

# Combining Stream-Based HAZOPs, LOPAs & STPAs into an All-In-One Assessment

## A Systems Approach to Process Hazard Analysis & Risk Assessment

HAZOP is the most commonly applied process hazard analysis (PHA) methodology in the processing industries.

**It is also the most flawed!**

### Why don't we learn what we should from HAZOPs?

- Tunnel vision - The focus on small nodes obscures the big picture. Systems issues and interface issues are easily missed.
- Guideword overlap causes excessive repetition, tedium and poorly organized HAZOP reports.
- Ineffective risk ranking often results in many spurious findings.
- No explicit method for evaluating operability.
- Most people don't like them.

## Tunnel Vision: Small Nodes, Contract Driven

As facilities have become more and more complex we have seen increasingly problematic interfaces.

HAZOPs are generally conducted with very small nodes. These small nodes tend to create tunnel vision which may miss interface issues.

Further, it is common practice to HAZOP individual contractor scopes individually. For example, the subsea and topsides systems of an oil development are frequently HAZOPed independently by different teams. Complex subsystems, such as the gas compression system, may be HAZOPed separately by a separate team.

While some division of HAZOPs may be necessary to get the right skill sets in the room at the right time, there is certainly a risk of missing important interface issues.

## Guideword Overlap, Tedium, & Disorganized Reports

The guidewords for a typical HAZOP are FLOW, PRESSURE, TEMPERATURE, and LEVEL.

But FLOW deviations cause most PRESSURE, TEMPERATURE, and LEVEL deviations (Figure 1). Discussing all four of the guidewords duplicates effort and causes tedium.

It is now relatively common for facilitators to start with FLOW deviations and effectively do the entire HAZOP under the FLOW deviation guideword. This causes multiple problems, for example:

1. PRESSURE deviation discussions, usually the most important discussions, are often almost after-thoughts and may be captured in the report simply as "see High FLOW" and "see Low FLOW".
2. Since a FLOW deviation in one node usually affects other nodes, we often discuss and document PRESSURE deviation of one node in the FLOW deviation section of another node.

The two above issues cause a great deal of repetition which is very tedious for the participants and results in disorganized reports.

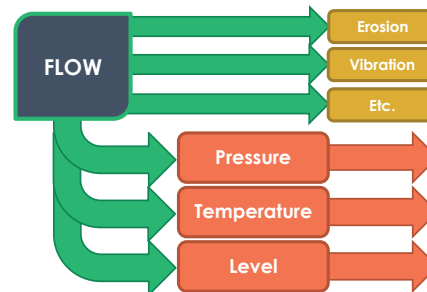


Figure 1: Guidewords Are Not Independent

## Ineffective Risk Assessment

Risk assessment in HAZOPs is typically conducted via color-coded risk matrices as seen in Figure 2. These typically rely on ambiguous definitions of probability and consequence.

Further, it is often unclear to participants whether they are ranking the mitigated or unmitigated risk.

Ineffective risk ranking may understate the risk of a serious hazard, but probably more frequently overstates the risks resulting in many spurious findings. Both are problematic.

5	Catastrophic Multiple fatalities, Loss of Platform, Long-lasting environmental damage					
4	Major Single fatality, Significant equipment damage, lasting environmental damage					
3	Severe Lifetime injury, Significant equipment damage, release requires cleanup					
2	Minor Reportable injury, Equipment maintenance report, Reportable release, no cleanup					
1	Slight First aid case, Shutdown without damage, Flaring within permitted amount					
		A	B	C	D	E
		Never heard of in industry	Happens in the industry	Happens in our company	Likely on our platform	Multiple times on our platform

Figure 2: Typical Risk Ranking Matrix

The inadequacy of risk assessment in HAZOPs is well-recognized. To address this deficiency, many projects perform a Level of Protection Analysis (LOPA) review of high impact scenarios discovered in the HAZOP.

## No Explicit Way to Address Operability

HAZOPs are supposed to identify operability issues, but there is no explicit consideration of operability in a typical HAZOP and no effective way to identify operability issues. Success at identifying operability issues depends more on having the right people in the room, such as experienced operators, than on the process itself.

## Systems-Based Risk Assessment – The GATE Approach To PHA

GATE Energy has developed a systems approach to PHA that addresses each of the HAZOP process flaws noted above. The 3-step process is illustrated in Figure 3 and includes:

1. HAZOP Phase 1: FLOW Discussion Based on Stream-Based Nodes
2. HAZOP Phase 2: PRESSURE, TEMPERATURE and LEVEL Discussion Based on Typical Equipment-Based Nodes
3. STPA Phase 3: Application as Needed For Significant Risk Scenarios

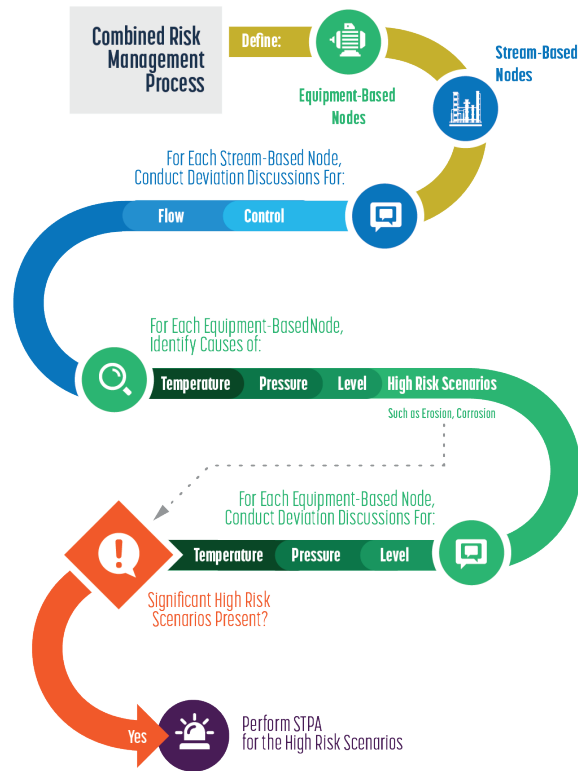


Figure 3: GATE Risk Management Process Summary

## Phase 1: Stream-Based HAZOP for the Flow Deviation Discussion

FLOW is a fundamentally different property of the system than PRESSURE, TEMPERATURE and LEVEL. FLOW occurs through the process. PRESSURE, TEMPERATURE and LEVEL are point functions.

The first step is to conduct the FLOW discussion on stream-based node follows an identifiable stream through multiple equipment-based nodes.

Figure 4 shows a single stream-based node for a produced oil stream from the reservoir to the Dry Oil Tank.

In a typical HAZOP, this system would be divided into 6 to 9 equipment-based nodes.

Stream-based nodes are much better for the FLOW deviation discussions. Change the flow anywhere in the node and you change it everywhere, or at least everywhere downstream.

The stream-based FLOW discussions are used mainly to identify PRESSURE, TEMPERATURE and LEVEL deviations for each equipment-based node. These are discussed in Phase 2.

Because no value judgements and no brainstorming are required in this phase, it can be done as pre-work or conducted with a much smaller team than the equipment-based HAZOP in Phase 2.

Stream-based nodes also allow for a meaningful discussion of operability. For example, it is possible to discuss the startup and shutdown of the system in Figure 4.

## Phase 2: PRESSURE, TEMPERATURE, LEVEL Discussions

The FLOW discussions in Phase 1 identify all the PRESSURE, TEMPERATURE and LEVEL deviations for each equipment-based node. These deviations are discussed for each equipment-based node in Phase 2.

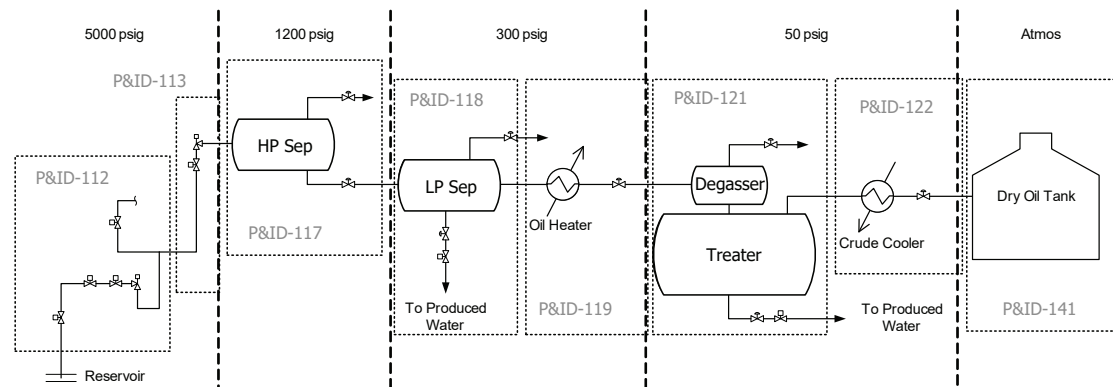


Figure 4: Oil Production Stream-based Node (One 'Stream' from Reservoir to the Dry Oil Tank)

The stream-based node is an excellent vehicle for the FLOW deviation discussions, but stream-based nodes don't work for the PRESSURE, TEMPERATURE and LEVEL discussions. Pressure, temperature and level control and safeguarding are all done primarily at the equipment level. For these discussions, we use equipment-based nodes.

Equipment-based nodes are what we commonly see in a HAZOP – one equipment item or a very few related items make up a node.

The advantage of doing the stream-based FLOW discussions first is that we identify most of the causes of PRESSURE, TEMPERATURE and LEVEL deviations during the FLOW discussion. Then, we only need to discuss PRESSURE, TEMPERATURE and LEVEL deviation once.

In addition to simplifying the deviation discussions, this approach also effectively organizes the HAZOP record.

LOPA-based risk assessment in this phase adds rigor and repeatability to the risk assessment. This minimizes the spurious findings.

### LOPA-based Risk Ranking

A key feature of the GATE System PHA process is more effective risk ranking.

Typical risk ranking in HAZOPs is a relatively informal and unstructured process conducted via a color coded risk matrix (usually red, yellow, green) as seen in Figure 1. This three-level ranking provides imprecise ranking and measurement of risks and the results are heavily dependent on the experiences of the people in the room.

The GATE risk ranking methodology replaces the color-coded matrix with a Required Risk Reduction (RRR) matrix (Figure 5).

The important features of this matrix are:

1. The frequency axis is a logarithmic scale, with an order of magnitude change from one column to the next.
2. The consequence axis is also a logarithmic scale with order of magnitude differences between rows.
3. The numeric cell entries represent order of magnitude risk reductions required to reach a 'target' or 'maximum acceptable' risk level (0).

5	Catastrophic Multiple fatalities	1	2	3	4	5	6
4	Major Single fatality	0	1	2	3	4	5
3	Severe Lost time injury	0	0	1	2	3	4
2	Minor Reportable injury	0	0	0	1	2	3
1	Slight First aid case	0	0	0	0	1	2
		A	B	C	D	E	F
		1/10,000 Years	1/1,000 Years	1/100 Years	1/10 Year	1/1 Year	10/1 Year

Figure 5: Example Risk Reduction Target Matrix

Defendable frequency data, as used in a typical LOPA, is used to make the frequency judgments. For example, a control loop is expected to fail approximately once every 10 years, so a scenario with "Major" potential consequence triggered by a single control valve failure will be a D4 with an RRR = 3.

The SIL value of individual safeguards are used to assess the adequacy of safeguarding.

For a more detailed description of risk ranking using the RRR matrix see the GATE Arrow HAZOP Risk Assessment via the RRR Matrix.

### Phase 3: Conduct STPA for Significant Hazards

This phase applies the most rigorous hazard assessment methodology currently available to the most significant hazards, the system theoretic process analysis (STPA).

The scenarios generated by most PHAs are based on component failures or human errors.

STPA takes a fundamentally different perspective. STPA assumes that incidents happen when we lose control. It is possible to lose control even if no component has failed and no human-error was made. This is especially true in complex systems.

STPA is the third step in the GATE Risk Management process. Significant risks identified in the HAZOP are studied further using the STPA methodology.

For a more detailed discussion of STPA see the GATE Arrow on STPAs.

### Viking Can Help

With our legacy of experience in process design, materials selection, risk assessment and systems analysis, we can provide effective and efficient design, fabrication, and operational support as the energy industry moves into a renewable future.

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