Hazard Identification (HAZID) Study Report

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DATE	**REV.**	**STATUS**	**PREPARED BY**	**CHECKED BY**	**APPROVED BY**

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1. Introduction

The Hatch Risk Management process requires that projects undergo risk reviews to demonstrate that potential hazards related to the operation, equipment, locations and maintenance of an asset have been assessed and are controlled as per the tolerance level indicated to Hatch. The intent of the risk reviews is to document at a high-level the critical safeguards any special control actions that may be required to manage residual risk to a tolerable level.

As part of the project scope and deliverables for the End-to-End Hydrogen Value Chain Development, a Hazard Identification (HAZID) study workshop was conducted on January 10, 14 and 15, 2025. The risk review workshop was held by remote connection via Microsoft Teams™.

The HAZID provides the ability to identify the potential risks related to the initial design, its functionality, operability, and maintainability. Which in turn allows the identification and evaluation of appropriate mitigative measures.

This report summarises the HAZID study workshop methodology and outcomes of the risk review workshop and records the participants. The result is documented as a single technical risk register as part of the workshop minutes in Appendix B.

2. Abbreviations

Table 2-1 below contains the list of abbreviations used in this document:

Table 2-1: Abbreviations

Abbreviation	Meaning
ALARP	As Low As Reasonably Practical
FEED	Front-End Engineering and Design
HAZOP	Hazard and Operability Study
HGP	Hydrogen Generation Plant
LHSV	Liquid Hourly Space Velocity
LOHC	Liquid Organic Hydrogen Carrier
LOPA	Layer of Protection Analysis
LTI	Loss Time Injury
[redacted]	[redacted]
MCH	Methylcyclohexane
MTI	Medical Treatment injury
NA	North Atlantic Refining Corporation
P&ID's	Piping and Instrumentation Diagrams
PHA	Process Hazard Analysis

Abbreviation	Meaning
PLP	Project Lifecycle Process
PPE	Personal Protective Equipment
PSA	Pressure Swing Adsorption
TPS	Toluene Purification Section

3. Project Overview

[redacted] North Atlantic Refinery Corp. (NA) are developing a project where renewable hydrogen will be produced in Newfoundland and Labrador (NL) in Canada by NA and transported to Western Europe in the form of methylcyclohexane (MCH). The project will be based on the use of liquid organic hydrogen carrier (LOHC) technology where hydrogen as liquid MCH, which is produced from toluene and hydrogen, can be safely and economically stored, and transported. A schematic for the overall development scheme is shown in Figure 3-1.

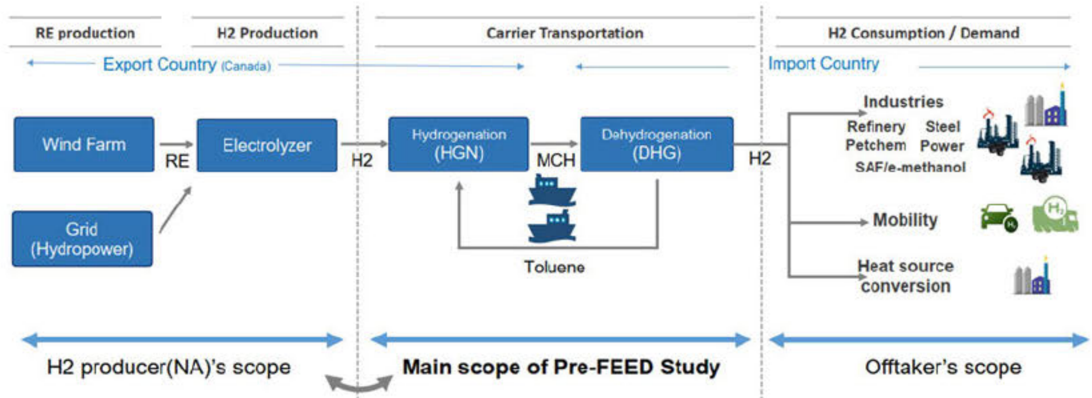

Figure 3-1: Project Development Schematic ([redacted] North Atlantic Refining Corporation, 2024)

The Hydrogenation Plant will be located on the hydrogen export side. In the Hydrogenation Plant, hydrogen produced by the hydrogen generation plant (HGP) will be catalytically hydrogenated with toluene to form MCH before being transported to Europe via marine shipping.

[redacted] Toluene Hydrogenation technology will be utilized in the Hydrogenation Plant. The plant will also include all necessary utilities to support hydrogenation. Refer to Figure 3-2 for a Block Flow Diagram layout of the proposed facility and to Appendix D for the [redacted] Toluene Hydrogenation Schematic.

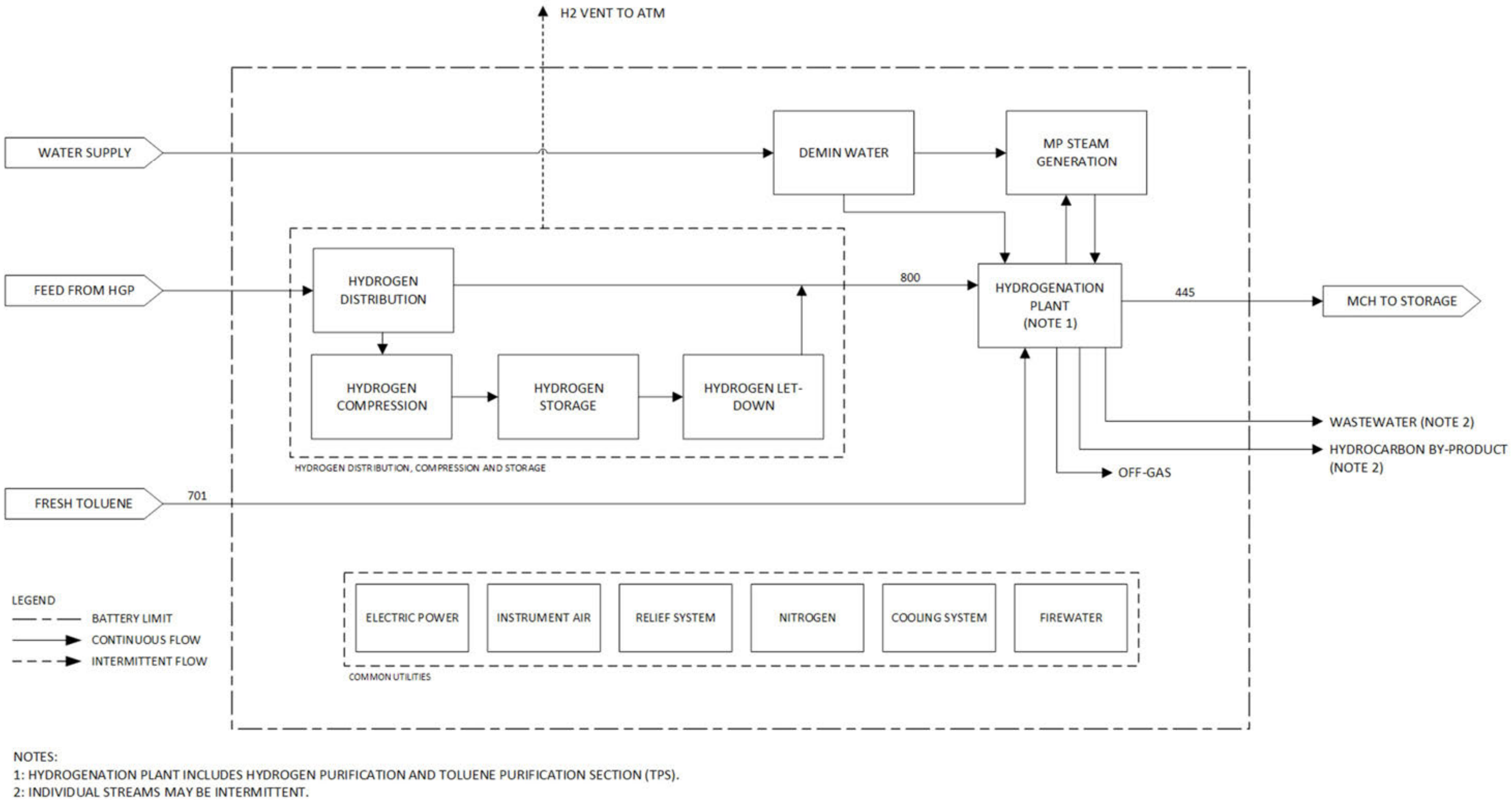

Figure 3-2: Block Flow Diagram of the Facility

4. Definitions

Table 4-1 below contains the list of definitions used in this report:

Table 4-1: Definitions

Term	Description
Hazard	A source of potential harm, which may be associated with the physical, chemical, or biological aspects of a process plant, operational facility, pipeline system, system design, or may arise during construction, manufacturing, maintenance, transportation, storage, or other operations
Risk	A potential event that, should it occur, will have an impact on the organization's objectives, plant operations, costs, safety, health and/or environmental standards
Initial Risk	The risk level or classification posed by the hazard with existing controls in place as well as controls that form part of the design basis, to be in place and effective.
Residual Risk	The risk level or classification posed by the hazard with the existing, plus any additional controls and/or mitigation actions in place. In general, sufficient risk controls must be establish such that the risk associated with a given hazard can moved into the 'ALARP' or 'Tolerable' zones of the agreed risk matrix
Risk Criteria	A quantified expression of the level of risk an entity is prepared to tolerate and illustrated on an agreed risk matrix. A tolerable risk level does not mean an acceptable risk level, it indicates a willingness to work/operate with an identified hazard/risk to secure certain benefits, with the provision that the hazard/risk scenario remains under review and the risk level should be reduced when feasible and practical
ALARP	The ALARP principle states that the residual risk of a hazard, after controls and response plans have been implemented, shall be "As Low As Reasonably Practicable." ALARP is achieved when a risk has been made low enough that further efforts to make it any lower would be grossly disproportionate to the incremental benefits gained

5. HAZID Study Workshop Participants

The HAZOP workshop was attended by identified representatives from North Atlantic [redacted] and Hatch (refer to Appendix A) for the workshop attendance register.

6. HAZID Study Methodology

The HAZID study process (refer to Figure 6-1) is a structured and systematic technique for examining a defined process system, operational facility, plan layout, building locations, logistic hazards, and process equipment.

The result of systematically applying this methodology is early identification, and mitigation of hazards. It allows the incorporation of mitigations to ensure regulatory compliance, safety in design and into maintenance and operations phases. The response plans will either eliminate or reduce the hazard risk levels to ALARP.

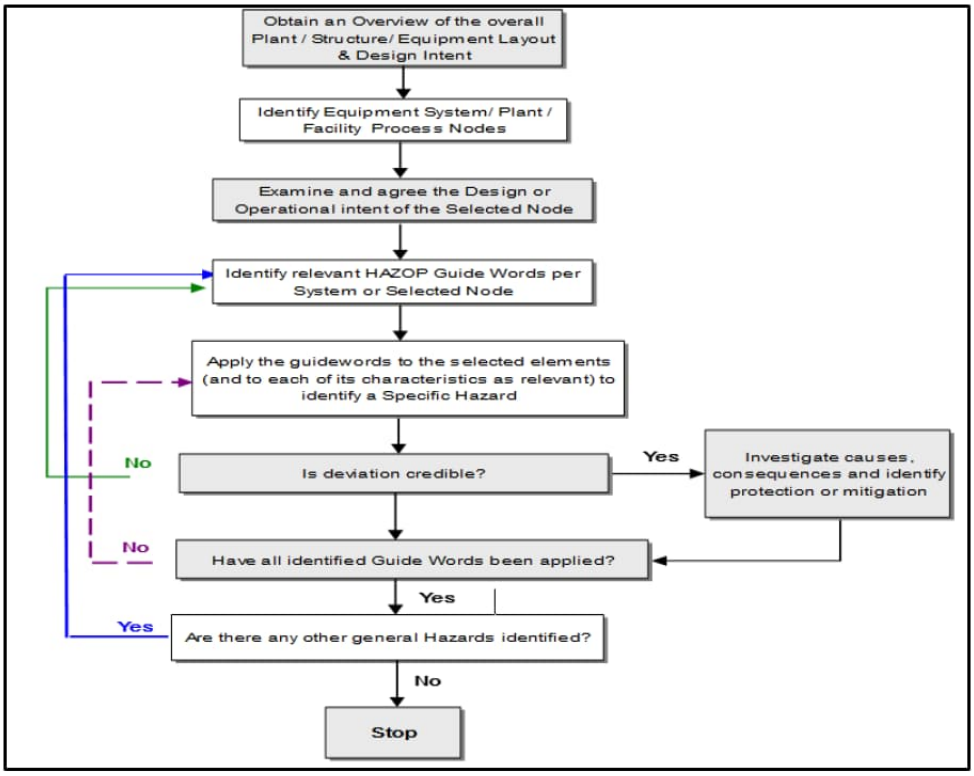

Figure 6-1: Flow Chart of the Risk Review Process[1]

7. Risk Criteria

Risk criteria refer to standards, measures, or expectations used in assessing a given risk in context with strategic goals, the threshold or other decision rules by which the significance of risk is assessed, to determine whether risk treatment actions are required. Risk criteria also relate to a quantified expression of the level of "risk" a company, individuals or a Regulating Body is prepared to tolerate.

These are normally based on regulator or corporate risk appetite, legal or inherent safe design requirements, ethical and social considerations, financial prudence and/or broadly acceptable risk levels within society of what can and cannot be construed as a tolerable level of risk. A tolerable risk level does not mean an acceptable risk level, it indicates a willingness to work/operate with the identified hazards or risks, with the provision that the hazard/risk scenario is kept under review.

Risks are usually measured in terms of likelihood and consequences which, unless a risk is eliminated, will always be non-zero quantities. The ALARP principle dictates that if there are simple or low-cost risk reduction options available, then they should be implemented. It must be stressed that it is not sufficient to just reduce risks to "Tolerable" risk level. It should also be demonstrated that it is "reasonably impracticable" to reduce them any further. The risk level should be reduced as and when feasible and practical to

[1] Source: adapted from Chemical Process Safety Fundamental with Applications – Daniel Crow

ensure the risk is maintained within the As Low as Reasonably Practicable (ALARP) ranges.

The risk rankings results determined during the risk review workshop did consider the existing controls (standard practices) to be in place and that those included in the design basis of the project.

The identified hazards will be assessed on a qualitative basis, using the agreed risk matrix and risk criteria (refer to Figure 7-1, Table 7-1 and Table 7-2).

Applying this methodology resulted in the identification of appropriate remedial measures through the knowledge obtained during the risk review workshop.

Probability / Likelihood							
	P - 6	16 Tolerable (Medium)	21 Tolerable (Medium)	27 (High)	30 Intolerable (Extreme)	34 Intolerable (Extreme)	36 Intolerable (Extreme)
	P - 5	11 Tolerable (Medium)	17 Tolerable (Medium)	22 (High)	28 (High)	32 Intolerable (Extreme)	35 Intolerable (Extreme)
	P - 4	7 Broadly Acceptable (Low)	12 Tolerable (Medium)	18 Tolerable (Medium)	24 (High)	29 (High)	33 Intolerable (Extreme)
	P - 3	4 Broadly Acceptable (Low)	8 Broadly Acceptable (Low)	13 Tolerable (Medium)	19 Tolerable (Medium)	25 (High)	31 Intolerable (Extreme)
	P - 2	2 Broadly Acceptable (Low)	5 Broadly Acceptable (Low)	9 Broadly Acceptable (Low)	14 Tolerable (Medium)	23 (High)	26 (High)
	P - 1	1 Broadly Acceptable (Low)	3 Broadly Acceptable (Low)	6 Broadly Acceptable (Low)	10 Tolerable (Medium)	15 Tolerable (Medium)	20 Tolerable (Medium)
		C - 1	**C - 2**	**C - 3**	**C - 4**	**C - 5**	**C - 6**

Figure 7-1: HAZID Study Risk Matrix

Table 7-1: HAZID Study Likelihood/Frequency Table

Rating	Qualitative Probability	Descriptive Frequency	Indicative Probability
P- 6	**Almost Certain**	Very high probability of occurrence once a year. The event is expected to occur during the project phase or facility operation and has occurred several times on similar projects or facilities	>0.75 or $>10^{-1}$
P - 5	**Likely**	High probability, likely to occur during the operation of the facilities. Similar event has occurred once per 10 to 100 years on similar projects or facility operation for this type of organisation.	0.5 to 0.75 or 10^{-1} **to** 10^{-2}
P - 4	**Possible**	Plausible to occur during the project phase or facility operation (Once in 100 to 1,000 years) Note: This is the Maximum Tolerable Risk to **ADMINISTRATION** employees in terms of human safety impact.	0.25 to 0.5 or 10^{-2} **to** 10^{-3}
P - 3	**Unlikely**	The event may occur in certain circumstances during the project phase or facility operation (Once in 1,000 to 10,000 years) Note: This is the Maximum Tolerable Risk for **PLANT OPERATIONAL** (Own Employees) in terms of human safety impact.	0.5 to 0.25 or 10^{-3} **to** 10^{-4}
P - 2	**Rare**	The event may occur in exceptional circumstances during the project phase or facility operation (Once in 10,000 to 1,000,000 years). Note: This is the Maximum Tolerable Risk for **PUBLIC** members in terms of human safety impact.	0.1 to 0.5 or 10^{-4} **to** 10^{-6}
P - 1	**Unforeseen**	Very low likelihood but not impossible. The event is not foreseen to occur during the project phase or plant life, a similar event has occurred elsewhere in the world in this industry. (Less than once in 1,000,000 years)	<0.1 or $<10^{-6}$

Table 7-2: HAZID Study Consequence/Severity Table

Rating	Consequence Level	Technical Performance	Project Cost	Project Schedule	Health & Safety	Reputation	Legal / Regulatory	Environment
C- 6	**Catastrophic**	Cannot achieve more than 60% of design capacity without extreme expenditure > 50% increase in OPEX	Greater than 50% cost overrun >$100m financial impact	Greater than 50% delay in project completion	Multiple fatalities	Global media coverage Government inquiry Major public concerns Major loss of shareholder support	Very significant fines and prosecutions Multiple litigations	Very serious long term >5 years reversible impact at national level. Clean-up requiring >30% of project budget
C - 5	**Major**	Cannot achieve 60%- 80% of design capacity without major capital expenditure 25% - 60% increase in OPEX	25% to 50% cost overrun >$80m but <$100m financial impact	25% to 50% delay in project completion	Single fatality or injury resulting in permanent incapacity (Occupational disability)	National media coverage Government member involved Senior management changed and Significant decrease in shareholder support	Major fines and prosecution. Very serious litigation, including class actions	Major long-term, >5 years reversible impact at regional level. Clean-up requiring 20% - 30% of project budget
C - 4	**Significant**	Cannot achieve 80% of design capacity without significant capital expenditure 10% to 25% increase in OPEX	10% to 25% cost overrun >$50m but <$80m financial impact	10% to 25% delay in completion of the project	Significant injury result in extensive lost time/ incident Long term health effects hospitalization absentee >14 days)	Significant regional media attention and requires Board of Directors action	Significant breach of regulation. Definite litigation	Significant reversible short term <1 year impact at regional level. Clean-up requiring 10% - 20% of project budget
C - 3	**Moderate**	Cannot achieve 90% design capacity without some capital expenditure 5% to 10% increase in OPEX	5% to 10% cost overrun >$20m but <$50m financial impact	5% to 10% delay in the completion of the project	Moderate injury result in lost workday incident Short term health effects absentee >1 day but less than 14 days	Local media coverage and requires Board of Directors action due to shareholder concerns raised	Moderate breach of regulation result in moderate fines and possible. litigation	Moderate reversible short term <1 year impact at local community. Clean-up requiring 5% - 10% of project budget

Rating	Consequence Level	Technical Performance	Project Cost	Project Schedule	Health & Safety	Reputation	Legal / Regulatory	Environment
C - 2	**Minor**	Cannot achieve 100% design capacity without minor capital expenditure 1% to 5% increase in OPEX	1% to 5% cost overrun >$1 but <$20m financial impact	1% to 5% delay in the completion of the project	Minor injury requires medical treatment In terms of health effects recovery is within hours same shift (restricted workday incident)	Minor adverse local public media attention resulting in Shareholder concerns raised	Minor breach of regulation result in minor fines No litigation	Minor effects extending beyond boundaries of installation Clean-up requiring <5% of project budget
C - 1	**Insignificant**	Minor difficulties to achieve design capacity <1% increase in operating costs (OPEX)	Less than 1% cost overrun <$1m financial impact	Less than 1% delay	Near miss or Minor injuries (first aid) treatment required with minor health effects	No media attention raised by workers Insignificant adverse local public media attention with no Shareholder concerns raised	Low level legal or approval issue	Limited impact within plant boundaries. Clean-up requiring <1% of project budget

8. HAZID Study Workshop

The Hazard 1 study workshop is considered an enhancement to evaluate a predefined system, process, plant or facility by using deviations and guide words to identify possible safety, health, environmental, design or operating hazards particularly through a systematic and careful consideration of deviations that may occur.

The steps followed during the risk review workshop are as follows:

i. Copies of facility site layout (aerial map) and process plant layout was distributed amongst all stakeholders.

   - The site layout and facility locations were then split into hazard study “Nodes” based around a consolidated operational function or process facility.

ii. Each “Node” was then evaluated applying the hazard study process (refer to Figure 6-1 above) by discussing the hazards and risks related to the site/equipment location and operational interface hazards that could lead to fatal flaws.

iii. Each identified potential deviation was then analysed further in order to determine what control and/or preventative measures were currently in place in order to either mitigate the consequence or probability/likelihood of the potential deviation.

iv. The potential deviation was then ranked based on a series of the pre-defined PROBABILITY and CONSEQUENCE tables, of the existing controls in order to determine whether any additional mitigation actions were required for the potential deviation.

v. All potential deviations and hazard scenarios with an initial risk classification of extreme or high (or exceeding a risk value of 21), refer to the risk matrix and criteria Figure 7-1 above were assigned additional mitigation actions, which were then assigned to a relevant stakeholder.

vi. The hazard scenario was then re-evaluated (analysed) in order to determine the residual risk based on the additional mitigation or control assigned.

Note:

The residual risk value can only be accepted as a final risk value after implementation and evaluation of the effectiveness of the proposed mitigation action.

The following hazard study guidewords were considered relevant and typical for the workshop. The guidewords are aligned with international guidewords for hazard studies and risk reviews. However, any additional guidewords were added during the risk workshop by a team member for a relevant scenario not covered by the generic guidewords listed below.

Following a team evaluation, where it was found that NO hazards could be identified for a specific deviation or hazard guide word, based on the information available, indicating the required controls in place, the team decided not to record any comments or notes in the risk review report with respect to the relevant hazard guide *word. The team then agreed and accepted the status, that "No hazards" or "No causes for concern" or relevant risks could be identified for the said deviation or hazard guide word.*

9. HAZID Study Scope

The HAZID Study for the End-to-End Hydrogen Value Chain Development covered only the Hydrogenation plant, which was analyzed as the only node for this study.

10. Risk Review Results

The risk review workshop specifically addressed the proposed operational disturbances on process systems, equipment locations, maintenance isolation/access and control functional requirements as contained in the Block Flow Diagram (Figure 3-2: Block Flow Diagram of the Facility) and in the [redacted] Toluene Hydrogenation Schematic (Appendix D).

Issues that were identified during the workshops which need to be addressed but were not part of the HAZID study (e.g. design discussions) were listed in the "Parking Lot", presented in Appendix C.

There was a total of 14 hazards identified and recorded for the HAZID study minutes.

By applying qualitative risk evaluation techniques, a total of 18 mitigation actions were recommended for risk scenarios which require additional controls based on the risk review team evaluation.

Figure 10-1 presents the obtained risk profile.

Unmitigated Risk Profile							
Severity		Likelihood					
		1	2	3	4	5	6
		Unforeseen	Rare	Unlikely	Possible	Likely	Almost Certain
6	Catastrophic	1	4	0	0	0	0
5	Major	0	3	0	2	0	0
4	Significant	0	1	1	0	0	0
3	Moderate	0	0	0	0	0	0
2	Minor	0	1	0	0	0	0
1	Insignificant	0	1	0	0	0	0

Figure 10-1: Risk Profile

All hazard scenarios with a business or non-safety impact (refer to Figure 7-1), with a risk ranking value between 10 and 21 are considered in terms of risk criteria to be a tolerable risk. When a risk scenario results in the highest consequence with the lowest probability, and it cannot be further mitigated due to the inherent risk condition such an event or risk scenario is considered to be a tolerable risk based on ALARP.

Hazards with an initial risk value greater or equal to 22 or with a 5-Major or higher severity rating should be further reviewed during the futures stages of the project, when further clarity on design and safeguards will be developed. This can be achieved using quantitative techniques such as LOPA (Layer of Protection Analysis) or FMEA (Failure Mode Effect Analysis) or Fault Tree Analysis to determine whether they require further risk mitigation and to evaluate the validation and effectiveness of the proposed mitigation action.

Risk mitigation based on international guidelines needs to consider the recommended hierarchy, which may be subjected to a cost-benefit analysis where appropriate.

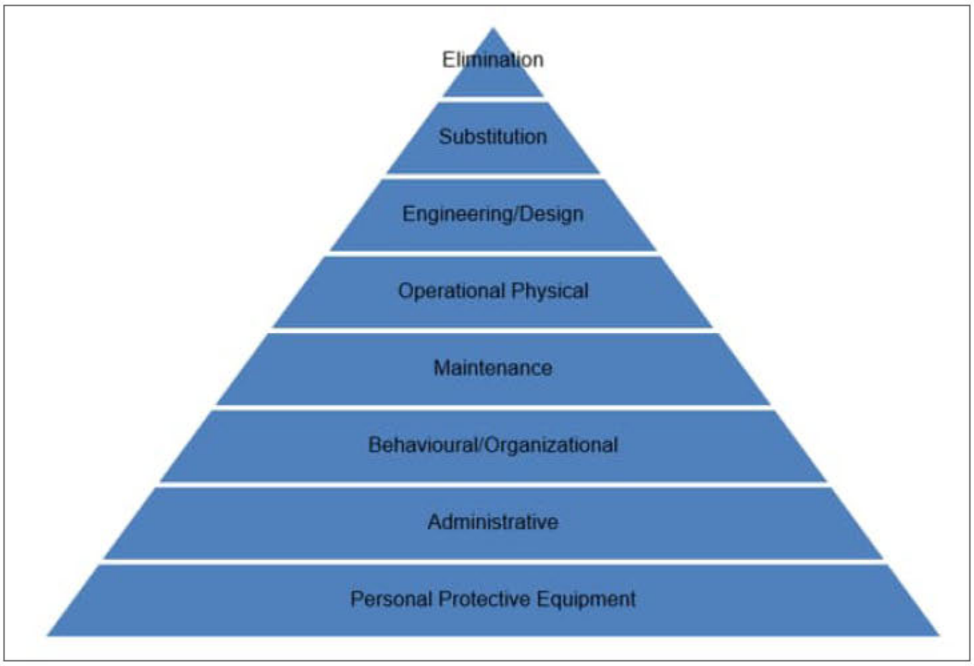

Figure 10-2: Risk Mitigation Hierarchy

For a summary of proposed mitigation actions, refer to Appendix A, and for the detailed HAZID Register spreadsheet refer to Appendix B.

Appendix E provides HAZOP study Attendance register.

11. Reference Documents

The documents and drawings listed in Table **11-1** below will be referenced, where applicable, during the HAZID.

Table 11-1: Reference Documentation

Document Number	Rev No.	Document or P&ID Description
H374972-0000-210-226-0001	D	Hydrogenation Study Design Basis
H374972-0000-251-272-0001	A	Site Plot Plan

Appendix A
Summary of Proposed Mitigation Actions

These are the recommendations for preventative or corrective actions made as the risks were identified. Note that some of recommendations were made to cover more than one risk.

Preventative or Corrective Action	Related Risk				
	ID No.	Possible & Credible Cause	Likely & Credible Consequences	Initial Risk Rating	Rating On
Ensure vehicle impact protection for pressurized hydrogen storage.	1.01	About 5 tons of Hydrogen is stored at site in cylinders (100 bar g). Loss of containment would create hazardous conditions.	Potential for jet fire that is not visible. Anything subjected to jet fire would have to be inspected for potential repairs. Potential for multiple fatalities if a crews on site were hit by the jet fire. Worst case would be damaging other installations leading into a pool fire.	26	H&S
Consider removing the pressurised hydrogen storage by altering the design (ex. improving ramp rates)	1.02	Pressurized hydrogen is provided by the HGP (30 bar g). Loss of containment would create hazardous conditions with a significant source of heat.	Pressurized tank explosion Potential for multiple fatalities. Significant damage to surrounding plant.	26	H&S
Ensure vehicle impact protection for pressurized hydrogen storage.	1.02	Pressurized hydrogen is provided by the HGP (30 bar g). Loss of containment would create hazardous conditions with a significant source of heat.	Pressurized tank explosion Potential for multiple fatalities. Significant damage to surrounding plant.	26	H&S
Consider routing the feed and product pipes above the road.	1.03	Cracking of pipes under the road at locations that are crossing under roads used by heavy vehicles	Would result in underground leaks. Potential creating a build-up of hydrogen. In the presence of ignition sources, this may explode. This may cause multiple fatalities in case crews are circulating nearby or by projected objects.	20	H&S
Use material with impact toughness properties ASTM A333	1.03	Cracking of pipes under the road at locations that are crossing under roads used by heavy vehicles	Would result in underground leaks. Potential creating a build-up of hydrogen. In the presence of ignition sources, this may explode. This may cause multiple fatalities in case crews are circulating nearby or by projected objects.	20	H&S
Implement hydrogen gas detection under the road (if the pipeline remains under the road).	1.03	Cracking of pipes under the road at locations that are crossing under roads used by heavy vehicles	Would result in underground leaks. Potential creating a build-up of hydrogen. In the presence of ignition sources, this may explode. This may cause multiple fatalities in case crews are circulating nearby or by projected objects.	20	H&S

Preventative or Corrective Action	Related Risk				
	ID No.	Possible & Credible Cause	Likely & Credible Consequences	Initial Risk Rating	Rating On
Place the underground pipelines in a culvert to make inspections easier	1.03	Cracking of pipes under the road at locations that are crossing under roads used by heavy vehicles	Would result in underground leaks. Potential creating a build-up of hydrogen. In the presence of ignition sources, this may explode. This may cause multiple fatalities in case crews are circulating nearby or by projected objects.	20	H&S
Consider removing the pressurized hydrogen storage by altering the design (ex. improving ramp rates)	1.04	Ignition is possible at the hydrogen vent stack by the flare (in cases of high wind directed from the flare to the vent stack). Potentially igniting the hydrogen by a lightning storm.	Resulting in a fire and the heat can cause burns resulting in LTI	14	H&S
Consider adding guard beds at the pre-treatment plant	1.08	Poisoning of the catalyst (Toluene feed) may occur from: - improper cleaning of the bed - possibility of introducing sea water in the tanks storing the toluene - storage issues at the tank	Poisoning potentially with chloride or sulfur. Impacts to production, requiring downtime in the order to 6 weeks considered Major (replace the catalyst and treatment of the contaminated toluene inventory) plus additional costs to replace the catalyst (this event should not result in a thermal runaway)	29	Prod
Follow-up [redacted] on how to clean the contaminated catalyst (toluene and MCH purification)	1.08	Poisoning of the catalyst (Toluene feed) may occur from: - improper cleaning of the bed - possibility of introducing sea water in the tanks storing the toluene - storage issues at the tank	Poisoning potentially with chloride or sulfur. Impacts to production, requiring downtime in the order to 6 weeks considered Major (replace the catalyst and treatment of the contaminated toluene inventory) plus additional costs to replace the catalyst (this event should not result in a thermal runaway)	29	Prod
List the elements providing monitoring of the toluene quality at the TPS	1.08	Poisoning of the catalyst (Toluene feed) may occur from: - improper cleaning of the bed - possibility of introducing sea water in the tanks storing the toluene - storage issues at the tank	Poisoning potentially with chloride or sulfur. Impacts to production, requiring downtime in the order to 6 weeks considered Major (replace the catalyst and treatment of the contaminated toluene inventory) plus additional costs to replace the catalyst (this event should not result in a thermal runaway)	29	Prod

Preventative or Corrective Action	Related Risk				
	ID No.	Possible & Credible Cause	Likely & Credible Consequences	Initial Risk Rating	Rating On
Ensure walkways are delineated and protected from pipe racks	1.09	Steam is produced in each of the reactors of heat exchangers. Loss of containment can take place.	Steam leaks can create severe burns to plant personnel, resulting in permanent disabilities. Loosing cooling capacity can result in damages to the reactors the reaction will reach a stable temperature within the design temperature of the vessel.	23	H&S
Ensure the presence of a pressure relief device	1.10	Loss of boiler feed water circulation at the reactors	Bed overheating resulting in a reactor explosion. Multi fatality event, as well as property damages and loss of production	26	H&S
Validate [redacted] the control of reactor temperature in cases of loss of circulation of water	1.10	Loss of boiler feed water circulation at the reactors	Bed overheating resulting in a reactor explosion. Multi fatality event, as well as property damages and loss of production	26	H&S
Ensure the vent from the condensate tank is routed to a safe location (defined in the next stage)	1.11	In case of tube rupture or leak in one of the exchangers, steam side pressure would lower than the process side pressure. MCH and Toluene would backflow into the steam system where it would vaporize and release to atmosphere via the condensate tank. Flammable vapor cloud can be vented in aeras attended by plant personnel.	In case of ignition, there would be a vapor cloud explosion, potentially leading to multiple fatalities	26	H&S
Validate if the Braya refinery full flare is appropriate for the site's protection. Validate if flare studies were performed.	2.02	Braya refinery located 500 m away on the site. Normal operation of the flare.	Heat radiation of the flare creates a potential impact to people (burns and LTI)	19	H&S
Consider a spare load of catalyst.	5.06	Power could be lost locally within this site, while hydrogen is still fed to the reactors.	Sudden loss of feed rate to the reactors and [redacted] system. Liquid stagnant in the reactors could lead to coking of the catalyst in hot conditions. Resulting in a shutdown of the plant while the catalyst is replaced (about 3 weeks to procure and 3 weeks to replace)	29	Prod

Preventative or Corrective Action	Related Risk				
	ID No.	Possible & Credible Cause	Likely & Credible Consequences	Initial Risk Rating	Rating On
Add the make up compressor on emergency power.	5.06	Power could be lost locally within this site, while hydrogen is still fed to the reactors.	Sudden loss of feed rate to the reactors and [redacted] system. Liquid stagnant in the reactors could lead to coking of the catalyst in hot conditions. Resulting in a shutdown of the plant while the catalyst is replaced (about 3 weeks to procure and 3 weeks to replace)	29	Prod

Appendix B
HAZID Study Minutes

[redacted] North Atlantic Refining Corporation - Pre-FEED End-to-End Hydrogen Value Chain

HAZID Risk Register - Hydrogenation Plant

Line No.	Hazard	Possible & Credible Cause	Likely & Credible Consequences	Existing Safeguards	C1	L1	Initial Risk Rating	Rating On	Preventative or Corrective Action	Comments
1	**Material Related Hazards**									
1.01	**Process Materials & Flow Sheets {Are there any hazards during storage/ transportation of materials?}**	About 5 tons of Hydrogen is stored at site in cylinders (100 bar g). Loss of containment would create hazardous conditions.	Potential for jet fire that is not visible. Anything subjected to jet fire would have to be inspected for potential repairs. Potential for multiple fatalities if a crews on site were hit by the jet fire. Worst case would be damaging other installations leading into a pool fire.	The layout with distances and protections for vehicle impacts. Material selection for cylinders, meeting ASME & CSA B51 requirements. Fire detection and protection (water). Leak detection on pipe racks Piping welded (instead of flanged)	**6**	**2**	**26**	H&S	Ensure vehicle impact protection for pressurized hydrogen storage.	
1.02	**Process Materials & Flow Sheets {Are there any hazards during storage/ transportation of materials?}**	Pressurized hydrogen is provided by the HGP (30 bar g). Loss of containment would create hazardous conditions with a significant source of heat.	Pressurized tank explosion Potential for multiple fatalities. Significant damage to surrounding plant.	Overpressure protection All tanks have overpressure protection. Tank storage requirements compliant with ASME & CSA B51. Drainage system for pool fire. Fire detection and suppression on tanks.	**6**	**2**	**26**	H&S	Ensure vehicle impact protection for pressurized hydrogen storage. Consider removing the pressurised hydrogen storage by altering the design (ex. improving ramp rates)	
1.03	**Process Materials & Flow Sheets {Are there any hazards during storage/ transportation of materials?}**	Cracking of pipes under the road at locations that are crossing under roads used by heavy vehicles	Would result in underground leaks. Potential creating a build-up of hydrogen. In the presence of ignition sources, this may explode. This may cause multiple fatalities in case crews are circulating nearby or by projected objects.	Use of standards for the design of underground piping. Leak detection on pipe rack. Complying with regulations imposes to inspect the pipeline road crossing.	**6**	**1**	**20**	H&S	Consider routing the feed and product pipe above the road. Use material with impact toughness properties ASTM A333 Implement hydrogen gas detection under the road (if the pipeline remains under the road). Place the underground pipeline in a culvert to make inspections easier	
1.04	**Process Materials & Flow Sheets {What potential fire can occur, is there a fire philosophy in place?}**	Ignition is possible at the hydrogen vent stack by the flare (in cases of high wind directed from the flare to the vent stack). Potentially igniting the hydrogen by a lightning storm.	Resulting in a fire and the heat can cause burns resulting in LTI	Spacing and distance in the design of the flare and stack. Vent normally not in use	**4**	**2**	**14**	H&S	Consider removing the pressurized hydrogen storage by altering the design (ex. improving ramp rates)	

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HAZID Risk Register - Hydrogenation Plant

Line No.	Hazard	Possible & Credible Cause	Likely & Credible Consequences	Existing Safeguards	C1	L1	Initial Risk Rating	Rating On	Preventative or Corrective Action	Comments
1.05	**Process Materials & Flow Sheets {Is there a hazard due to loss of containment?}**	Toluene and MCH are handled at site. Loss of containment is possible	Pool fire, damaging the installation. This can result in a single fatality.	Drainage design to prevent a liquid pool, routed to a retention pond. Level and pressure detection on vessels would alarm operators to leaks. Fire gas detection. Fire water protection system to prevent escalation. Routine inspection by plant personnel.	**5**	**2**	**23**	H&S	ALARP based on industry practices	
1.06	**Process Materials & Flow Sheets {Is there a hazard due to loss of containment?}**	By-product storage (diesel blending, gasoline blending) could suffer loss of containment	Pool fire, damaging the installation. This can result in a single fatality.	By products located in a dedicated bund for the 2 tanks. Level detection on vessels would alarm operators to leaks. Fire gas detection. Fire water protection system to prevent escalation. Routine inspection by plant personnel.	**5**	**2**	**23**	H&S	ALARP based on industry practices	
1.07	**Process Materials & Flow Sheets {Is there a hazard due to loss of containment?}**	Gas is produced at toluene pre-treatment station and is combustible. A loss of containment combined with an ignition source may take place.	Refer to hydrogen jet fire or explosions scenarios in #1.01 and 1.02	N/A	N/A	N/A	N/A	N/A	N/A	
1.08	**Process Materials & Flow Sheets {Are process materials compatible?}**	Poisoning of the catalyst (Toluene feed) may occur from: - improper cleaning of the bed - possibility of introducing sea water in the tanks storing the toluene - storage issues at the tank	Poisoning potentially with chloride or sulfur. Impacts to production, requiring downtime in the order to 6 weeks considered Major (replace the catalyst and treatment of the contaminated toluene inventory) plus additional costs to replace the catalyst (this event should not result in a thermal runaway)	Sampling program applied to the supply of toluene. In cases of slow burn, temperature profiles can provide hints to operators	**5**	**4**	**29**	Prod	Consider adding guard beds at the pre-treatment plant Follow-up [redacted] on how to clean toe contaminated catalyst (toluene and MCH purification) List the elements providing monitoring of the toluene quality at the TPS	
1.09	**Process Materials & Flow Sheets {Is there a hazard due to loss of containment?}**	Steam is produced in each of the reactors of heat exchangers. Loss of containment can take place.	Steam leaks can create severe burns to plant personnel, resulting in permanent disabilities. Loosing cooling capacity can result in damages to the reactors the reaction will reach a stable temperature within the design temperature of the vessel.	Material selection for steam systems. Piping is routed on racks. Pressure detection is interlocked to system shutdown. Compliance with pressure vessel act CSA B51 PPE is mandatory for operators	**5**	**2**	**23**	H&S	Ensure walkways are delineated and protected from pipe racks	

[redacted] North Atlantic Refining Corporation - Pre-FEED End-to-End Hydrogen Value Chain

HAZID Risk Register - Hydrogenation Plant

Line No.	Hazard	Possible & Credible Cause	Likely & Credible Consequences	Existing Safeguards	C1	L1	Initial Risk Rating	Rating On	Preventative or Corrective Action	Comments
1.10	**Process Materials & Flow Sheets {What provisions are made to prevent runaway reaction?}**	Loss of boiler feed water circulation at the reactors	Bed overheating resulting in a reactor explosion. Multi fatality event, as well as property damages and loss of production	Temperature monitoring in the reactor as well as the cooling water temperature. Monitoring the hydrogen flowrate to the reactor. Pressure monitoring in the system.	6	2	26	H&S	Ensure the presence of a pressure relief device Validate [redacted] control of reactor temperature in cases of loss of circulation of water	
1.11	**Process Materials & Flow Sheets {Is there a hazard due to loss of containment?}**	In case of tube rupture or leak in one of the exchangers, steam side pressure would lower than the process side pressure. MCH and Toluene would backflow into the steam system where it would vaporize and release to atmosphere via the condensate tank. Flammable vapor cloud can be vented in aeras attended by plant personnel.	In case of ignition, there would be a vapor cloud explosion, potentially leading to multiple fatalities	Exchangers are designed to CSA B51. Tube to tube sheet is welded. Materials of construction are chosen in order to mitigate damage. Online hydrocarbon analyzer on the steam line, alert operators immediately and allowing for a controlled shutdown and evacuation of the vented area.	6	2	26	H&S	Ensure the vent from the condensate tank is routed to a safe location (defined in the next stage)	
1.12	**Process Materials & Flow Sheets {What potential fire can occur, is there a fire philosophy in place?}**	Components in vapour cloud in the off-gas are normally flared could be unignited if the pilots fail at the flare. Accumulation of a flammable gas cloud.	Resulting in an environmental release, fairly toxic. Vapor cloud dispersion without ignition. Minor impact in terms of environment, health & safety, reputation and regulation	Monitoring program on the flare (optical or other linked to the DCS)	2	2	5	Env	ALARP based on industry practices	
2	**Site or Equipment layout**									
2.01	**Site or Equipment layout {Is the unit location properly done to minimize exposure to public and workers?}**	No material changes to the risk exposure of nearby town and industrial area (1.2 km away) from the existing plant.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
2.02	**Site or Equipment layout {What hazardous adjacent facilities are in close range?}**	Braya refinery located 500 m away on the site. Normal operation of the flare.	Heat radiation of the flare creates a potential impact to people (burns and LTI)	Distance and exclusion zone around the flare.	4	3	19	H&S	Validate if the Braya refinery full flare is appropriate for the site's protection. Validate if flare studies were performed.	
3	**Unit site location**									
3.01	**Unit site location {What external forces or facility could impact the site location?}**	Loss of containment of the materials stored at site (refer to scenario developed above)	Environmental release of liquids (120 m3 is the largest storage tank, about 700 barrels)	Existing drainage and spill containment system at the logistic terminal (bunding capacity in excess of 9000 barrels) Limited inventory within the hydrogen system. Storage tanks design as per API 650.	1	2	2	Env	ALARP based on industry practices	

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HAZID Risk Register - Hydrogenation Plant

Line No.	Hazard	Possible & Credible Cause	Likely & Credible Consequences	Existing Safeguards	C1	L1	Initial Risk Rating	Rating On	Preventative or Corrective Action	Comments
3.02	**Unit site location {Are there any civil construction excavation hazards, related to the site location**	No causes for concern	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
3.03	**Unit site location {Any hazards caused by equipment location which could result in ventilation**	No causes for concern	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
4	**Equipment**									
4.01	**Equipment layout {Are equipment/buildings located at safe distance regarding fire/explosion?}**	Refer to hazards on fire and explosion. Distances will be validated in the next study phase.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
4.02	**Equipment layout {Are there any transportation road/conveyor/rail, shipping air freight hazards?}**	Vehicle impacts covered in #1.01; 1.02 and 1.03	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
4.03	**Equipment layout {Is sufficient equipment accessibility provided for installation and maintenance?}**	Following [redacted] recommended layout, distances will be validated at the next stage.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
4.04	**Equipment layout {Is there adequate access provided for emergency vehicles?}**	Similar to the existing Braya refinery, two excess roads.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
4.05	**Equipment layout {Are sufficient ventilation / purging facilities included into the design?}**	Too early to assess in details, HAZOP will be performed once P&Ids are developed. No concern at this stage.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
4.06	**Equipment layout {Any hazards due to high winds, noise, vibration, etc.?}**	No causes for concern	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
4.07	**Equipment layout {Any hazards due to location which could result in falling objects from conveyors ruptures, hoppers in/on rivers, public roads, community facilities, etc. ?}**	Falling ice will be studied when designing pipe racks (natural consideration)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
4.08	**Maintenance {Accessibility for removing, inspection, testing and/or replacing?}**	Common to similar industrial facilities.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
4.09	**Equipment Compressor {Are air compressor intake protected against contaminants?}**	Too early to assess in details, HAZOP will be performed once P&Ids are developed. No concern at this stage.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
4.10	**Equipment selection {Can the temperature/pressure of equipment exceed the design parameters?}**	Adequate consideration is required on materials of construction. Will be assess in further details in next stages with suppliers.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
4.11	**Equipment selection {Are there any special conditions to consider, isolation, heat exposure or winterization?}**	Covered by the previous scenarios	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
4.12	**Equipment selection {Are stress calculations done and supports/damping systems specified?}**	Adequate consideration is required on materials of construction. Will be assess in further details in next stages with	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
5	**Miscellaneous**									
5.01	**Miscellaneous {Is there sufficient ablution facilities, offices, stores, control rooms, etc.?}**	Office facilities meet building code requirements and occupational safety requirements. On that basis, no causes for concern	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

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HAZID Risk Register - Hydrogenation Plant

Line No.	Hazard	Possible & Credible Cause	Likely & Credible Consequences	Existing Safeguards	C1	L1	Initial Risk Rating	Rating On	Preventative or Corrective Action	Comments
5.02	**Miscellaneous {Any hazards due to falling objects from conveyors, hoppers, bins, etc.?}**	No causes for concern	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
5.03	**Miscellaneous {Are there any waste management or environmental hazards?}**	To be developed in basic engineering, no specific difficulties with the handling of materials, no causes for concern.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
5.04	**Miscellaneous {Are there any static, lightening, thunder, heavy rain, hazards?}**	Adequate grounding in the design as per the Canadian Electrical Code. C5 environment is taken into account in the design. Events are mitigated through current design practices.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
5.05	**Miscellaneous {Are there any hazards regarding operation, training / competency of personnel**	Operations are typical to refinery units, the training requirements are similar to other industrial site. Personnel with such training is common within the local labor pool. Hiring and procurement practices validate that plant personnel and service contractors are competent in line with regulations.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
5.06	**Miscellaneous {Electrical power supply availability for propose equipment/site location? }**	Power could be lost locally within this site, while hydrogen is still fed to the reactors.	Sudden loss of feed rate to the reactors and [redacted] system. Liquid stagnant in the reactors could lead to coking of the catalyst in hot conditions. Resulting in a shutdown of the plant while the catalyst is replaced (about 3 weeks to procure and 3 weeks to replace)	Emergency depressurizing system.	5	4	**29**	Prod	Consider a spare load of catalyst. Add the make up compressor on emergency power.	
5.07	**Miscellaneous {Are sufficient utilities e.g. water, raw material available based on site location?}**	Any event of nitrogen loss would only impact the ability of proceeding to maintenance purging.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
5.08	**Miscellaneous {Are sufficient utilities e.g. water, raw material available based on site location?}**	Any event of instrument air loss, would result in minor production losses. No issues for concern.	N/A	Remote blow down can be performed on the reactors to depressurize them.	N/A	N/A	N/A	N/A	N/A	
5.09	**Miscellaneous {Legal impact and considerations based on process flow data and site location?}**	Located within the Braya refinery, no issues for concern	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

[redacted] North Atlantic Refining Corporation - Pre-FEED End-to-End Hydrogen Value Chain

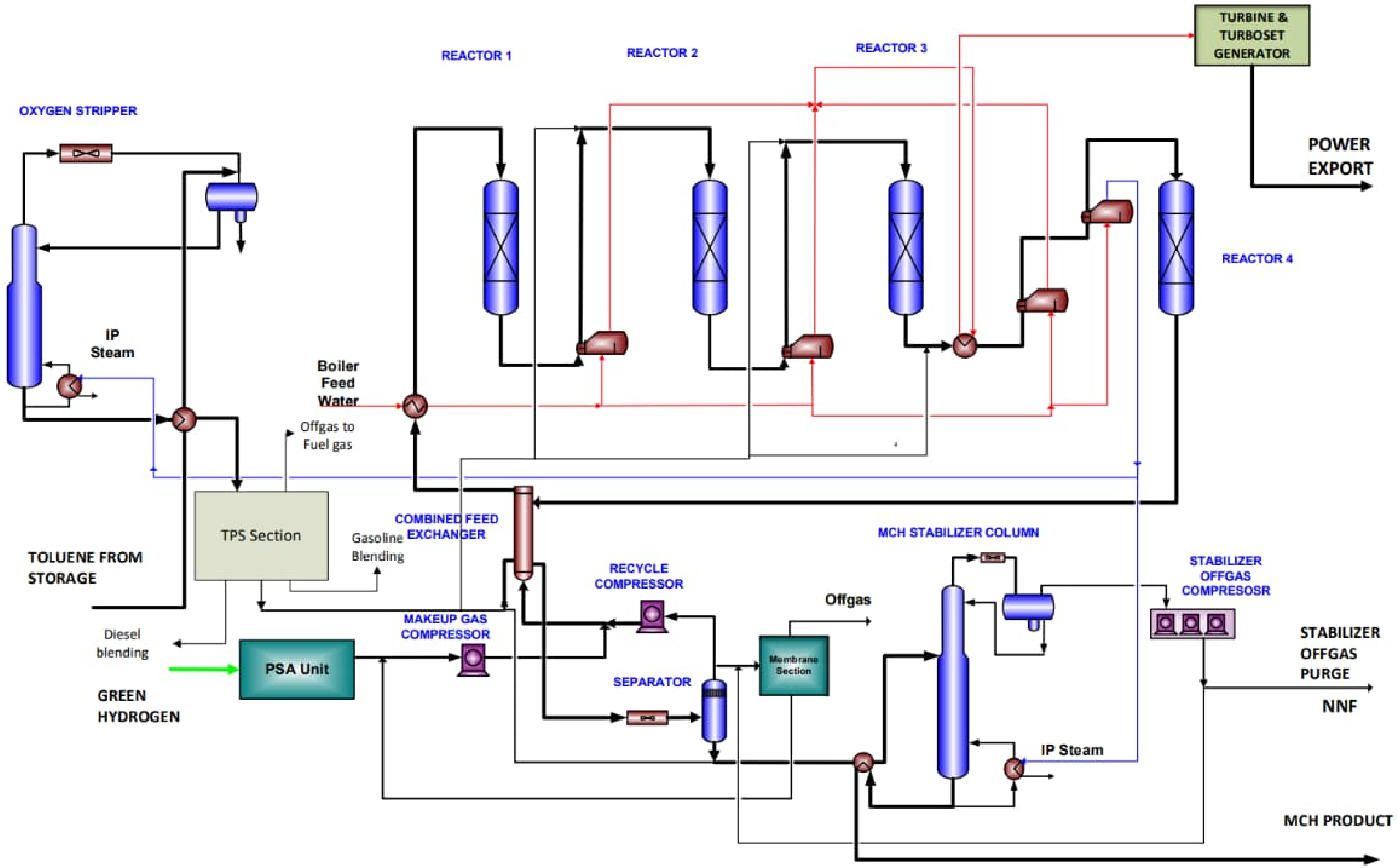
HAZID Risk Register - Hydrogenation Plant

Line No.	Hazard	Possible & Credible Cause	Likely & Credible Consequences	Existing Safeguards	C1	L1	Initial Risk Rating	Rating On	Preventative or Corrective Action	Comments
5.10	**Miscellaneous {Confined space entry, congestion, equipment movement, heavy vehicles, etc.?}**	Leveraging the use of non intrusive inspection technologies. Confined space entry is a common hazard in this industry, respecting standard operating practices. All activities on site required vehicle movements, follow authorizations. Circulation layout planned accordingly. Collisions with installations are covered in hazards #1.01, 1.02 and 1.03.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
5.11	**Miscellaneous {Are there any security system hazards due to site or equipment location?}**	All within the existing fence line at the Braya refinery. No causes for concern.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

Appendix C
Parking Lot

Item	Description
1	Hydrogen Generation Plant: ensure that sufficient protection exist to prevent significant quantity of oxygen to be fed to the Hydrogenation facility. Confirm the location of the deoxo/dryer.
2	Consider, in the material selection, if there is value in specifying materials to meet ISO 15156 (protection against stress corrosion cracking)
3	Ensure that the existing snow plowing program is extended to cover the hydrogenation site

Appendix D
[redacted] Toluene Hydrogenation Schematic


TURBINE & TURBOSET GENERATOR
REACTOR 1
REACTOR 2
REACTOR 3
OXYGEN STRIPPER
POWER EXPORT
REACTOR 4
IP Steam
Boiler Feed Water
Offgas to Fuel gas
TPS Section
Gasoline Blending
COMBINED FEED EXCHANGER
MCH STABILIZER COLUMN
TOLUENE FROM STORAGE
RECYCLE COMPRESSOR
STABILIZER OFFGAS COMPRESOSR
Offgas
MAKEUP GAS COMPRESSOR
Diesel blending
PSA Unit
Membrane Section
STABILIZER OFFGAS PURGE
GREEN HYDROGEN
SEPARATOR
NNF
IP Steam
MCH PRODUCT

Appendix E
HAZID Attendance Register

Name	Organization	2025-01-10	2025-01-14	2025-01-15
Jeff Murphy	NARC	✔	✔	✔
Jenna Broders	NARC	✔	✔	✔
Sid Cherukupalli	MC	✔	✔	✔
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]		[redacted]	[redacted]
[redacted]	[redacted]		[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]			✔
Kathleen O'Grady	Hatch	✔	✔	✔
Karry McKenna	Hatch	✔	✔	✔
Ross Haimes	Hatch	✔	✔	✔
Sean Keay	Hatch	✔	✔	✔
Bir Khanqura	Hatch		✔	✔
Nuru Kimayo	Hatch		✔	
Loïc Reny	Hatch	✔	✔	✔