for many countries, the patterned-brainstorming approach to HAZOP/LOPA is unfamiliar and not consistent with typical business approaches. Providing examples of HAZOP/LOPA scenario development and creating a list of specific questions (typically regarding the basis-of-design for the equipment that they are responsible for) can be very helpful, especially for members of the team that are inexperienced in HAZOP/LOPA best practices. Pre-defining causes and questions can be beneficial for all HAZOP/LOPA efforts and even more beneficial when involving remote HAZOP/LOPA Team members.

7.3 P&ID Grid Format

During any HAZOP/LOPA, the Facilitator will likely need help in focusing the team's attention to a specific location on the P&ID. If possible, margin grids should be included on all engineering drawings to be used for the Study.

8. Summary

Taking the appropriate steps to be sufficiently prepared for a HAZOP/LOPA can help improve the quality and efficiency of the HAZOP/LOPA study, and put a successful framework in place. This can be accomplished by first acknowledging the most important objectives for the particular project. For Capital Projects, this includes focusing on optimizing the process design and minimizing costs. Operating facilities should focus more on mitigating current risks and vulnerabilities in the process, and adhering to regulatory requirements.

Regardless of the focus, all HAZOP/LOPA studies require basic planning to be successful. This includes scheduling all key members as soon as possible to ensure their attendance. Additionally, the Team needs to obtain and update all necessary PSI, prepare the appropriate technical questions that need to be asked during the study, and secure a venue that will optimize productivity. Overall, properly preparing for a HAZOP/LOPA study can significantly decrease the amount of time and money invested into a project, and improve the quality of the design, while also accomplishing the main objective of mitigating risks in the hazardous process.

9. References

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