DET NORSKE VERITAS™

Report

HAZID - METHANOL DISTRIBUTION FOR CLEAN-COOK STOVES

SHELL INTL EXPLORATION & PRODUCTION BV

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MANAGING RISK

HAZID - Methanol Distribution for Clean-Cook Stoves

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Summary:
Project Gaia, Inc. has been part of a global initiative promoting the use of ethanol and methanol as clean-cooking fuels that can supplant traditional solid fuels and hydrocarbon or petroleum fuels cost-effectively. Shell has been in discussion with Project Gaia, Inc. about using methanol from natural gas production as a fuel for clean-cook stoves in developing countries. This report presents the results of a DNV facilitated and recorded HAZID session for a proposed methanol distribution concept by Shell.

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☐ Unrestricted distribution (internal and external)
☐ Unrestricted distribution within DNV
☐ Limited distribution within DNV after 3 years
☐ No distribution (confidential)
☐ Secret

Keywords
Methanol, natural gas, clean-cook stove

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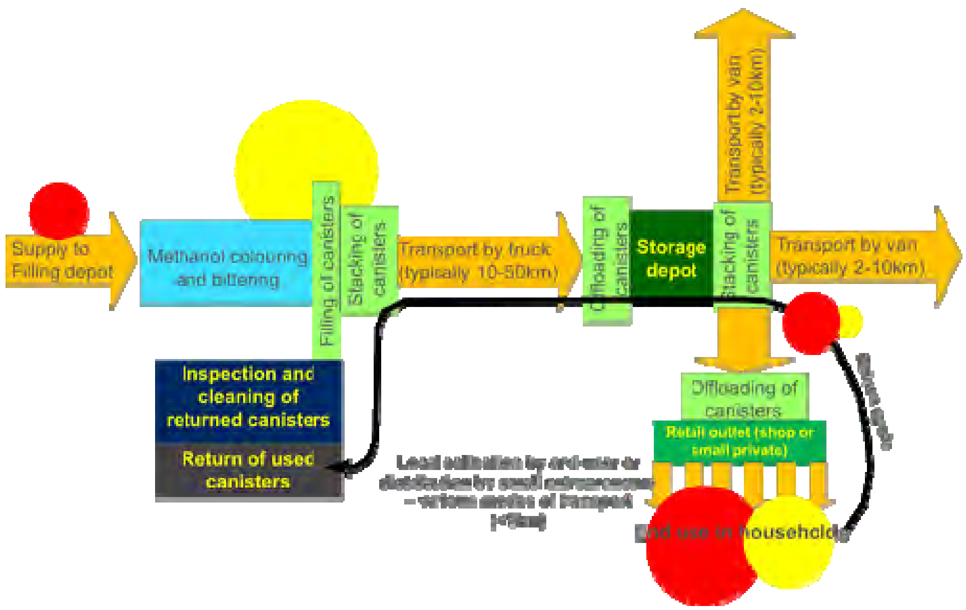
Table of Contents ***Page***

1 EXECUTIVE SUMMARY

Shell International Exploration & Production BV (Shell) has been in discussions with Project Gaia, Inc. (PGI) about creating methanol from natural gas production, and the feasibility of a distribution system for the methanol as a fuel for clean-cook stoves in developing countries.

Det Norske Veritas (U.S.A.), Inc. (DNV) was contacted by PGI initially and subsequently contracted by Shell to facilitate and record a Hazard Identification (HAZID) session for a proposed methanol clean-cook stove distribution concept. The figure below shows the steps of the distribution concept reviewed as well as the distribution of the high (red) and medium (yellow) risks identified in the HAZID session.



The study identified 27 HAZID scenarios and 26 actions. The table below shows the number of risks identified in the HAZID session and their associated ranking.

	1	2		1
		1		1
	1	2		
	2	5		1
		1	3	6

Key conclusions are that the majority of risk and primary focus should be on activities associated with the filling depot and household end use. Remaining risk and focus pertains to transportation (supply to filling depot and return cycle to storage depot).

2 INTRODUCTION

Project Gaia, Inc. (PGI) is part of a global initiative for the development of clean-cooking fuels. It seeks to establish and promote the use of alcohol fuels for household energy for all who have limited access to clean energy. Ethanol and methanol are clean-cooking fuels that can supplant traditional solid fuels and hydrocarbon or petroleum fuels cost-effectively. They can be locally manufactured and commercialized on a small or large scale, from production to end-use.

Shell International Exploration & Production BV (Shell) has been in discussions with PGI about creating methanol from natural gas production, and the feasibility of a distribution system for the methanol as a fuel for clean-cook stoves in developing countries.

Det Norske Veritas (U.S.A.), Inc. (DNV) was contacted by PGI initially and subsequently contracted by Shell to facilitate and record a Hazard Identification (HAZID) session for a proposed methanol clean-cook stove distribution concept. Figure 2-1 shows the distribution concept.

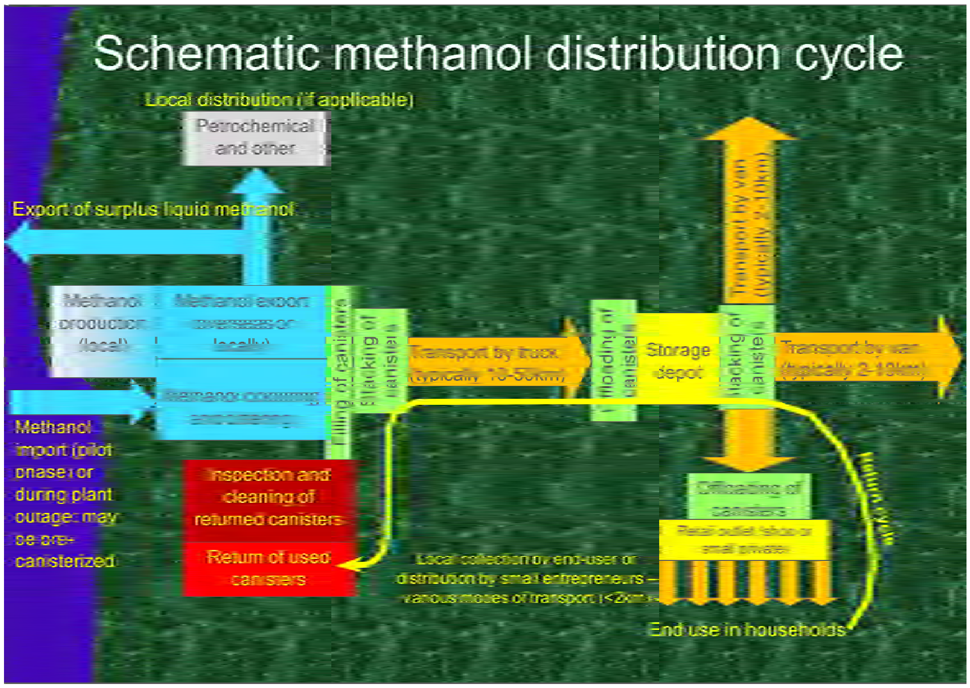


Figure 2-1 Distribution Cycle

The HAZID workshop session was held at the Shell offices in Rijswijk, Netherlands, on 28th February and 1st March, 2013.

This document details the scope of work, objectives, methodology, results and recommendations for the HAZID session.

3 SCOPE AND OBJECTIVES

3.1 Scope of Study

The scope of work was to facilitate and conduct the HAZID for the proposed methanol clean-cook stove distribution cycle (Figure 2-1). The HAZID focused on the distribution cycle beginning with methanol supply to the filling depot through to use in clean-cook stoves at the household and back through the distribution cycle to the filling depot.

The scope included the following steps in the distribution cycle:

- Methanol supply to filling depot
- Adding of colouring / bittering to methanol
- Clean-cook stove canister filling
- Canister stacking / storage at filling depot (full canisters)
- Transport loading at filling depot (full canisters)
- Transport of full canisters to storage depot
- Offloading at storage depot (full canisters)
- Canister stacking / storage at storage depot (full canisters)
- Transport loading at storage depot (full canisters)
- Transport of full canisters to distribution centers
- Distribution to households
- End use in households
- Return to distribution centers (empty canisters)
- Return to storage depot (empty canisters)
- Offloading at storage depot (empty canisters)
- Canister stacking / storage at storage depot (empty canisters)
- Transport loading at storage depot (empty canisters)
- Return to filling depot (empty canisters)
- Canister stacking / storage at storage depot (empty canisters)
- Inspection / cleaning of empty canisters at filling depot

Outside of the scope of the HAZID were the methanol production facility, export of surplus methanol and supply to other facilities (such as chemical plants).

3.2 Objectives

The objectives of the HAZID were to:

- Identify potential hazards scenarios associated with:
  - Methanol toxicity during intended use
  - Methanol toxicity during unintended use
  - Other hazards during intended use
  - Other hazards during unintended use
- Determine the cause(s) and consequences for the hazard scenarios
- Identify any existing controls in place that could mitigate or prevent the hazard scenarios
- Estimate the risk of hazard scenarios utilizing a risk matrix (see Section 4)
- Develop risk mitigation measures and recommend actions for further reduction of estimated risks.

4 HAZID METHODOLOGY

The HAZID methodology employed the following steps:

- Select a distribution cycle step to prompt hazard brainstorming
- Define the activities/equipment involved in the step
- Using guidewords if necessary, brainstorm potential hazards and define scenarios
- Brainstorm potential causes for the hazard scenarios
- Determine the ultimate consequences that could occur, assuming no control in place
- Identify controls to prevent, or mitigate the risk
- Qualitatively assess the severity of consequences using the criteria provided in the risk matrix.
- Qualitatively assess the likelihood of consequences with the identified controls in place using the criteria provided in the risk matrix
- Qualitatively assess the risk of the scenario using the risk ranking matrix. The risk is obtained by matching the severity of the identified consequence without controls against the likelihood of occurrence of the event and its consequence with controls in place
- Make recommendation(s) as necessary to reduce risk and/or to provide a better understanding of the risk

This process was repeated until all of the distribution cycles steps had been analyzed. Findings and actions identified during the HAZID session are listed in Appendix A and in the HAZID worksheets (Appendix B).

4.1 Distribution Cycle Steps

Prior to commencement of the HAZID sessions, the proposed methanol clean-cook stove distribution concept was divided into the distribution cycle steps presented in Section 3.1.

4.2 Guidewords

Guidewords were utilized to assist with hazard scenario brainstorming. Common guidewords represented deviations from normal operation or activities. Deviations helped to stimulate discussion and define hazard scenarios. Table 4-1 lists the guidewords used in the HAZID session.

Table 4-1 HAZID Guidewords

Guidewords
Off-spec supply
Contamination
Improper storage
Lifting injury
Unsecured load
Vehicle accident
Unauthorized filling
Damaged container
Cheaper fuel alternatives
Counterfeit equipment
Sub-standard equipment
Improper disposal
Lack of training
Improper use of fuel
Accidental contact/ingestion/inhalation

4.3 Hazard Scenarios

The combination of distribution cycle steps and guidewords were used to identify hazard scenarios. In some instances, hazard scenarios for cycle steps were essentially identical. Where such instances occurred, the scenario was captured only once for a specific cycle step and cross-referenced in later cycle steps. A barrier diagram (shown in Figure 4-1) was used to help define the difference between a hazard and a hazard scenario.

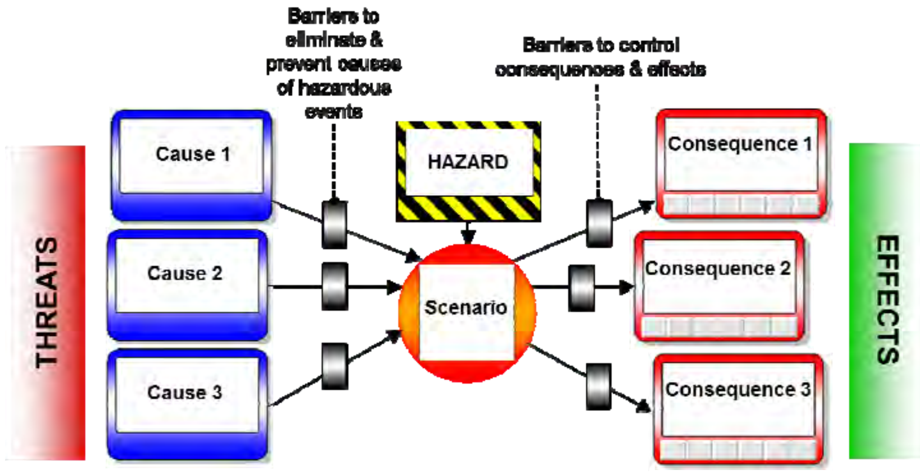


Figure 4-1 Barrier Diagram

4.4 Causes

A cause is an event that permits a threat to become a hazard scenario, such as human error or equipment failures. All potential causes were established for each hazard scenario. The cause was identified within the distribution cycle step being studied. However, the resulting consequence could have impacted other parts of the distribution cycle.

Where multiple causes for a scenario were credible, each cause was listed separately. In some cases, the same cause was identified for multiple scenarios.

4.5 Consequences

The potential consequences for each scenario were discussed and assessed within the limits of the information available and the expertise of the team. The team considered facility layout with respect to potential hazards impacting personnel. The team considered relative location and proximity of personnel to hazardous inventories, flammable materials to ignition sources and other relative hazards. All potential practical consequences of each cause were identified, especially the potential for harm to people and the environment.

4.6 Controls (Barriers)

The team identified the engineered system and administrative controls (such as procedures) that could prevent or mitigate identified hazard scenarios. The controls were measured against each of the consequences and assessed to give the net overall effect. If the controls were inadequate, then recommendations were made to rectify the situation.

4.7 Risk Ranking

In order to facilitate the risk ranking of each scenario, the team discussed and established the 5 x 5 risk matrix shown in Figure 4-2. The consequence severity categories (shown in Figure 4-3) were defined for Asset Damage, People and Environment. The likelihood categories were established as defined in Figure 4-4.

Scenario consequences were unmitigated consequences, namely, those consequences without giving any credit to the controls. The scenario likelihood was determined by considering available controls, recognizing that not all controls listed could be credited in determining the likelihood.

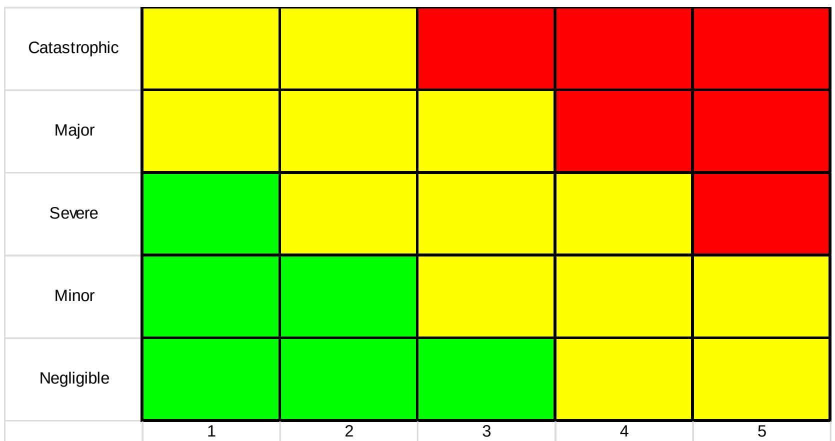


Figure 4-2 Risk Matrix

	Asset Damage	People	Environment
Catastrophic	≥ $1M	Multiple fatalities	Long term external impact requiring remeditation
Major	≥ $100K	Single fatality	Major external impact resulting in restricted access to area for limited time period
Severe	≥ $50K	Serious injury requiring hospitalization or long term health issue	Impact external to controlled facilities requiring cleanup or lasting for days
Minor	≥ $10K	Requires medical attention or short term health issue	Impact external to controlled facilites, no cleanup required
Negligible	<$10K	Minor first aid or no injury	Impact confined to controlled facilities or lasting for a few days

Figure 4-3 Consequence Categories

	1	2	3	4	5
Likelihood	Not known to have occurred	Known to have occurred in other situations	Has occurred in similar situation	Will occur once a year	Will occur multiple times on annual basis
	0.001	0.01	0.1	1	> 1

Figure 4-4 Likelihood Categories

4.8 Actions

For hazard scenarios that were ranked as high risk (red on the risk matrix), actions were captured to:

- Strengthen existing controls or put in place new controls to reduce risk, or
- Provide a better understanding of the risk

Hazard scenarios that were ranked as medium risks (yellow on the risk matrix) were considered to be in the ALARP region, and required capturing any actions that could reduce the risk to As Low As Reasonably Practicable (ALARP).

Hazard scenarios that were ranked as low risks (green on the risk matrix) were considered to be acceptable risks. Where appropriate, some actions were captured to further validate the ranking.

5 HAZID WORKSHOP

The team members and company affiliations of the HAZID workshop are presented below.

Table 5-1 List of HAZID Team Members

Name	Company	Title	28 Feb 2013	01 Mar 2013
Bryce Levett	DNV	Facilitator	✓	✓
Rich Green	DNV	Deputy Director	✓	✓
Ted Örbrink	Dometic	Special Projects	✓	✓
Robert Sagulin	Dometic	New Products	✓	✓
Håvard Norstebo	Green Development	General Manager, Carbon Credits	✓	✓
Greg Dolan	Methanol Institute	Acting CEO	✓	✓
Harry Stokes	PGI	Executive Director	✓	
Brady Luceno	PGI	Assistant Executive Director	✓	✓
Rupert Taylor	Shell	Energy Consultant	✓	✓
Alan Davies	Shell	Venture Implementation Advisor	✓	✓
Marjoke Heneweer	Shell	Toxicologist - Shell Health	✓	✓
Klaus Semmler	Shell	Product Steward, Chemicals	✓	✓
Anna van Remundt	Shell	Social Investment Advisor	✓	✓
Anna Halpern-Lande	Shell	Sr. NBD Manager Upstream	✓	
Sam Aiboni	Shell	Legal Counsel	✓	
Paul Merridan	Shell	Risk & Assurance Manager	✓	
Jeroen Blüm	Shell Foundation	Deputy Director	✓	
Helen Sullivan	Shell	Global Social Investment Manager		✓
Emmanuel Ekpenyong	Shell	SE & SP		✓

6 CONCLUSIONS

Table 6-1 summarizes the total number of risks identified in the HAZID session and their associated ranking.

Table 6-1 HAZID - Risk Ranking Results

	1	2	3	4	5
Catastrophic		1	2		1
Major			1		1
Severe		1	2		
Minor		2	5		1
Negligible			1	3	6

The study identified 27 HAZID scenarios and 26 actions. It is important to note that actions, as referenced in this document, were determined based on the information available to the HAZID team at the time of the review. The HAZID actions are presented in Appendix A, sorted in order of high to low risks. Full details of the hazard scenarios that were discussed by the team are presented in the HAZID worksheets in Appendix B.

Figure 6-1 below shows the distribution of high (red) and medium (yellow) risks across the proposed methanol distribution cycle. 1 high risk was identified for the supply to filling depot. 12 medium risks were identified at the filling depot. 1 high and 1 medium risk were identified for the return cycle to storage depot. 2 high risks and 7 medium risks were identified for household end use.

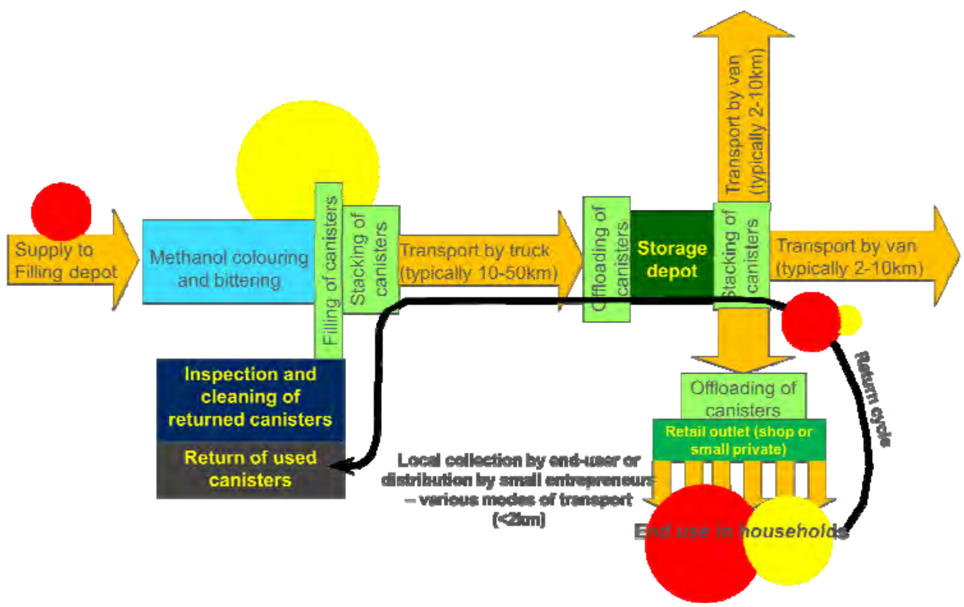


Figure 6-1 Risk Distribution

The key conclusions of the HAZID were:

- The assembled team were knowledgeable of the subject matter reviewed
- Information made available to the team ahead of and during the HAZID was appropriate
- HAZID team contributed openly and effectively during the HAZID
- There were 4 significant hazard scenarios (red on the risk matrix) identified that require review and appropriate action.
    - 2 of the 4 risks pertain to transportation accidents during intended use,
    - The remaining 2 risks pertain to methanol toxicity during unintended use
- There were 20 medium risk hazard scenarios (yellow on the risk matrix) that require a review of recommended actions to determine if risk can be practicably lowered.
    - 9 of the 20 risks pertain to methanol toxicity during intended use
    - 5 of the 20 risks pertain to other hazards during intended use
    - 6 of the 20 risks pertain to other hazards during unintended use
- The majority of risk and primary focus should be on activities associated with the filling depot and household end use
- Remaining risk and focus pertains to transportation (supply to filling depot and return cycle to storage depot)

Appendix A
Recommended Actions

No	Distribution Step	Hazard Scenario	Risk	Actions
22	End use in households	Ingestion of Methanol		Investigate if any additives can be introduced to all supply from Methanol plant that will act as deterrent to illegal use but not interfere with further legal processing. Look at Methanol co-location design with filling depot(s) and secondary processing facilities to reduce the need for bulk transport.
20	End use in households	Refilling of canister in houses with Methanol		Develop education program for use of proper equipment (canisters not refilled in homes). Develop branding that does not associate with liquid methanol. Look at supply cost and regulatory control to minimize/marginalize alternate supply market. Monitor canister return volume for threat of alternate supply.
1	Supply to filling depot	Vehicle accident with bulk transportation of Methanol		1) Co-locate Methanol plant and filling depot(s) where feasible 2) Utilize inherently safer bulk transport (such as rail) where feasible
24	Return to storage depot (empty)	Vehicle accident - applicable for full or empty canister transport		No actions identified in workshop. Review further for appropriate actions to reduce risk.
2	Colouring / bittering	Exposure/inhalation of methanol during adding process		Review exposure scenarios with Industrial Hygienist and develop appropriate procedural controls. Consider automation where practicable as part of control. Consider human factors in design.
3	Colouring / bittering	Exposure to methanol from bulk tank rupture or transfer spill		Review Methanol Plant/Filling Depot location model to minimize number of separate facilities. Research colour used (i.e. red for danger) for most impactful warning based on local culture.
14	End use in households	Exposure (skin contact) to methanol		Investigate modifying mesh (thickness and/or securing to canister) to reduce potential skin contact.
4	Canister filling	Exposure to methanol from transfer spill		Review exposure scenarios with Industrial Hygienist and develop appropriate procedural controls. Consider automation where practicable as part of control. Consider human factors in design.
5	Canister filling	Exposure to methanol during repair and maintenance of equipment		Consider design of maintenance requirements for safety without PPE or limited duration PPE to minimize exposure risk
6	Canister stacking / storage (full)	Exposure to methanol inhalation from either overstacked/crushed canisters or from storage without lids		Consider design of storage facility for ventilation and safety without PPE. Consider open storage facility to eliminate vapour build up.
7	Canister stacking / storage (full)	Lifting injury		Consider human factors in design of storage/stacking. Consider automation where practicable.
9	Canister stacking / storage (full)	Exposure to solar radiation		Test canister for exposure to solar radiation and pressure build up. Test using both Methanol and Ethanol.
10	Transport loading (full)	Lifting injury		Consider human factors in design of transfer. Consider automation or lift assist equipment where practicable.
11	Transport loading (full)	Dropping of large quantity of canisters (palletized)		Consider human factors in design of transfer. Consider minimizing human presence during transfer where practicable.
27	Inspection / cleaning of empty canisters	Damaged canister placed back in supply cycle		Develop inspection protocols including automation where practicable.
15	End use in households	Exposure (inhalation) to methanol		Investigate snap-on lid design that can be re-applied to partial empty canisters. Investigate evaporation volume of empty canisters.

No	Distribution Step	Hazard Scenario	Risk	Actions
16	End use in households	Low visibility flame		Investigate chemical additive to make flame more visible, potential dual purpose for added colourant. Consider labeling to warn of low flame visibility.
19	End use in households	Operating with sub-standard equipment		Investigate return program (credit) for worn stoves. Develop education program for use of proper equipment. Work with regulators/local authorities to police inferior/counterfeit equipment.
21	End use in households	Refilling of canister in houses with alternate fuel		Design and perform test on canisters with alternate fuels to verify consequence. Develop education program for use of proper fuel.
23	Return to storage depot (empty)	Increased target for theft		Investigate alternate supply chain examples for crediting without cash exchange - eliminate drivers carrying large amounts of cash.
25	Inspection / cleaning of empty canisters	Inhalation or skin contact with Methanol		Review exposure scenarios with Industrial Hygienist and develop appropriate procedural controls. Consider automation where practicable as part of control. Consider human factors in design.
17	End use in households	Operating damaged stove resulting in malfunction		Design and perform drop test on stoves. Investigate return program (credit) for worn stoves.
18	End use in households	Operating stove with offset/unsecured canister		Investigate design improvement to eliminate incorrect assembly
26	Inspection / cleaning of empty canisters	Return of canister partially filled with foreign substance		Develop canister inspection/cleaning procedures for proper handling/disposal of unknown substance in returned canisters. Develop waste disposal plan for damaged canisters, damaged stoves and canister residuals.
8	Canister stacking / storage (full)	External fire in storage facility or impacting storage facility		Test canister for exposure to external fire and consequence. Determine potential regulations on storage quantities and develop (if necessary) storage quantity specifications and appropriate labeling. Review European and US regulations (27 CFR) for examples.
13	Transport to storage depot	Exposure to solar radiation		Test canister for exposure to solar radiation and pressure build up. Test using both Methanol and Ethanol.

Appendix B
HAZID Worksheets

No	Distribution Step	Hazard Scenario	Causes	Consequences	Existing Controls	Severity	Likelihood	Risk	Actions	Comments
1	Supply to filling depot	Vehicle accident with bulk transportation of Methanol	Methanol plant and filling depot(s) not co-located	Large release, potential multiple fatalities or injuries from either crash or exposure to spill	1) Road transportation standards and regulations 2) Driver fatigue management 3) Transportation vendor qualification	Catastrophic	3		1) Co-locate Methanol plant and filling depot(s) where feasible 2) Utilize inherently safer bulk transport (such as rail) where feasible	Transport by rail inherently safer than trucks
2	Colouring / bittering	Exposure/inhalation of methanol during adding process	Improper PPE and manual process for adding colouring/bittering	Potential single fatality	1) PPE 2) 8 hour exposure limits 3) Acute (15 min) exposure limits	Major	3		Review exposure scenarios with Industrial Hygienist and develop appropriate procedural controls. Consider automation where practicable as part of control. Consider human factors in design.	
3	Colouring / bittering	Exposure to methanol from bulk tank rupture or transfer spill	Equipment failure or operational error	Potential multiple fatalities from skin contact or inhalation	1) Bulk tank storage design 2) Tank storage maintenance 3) Transfer protocol and training 4) PPE 5) Emergency response plan	Catastrophic	2		Review Methanol Plant/Filling Depot location model to minimize number of separate facilities. Research colour used (i.e. red for danger) for most impactful warning based on local culture.	Also applicable for filling step
4	Canister filling	Exposure to methanol from transfer spill	Improper PPE and manual process for filling	Potential serious injury	1) PPE 2) Emergency response plan 3) Transfer protocol and training	Severe	3		Review exposure scenarios with Industrial Hygienist and develop appropriate procedural controls. Consider automation where practicable as part of control. Consider human factors in design.	

No	Distribution Step	Hazard Scenario	Causes	Consequences	Existing Controls	Severity	Likelihood	Risk	Actions	Comments
5	Canister filling	Exposure to methanol during repair and maintenance of equipment	Improper PPE	Potential serious injury	1) PPE 2) Emergency response plan 3) Maintenance protocol and training	Severe	3		Consider design of maintenance requirements for safety without PPE or limited duration PPE to minimize exposure risk	
6	Canister stacking / storage (full)	Exposure to methanol inhalation from either overstacked/crushed canisters or from storage without lids	Improper storage	Potential serious injury or explosion from vapour build up in storage facility	1) Industry standards for storage facility	Severe	2		Consider design of storage facility for ventilation and safety without PPE. Consider open storage facility to eliminate vapour build up.	Applicable to both filling depot and storage depot
7	Canister stacking / storage (full)	Lifting injury	Improper lifting during manual transfer	Potential injury requiring medical attention	1) Proper lifting procedures and training	Minor	3		Consider human factors in design of storage/stacking. Consider automation where practicable.	Applicable to both filling depot and storage depot
8	Canister stacking / storage (full)	External fire in storage facility or impacting storage facility	Flammable products stored nearby or fire caused by maintenance activity (hot work)	Additional fuel for fire causing increased intensity and duration	1) Industry standards for storage facility	Minor	2		Test canister for exposure to external fire and consequence. Determine potential regulations on storage quantities and develop (if necessary) storage quantity specifications and appropriate labeling. Review European and US regulations (27 CFR) for examples.	Applicable to both filling depot and storage depot
9	Canister stacking / storage (full)	Exposure to solar radiation	Storage in open without roof or shade	Potential vapour build-up and release in canister. Degradation of canister lid.		Minor	3		Test canister for exposure to solar radiation and pressure build up. Test using both Methanol and Ethanol.	Applicable to both filling depot and storage depot
10	Transport loading (full)	Lifting injury	Improper lifting during manual transfer	Potential injury requiring medical attention	1) Proper lifting procedures and training	Minor	3		Consider human factors in design of transfer. Consider automation or lift assist equipment where practicable.	Applicable to both filling depot and storage depot

No	Distribution Step	Hazard Scenario	Causes	Consequences	Existing Controls	Severity	Likelihood	Risk	Actions	Comments
11	Transport loading (full)	Dropping of large quantity of canisters (palletized)	Operator error	Potential injury requiring medical attention	1) Proper lifting procedures and training	Minor	3		Consider human factors in design of transfer. Consider minimizing human presence during transfer where practicable.	
12	Transport to storage depot	Dropping of large quantity of canisters (palletized)	Improper securing of load on transport	Potential injury requiring medical attention	1) Load securing procedures	Minor	2			
13	Transport to storage depot	Exposure to solar radiation	Transport in open without roof or shade	Potential vapour build-up and release in canister.		Negligible	3		Test canister for exposure to solar radiation and pressure build up. Test using both Methanol and Ethanol.	
	Offloading (full)	Offloading (full) at storage depot - same risks as Transport loading at filling depot see Hazards 10, 11								
	Distribution to households	No identified hazards								
14	End use in households	Exposure (skin contact) to methanol	Touching opening on uncovered canister	Potential secondary ingestion or transfer to others (additional skin contact)	1) Bitrex deterrent to significant ingestion	Minor	5		Investigate modifying mesh (thickness and/or securing to canister) to reduce potential skin contact.	Quantities of methanol are not significant enough to cause health issues through ingestion or skin contact
15	End use in households	Exposure (inhalation) to methanol	Uncovered (removed lid) canisters or vapour build up and release from improper storage	Insignificant amount of vapour build up. No potential injury		Negligible	5		Investigate snap-on lid design that can be re-applied to partial empty canisters. Investigate evaporation volume of empty canisters.	Empty canisters still have residual fuel that can evaporate

No	Distribution Step	Hazard Scenario	Causes	Consequences	Existing Controls	Severity	Likelihood	Risk	Actions	Comments
16	End use in households	Low visibility flame	Methanol has low visibility flame	Potential minor burn injury	1) Stove design with flame spreader for visibility	Negligible	5		Investigate chemical additive to make flame more visible, potential dual purpose for added colourant. Consider labeling to warn of low flame visibility.	
17	End use in households	Operating damaged stove resulting in malfunction	Dropped stove	Fire and potential minor burn injury	1) Robust design	Negligible	4		Design and perform drop test on stoves. Investigate return program (credit) for worn stoves.	
18	End use in households	Operating stove with offset/unsecured canister	Improper canister loading	Fire and potential minor burn injury		Negligible	4		Investigate design improvement to eliminate incorrect assembly	
19	End use in households	Operating with sub-standard equipment	Counterfeit or damaged/worn equipment	Fire and potential minor burn injury		Negligible	5		Investigate return program (credit) for worn stoves. Develop education program for use of proper equipment. Work with regulators/local authorities to police inferior/counterfeit equipment.	5 to 6 year design life for aluminium body
20	End use in households	Refilling of canister in houses with Methanol	Alternate market supply of bottled methanol	Accidental ingestion and potential fatality	1) Bitrex deterrent to significant ingestion for bulk supply from Methanol plant to filling depot(s)	Major	5		Develop education program for use of proper equipment (canisters not refilled in homes). Develop branding that does not associate with liquid methanol. Look at supply cost and regulatory control to minimize/marginalize alternate supply market. Monitor canister return volume for threat of alternate supply.	
21	End use in households	Refilling of canister in houses with alternate fuel	Canister cost or supply issue driving use of alternate fuel	Larger flame with less control. Potential fire.		Negligible	5		Design and perform test on canisters with alternate fuels to verify consequence. Develop education program for use of proper fuel.	

No	Distribution Step	Hazard Scenario	Causes	Consequences	Existing Controls	Severity	Likelihood	Risk	Actions	Comments
22	End use in households	Ingestion of Methanol	Illegal/counterfeit source for alcoholic beverages	Potential multiple fatality	1) Bitrex deterrent to significant ingestion for bulk supply from Methanol plant to filling depot(s)	Catastrophic	5		Investigate if any additives can be introduced to all supply from Methanol plant that will act as deterrent to illegal use but not interfere with further legal processing. Look at Methanol co-location design with filling depot(s) and secondary processing facilities to reduce the need for bulk transport.	
	Return to distribution centers (empty)	No identified hazards								
23	Return to storage depot (empty)	Increased target for theft	Driver carrying cash for returns	Potential personal injury		Negligible	5		Investigate alternate supply chain examples for crediting without cash exchange - eliminate drivers carrying large amounts of cash.	
24	Return to storage depot (empty)	Vehicle accident - applicable for full or empty canister transport	Driver fatigue, road conditions	Potential multiple fatalities or injuries from either crash	1) Road transportation standards and regulations 2) Driver fatigue management 3) Transportation vendor qualification	Catastrophic	3		No actions identified in workshop. Review further for appropriate actions to reduce risk.	
	Offloading (empty)	Offloading (empty) at storage depot - same risks as Transport loading at filling depot see Hazards 10, 11								
	Transport loading (empty)	Same risks as Transport loading (full) see Hazards 10, 11								

No	Distribution Step	Hazard Scenario	Causes	Consequences	Existing Controls	Severity	Likelihood	Risk	Actions	Comments
	Canister stacking / storage (empty)	Same risks as Canister stacking / storage (full) see Hazards 6, 7, 8, 9								
	Return to filling depot (empty)	Same risks as Transport to storage depot with full canisters see Hazards 12, 13								
25	Inspection / cleaning of empty canisters	Inhalation or skin contact with Methanol	Improper PPE and manual process	Negligible injury due to exposure		Negligible	5		Review exposure scenarios with Industrial Hygienist and develop appropriate procedural controls. Consider automation where practicable as part of control. Consider human factors in design.	
26	Inspection / cleaning of empty canisters	Return of canister partially filled with foreign substance	Improper receipt of returned canisters	Potential exposure hazard or environmental hazard from disposal	1) Canister return procedures	Negligible	4		Develop canister inspection/cleaning procedures for proper handling/disposal of unknown substance in returned canisters. Develop waste disposal plan for damaged canisters, damaged stoves and canister residuals.	
27	Inspection / cleaning of empty canisters	Damaged canister placed back in supply cycle	Improper inspection	Potential malfunction in stove - possible fire		Minor	3		Develop inspection protocols including automation where practicable.	

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