4 Square Engineering Consultancy Limited

HAZOP Study for the Refrigerant Transfer Package

Report provided for: GAP Group

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Prepared by:

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1.0 SUMMARY

This Refrigerant Transfer Package HAZOP study was carried out to assess the potential hazards and operability issues associated with the operation of the new transfer package being installed.

The HAZOP study generated twelve recommendations for further analysis or additional control & mitigation measures.

Where possible, each identified cause / consequence scenario was allocated a likelihood and severity value to ascertain the perceived risk level present. The risk criteria adopted for the purposes of prioritising and measuring risk is detailed in this document.

The HAZOP study was held on Friday 6th May 2022.

2.0 INTRODUCTION

2.1 GAP Gateshead Refrigerant Transfer Package

The new package is designed to transfer the refrigerant contents of 1-tonne “bombs” into an isotanker. The tanker has a volume of approximately 22m^3. The intended operation of the system is to decant twenty bombs and then transport the tanker elsewhere for recycling.

2.2 HAZOP Scope

The HAZOP study examined the potential hazards associated with the operation of the transfer package.

2.3 HAZOP Study Format

The HAZOP was carried out and recorded using a proprietary HAZOP software package (PHA Pro 8). The worksheets produced from this package are included below. This is in tabular form and records the hazards, deviations, safeguards and recommendations noted during the formal assessment session.

3.0 HAZOP RECOMMENDATIONS

Recommendations	Place(s) Used	Maximum Current Risk Ranking	Responsibility	Due Date
1. Confirm hoses are fitted with valves at the end to minimise volume of gas released at each operation.	Consequences: 1.13.1.1, 2.11.1.1, 3.13.1.1, 3.14.2.1	R		
2. Confirm how pump startup is to be controlled in practice.	Consequences: 1.13.2.1, 2.11.2.1	C		
3. Complete DSEAR review.	Consequences: 1.14.1.1, 2.12.1.1	R		
4. Consider installation of weigh scales to confirm cylinder is being emptied.	Consequences: 2.4.1.1, 2.4.1.2, 2.7.1.1, 2.7.2.1, 2.7.3.1	C		
5. Confirm maximum physical head pressure capability of pump / motor set.	Consequences: 2.5.1.1, 2.5.2.1	R		
6. Confirm SIL rating / requirement of high pressure trip safety instrumented system.	Consequences: 2.5.2.1	R		
7. Confirm contents of "empty" iso-tanks when delivered.	Consequences: 2.6.1.1	C		
8. Confirm only CompEx-trained personnel will carry out intrusive maintenance / inspection on ATEX-certified equipment.	Consequences: 2.6.1.2	R		
9. Confirm scales are ATEX-certified.	Consequences: 2.7.1.1, 2.7.2.1, 2.7.3.1	C		
10. Consider installation of excess flow valves in system to protect against full bore release from equipment / hose failure.	Consequences: 2.9.1.1, 3.11.1.1	R		
11. Confirm tank is fitted with level instrumentation and associated pump trip interlock.	Consequences: 3.7.1.1	R		
12. Confirm isotank will be connected to plant earthing system prior to fluid flow occurring.	Consequences: 3.14.2.1	R		

4.0 HAZOP ADMINISTRATION

4.1 Team Members

First Name	Last Name	Title	Company/Department
William	Rose	HAZOP Facilitator	4 Square Engineering
Matthew	Cullen	Graduate Process Safety Engineer	4 Square Engineering
Ian	Bell	Process Engineer	IMBNZ
William	Nicholson	Mechanical Engineer	IMBNZ
Andy	Wiltshire	Director	GAP-Ice
Peter	Young	Director	GAP-Ice
Garry	Harbottle	Director	GAP-Ice

4.2 Drawings

Document Number	Rev.	Place(s) Used
IMB-PID-001-A1	A1	Nodes: 1, 2, 3

5.0 HAZOP STUDY DATA

5.1 HAZOP Nodes

Nodes	Type	Design Conditions/Parameters	Drawings / References	Equipment		Comment
				Tag	Description	
1. Cylinder discharge / pump suction	Drum Line Vessel	Cylinder pressure (Freon): 7Barg (full) to 0Barg. Cylinder pressure (Pentane only): Atmospheric pressure	IMB-PID-001-A1			
2. Multi-phase double screw pump & discharge line	Line Compressor Compressor (Positive Displacement) Pumps (Positive Displacement)	Isotank arrives with 0Barg, Compressor will charge tank to 10Barg. (Design pressure 27.5Barg). Operates at ambient temperature. Max 5m3/hr (liquid). Expected transfer time 28minutes maximum. Expected one cylinder / day.	IMB-PID-001-A1			
3. ISO tank	Line Tank Tanker Vessel	Isotank arrives with 0Barg, Design pressure 27.5Barg. Operates at ambient temperature. Rupture disc: 30.36Barg Expected replacement ~every 20 days.	IMB-PID-001-A1			

5.2 HAZOP Deviations

Node: 1. Cylinder discharge / pump suction

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Cylinder pressure (Freon): 7Barg (full) to 0Barg.

Cylinder pressure (Pentane only): Atmospheric pressure

Deviations	Guide Word	Parameter	Comments
1. Contamination	As well as	Composition	
2. High Flow	High	Flow	
3. Low/No Flow	Low/No	Flow	
4. Reverse/Misdirected Flow	Reverse/Misdirected	Flow	
5. High Pressure	High	Pressure	
6. Low Pressure	Low	Pressure	
7. High Level	High	Level	
8. Low Level	Low	Level	
9. High Temperature	High	Temperature	
10. Low Temperature	Low	Temperature	
11. Leak	As well as	Flow	
12. Rupture	Other than	Flow	
13. Start-up/Shutdown Hazards	Other than	Start-up / shutdown	
14. Maintenance / Operational Hazards	Other than	Maintenance / operations	

Node: 2. Multi-phase double screw pump & discharge line

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Compressor will charge tank to 10Barg. (Design pressure 27.5Barg).

Operates at ambient temperature.

Max 5m3/hr (liquid).

Expected transfer time 28minutes maximum.

Expected one cylinder / day.

Deviations	Guide Word	Parameter	Comments
1. Contamination (foreign objects / debris)	As well as	Composition	
2. High Flow	High	Flow	
3. Low/No Flow	Low/No	Flow	
4. Reverse/Misdirected Flow	Reverse/Misdirected	Flow	
5. High Pressure	High	Pressure	
6. Low Pressure	Low	Pressure	
7. High Temperature	High	Temperature	
8. Low Temperature	Low	Temperature	
9. Leak	As well as	Flow	
10. Rupture	Other than	Flow	
11. Start-up/Shutdown Hazards	Other than	Start-up / shutdown	
12. Maintenance / Operational Hazards	Other than	Maintenance / operations	

Node: 3. ISO tank.

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Design pressure 27.5Barg.

Operates at ambient temperature.

Rupture disc: 30.36Barg

Expected replacement ~every 20 days.

Deviations	Guide Word	Parameter	Comments
1. Contamination	As well as	Composition	
2. High Flow	High	Flow	
3. Low/No Flow	Low/No	Flow	
4. Reverse/Misdirected Flow	Reverse/Misdirected	Flow	
5. High Pressure	High	Pressure	
6. Low Pressure	Low	Pressure	
7. High Level	High	Level	
8. Low Level	Low	Level	
9. High Temperature	High	Temperature	
10. Low Temperature	Low	Temperature	
11. Leak	As well as	Flow	
12. Rupture	Other than	Flow	
13. Start-up/Shutdown Hazards	Other than	Start-up / shutdown	
14. Maintenance / Operational Hazards	Other than	Maintenance / operations	

5.3 HAZOP Study Worksheets

5.3.1 Node: 1. Cylinder discharge / pump suction

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Cylinder pressure (Freon): 7Barg (full) to 0Barg.

Cylinder pressure (Pentane only): Atmospheric pressure

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
1. Contamination	1. Unexpected gas present (R32)	1. Fire / explosion	BUI	5	1	R	1. Upstream fridge plant process controls 2. Operating procedures 3. Trained / competent personnel	
	2. Water (freezing)	1. Time delay to operations	BUI	1	3	C	2. Operating procedures 3. Trained / competent personnel 4. Trace heating on hoses between cylinder and pump	
2. High Flow	1. None							
3. Low/No Flow	1. Blockage (foreign objects / debris / water freezing)	1. Time delay to operations	BUI	1	3	C	2. Operating procedures 3. Trained / competent personnel 4. Trace heating on hoses between cylinder and pump 5. Upstream fridge plant filtration 16. Sight glass fitted to top of vertical leg	
		2. Pump damage	AST	1	2	A	2. Operating procedures 3. Trained / competent personnel 6. Pump specified to be able to run dry	

5.3.1 **Node:** 1. Cylinder discharge / pump suction

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Cylinder pressure (Freon): 7Barg (full) to 0Barg.

Cylinder pressure (Pentane only): Atmospheric pressure

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
							7. NRV on suction / discharge pipe work to maintain primed configuration	
							15. Continuous column of pentane fluid on discharge line	
							16. Sight glass fitted to top of vertical leg	
	2. Operator error (closed valves)	1. Time delay to operations	BUI	1	3	C	2. Operating procedures	
							3. Trained / competent personnel	
							5. Upstream fridge plant filtration	
							16. Sight glass fitted to top of vertical leg	
		2. Pump damage	AST	1	2	A	2. Operating procedures	
							3. Trained / competent personnel	
							6. Pump specified to be able to run dry	
							7. NRV on suction / discharge pipe work to maintain primed configuration	
							15. Continuous column of pentane fluid on discharge line	
							16. Sight glass fitted to top of vertical leg	

5.3.1 Node: 1. Cylinder discharge / pump suction

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Cylinder pressure (Freon): 7Barg (full) to 0Barg.

Cylinder pressure (Pentane only): Atmospheric pressure

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
4. Reverse/Misdirected Flow	1. None							
5. High Pressure	1. Unexpected gas present (R32)	1. Fire / explosion	PER	5	1	R	1. Upstream fridge plant process controls 2. Operating procedures 3. Trained / competent personnel	
6. Low Pressure	1. Pentane only in cylinder (Vapour pressure ~0,5Bara)	1. None	BUI	1	4	R		
7. High Level	1. None							
8. Low Level	1. None							
9. High Temperature	1. None							
10. Low Temperature	1. Blockage (water freezing)	1. Time delay to operations	BUI	1	3	C	2. Operating procedures 3. Trained / competent personnel 4. Trace heating on hoses between cylinder and pump	
		2. Pump damage	AST	1	2	A	2. Operating procedures 3. Trained / competent personnel 6. Pump specified to be able to run dry	
11. Leak	1. Equipment failure / operator error	1. Fire / explosion	PER	5	1	R	3. Trained / competent personnel 2. Operating procedures	

5.3.1 **Node:** 1. Cylinder discharge / pump suction

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Cylinder pressure (Freon): 7Barg (full) to 0Barg.

Cylinder pressure (Pentane only): Atmospheric pressure

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
							8. Equipment design / specification	
							9. Periodic inspection / maintenance	
							10. Continuously supervised operation	
							11. ATEX-certified equipment (Z1, IIA, T3)	
							12. Outdoors location - freely ventilated	
13. Start-up/Shutdown Hazards	1. Connection / disconnection of hoses (leaks)	1. Fire / explosion	PER	5	1	R	3. Trained / competent personnel	1. Confirm hoses are fitted with valves at the end to minimise volume of gas released at each operation.
							2. Operating procedures	
							8. Equipment design / specification	
							9. Periodic inspection / maintenance	
							10. Continuously supervised operation	
							11. ATEX-certified equipment (Z1, IIA, T3)	
							12. Outdoors location - freely ventilated	
	2. Pump speed control on start up	1. Equipment damage	AST	1	3	C	3. Trained / competent personnel	2. Confirm how pump startup is to be controlled in practice.
							2. Operating procedures	

5.3.1 **Node:** 1. Cylinder discharge / pump suction

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Cylinder pressure (Freon): 7Barg (full) to 0Barg.

Cylinder pressure (Pentane only): Atmospheric pressure

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
14. Maintenance / Operational Hazards	1. Maintenance between operations only	1. Fire / explosion	PER	5	1	R	2. Operating procedures 3. Trained / competent personnel 11. ATEX-certified equipment (Z1, IIA, T3) 13. Planned preventative maintenance schedule in place (PPM) 14. Safe system of work in place for intrusive maintenance (draining / purging)	3. Complete DSEAR review.

5.3.2 Node: 2. Multi-phase double screw pump & discharge line

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Compressor will charge tank to 10Barg. (Design pressure 27.5Barg).

Operates at ambient temperature.

Max 5m3/hr (liquid).

Expected transfer time 28minutes maximum.

Expected one cylinder / day.

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
1. Contamination (foreign objects / debris)	1. Water (freezing)	1. Time delay to operations	BUI	1	3	C	2. Operating procedures 3. Trained / competent personnel 4. Trace heating on hoses between cylinder and pump	
	2. Poor operating practice (introduction of debris during conenction / disconnection)	1. Time delay to operations	BUI	1	3	C	2. Operating procedures 3. Trained / competent personnel 4. Trace heating on hoses between cylinder and pump	
		2. Equipment damage	AST	1	2	A	2. Operating procedures 3. Trained / competent personnel	
2. High Flow	1. None							
3. Low/No Flow	1. Blockage (foreign objects / debris / water freezing)	1. Time delay to operations	BUI	1	3	C	2. Operating procedures 3. Trained / competent personnel 4. Trace heating on hoses between cylinder and pump	

5.3.2 **Node:** 2. Multi-phase double screw pump & discharge line

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Compressor will charge tank to 10Barg. (Design pressure 27.5Barg).

Operates at ambient temperature.

Max 5m3/hr (liquid).

Expected transfer time 28minutes maximum.

Expected one cylinder / day.

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
							5. Upstream fridge plant filtration	
							16. Sight glass fitted to top of vertical leg	
		2. Pump damage	AST	1	2	A	2. Operating procedures	
							3. Trained / competent personnel	
							6. Pump specified to be able to run dry	
							7. NRV on suction / discharge pipe work to maintain primed configuration	
							15. Continuous column of pentane fluid on discharge line	
							16. Sight glass fitted to top of vertical leg	
	2. Operator error (closed valves)	1. Time delay to operations	BUI	1	3	C	2. Operating procedures	
							3. Trained / competent personnel	
							5. Upstream fridge plant filtration	

5.3.2 **Node:** 2. Multi-phase double screw pump & discharge line

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Compressor will charge tank to 10Barg. (Design pressure 27.5Barg).

Operates at ambient temperature.

Max 5m3/hr (liquid).

Expected transfer time 28minutes maximum.

Expected one cylinder / day.

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
							16. Sight glass fitted to top of vertical leg	
		2. Pump damage	AST	1	2	A	2. Operating procedures	
							3. Trained / competent personnel	
							6. Pump specified to be able to run dry	
							7. NRV on suction / discharge pipe work to maintain primed configuration	
							16. Sight glass fitted to top of vertical leg	
4. Reverse/Misdirected Flow	1. Operator error (bypass valve open)	1. Time delay to operations	BUI	1	3	C	2. Operating procedures	4. Consider installation of weigh scales to confirm cylinder is being emptied.
							3. Trained / competent personnel	
		2. Heat build up / equipment damage	AST	1	2	A	2. Operating procedures	4. Consider installation of weigh scales to confirm cylinder is being emptied.
							3. Trained / competent personnel	
5. High Pressure		1. Equipment damage	AST	1	2	A	2. Operating procedures	

5.3.2 **Node:** 2. Multi-phase double screw pump & discharge line

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Compressor will charge tank to 10Barg. (Design pressure 27.5Barg).

Operates at ambient temperature.

Max 5m3/hr (liquid).

Expected transfer time 28minutes maximum.

Expected one cylinder / day.

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
	1. Operator error (closed discharge valves)		PER	5	1	R	3. Trained / competent personnel	5. Confirm maximum physical head pressure capability of pump / motor set.
							8. Equipment design / specification	
							11. ATEX-certified equipment (Z1, IIA, T3)	
							17. Pressure relief valve fitted to tank	
	2. NRV stuck closed	1. Equipment damage	AST	1	2	A	2. Operating procedures	5. Confirm maximum physical head pressure capability of pump / motor set.
			PER	5	1	R	3. Trained / competent personnel	6. Confirm SIL rating / requirement of high pressure trip safety instrumented system.
							8. Equipment design / specification	
							11. ATEX-certified equipment (Z1, IIA, T3)	
							17. Pressure relief valve fitted to tank	
							18. Pump high pressure trip (10bar)	
6. Low Pressure			BUI	1	3	C	2. Operating procedures	

5.3.2 Node: 2. Multi-phase double screw pump & discharge line

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Compressor will charge tank to 10Barg. (Design pressure 27.5Barg).

Operates at ambient temperature.

Max 5m3/hr (liquid).

Expected transfer time 28minutes maximum.

Expected one cylinder / day.

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
	1. Equipment containment failure	1. Time delay to operations					3. Trained / competent personnel	7. Confirm contents of "empty" iso-tanks when delivered.
		2. Fire / explosion	AST	1	2	A	2. Operating procedures	8. Confirm only CompEx-trained personnel will carry out intrusive maintenance / inspection on ATEX-certified equipment.
			PER	5	1	R	3. Trained / competent personnel	
							8. Equipment design / specification	
							11. ATEX-certified equipment (Z1, IIA, T3)	
							17. Pressure relief valve fitted to tank	
	2. Operator error (suction valves closed)	1. Time delay to operations	BUI	1	3	C	2. Operating procedures	
							3. Trained / competent personnel	
7. High Temperature	1. Operator error (closed discharge valves)	1. Time delay to operations	BUI	1	3	C	2. Operating procedures	4. Consider installation of weigh scales to confirm cylinder is being emptied.
							3. Trained / competent personnel	9. Confirm scales are ATEX-certified.
							4. Trace heating on hoses between cylinder and pump	

5.3.2 **Node:** 2. Multi-phase double screw pump & discharge line

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Compressor will charge tank to 10Barg. (Design pressure 27.5Barg).

Operates at ambient temperature.

Max 5m3/hr (liquid).

Expected transfer time 28minutes maximum.

Expected one cylinder / day.

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
							5. Upstream fridge plant filtration	
							16. Sight glass fitted to top of vertical leg	
							15. Continuous column of pentane fluid on discharge line	
		2. Pump damage	AST	1	2	A	2. Operating procedures	
							3. Trained / competent personnel	
							6. Pump specified to be able to run dry	
							7. NRV on suction / discharge pipe work to maintain primed configuration	
							15. Continuous column of pentane fluid on discharge line	
							16. Sight glass fitted to top of vertical leg	
			BUI	1	3	C	2. Operating procedures	9. Confirm scales are ATEX-certified.

5.3.2 **Node:** 2. Multi-phase double screw pump & discharge line

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Compressor will charge tank to 10Barg. (Design pressure 27.5Barg).

Operates at ambient temperature.

Max 5m3/hr (liquid).

Expected transfer time 28minutes maximum.

Expected one cylinder / day.

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
	2. Equipment failure (no flow route)	1. Time delay to operations					3. Trained / competent personnel	4. Consider installation of weigh scales to confirm cylinder is being emptied.
							4. Trace heating on hoses between cylinder and pump	
							5. Upstream fridge plant filtration	
							16. Sight glass fitted to top of vertical leg	
							15. Continuous column of pentane fluid on discharge line	
		2. Pump damage	AST	1	2	A	2. Operating procedures	
							3. Trained / competent personnel	
							6. Pump specified to be able to run dry	
							7. NRV on suction / discharge pipe work to maintain primed configuration	
							15. Continuous column of pentane fluid on discharge line	

5.3.2 Node: 2. Multi-phase double screw pump & discharge line

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Compressor will charge tank to 10Barg. (Design pressure 27.5Barg).

Operates at ambient temperature.

Max 5m3/hr (liquid).

Expected transfer time 28minutes maximum.

Expected one cylinder / day.

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
							16. Sight glass fitted to top of vertical leg	
	3. Blockage (foreign objects / debris / water freezing)	1. Time delay to operations	BUI	1	3	C	2. Operating procedures	4. Consider installation of weigh scales to confirm cylinder is being emptied.
							3. Trained / competent personnel	9. Confirm scales are ATEX-certified.
							4. Trace heating on hoses between cylinder and pump	
							5. Upstream fridge plant filtration	
							16. Sight glass fitted to top of vertical leg	
		2. Pump damage	AST	1	2	A	2. Operating procedures	
							3. Trained / competent personnel	
							6. Pump specified to be able to run dry	
							7. NRV on suction / discharge pipe work to maintain primed configuration	

5.3.2 **Node:** 2. Multi-phase double screw pump & discharge line

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Compressor will charge tank to 10Barg. (Design pressure 27.5Barg).

Operates at ambient temperature.

Max 5m3/hr (liquid).

Expected transfer time 28minutes maximum.

Expected one cylinder / day.

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
							15. Continuous column of pentane fluid on discharge line	
							16. Sight glass fitted to top of vertical leg	
8. Low Temperature	1. None							
9. Leak	1. Equipment failure / operator error	1. Fire / explosion	PER	5	1	R	3. Trained / competent personnel	10. Consider installation of excess flow valves in system to protect against full bore release from equipment / hose failure.
							2. Operating procedures	
							8. Equipment design / specification	
							9. Periodic inspection / maintenance	
							10. Continuously supervised operation	
							11. ATEX-certified equipment (Z1, IIA, T3)	
							12. Outdoors location - freely ventilated	
11. Start-up/Shutdown Hazards		1. Fire / explosion	PER	5	1	R	3. Trained / competent personnel	

5.3.2 **Node:** 2. Multi-phase double screw pump & discharge line

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Compressor will charge tank to 10Barg. (Design pressure 27.5Barg).

Operates at ambient temperature.

Max 5m3/hr (liquid).

Expected transfer time 28minutes maximum.

Expected one cylinder / day.

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
	1. Connection / disconnection of hoses (leaks)						2. Operating procedures 8. Equipment design / specification 9. Periodic inspection / maintenance 10. Continuously supervised operation 11. ATEX-certified equipment (Z1, IIA, T3) 12. Outdoors location - freely ventilated	1. Confirm hoses are fitted with valves at the end to minimise volume of gas released at each operation.
	2. Pump speed control on start up	1. Equipment damage	AST	1	3	C	3. Trained / competent personnel 2. Operating procedures	2. Confirm how pump startup is to be controlled in practice.
12. Maintenance / Operational Hazards	1. Maintenance between operations only	1. Fire / explosion	PER	5	1	R	2. Operating procedures 3. Trained / competent personnel 11. ATEX-certified equipment (Z1, IIA, T3)	3. Complete DSEAR review.

5.3.2 **Node:** 2. Multi-phase double screw pump & discharge line

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Compressor will charge tank to 10Barg. (Design pressure 27.5Barg).

Operates at ambient temperature.

Max 5m3/hr (liquid).

Expected transfer time 28minutes maximum.

Expected one cylinder / day.

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
							13. Planned preventative maintenance schedule in place (PPM)	
							14. Safe system of work in place for intrusive maintenance (draining / purging)	

5.3.3 Node: 3. ISO tank

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Design pressure 27.5Barg.

Operates at ambient temperature.

Rupture disc: 30.36Barg

Expected replacement ~every 20 days.

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
1. Contamination	1. Unexpected gas present (R32)	1. Fire / explosion	BUI	5	1	R	1. Upstream fridge plant process controls 2. Operating procedures 3. Trained / competent personnel	
2. High Flow	1. None							
3. Low/No Flow	1. None							
4. Reverse/Misdirected Flow	1. None							
5. High Pressure	1. Unexpected gas present (R32)	1. Fire / explosion (operation of PRV / BD)	BUI	5	1	R	1. Upstream fridge plant process controls 2. Operating procedures 3. Trained / competent personnel 11. ATEX-certified equipment (Z1, IIA, T3) 12. Outdoors location - freely ventilated	
6. Low Pressure	1. Equipment failure (PRV/BD)	1. Time delay to operations	BUI	1	3	C	2. Operating procedures 3. Trained / competent personnel 19. Pump discharge pressure monitoring (manual)	

5.3.3 Node: 3. ISO tank

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Design pressure 27.5Barg.

Operates at ambient temperature.

Rupture disc: 30.36Barg

Expected replacement ~every 20 days.

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
							20. Iso tank fitted with pressure guage	
7. High Level	1. Operator error	1. Fire / explosion (operation of PRV / BD)	BUI	5	1	R	1. Upstream fridge plant process controls 2. Operating procedures 3. Trained / competent personnel 11. ATEX-certified equipment (Z1, IIA, T3) 12. Outdoors location - freely ventilated	11. Confirm tank is fitted with level instrumentation and associated pump trip interlock.
8. Low Level	1. None							
9. High Temperature	1. None							
10. Low Temperature	1. None							
11. Leak	1. Equipment failure / operator error	1. Fire / explosion	PER	5	1	R	3. Trained / competent personnel 2. Operating procedures 8. Equipment design / specification 9. Periodic inspection / maintenance	10. Consider installation of excess flow valves in system to protect against full bore release from equipment / hose failure.

5.3.3 **Node:** 3. ISO tank

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Design pressure 27.5Barg.

Operates at ambient temperature.

Rupture disc: 30.36Barg

Expected replacement ~every 20 days.

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
							10. Continuously supervised operation	
							11. ATEX-certified equipment (Z1, IIA, T3)	
							12. Outdoors location - freely ventilated	
13. Start-up/Shutdown Hazards	1. Connection / disconnection of hoses (leaks)	1. Fire / explosion	PER	5	1	R	3. Trained / competent personnel	1. Confirm hoses are fitted with valves at the end to minimise volume of gas released at each operation.
							2. Operating procedures	
							8. Equipment design / specification	
							9. Periodic inspection / maintenance	
							10. Continuously supervised operation	
							11. ATEX-certified equipment (Z1, IIA, T3)	
							12. Outdoors location - freely ventilated	
	1. Statutory inspections	1. Fire / explosion	PER	5	1	R	21. Completed by off-site specialists	

5.3.3 Node: 3. ISO tank

Drawings / References: IMB-PID-001-A1

Design Conditions/Parameters: Isotank arrives with 0Barg,

Design pressure 27.5Barg.

Operates at ambient temperature.

Rupture disc: 30.36Barg

Expected replacement ~every 20 days.

Deviations	Causes	Consequences	Cons Cat	Current Risk			Safeguards	Recommendations
				S	L	RR		
14. Maintenance / Operational Hazards	2. Tank earthing (electrostatic discharge)	1. Fire / explosion	PER	5	1	R	3. Trained / competent personnel	1. Confirm hoses are fitted with valves at the end to minimise volume of gas released at each operation.
							2. Operating procedures	12. Confirm isotank will be connected to plant earthing system prior to fluid flow occurring.
							8. Equipment design / specification	
							9. Periodic inspection / maintenance	
							10. Continuously supervised operation	
							11. ATEX-certified equipment (Z1, IIA, T3)	
							12. Outdoors location - freely ventilated	

6.0 HAZOP STUDY OVERVIEW

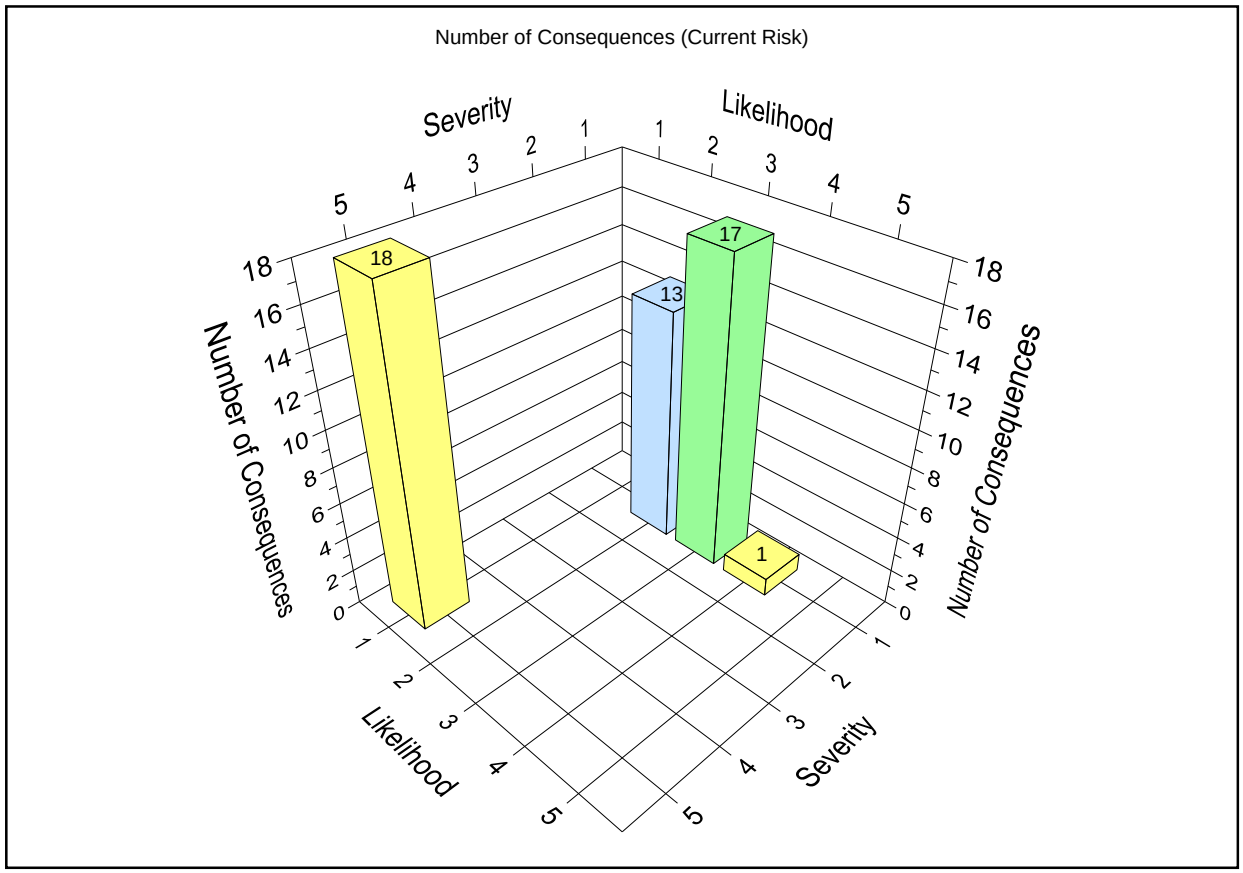
Number of Study Items:

Nodes: 3
Causes: 48
Unique Safeguards: 21
Deviations: 40
Consequences: 46
Recommendations: 12

Node	Number of Study Items				
	Deviations	Causes	Consequences	Safeguards	Recommendations
1. Cylinder discharge / pump suction	14	16	14	16	3
2. Multi-phase double screw pump & discharge line	12	18	24	17	17
3. ISO tank	14	14	8	11	5

Risk Heat Map

Severity	Likelihood				
	5	4	3	2	1
5	0	0	0	0	18
4	0	0	0	0	0
3	0	0	0	0	0
2	0	0	0	0	0
1	0	1	17	13	0



HAZOP RISK CRITERIA

Severity							Likelihood				
Severity	Personnel	Environment	Asset / Property	Business Interruption	Media	Public	5	4	3	2	1
5	Multiple fatalities	Extensive, persistent or irreversible damage to ecosystem function - public affected	Total or extensive damage to on-site equipment requiring complete replacement and significant (in excess of £1M). Extensive damage to off-site property (in excess of £300k) Dwelling(s) off-site damage and uninhabitable	Disruption to dependent operations for more than 1 year	International media attention. Severe adverse public reaction threatening facility operations.	Single fatality	U	U	U	ND	R
4	Single fatality	Significant loss of containment resulting in widespread moderate-long term ecosystem damage - external help required - public not affected.	Major damage to onsite equipment repaired within 4 to 12 months. requiring significant capital expenditure (£300k to £1M) Major damage to offsite property (up to £300k) Dwelling off-site damage and uninhabitable	Disruption to dependent operations for 3 to 12 months	National media attention Moderate public concern / reaction	Multiple injury - Impairment to several persons. Hospitalization > 24 hrs. Delayed recovery	U	U	ND	ND	R
3	Multiple injury - impairment to several persions. Hospitalization > 24 hrs. Delayed recovery	Significant loss of containment resulting in short term damage imparing local ecosystem - no external help required - public not affected	On-site equipment damage repaired within 7 to 120 days with loss of production, requiring capitial expenditure (£100k to £300k)	Disruption to dependent operations for 7 to 90 days	State media attention. Adverse public reaction	Medical treatment injury with rapid recovery. Hospitalization < 24 hrs	ND	ND	R	R	C
2	Medical treatment injury with rapid recovery. Hospitalization < 24 hrs	Insignificant loss of conatinment resulting in minor biological effects across limited area onsite	On-site damage repaired within 7 days with loss of production, requiring capital expenditure (£30k to £100k)	Disruption to dependent operations for less than 7 days	Local media attention. Possible adverse public reaction	First aid treatment	ND	R	R	C	A
1	First aid treatment	On-site release immediately contained and readily cleaned up with onsite or locally available technology	On-site equipment damage repaired within 24 hours, without loss of production, requiring capital expenditure (less than £30k)	Disruption to dependent operations for less than one day	No effect	No effect	R	R	C	A	A

Risk Ranking

Risk Ranking	Description
U	**UNACCEPTABLE:** Risk cannot be tolerated or justified unless there are exceptional reasons for the activity to take place. Control measures to be introduced to drive risk downward.
ND	**NOT DESIRABLE:** Risk may be tolerated but shall only be accepted when risk reduction is impracticable and when authorised by a senior manager.
R	**ACCEPTABLE WITH REVIEW:** Must be reviewed to ensure risk is ALARP - additional measures may be required.
C	**ACCEPTABLE WITH CONTROLS:** Adequate risk control measures are in place.
A	**ACCEPTABLE:** No additional risk control measures are needed.

Likelihood

Likelihood	Description
5	Likely to be experienced every time or frequently
4	Likely to be experienced annually or more often
3	Unlikely, but reasonably expected to occur sometimes in the life of an item
2	Unlikely to be experienced, but credible to occur in the life of an item
1	Extremely unlikely to be experienced but not physically impossible