

## Management of HAZOP Recommendation Resolution Activities

**The success of a HAZOP meeting doesn't depend entirely on the quality of the HAZOP meeting itself; pre- and post-HAZOP activities also play a big role.**

The author has been faced with quite a few plant designs where some important safety measures were missed, even after HAZOP activities were finished. It is generally said that the quality of HAZOP results are as good as the quality of the participants. However, a missed safety measure from a HAZOP activity doesn't necessarily mean that the HAZOP participants were unqualified; at the least, it can be assumed that the HAZOP stakeholders didn't actively participate in HAZOP activities before, during and after the HAZOP meeting.

The knowledge level and soft skills of a process engineer may affect the results of a HAZOP study. A good process design engineer is not necessarily a good Process representative in HAZOP meetings. It is a good idea to bring an external consultant to the HAZOP meeting if it is believed that the process design engineer is lacking enough practical and in-depth knowledge of the system, or the required soft skills (for example, being outspoken).

There are plenty of articles on HAZOP meetings, both on their structure and on the measures of their success. However, there has been less focus on the activities before and after HAZOP meetings; these activities play as much of a role in the success of the HAZOP activity as the HAZOP meeting itself does.

Therefore, the focus of this article is on the activities that need to be done before and after HAZOP meetings.

## Best Timing for a HAZOP

First of all, the best time for a HAZOP evaluation/meeting relative to P&ID milestones should be considered. Although a HAZOP can be done any time during the design phase of a plant, from an economical viewpoint, since the HAZOP and the HAZOP resolutions may create big changes in the design, it is better to hold the HAZOP before the non-process disciplines start getting into the detailed portion of their work, or, in other words, before the P&IDs are issued as IFD (issued for design). However, the flaw in this logic is that generally there is no detailed information available for vendor-supplied packages before the IFD version of the P&IDs. Therefore, a complete HAZOP cannot be done at this time. This sometimes makes it inevitable to have another HAZOP after the IFD and before the IFC version of the P&IDs.

Performing a HAZOP too long before the IFD issue of the P&IDs makes it a low-quality HAZOP from a technical perspective; performing it too long after IFD makes it economically questionable.

Performing a HAZOP in the earlier stages of design (i.e. long before IFD) may be required in some cases; however, since the design is not yet firm enough, a “milder” version of a hazard assessment (such as a “what-if”) may be more logical.

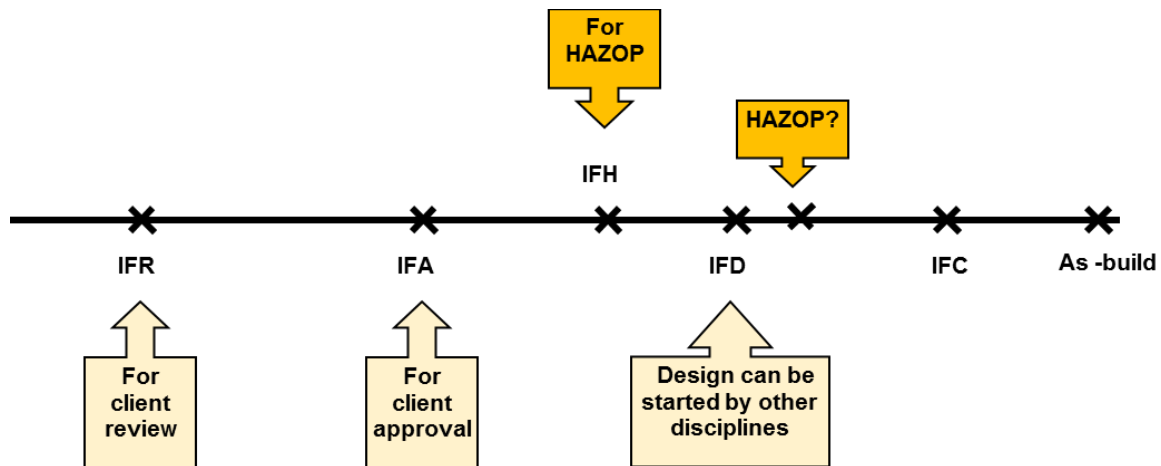


Figure 1: Timing of a HAZOP

A HAZOP may be needed not only during a design project, but also for an existing plant. The need for a HAZOP could be triggered whenever a risk(s) is recognized. In some plants, a HAZOP (or re-HAZOP) is triggered because of an accident in a similar plant or with similar equipment.

### **Pre-HAZOP Activities**

Different documents are required to perform a quality HAZOP, but the P&ID is possibly the most important document.

Before starting a HAZOP, a set of “clean” P&IDs needs to be provided to the HAZOP facilitator. The definition of “clean” is different from company to company. A strict approach would interpret “clean” as a new version of the P&IDs, specifically issued for the purposes of the HAZOP, or “issued for HAZOP” (IFH). Some other companies accept the use of CADDed copies of the P&IDs with no mark-ups as the clean copy.

Using a set of P&ID sheets with many clouds, representing hold items, and/or several mark-ups, is not a very good idea and may lead to confusion during the HAZOP.

The HAZOP facilitator identifies the “nodes” on the P&ID for discussion in the HAZOP meeting. He/she also estimates the number of days required to finish the HAZOP meetings, which may be one to two P&ID sheets per each day of HAZOP meeting, or 2-4 hours per each node.

One problem that is often raised is the lack of access to the master P&IDs during the HAZOP meeting. During the HAZOP meetings, the latest and greatest P&ID set (master copies) is in the HAZOP meeting, so the rest of the design engineers (who are not attending the HAZOP meeting) don't have access to them. On one hand, the HAZOP should be done on a “frozen” set of P&IDs. On the other, P&ID development cannot be stopped because of the HAZOP meeting. Management needs to decide how to collect the mark-ups that are generated during the time that the “master P&IDs” are in the HAZOP meeting.

Although there are representatives from different disciplines in a HAZOP meeting and each of them needs to prepare themselves to do a quality HAZOP, the subject of this article focuses only on the process engineer's duty in terms of preparation. A well-prepared process engineer needs more information than what is seen on the P&IDs during a HAZOP meeting. A process design engineer attending a HAZOP meeting should be equipped with the following design information and/or documents:

- Container dimensions: residence time and time between each level in the container (for example, the time elapsed between normal liquid level and low liquid level)
  
- Pumps and compressors: flow and head are the most important specifications, plus pump power (some operators and managers visualize the magnitude of fluid movers mainly based on their horsepower), pump/compressor curve features, or at least the shut-off pressure (for centrifugal types)
  
- Heat exchanger: type, inlet/outlet temperature and heat duty (this may be more important than the heat transfer area)
  
- Piping: pressure rating, approximate length, whether it is insulated or not, whether it is in continuous or intermittent use
  
- Process fluid temperatures & pressures at different points, along with their boiling temperatures
  
- Rough cost of chemicals and selling price of products
  
- Approximate maintenance frequency and repair time of different pieces of equipment

Some process design engineers decide to give a short presentation at the beginning of a HAZOP meeting and provide all of the above information, rather than providing it piece by piece during the HAZOP meeting. In such cases, they may choose to use the PFDs (process flow diagrams) for this purpose.

### **During the HAZOP Activity**

A HAZOP is a structured method to identify operability and safety issues in a proposed design or an existing design (in the case of an existing plant). However, since it is not a purely quantitative method, some human factors may also impact the result of a HAZOP evaluation. HAZOP facilitators are trained to minimize these human factors. However, participants can make the facilitator's job easier and make the HAZOP more efficient by following HAZOP etiquette. A few important rules of etiquette points for HAZOP meetings are listed in Table 1.

*Table 1: HAZOP Meeting Etiquette*

- \* Be punctual, even if you are not part of the core team.
- \* Be prepared and bring all the required documents.
- \* Identify a stand-by person if necessary.
- \* Don't initiate "side discussions" during the meeting.
- \* Don't talk if the point has already been made.
- \* Speak out if you believe something has been missed.
- \* Don't be shy to ask for something to be repeated if the team went fast and missed something.

- \* Don't try to "design" in the meeting. The meeting only "identify" the concerns.
- \* Don't be shy about offering your ideas, even if they are not in line with those of others. The HAZOP facilitators generally record the results based on consensus.

### **Post-HAZOP Activities**

The result of the HAZOP study is the "HAZOP study report", which generally consists of the following sections:

- Basic assumptions for the study and risk matrix
- Node list
- Node discussion based on guide words
- HAZOP recommendations (or HAZOP items)
- “Non-safety-related” HAZOP recommendations (may be listed as parking lot items)

The “Basic Assumptions” for a HAZOP study is a set of rules that work as underlying assumptions for all of the discussion during the HAZOP.

Generally, these assumptions are read out by the facilitator at the beginning of a chain of HAZOP meetings, and whenever a new member joins the HAZOP team.

Some people may be tempted to take this part lightly and not listen carefully, since “they are just general things”. But this is not true, and these assumptions are not the same for all projects!

For example, in the “basic assumptions” of the study, it may be mentioned that one assumption is that the operators are skillful and will definitely follow operational procedures, or that the operators are semi-skilled and may miss some procedures. Or, it may be stated that inadvertent interference (but not sabotage) in the process may be done by operators.

The basic assumptions of a HAZOP study have a very important role. If this part of a HAZOP study is listened to carefully and followed, a lot of time is saved because of less repetition of questions and answers during the meeting.

A “HAZOP risk matrix” is the same as the “basic assumptions of a HAZOP study”, in that it is not general either.

### **HAZOP Meeting Deliverables**

A HAZOP report has two main sections: 1. A brief HAZOP discussion for each node, and 2. HAZOP recommendations.

The “Brief HAZOP Discussion”, or the “HAZOP Worksheets”, are the tabulated discussion of each node.

“HAZOP Recommendations” is a list of all recommendations made by the HAZOP team to address their concerns. This is the primary document used to adjust the current design by the responsible engineers. Because of this, some people call it the “HAZOP Action Item List”.

If the wording in the HAZOP recommendation list is not clear, the responsible engineers can refer to the “HAZOP Worksheets” to see what the discussion was that led to the recommendation.

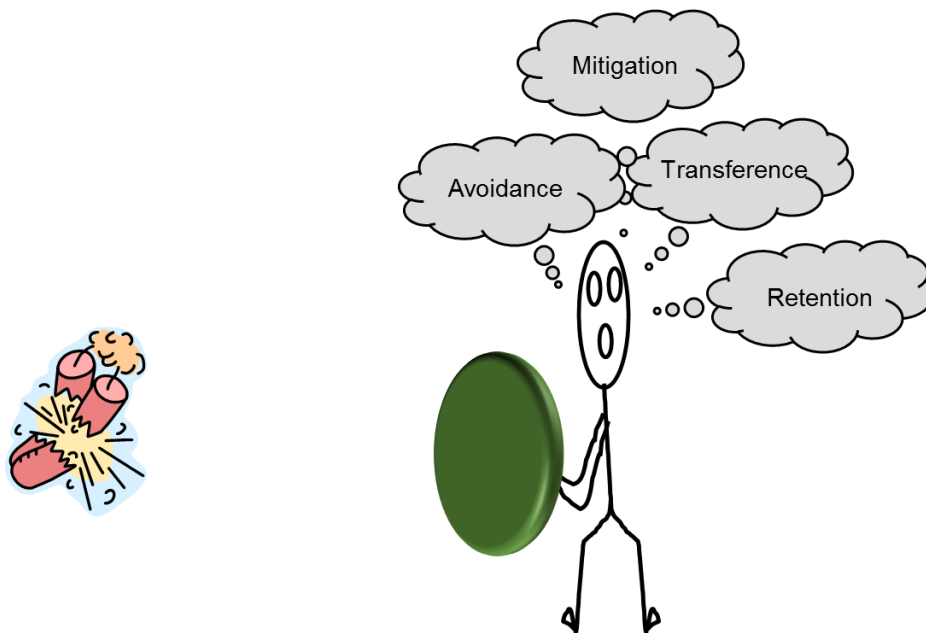
The “HAZOP Recommendations” document could be short or long, depending on the number of HAZOP days and the skill levels of the

designers. It may range from 10 to 50 items per day of HAZOP meeting, per author's experience.

### HAZOP Item Close-Out

Basically, a HAZOP action item is generated because of a lack of enough protective layers to guard against the risk of a specific hazardous event.

There are four main types of risk treatment: Avoidance, Transference, Mitigation and Retention.



*Figure 2: Risk Treatment Methods*

Among the four risk treatment methods, avoidance and mitigation are the most commonly used methods in resolving HAZOP items.

Transfer of risk to a third party is beyond the expectations of the HAZOP team members. This would be handled by a team of technical and financial professionals together with insurance company's representatives.



Retention is not a solution either, as it has already been identified that the risk is higher than the tolerable level.

By this definition, closing out or resolving a HAZOP item means providing additional independent protective layer(s).

Resolution of each HAZOP item can be formalized through a “HAZOP action sheet”. A blank sample of such a sheet is shown in Figure 219.

ABC Client

"Brown Field" Project

Issued (M/D/Y): 01/01/15

**HAZOP Action Sheet**

<b>Area:</b> 200- Water treatment		P&ID: 200-PID-301 Rev H
<b>HAZOP Report Reference (Node-Parameter-deviation-Item):</b> 7-Pressure- More-4		
<b>Recommendation:</b> 1. Consider adding a check valve on the outlet of the vessel		
<b>Responsibility:</b> John Doe – Process Group- EPC company		
<b>Delegated to:</b> Jane Doe – Process Group- EPC company		
<b>Resolution:</b>		
<b>Attachment(s):</b>		
<input type="checkbox"/> <b>Resolved (as proposed or not?):</b> <input type="checkbox"/> <b>Deferred to:</b> e.g. detail engineering stage <input type="checkbox"/> <b>Proposed to be discredited</b> (Needs Re-HAZOP)		
<b>Resolved By:</b> Jane Doe	Signature:	Date:
<b>Reviewed By:</b>	Signature:	Date:
<b>Approved By:</b>	Signature:	Date:
<b>Rejected By:</b>	Reason:	

*Figure 3: Typical HAZOP Action Sheet*

A person in charge of resolving a HAZOP item needs to have high-level critical thinking skills.

HAZOP resolution, as a problem solving process, has four steps:

1. Problem identification by studying the recorded discussion during the HAZOP, in the main “HAZOP report”
2. Alternatives generation through creative thinking and/or brainstorming
3. Evaluation of each alternative based on different criteria, including technical and economical
4. Selection of the best alternative, which has the minimum impact on the project, while providing an independent layer of protection

In the end, detailed documentation must be provided for the selected solution.

Following are more details for each step.

### 1. Issue identification

To be able to understand the issue, studying the brief issue presented in the “HAZOP item list” is not always enough. Sometimes, due to time constraints, the explanation is so abridged that the concepts are not conveyed correctly.

It is a good idea to study the node discussion & guide word discussion too, to grasp the issue accurately and completely.

During this step, the different HAZOP items may be classified into the following groups:

- a) Presently closeable items (hopefully the majority)

- b) Deferred HAZOP items
- c) Delegated HAZOP items
- d) Discredited HAZOP items
- e) Raising a HAZOP item as a “general” issue
- f) Conflicting HAZOP items

When the list of closeable HAZOP item is generated, the closeout process needs to be started.

However, sometimes it is inevitable to defer a HAZOP to another phase of the project (for example, to the “detailed engineering” stage).

If the decision for a given HAZOP item is to defer it, it is a good idea to briefly explain why it is being deferred and which piece of information is needed to close out the item. This action is important as it is not always the same group or company that will be involved in the next step of the project. For example, if some items are deferred to the detailed engineering stage and the detailed engineering tasks end up being awarded to a company other than the company that was awarded the FEED (Front End Engineering & Design) stage, the process engineers in the detailed engineering stage may need this information to be able to close out the item accurately since they didn't attend the HAZOP meetings.

If resolving a HAZOP item needs a piece of information that will be available later, the HAZOP can be deferred to a later date.

#### - Delegating a HAZOP item

Sometimes a HAZOP item needs to be delegated to a more qualified party. This delegation could be to another person within the process discipline, to someone in another discipline, to another person who attended the HAZOP meeting, or someone else.

“Delegation” could be performed by asking someone to perform the closing out a HAZOP item AND asking him to submit the resolution as the

responsible party, or just by asking the other party to perform the closing out but retaining the responsibility of submitting still with the original party.

The best person to resolve a HAZOP item is a person who attended the HAZOP meeting. However, this is not always doable from a practical standpoint. If this is not doable, it is a good idea to at least keep the responsibility of the HAZOP item closeout on the shoulders of a HAZOP attendant.

Some engineering companies have strict rules against delegating HAZOP items “AND” the responsibility to other persons, especially if the other person is not very familiar with HAZOP practices. Sometimes a HAZOP item that needs to be closed out via a “procedural solution” can be delegated to the client, if they are the ones who are responsible for developing the procedures.

#### - Discrediting a HAZOP item

It is not good practice to drop a HAZOP item that was generated based on the discussion of a group of qualified people, based solely on the criteria of a process engineer. Some companies have strict instructions around discrediting a HAZOP item and don't allow a HAZOP item to be discredited, and only allow for the issue to be re-HAZOPed instead.

#### - Raising a HAZOP item as a “general” issue

Each of the above doable, or potentially doable, HAZOP items can be tagged as a “general HAZOP item” if the cases and/or their resolution impact the system outside of the HAZOPed area. These are cases where the responsible process engineer feels that the case is general to all areas and is applicable to some other part of the plant, whose representatives were not in the HAZOP meeting and may not have received similar HAZOP items in their own HAZOP meetings. Raising such items has the benefit of

warning others about a general concern (if it was missed in their HAZOP meeting) and also to close it out with a common solution (if possible), to minimize cost and achieve consistency.

#### -Conflicting HAZOP items

Sometimes during the process of HAZOP resolution, it is discovered that some HAZOP items conflict with each other. While this is not a good sign, it can happen for different reasons including the handling of a HAZOP meeting by different groups of people. These HAZOP items should be carefully examined and removed from the list of HAZOP items.

## 2. Alternative resolution development

Proposing a solution for a HAZOP item is not always easy. If we are lucky, it may only require a small design change; on the other hand, it could also end up requiring a complicated design change, necessitating multiple calculations, or even a detailed study. In some cases, the lead may decide to involve a consultant for specific cases such as safety valve sizing, safety management, or electrical hazardous area classification.

It should be noted that sometimes solutions are proposed during the HAZOP meeting, but the responsible person doesn't need to stick to that. A HAZOP meeting is not a design meeting; it is only for the purpose of raising red flags for safety issues. Any solutions that are proposed in the HAZOP meeting and recorded in HAZOP documents are non-obligatory, but can be used as guidelines. The responsible person should avoid falling into the trap of selecting a very costly proposed solution when a better solution is available.

The other point to check is to make sure the proposed solution provides an "additional, independent" protective layer while not removing the current protective layers (the ones that were already existing during the HAZOP),

and not inter-relating the solution with the existing protective layer in a way that would disqualify them as “independent” protective layers.

To resolve a HAZOP item, a solution can be selected from the following list:

- i. Converting the system into an inherently safe system
- ii. Implementing a passive solution
- iii. Implementing an active solution
- iv. Mitigating the safety risk by implementing a specific procedure

The above list is in preferred order, meaning that solution (i) is the best and provides the most positive solution against the safety risk, and solution (iv) is the worst. For cases where the risk is high, solution (iv) is not acceptable.

Converting a system into an inherently safe system is basically resolving the risk by avoidance. To resolve a HAZOP item through avoidance, a responsible engineer should focus on the node and the guide words rather than consequences. He may ask: “if the risk here is created because the control valve is fail open, can I change it to fail close?” However, the system must be checked carefully to make sure that by changing the fail position of the valve from fail open to fail close we don’t eliminate an existing protective layer which is used in other nodes. Resolving a HAZOP item through avoidance (converting a system into an inherently safe system) is not easy, if not impossible. The middle of the project is generally too late to be able to avoid a risk completely. Avoidance may be an effective strategy during the FEED or pre-FEED stages of a project.

To illustrate the different solutions discussed above, an example of a HAZOP item is considered here. For example, a HAZOP item raises the issue of cross-contamination for a system with multiple chemical tote tanks

and the chance of mismatching the chemicals during replacement of the empty tote tanks with full ones.

(i) Inherent safe solution:

The way the case can be solved through inherent safe design is by asking the question: “Can we have only one chemical with the collective properties of multiple chemicals?” Having one chemical inherently removes the chance of mismatching tote tanks.

If there is no such solution, we move on to the next solution.

(ii) Passive solution: This solution calls for a system that passively prevents the operator from mismatching the chemical tote tanks.

For example, if there are three chemicals, can we use three different and unique connections for each chemical system to its tote tank? This solution basically uses “fool-proof” connections for each chemical.

(iii) Active solution: can a specific alarm system be implemented to warn the operator in case of mismatching?

(iv) Procedural solution

Color-coding the matching connections (tote tank side and chemical injection side) and writing up an “operational procedure” to be followed by the operator.



It is clear that the best solution is the first one. Generally speaking, the procedural solution is not acceptable for resolving a HAZOP item.

The last solution, procedural, could be acceptable if the result of cross-contamination of the chemicals is only a slight drop in the quality of product, but it is not acceptable if the result of mismatching is an explosion.

### 3. Selecting the best alternative

The best solution for a HAZOP item is obviously the solution with the minimum cost and schedule impact on the project.

Sometimes there are HAZOP items that need to be closed out late in the project, because of a late HAZOP meeting or a missed item. In such cases, the cost of the solution may be less important than the impact on the schedule. We may accept to pay more by making sure there is less impact on the project schedule towards the end.

Before selecting the best solution, we need to ensure that all solutions are valid solutions. The following list gives some rules to check the validity of solutions:

- A HAZOP resolution cannot be just an “idea”; it must be a real design.
- A HAZOP resolution cannot invalidate an existing protective layer (this can be checked by a person who has a big picture view)
- A HAZOP resolution cannot be based on a general statement made by someone. Everything must be documented.
- A HAZOP resolution must be based on current technology, not future technologies.
- If a vendor-supplied item needs to be used, it must be checked with the client to make sure the vendor and the product are acceptable to them.

- Every statement in a HAZOP resolution form needs to be backed up by an excerpt from a code or standard, or generally accepted facts in the industry.

### **HAZOP resolution documentation**

At the end of the HAZOP resolution phase, four different lists/documents are generated:

1. Resolved items: Each HAZOP resolution “package” may include:

- HAZOP resolution form & sign-off sheet, plus back-up documents including:
  - Unofficial marked-up P&ID(s)
  - Cause & effect table
  - Calculation sheets
  - Study report
  - Simulation snapshots
  - Excerpts from codes for standards
  - MSDS for chemicals
  - Print-outs of communications with other disciplines, vendors, clients, regulatory bodies

Plus whether re-HAZOP is required or not by regulatory bodies.

2. Delegated HAZOP items, the responsible person, and a list of reasons for the delegation, sign-off by the recipient (“surprise” delegation is not acceptable)

3. Deferred HAZOP items with a table including:

- The reason for delegation (the unknown information which will be available later)
- The timeline for the deferred item.

4. Unresolved HAZOP items: ambiguous items can be sent for re-HAZOP.

### **Do We Need to Re-HAZOP?**

The decision to do a re-HAZOP is the sole responsibility of the process design engineer. After finishing the HAZOP study, the P&ID development proceeds and it may or may not lead to the requirement for another HAZOP on one or a few nodes.

It is the responsibility of the process engineer to log all the nodes for re-HAZOP and to ask the project to accommodate that. Sometimes, a fast-track feature of a project pushes the process engineer to minimize the number of re-HAZOPed nodes, or even to delete all of them, claiming no need for a re-HAZOP. In this case he needs to know if a safety flaw is discovered later. The process engineer is the first person who could be investigated.

There are some rules of thumb that some engineers use to evaluate whether re-HAZOPing is required, but none of them are reliable. For example, some people believe that if the arrangement of the system doesn't change and the only change is in the capacities, there is no need for a re-HAZOP. However, this cannot be true since a release from a high-volume tank vs. from a small-volume tank may have larger consequences, and higher risk would be involved. Theoretically speaking, to evaluate if there is a need for re-HAZOPing after a change in a system, the process engineer needs to do a "mini HAZOP" in his mind. One easy way to do this is to study the HAZOP report and review the guide words for the affected node, along with the risk level in each case, and analyze whether the

change may affect the result risk level or not. However, if he is in doubt, it is better to assign the node to be re-HAZOPed.

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