Winnipeg

The City of Winnipeg

Water and Waste Department

HAZOP Procedure Guideline

Revision: 01-Final

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Rev.	Description	Date	By	Approved
00	Adapted from the WSTP HAZOP Procedure CD-PD-PC-01	2020-02-28	R. Adedapo	D. Griffin
01	Draft – review of R00	2022-06-17	N.Abercrombie	
01	Final - Reviewed and updated 2022.	2022-09-14	N.Abercrombie	M.Paetkau

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2 Introduction

2.1 Purpose

This guideline is designed to provide the general approach to conducting a **HAZ**ard and **OP**erability Study (HAZOP).

The purpose of the HAZOP is to conduct a systematic examination to:

- Review the project design to ensure that hazards and operability issues will be minimized in a process plant.
- Identify potential operability problems that may result in other losses such as reduced capacity or effluent quality.

HAZOP can be performed during design phase of a new process; design phase when modifying an existing process; or used as a risk assessment tool when reviewing an existing facility.

It is expected that the HAZOP Facilitator, engaged by an engineering consultant or Design Builder, will have prior training from an accredited organization or equivalent experience in undertaking HAZOP studies and in tailoring the approach to meet the specific requirements of the project. The HAZOP Facilitator's credentials must be submitted to the City's Project Manager or City Representative for approval.

2.2 Scope

This document explains the preparation, conduct and reporting requirements for undertaking a HAZOP. It does not address technical engineering matters that are identified during the HAZOP.

2.3 Background

The HAZOP methodology was developed by the English-based company ICI in the mid-1960's. It is considered as an inductive hazard analysis methodology used to identify all potential outcomes related to equipment failures on processing and similar plants. It is a "bottom – up" methodology.

The objectives of the HAZOP methodology are to ensure that:

- Design choices will not be the source of operating faults;
- Identifying which process Deviations can lead to unfavorable consequences generating a risk; and
- Ranking identified risks, in order to manage all risks initially classified as non-tolerable.

HAZOP can also be modified to utilize different sets of Key-words for non-process plant related projects. Suggested guidewords for process mechanical plants are included in Section 4.8.

The use of the HAZOP methodology should be considered whenever changes are proposed to a Process Piping and Instrumentation Drawing (PPID or P&ID).

2.4 HAZOP Method Strengths and Benefits

The strengths and benefits of the HAZOP methodology are:

- It is a universally accepted industry standard that can be used during design stage, or on existing facilities for all treatment and pumping processes;
- Ensures an exhaustive failure risk analysis for any operating system with identification of failure causes and of consequences of these failures on performance indicators;
- The methodology is particularly suitable for the identification of feared events resulting from human errors occurring during normal operations;
- HAZOP contributes in improving operational performance;
- Since it is a brainstorming exercise, it can bring better understanding of process design to operations staff, and of process operation to designers.

2.5 Limitations of the Method

The methodology has limitations which include:

- It is a resource intensive and time-consuming analysis, due to its iterative approach;
- This tool brings less added value when it is deployed on low-technology processes that are not safety-sensitive, and for which feared events impacts remain low;
- HAZOP is less suitable for consideration of simultaneous or common modes failures;
- HAZOP requires the process design to be well advanced with P&IDs which include all designed controls and safety measures. Note, the HAZOP is a design review method and should not be used as a substitute for experienced designers.

3 RESPONSIBILITIES

Table 1 - Responsibilities

Task		Responsibility (Role)	Notes
1	Creates requirement for HAZOP	Project Manager or City Representative	Identifies the requirements for HAZOP in the project plan.
2	Initiates HAZOP	Design Manager (Consultant/Design Builder)	Arranges for an experienced independent HAZOP Facilitator.
3	Arranges HAZOP	Design Engineer or Design Manager (Consultant/Design Builder)	Identifies the necessary participants and resources required. Plans the sessions, venue and supporting materials.
4	Conducts HAZOP	HAZOP Facilitator	The HAZOP Facilitator has overall responsibility for carrying out a HAZOP workshop and for controlling the extent of the application including: Deciding on the division of the Process and Instrumentation Diagrams (P&IDs) into elements or nodes suitable for reviewing one at a time. Leading the questioning in accordance with the selected guidewords. Instructing the scribe on what information needs to be recorded. Ensuring that specific engineers are named and designated to implement the HAZOP actions.
5	Explains the function and operation of the system.	Process Engineer or Lead Design Engineer (Consultant/Design Builder)	The explanation should include all process conditions, instrumentation controls, rationale for process equipment selection, start-up and shutdown considerations.
6	Records HAZOP information	Scribe	Scribe needs to be familiar with the HAZOP technique and the software used to capture the HAZOP.

Task		Responsibility (Role)	Notes
7	Provides written report(s) on HAZOP	HAZOP Facilitator	The report should be completed and submitted to the City within seven (7) days of the HAZOP workshop
8	Tracks implementation of	Design Manager (Consultant/Design Builder)	

4 Methodology

4.1 Overview

A HAZOP is a systematic, detailed process following a preset agenda conducted by a team comprising of members with a variety of backgrounds and responsibilities. For example, a HAZOP of a new project in design build would have representatives from design, construction, the City operations and maintenance staff.

Basically, a HAZOP concentrates on exploring the possibility and consequences of deviations from normal or acceptable conditions and in this way forms a "check" of the design.

The HAZOP takes the form of a discussion which examines each element of a design or operation considering a list of key-words and possible deviations for each element. For each postulated deviation, an attempt is made to envisage ways in which the deviation could occur and an estimate of possible consequences is recorded. If the severity is sufficient, the deviation is noted as a problem to be resolved on the HAZOP record sheet.

TIP: It is good practice to avoid problem solving the deviations during the HAZOP as this may consume time and prevent the HAZOP meeting covering all of the intended process scope. Where a potential solution emerges from the identification discussion, make a note of this and move on.

4.2 Application to Project Life Cycle

The most valuable time to conduct a HAZOP is when the details of the P&IDs are effectively complete or frozen. Conducting the HAZOP earlier than this may assist designers in identifying the required process controls; however, the HAZOP process may need to be repeated during detail design due to incomplete data being available. It is essential that the project team consider this point and ensure that the drawings are in a state that is suitable for the HAZOP.

If it is determined that the design is not adequately defined to perform the HAZOP, then it will be necessary to defer examination of that particular section until the problem is rectified. Any attempt to finish off the design during the HAZOP will not be permitted as it undermines the principle of HAZOP to audit a complete design.

After a HAZOP has taken place, any modification to the drawings would need to be reviewed to determine whether a further HAZOP is required.

4.3 Participants

Representatives from all groups involved are required such as design, construction, operation, etc., with the representatives having both technical know-how and sufficient organizational authority to ensure all agreed actions will be implemented. It is best to keep the core HAZOP team to a minimum number of personnel required to participate in the workshop. Additional personnel may be invited based on the process being discussed and in consultation with the Project Manager or City Representative.

The City project team should be invited to participate in the HAZOP as well as wastewater facilities operating and maintenance personnel with relevant plant experience. To be effective, the HAZOP should involve the members of the consultant or Design Builder responsible for

P&IDs input and development. The team needs to be multi-disciplined with authority to make appropriate decisions.

In a HAZOP workshop for a new facility, the team would typically comprise of the following:

- Senior design engineer;
- Design engineer responsible for the section being studied;
- Specialists, such as an instrument engineer, mechanical engineer or an electrical engineer or other appropriate discipline engineer;
- Project engineer;
- Operations superintendent (designate);
- People who will be involved in the operation, maintenance and construction (in the case of a design build) of the plant;
- Commissioning engineer;
- Project manager or City Representative;
- City parties (in case of a design build);
- Facilitator;
- Scribe.

HAZOPs must be facilitated by a person who is independent from the design team and who has experience in conducting HAZOP workshop.

It is considered essential that the HAZOP Facilitator be separate from the Scribe so that the Facilitator is able to lead the workshop and focus on the pace and dynamics of the workshop.

The Scribe's main task is to record the details of the identified problems, and the nature of the agreed solution or investigation to be undertaken. The Scribe needs to be familiar with the project and competent to interpret the discussion in deciding what should be recorded.

The Scribe's role is critical to the outcome of the workshop as the information recorded is often the only source of information on which to proceed or rely after the workshop. It is highly recommended that the workshop proceedings be projected using a data projector so that the team can agree on the information during the workshop.

The final composition of the HAZOP team needs to be approved by the Project Manager.

Note: It is required that the HAZOP Nodes are determined and agreed with the City prior to the HAZOP workshop. Design reviews should be carried out separately from the HAZOP workshop.

4.4 Resources

It is recommended that the HAZOP be conducted away from the main design area to prevent distractions. The facility being used should have adequate space for laying out large scale drawings for markup plus a white board and data projector. It is also recommended that HAZOP outcomes be recorded directly onto a computer using a program such as PHA-Pro with the data projected for team feedback and review.

4.4.1 Remote Working

It is possible to perform a HAZOP remotely which can have benefit to a project, however the HAZOP methodology is a collaborative technique and remote working creates risks which the Project Manager must mitigate. Additional actions for preparation for a remote HAZOP include (applies where all or any participants are working remotely):

- Communicate with participants and ensure they have access appropriate IT equipment;
- Distribute all materials to remote parties and ensure documents are clearly identified;
- Select a Facilitator with experience running remote HAZOP reviews;
- Allow additional time as remote sessions can be less efficient;

4.4.2 Document Requirements

The documents required for the HAZOP should be agreed in advance with the Project Manager and the Facilitator.

Although specific documentation will be dependent upon the project and progress of the design, the following lists provide a guide. A Pre-HAZOP package should be developed and made available to the participants prior to the workshop.

Table 2 - HAZOP Inputs

HAZOP Inputs	
Required[1]	Optional
Process Flow Diagram(s). Complete and up-to-date Piping and Instrumentation Diagrams (P&ID). Operating philosophy. Safety philosophy. Control philosophy or Functional Design Specification. Equipment technical specifications (at minima, design pressure / temperature, materials). Material Safety Data Sheets for hazardous substances spent or generated by the process. Process mass balance (flowrates, pressures, temperatures).	Cause and effect diagrams (if available). Process specifications/equipment process data sheets. Process description document. Instrumentation schedule. Material balance, (if not included above). Facility layouts or site plan(s). Line classification lists. Valve schedule. Materials of construction diagram(s). Equipment list, and Building classification.
Note 1 – these documents may be in a draft state, they should be sufficiently advanced to understand the process, If the documents change materially after the HAZOP, the review may need to be repeated in part or completely.	

The outputs and deliverables from the HAZOP review are:

Table 3 - HAZOP Outputs and Deliverables

HAZOP Outputs
Exhaustive inventory of all potential equipment failures. List of all potential feared events resulting from these failures. Feared events ranking by their risk index. List of all recommendations to keep all feared events under control, with primary person responsible and due dates for each recommendation.
HAZOP Deliverables
HAZOP Minutes; Note: The HAZOP Record Sheet can be used as the minutes where agreed with the Project manager HAZOP Workshop Register (may be part of the minutes); Completed HAZOP Record sheet(s); Drawings (P&IDs etc..) marked up with any errors identified during the review; HAZOP Recommendations Register; HAZOP Closing Form.

4.5 Pre-Workshop Preparation

HAZOP review meetings work best when they are well prepared. Preparation for the HAZOP meeting will include:

- Collection and organization of all the required information and data;
- Selecting and agreeing analysis nodes;
- Assessment of time requirements;
- Identifying participants and determining their knowledge and experience with the method;
- Setting the meeting agenda, inviting participants and organizing a venue;
- Preparation of HAZOP record sheet.

4.6 HAZOP Workshop

The workshop should generally follow these steps:

- Introduction and training;
- System description and design intent;
- Select Nodes
- Examining deviations;
- Identifying causes;
- Evaluating consequences;
- Considering safeguards;
- Generating recommendations

The Scribe should record:

- The description of the elements or nodes and its design intent;
- Causes and consequences from each unacceptable deviation;
- Resolved problems and their solution(s);
- Unresolved problems, and the person nominated to arrange for resolution outside the workshop (this may be assigned after the session);
- The number associated with each recommendation on the drawing to highlight or clarify the intended location for the change;
- The solution by marking up the drawings using a distinct colored pen. Generally, records are not required on drawings where no issues are identified.

4.6.1 Introduction and Training

The Facilitator outlines the HAZOP procedure, agenda and timeframe at the first workshop and provides extra detail on the process if any member has not previously taken part in a HAZOP workshop. Where HAZOP participants have previous experience, this can be brief and should cover the-following-points:

- Objectives of HAZOP;
- Essential features of HAZOP;
- HAZOP focus on identifying abnormal circumstances which could upset normal operation.

If multiple HAZOP workshops are required, the time, date and location of the next workshop should be scheduled before completing each workshop or prior to starting any of the HAZOP workshops. Review actions/recommendations and progress at the end of each workshop. Ensure every participant obtains a copy of the actions as soon as possible after the workshop.

4.6.2 System Description and Design Intent

The Consultant or Design Builder should nominate personnel, with good understanding of the design, to provide a brief purpose of the area being reviewed including the normal mode of

operation or use of the area of the plant. Clarifications on the purpose or mode of operation should be provided to participants.

4.6.3 Selecting Nodes

Prior to the HAZOP workshop, the Facilitator should have selected nodes to be discussed in the HAZOP workshop. These nodes must have been previously agreed to with the Project Manager or City Representative either by sending the selected nodes for comments or carried out in a pre-HAZOP workshop.

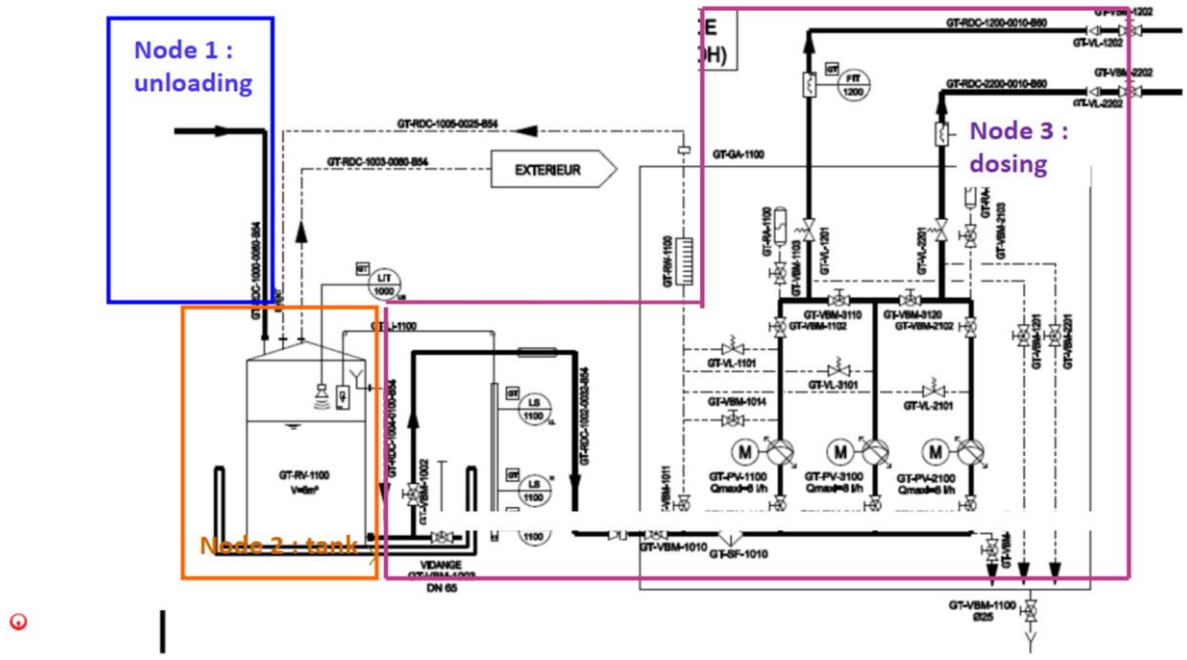

Figure 1 - Example Node Selection

4.6.4 Examining Deviations

A list of appropriate deviations and overview deviations for the particular HAZOP application should be agreed to from the lists indicated in Section 4.8.1. These deviations are to be used systematically and consistently for every node or element.

The Facilitator is expected to use the deviation to prompt the participants to identify:

- Whether deviations to the behavior of the intended system could occur and if so, whether these have a significant effect on safety and / or operability;
- How the deviation can impact upon the system;
- What are the possible consequences from the deviation;
- If the existing safeguards are sufficient to control or contain the effects from the deviation;
- Recommendations to address or identify any additional controls to contain the deviation.

When the deviations related to process plant and mechanical guidewords have been used for each node or element, the Facilitator indicates the appropriate drawing noting that the nodes or elements have been studied.

When all Nodes or elements of the drawing have been covered, the Facilitator proceeds to the Typical Overview Deviations. These are used to guide an overview of the whole drawing. When the overview is complete, the Facilitator signs the drawing as complete, and ensues that the report and outstanding actions are issued to the participants. Target dates for the completion and closeout of the HAZOP recommendations should be included in the report along with the person responsible for the action.

4.6.5 Generating Recommendations

Resolution of an identified problem can be undertaken in the workshop if this can be done efficiently and correctly. If it is apparent that more time will be needed for such things as consultation, research, validation or calculation then the resolution of the issue should be done outside of the HAZOP workshop. The priority of the HAZOP meeting is to identify and quantify the risks, mitigation and problem solving is better done outside of the HAZOP meetings as this may require expertise and resources not in the meeting. Ideas that emerge in the discussion can be noted and move on.

Actions or recommendations can take several forms. Some examples are:

- Requests for further information not available to the team such as "Will a particular relief valve handle a certain flow?"
- Note of the need for additional safety features to be engineered such as to add a high-pressure trip system.
- Requests for a quantitative assessment to be carried out for example to confirm that the failure rate of a system is acceptable.
- Requirement of notes/warnings to be added to operating instructions.
- Change of process, equipment or instrument.

4.7 Recording and Reporting

Decisions affecting the scope of the project shall be recorded in the HAZOP report as well as the agreed terms of reference. For instance, it may be agreed to only carry out HAZOP on sections of the P&IDs that have been modified as part of the project.

For a small HAZOP workshop; such as a small modification to an existing piece of equipment, the minutes may be all on one form (HAZOP Record Form). Where several workshops are needed, and many changes are expected, a separate form for each identified problem should be used.

If P&ID drafting errors are observed during the workshop, the Facilitator should mark the corrections and make a notation in the minutes.

Where possible, recording safety in design studies using PHA-Pro risk software (or similar) is considered advantageous to aid in the efficient capture of data, arrangement of information and presentation of results.

After each workshop, a copy of the minutes must be sent to those assigned for actions or

recommendations. As each action is completed, the resolution or outcome is recorded by the person responsible. These outcomes must be forwarded to the person responsible for monitoring the HAZOP workshop. All action items or recommendations must be closed out by the end of the project.

The level of recording is defined by the HAZOP team leader but may involve input from the project manager or client. The team should record as a minimum:

- Executive summary and general comments;
- Critical scenarios currently uncovered by safeguards;
- Date and time of the HAZOP;
- HAZOP attendees;
- List of P& ID's and design conditions if appropriate;
- Colored PIDs used during workshop scanned;
- List of nodes and deviations considered;
- List of causes, consequences, hazards; and
- List of recommendations or action items and persons responsible.

The HAZOP report should include the above information plus details of the methodology including the deviations used. The format may be project specific but should include necessary background to enable the reader to understand the scope and context for the HAZOP.

All registers, such as the following, are to be updated by the Design Manager after the workshop:

- HAZOP Record Form;
- HAZOP Workshop Register; and
- HAZOP Recommendations Register.

4.8 Deviations

The standard HAZOP methodology uses seven (7) key-words which are combined with process parameters or steps to create “Deviations”.

Additional key-words may be recommended by the Facilitator based on the system being analyzed and their experience. Process Parameters (or process steps) are specific to the system being analyzed.

Table 4 - Key-Words and Process Parameters

Key Words	Process Parameters
No (or none) More Less As well as Part of Reverse Other than	The following represent those used in the Water and Wastewater industry: Flow Temperature Pressure Concentration Level pH Viscosity Separation Mixing Composition Contamination Direction Speed Level Load Location Timing Force Quality Physical damage Control Protection

The methodology works by combining the key-words with each process parameter in a systematic manner for each node and asking the question “what happens if”.

For example:

Node 1: **FLOW**

what happens if there is –

NO Flow

More Flow

Less Flow

Flow **As well as** (e.g. could be another source of flow)

Part of a flow (e.g. expect two flow sources but only one is received)

Reverse Flow

Flow Other than

Node 1: **TEMPERATURE**

what happens if there is –

NO Temperature

More Temperature

Less Temperature

Temperature **As well as** (e.g. could be another heat source; two conflicting temperature signals)

Part of a Temperature (e,g, two temperature readings expected)

Reverse Temperature (e.g. falling temperature)

Temperature **Other than**

Repeat for each applicable Process Parameter of Process Step for Node 1, then move onto Node 2 and repeat.

Some of the key-word and Process Parameter combinations may not make sense at first glance, however the method encourages participants to think creatively and consider situations that may not be immediately obvious. The Facilitator should be skilled at challenging the team to think creatively and be experienced to have seen unusual key-word/Parameter combinations.

As can be seen, the combination of the seven Key-words with all possible Process Parameters can create over one hundred deviations for a single node. The Facilitator has the responsibility to lead the team to the most important deviations while being open minded to any that are less common for a specific node.

When considering Deviations, the Facilitator should lead the team to consider unusual operating

situations when applying the key-words, such as: Start-up; Shut Down; Breakdown; Testing; Weather and other environmental events.

Note: Commissioning is a time when a system is operating outside normal parameters for short or extended periods. The HAZOP methodology can add considerable value to managing risk during commissioning. The Project Manager should discuss commissioning with the Facilitator prior to the workshop and develop a plan for how to address commissioning.

4.8.1 Overview Deviations

The following Deviations are applied to each drawing as a roundup discussion, as appropriate.

Deviation	**Meaning**
Materials of construction:	Suitability for abnormal conditions, corrosion, erosion, wear.
Services needed	Air, nitrogen, water, steam, power etc.
Commissioning	Authorities, training, supervision, compliance checking.
Start up	Sequence, problems
Shutdown	Isolation, purging.
Breakdown	Loss of services, "fail sate" response, emergency procedures.
Electrical safety	Area classification, electrostatic discharge, grounding.
Fire & explosion	Prevention, detection, protection, control.
Toxicity	Acute, long term. Adequacy of ventilation
Environmental control	Effluent: gaseous, liquid, solid. Noise. Monitoring.
Access	For operation, maintenance, means of escape.
Testing	Raw materials, products, equipment, alarms and trips.
Safety equipment	Personal equipment, fixed safety equipment.
Output	Sources of unreliability, bottlenecks.
Efficiency	Potential for loss of material or performance

4.9 Follow up and Closing

HAZOP action close-out is to be controlled by the Design Manager and reported individually using an appropriate HAZOP Closing Form. The Design Manager needs to update the action status on a HAZOP Recommendation Register.

The HAZOP Closing Form must contain adequate design information to demonstrate that the design has incorporated the changes / elements agreed to prior to the closing of the HAZOP recommendations. The Design Manager must sign the document as a verifier.

5 Appendices

The following templates may be used by the Consultants or Design Builder if they do not have standard HAZOP templates and will be provided upon request to the Project Manager or City Representative.

1. HAZOP Minutes Template
2. HAZOP Record Form Template
3. HAZOP Workshop Register Template
4. HAZOP Recommendations Register Template
5. HAZOP Closing Form Template