Hazard Log (Rev.1-1) Last updated: 15 April 2015

Ref.	Potential Hazard	Guideword	Deviation	Cause	Safeguard	Consequence	Mitigation Measures / Recommendations	BLEVE Scenarios? (Y/N)
1	**ROAD TRANSPORT (onsite and offsite)**							
1.1	Fire on the road tanker leading to overheating and overpressure	Fire	Pressure: high Temperature: high	Tyre fire, engine fire	Vehicle fire extinguisher to control fire; Pressure relief valve; Fire services will be called in case of fire. The nearest fire station is located at the junction of Wan Po Road and Chun Yat Street. It is anticipated that fire services can be arrived in several minutes to bring the fire under control; Tyres on road tankers are filled with nitrogen instead of compressed air; The storage vessel is screened with fire resisting shield from fuel tank.	BLEVE if fire is not under control and safety device / emergency response fails; Damage to storage tanks, chemical building, chlorine building and cause escalation if BLEVE occurs close to storage area.		Y
1.2	Fire on the roadside leading to overheating and overpressure	External fire	Pressure: high Temperature: high	Set on fire, external fire	Not allowed to park on the street during delivery or overnight	Negligible risk		N
1.3	Impact with objects during manoeuvring of road tanker	Vehicle crash	-	Hit building or other structures	Dedicated access and unloading bay; Reversing or manoeuvring into unloading bay being watched out by plant operator;	Damage to the outer vessel; In the worst case gas release	Design of turning angle for access road within the desalination plant should cater for 40 feet container trailer to avoid reverse manoeuvring or impact to buildings / structures in cornering.	N
1.4	Road tanker over-turn / rollover	Vehicle crash	Pressure: high	Ditching, traffic accident	Protected by the outer vessel; Emergency venting to prevent pressure build-up	Gas or liquid release through manual venting; BLEVE possible if both inner and outer vessels as well as emergency action fail; Damage to storage tanks, chemical building, chlorine building and cause escalation if BLEVE occurs close to storage area.		Y
1.5	Collision with another vehicle	Vehicle crash	Pressure: -	Traffic accident	Crash protection at both sides apart from front and rear. Protected by the outer vessel; Pressure relief valve;	Damage to outer vessel; Collision to vessel side may cause instability of trailer leading to rollover (refer to 1.4). In case of head-on collision and rear-end collision, the driving cabinet and pump / control cabinet acts as a buffer to protect the vessel from damage. In minor side collision, crash protection fence at both sides act as buffers. Cosmetic damage to the outer vessel may be resulted. In serious side collision, rollover would likely occur. Therefore, BLEVE is considered in the rollover scenario in case of serious side collision.		N
1.6	Spontaneous failure (inner vessel)	Material failure	Corrosion	Corrosion / erosion	Inner vessel is made of resilient steel to resist low temperature and corrosion; Pressure relief device on the outer vessel	Gas release through the pressure relief device on the inner vessel; BLEVE possible if safety devices fail; Damage to storage tanks, chemical building, chlorine building and cause escalation if BLEVE occurs close to storage area.		Y

Ref.	Potential Hazard	Guideword	Deviation	Cause	Safeguard	Consequence	Mitigation Measures / Recommendations	BLEVE Scenarios? (Y/N)
1.7	Spontaneous failure (outer vessel)	Material failure	Corrosion	Corrosion / erosion	Pressure relief device on the inner vessel	Loss vacuum insulation; heating up CO2 content; may trigger safety device on inner vessel leading to gas release; BLEVE if safety devices fail; Damage to storage tanks, chemical building, chlorine building and cause escalation if BLEVE occurs close to storage area.		Y
1.8	Road tanker is overfilled in the gas supplier's plant and allowed leaving for the desalination plant	Human error	Level: high	Fail to open Trycock valve during refilling; Readings on gauges or instruments are ignored	Trycock, pressure gauge & content gauge on road tanker for monitoring of content level during refilling; Pre-trip inspection on tank pressure, content level, weight check using weighbridge before departure.	Risk negligible		N
2	**TRANSFER**							
2.1	Flexible hose failure	Material failure	-	Material fault	Emergency shutoff; Length of flexible hose is restricted to maximum 3m; Hose-to-hose connection is not allowed; Anti whip cable to restrict the hose movement in case of breakoff of joints at both ends	Liquid release and formation of dry ice; Injury to operator		N
2.2	Misconnecting hose	Human error	-	Human error	Emergency shutoff; Prior to the liquid filling, gas valve on road tanker is turned on to purge the hose using very low gas flow. The hose is connected to the storage tank inlet while CO2 gas is discharged from the road tanker. High pitch noise indicates improper hose connection. Liquid valve is turned on after the hose is properly connected.	Liquid release and formation of dry ice.		N
2.3	Disconnecting during unloading	Human error	-	Human error	Emergency shutoff; High pitch noise indicates undergoing transfer operation when the joint is loosened.	Liquid release and formation of dry ice		N
2.4	Overfilling / filling higher than the allowable level	Human error	Level: high Pressure: high	Human error, monitoring equipment failure	<u>On road tanker</u> Relief valves installed on delivery hose and delivery line; <u>On storage tank</u> Trycock High level alarm Safety relief valves on the inner and outer vessels	In case overfilling, liquid would circulate between road tank and storage tank through the vapour return line. Storage tank BLEVE if safety devices on both storage tank and road tanker fail, vapour return is not connected and Trycock is not opened or noise from Trycock is ignored.	Telemetry monitoring system may be installed to alert the content level in the control room for additional safety.	Y
2.5	Drive away during unloading	Human error; Communication breakdown;	-	Human error	Wheel chock; Interlock system (via a hydraulic switch on the cabinet door) to prevent brakes from being releases during transfer operation	Liquid release; BLEVE risk negligible		N
2.6	Vehicle impact	Vehicle crash	Pressure: high	Human error	Dedicated unloading bay; Fenced off with bollards; Speed control within desalination plant	Negligible risk		N

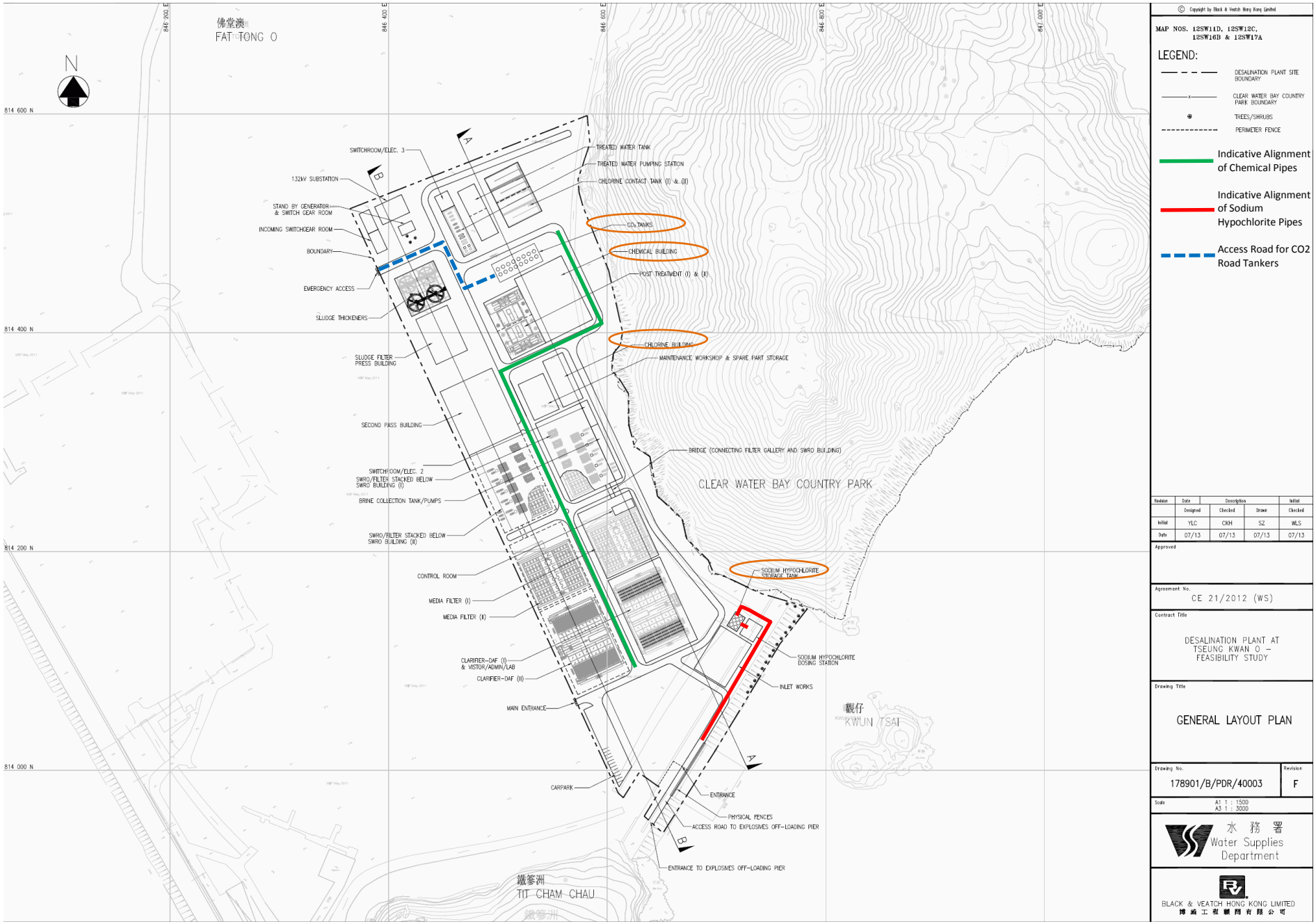
Ref.	Potential Hazard	Guideword	Deviation	Cause	Safeguard	Consequence	Mitigation Measures / Recommendations	BLEVE Scenarios? (Y/N)
2.7	Failure to open valve on storage tank filling line	Human error	Pressure: high	Human error, fail to follow procedure	Delivery hose relief valve; Delivery line relief valve;	The excessive pressure would lead to pipeline rupture / leakage when pressure relief valves fail to operate.		N
2.8	Failure to close valve on storage tank filling line after unloading	Human error		Human error, fail to follow procedure	Double valve design at the inlet	Negligible risk Liquid release and dry ice formation if fails to close (liquid flowing back from the storage tank towards the inlet)		N
2.9	Dry ice plug formation in flexible hose	Pump failure; Human error	Pressure at storage tank too low; Flow too high	Excessive withdrawal	Pressure gauges and flowmeter; Manned unloading operation; delivery relief valve	Unloading operation stopped because of the blockage		N
2.10	Fire during unloading	Fire	Escalation	External fire ; Pump fire on road tanker	Road tanker engine turned off; Operating procedure – would take 5-10 minutes to terminate the operation by stopping the pump and disconnecting the hose.	According to the layout plan, sufficient separation distance between road tank unloading bay and potential fire source (e.g. transformer room); Pump fire (on the road tank) would be put out by vehicle fire extinguisher; otherwise liquid CO2 release from the pump would extinguish the pump fire; BLEVE risk negligible		N
2.11	Damage to storage tanks in case of road tanker BLEVE				Failure of all safety measures	Storage tank BLEVE	Divide the storage area into a number of compartments to protect storage tanks from fire or pipeline / valve failure although escalation from BLEVE cannot be eliminated.	Y
3	**STORAGE**							
3.1a	Leaking tank (inner vessel)	Material failure	Corrosion	Corrosion / erosion	Monitoring through pressure gauge and temperature gauge; Inner vessel is made of resilient steel to resist low temperature and corrosion; Pressure relief device on the outer vessel;	Loss vacuum insulation; Heating up CO2 content; Trigger safety device on inner vessel leading to gas release; BLEVE if safety devices fail and abnormal storage conditions are ignored; BLEVE may cause escalation to other storage tanks and damages to chemical / chlorine building leading to DG releases within the desalination plant.	Use transfer pump to remove CO2 content to other storage tanks; Venting in case of emergency	Y
3.1b	Leaking tank (outer vessel)	Material failure	Corrosion	Corrosion / erosion	Monitoring through pressure gauge and temperature gauge; Pressure relief devices on the inner vessel	Loss vacuum insulation; Heating up CO2 content; Trigger safety device on inner vessel leading to gas release; BLEVE if safety devices fail and abnormal storage conditions are ignored. BLEVE may cause escalation to other storage tanks and damages to chemical / chlorine building leading to DG releases within the desalination plant.	Use transfer pump to remove CO2 content to other storage tanks; Venting in case of emergency	Y

Ref.	Potential Hazard	Guideword	Deviation	Cause	Safeguard	Consequence	Mitigation Measures / Recommendations	BLEVE Scenarios? (Y/N)
3.2	Overfilled containers leading to over-pressurization on thermal expansion (Refer to discussion of 2.4)	Human error	Level: high Pressure: high	Human error, monitoring equipment failure	<u>On road tanker</u> Relief valves installed on delivery hose and delivery line; <u>On storage tank</u> Trycock High level alarm Safety relief valves on the inner and outer vessels	In case overfilling, liquid would circulate between road tank and storage tank through the vapour return line. Storage tank BLEVE if all safety devices on storage tank and road tanker fail, vapour return of not connected and Trycock is not opened or noise from Trycock is ignored.		Y
3.3	Impurities in CO2 leading to corrosion / erosion problem	Material failure	Corrosion / erosion	Corrosion / erosion	Inner vessel is made of resilient steel and low temperature slows down the corrosion problem; Inlet filter installed to remove foreign material	Impurity is low. Corrosion to vessel is caused by acidity of CO2 rather than impurities. (Refer to 3.1 for discussion on corrosion)		N
3.4	Falling object damage to storage tanks	Falling object	Escalation	Lifting operation	Chain link fence installed surrounding storage area; No heavy lifting operation is anticipated in vicinity of the storage area; The outer vessel provides protection to impact of foreign objects	Negligible risk		N
3.5	Fire (external or internal) leading to overheating of storage tanks	Fire	Pressure: high Temperature: high	Hill fire, fire at chemical building	Away from the east boundary which is close to country park; No tree or shrub nearby; Adjacent chemical building is at least 2 hour fire rating; No storage of combustible material within the storage area	Negligible risk		N
3.6	External explosion due to explosive truck or explosives offloading operation	Explosion	Pressure: high	Explosive delivery from TKO 137 Pier passing outside the western boundary of the desalination plant or explosives offloading operation at the TKO Area 137 Pier	Set back the CO2 storage with sufficient clearance so that the overpressure resulting from explosion of explosive vehicle during offsite transport or explosives offloading operation that reaches the storage is less than 2 psi.	Negligible risk because there would be sufficient separation distance between explosive trucks / TKO 137 Pier and CO2 storage area.		N
3.7	Lightning strike	Lightning	Escalation	Electrical conductive nature of the storage tank	Lightning protection installed – lightning protection zone covers the storage area;	Negligible risk		N
3.8	Extreme wind	Extreme wind	Escalation	Outdoor installation subject to wind load / typhoon	Wind load design according to building requirements.	Negligible risk		N
3.9	Dislocation and damaged in flooding / tsunami	Flooding/ Tsunami	Escalation	Unstable in water current	Shielded by chemical building and post treatment facilities	Product release from pipelines into water prior to further damages to the tanks; Debris may cause damages to the outer vessels; BLEVE risk negligible		N
3.10	Damages to storage tanks due to construction activities in the desalination plant	Construction activities; Maintenance with CO2 in tank	Escalation	Maintenance of facilities, buildings and roads.	Chain link fence installed surrounding storage area; Work permit system imposed for any construction activities in vicinity of the tanks;	Negligible risk, Also refer to 3.4		N
3.11	Damages to storage tanks in subsidence	Subsidence	Escalation	Construction works or excavation outside the desalination plant;	The desalination plant built on concrete foundation;	Pipeline fracture leading to liquid release in the worst case.		N
3.12	Landslide due to heavy rain	Landslide	Escalation	Debris flow from the slope at the Clearwater Bay Country Park	Landslide barrier installed at the eastern boundary facing the Clearwater Bay Country Park; Sufficient separation distance, 55m, from the toe of the slope	Negligible risk		N

Ref.	Potential Hazard	Guideword	Deviation	Cause	Safeguard	Consequence	Mitigation Measures / Recommendations	BLEVE Scenarios? (Y/N)
3.13	Damage of storage tanks in earthquake	Earthquake	Escalation	Low frequency vibration in earthquake	-	Pipelines would fail leading to liquid releases through joints or bursting pipelines prior to more serious damage to storage tanks.		N
3.14	Aircraft / helicopter crash	Aircraft crash	Escalation	Air traffic accident close to the flight paths; Helicopters takeoff / landing at the helipad in vicinity of the desalination plant		The nearest helipads, which are not for the public transport, are located more than 2km away on Tung Lung Chau. There are regulations to control low flying aircrafts / helicopters over build-up areas. There is negligible helicopter crash risk; BLEVE possible due to high energy impact in aircraft crash;		Y
3.15	Sabotage	Sabotage	-	Access of unauthorized person causing damage to storage or control facilities	Perimeter fence installed; CCTV installed with 24-hr security guard;	Negligible risk		N
3.16	Vehicle crash	Vehicle crash	Escalation		Speed control imposed; Storage area fenced off by chain-link fence;	Negligible risk; Referring to the layout of the CO2 tanks, piping and vaporizer will be placed at the perimeter of the storage area. Vehicle crash into the storage area would damage to piping and vaporizers first. Considering the vehicle speed, the damage of vehicle crash would lead to rupture of piping in the worst case.		N
3.17	Electromagnetic interference	Electromagnetic interference	-	Equipment used within the desalination plant interferes the operation of CO2 storage and control panel	Equipment in the desalination plant satisfying EMC requirements; Safety devices are not affected by electromagnetic interference	Negligible risk		N
3.18	Extreme heat weather and solar radiation	Extreme hot weather	Temperature: high	Radiation heat from the sun in summer	Vacuum insulation; Pressure relief valves	Negligible risk while design of the storage tanks has already taken into account.		N
3.19	Extreme low temperature leading to embrittlement of materials	Material failure	Temperature: low	Leaking pipeline in the vacuum space	Pressure relief device on the outer vessel;	Gas discharge through pressure relief device on the outer vessel; Operator takes action to mitigate the leakage problem before embrittlement failure has developed; If dry ice is formed in a storage tank, the storage tank will be taken out of services according to the safety practices. (Also refers to 3.1a discussion)		N
3.20	Vacuum insulation failure	Material failure	Corrosion			Refers to 3.1a and 3.1b for discussion		Y

Ref.	Potential Hazard	Guideword	Deviation	Cause	Safeguard	Consequence	Mitigation Measures / Recommendations	BLEVE Scenarios? (Y/N)
3.21	Pressure building system failure	Pressure buildup	Pressure: low / high	Valve to pressure building system fails to open due to malfunction; Valve to pressure building system fails to close due to malfunction;	Monitoring through pressure gauge and temperature gauge and low pressure alarm; Pressure relief devices on inner and outer vessels	Fail to open valve to the pressure building coil Pressure at vapour space too low below 4 bar leading to dry ice formation; Fail to close valve to the pressure building coil Pressure build-up in the vapour space leading to venting through safety valves. Risk of BLEVE is considered as failure of pressure build-up system and pressure relief devices and alarm system at the same time.		Y
4	**DRAWOFF & DOSAGE SYSTEM**							
4.1	Failure of liquid line	Material failure	Corrosion	Excessive liquid withdrawal causes dry ice formation in pipeline leading to overpressure	Line pressure relief valve;	Liquid discharge through bursting pipeline and formation of dry ice in the worst case; Risk of BLEVE negligible;		N
4.2	Failure of vapor line	Material failure	Corrosion	Spontaneous failure	-	Pressurized gas release; Since vapour phase release is involved, dry ice plug will not form; Risk of BLEVE negligible		N
4.3	Flow regulation valve failure	Material failure	Flow: high	Material fault	Pressure sensor after vaporizer; Dual regulators to ensure the reliability; Temperature monitor after the vaporizer; Flowmeter monitor flowrate; Safety valves upstream and downstream of the regulators	Excessive flow rate leading to low temperature condition at downstream pipeline; Risk of damage to downstream system negligible.		N
4.4	Formation of ice at radiators of vaporizers	-	Temperature: low Flow: high	Low temperature ambient conditions; Usage exceeds the capacity	Low temperature protection installed on the pipeline;	Low temperature condition at downstream pipeline; Risk of damage to downstream system negligible.		N
5	**GAS DISPERSION SYSTEM**							
5.1	Vapor line failure	Material failure	Corrosion	Spontaneous failure	-	Indoor gas release; asphyxiation effect to operating staff.	CO2 / O2 sensor for indoor installation; Venting should be undertaken outdoor; Mechanical ventilation should be provided for indoor environment.	N

Dwg.1 Layout Plan of the Desalination Plant



MAP NOS. 12SW11D, 12SW12C, 12SW16B & 12SW17A

LEGEND:

- DESALINATION PLANT SITE BOUNDARY
- CLEAR WATER BAY COUNTRY PARK BOUNDARY
- TREES/SHRUBS
- PERIMETER FENCE
- Indicative Alignment of Chemical Pipes
- Indicative Alignment of Sodium Hypochlorite Pipes
- Access Road for CO2 Road Tankers

Revision	Date	Description			Initial
	Designed	Checked	Drawn		Checked
Initial	YLC	CKH	SZ		WLS
Date	07/13	07/13	07/13		07/13

Approved

Agreement No. CE 21/2012 (WS)

Contract Title: DESALINATION PLANT AT TSEUNG KWAN O – FEASIBILITY STUDY

Drawing Title: GENERAL LAYOUT PLAN

Drawing No. 178901/B/PDR/40003

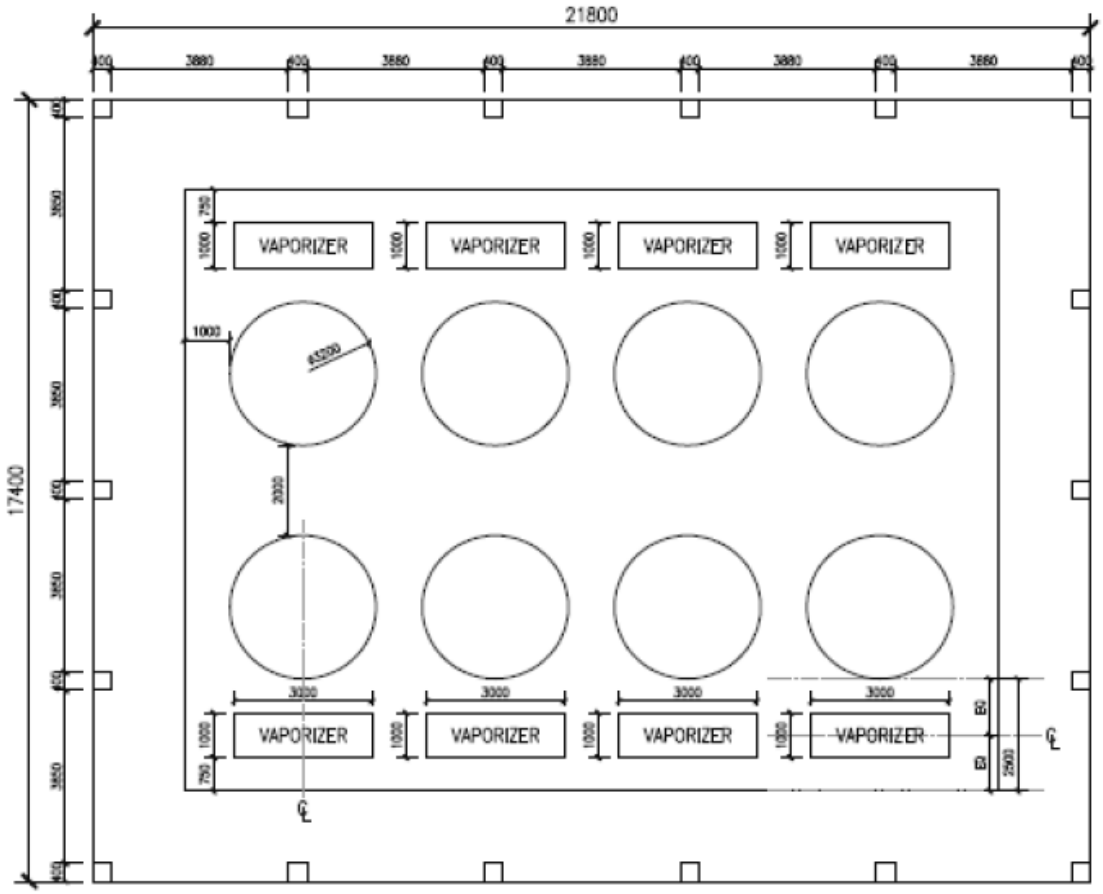
Revision F

Scale A1 1 : 1500, A3 1 : 3000

水務署 Water Supplies Department

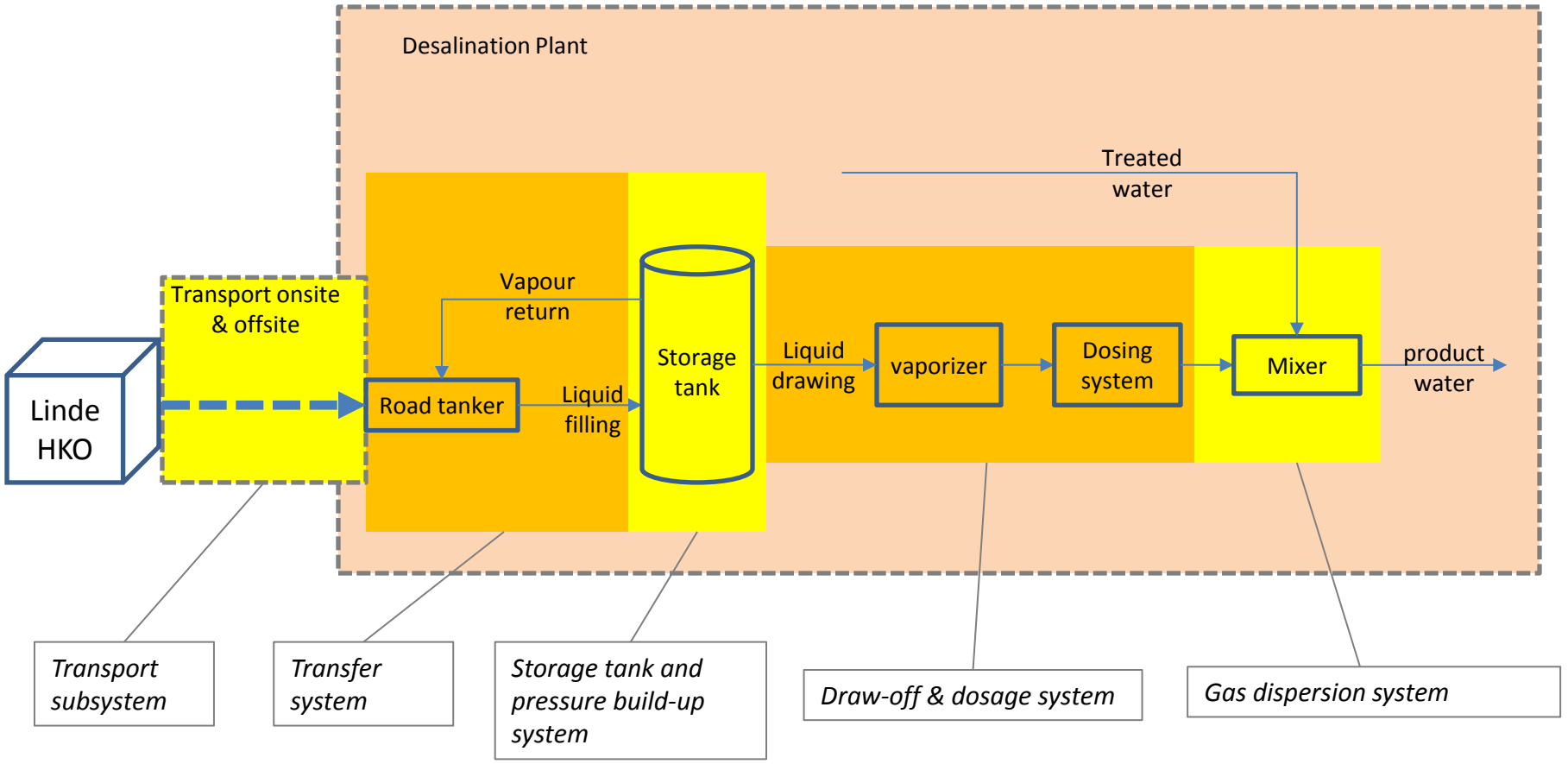
BLACK & VEATCH HONG KONG LIMITED 博威工程顧問有限公司

Dwg. 2 Indicative Layout of CO2 Storage Tanks

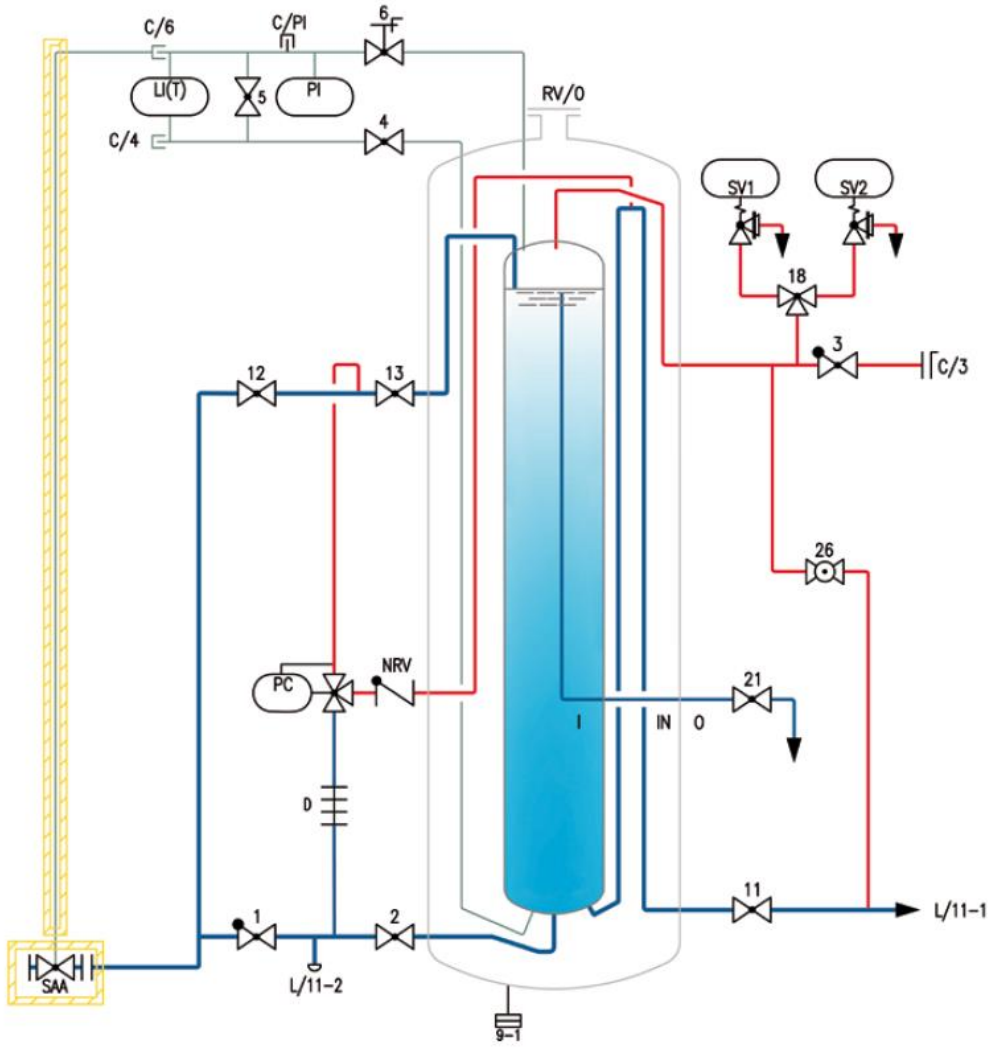


Remarks: only part of the total storage capacity is shown

Dwg. 3 Sub-systems



Dwg.4 Typical Storage Tank Flow Diagram



Flow diagramm - tanks for carbon dioxide.

Instrumentation and equipment, standard

C/3	Vent coupling
C/4, C/6	Connection add. transmitter
C/PI	Test connection pressure indicator
D	Pressure building coil
I	Inner vessel
IN	Insulation
LI(T)	Level indicator
L/11-1	Pipeline discharge
L/11-2	Pipeline discharge (plugged)
NRV	Non return valve
O	Outer vessel
PC	Pressure controller
PI	Pressure indicator
RV/O	Relief valve-outer vessel
SV1, SV2	Safety valve

Valves, standard

1	Filling
2	Pressure building valve
3	Vent
4	Bottom gauge (+)
5	Gauge bypass
6	Top gauge (-)
9-1	Evacuation connection
11	Discharge
12	Top filling
13	Gas shut-off
18	Change over
21	Trycock
26	Pressuring

Options

SAA	Safety shut-off valve, control line for SAA
LI(T)	Level indicator Samson Media 6 incl. instrument panel and standard programming, extra programming of Samson Media 6 acc. to customer requirements
LI(T)	Level indicator WIKA with transmitter output 4 - 20 mA

Remarks: This is only a typical schematic figure of CO2 storage tank. For CO2 storage tanks in the Desalination Plant, there will be 2 pairs of independent pressure relief valves (PRVs) installed on inner vessel. High level alarms will be installed and routed to control room to warn the operators when the tanks are overfilled.
Temperature gauge may be installed to enhance the monitoring capability for operating conditions.

Dwg. 5 Typical Ambient Vaporizer

Clip-on standard design.

Special VAP - Quality for specific use.

The vaporisers are suitable for a design over-pressure = max. allowable working pressure (PS) of 40 bar and an allowable operating temperature range (TS) of -269°C/+50°C.

Design and testing was carried out in accordance with the directive 97/23/EC concerning pressure equipment, AD 2000-Merkblätter and DIN EN.

The Linde finned tubes and connecting flanges are made of aluminium alloy and the seals are formed according to Linde Standards.

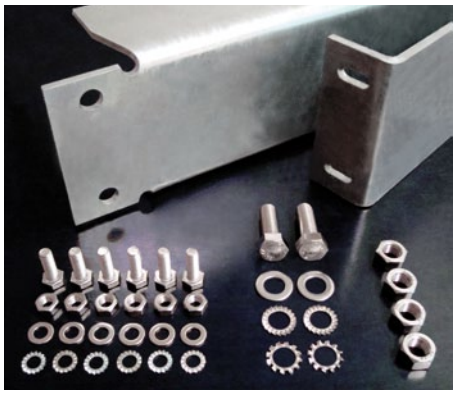
Clip-on standard design means the vaporiser without frame. Upon customer request, a mounting kit for installation on a cryo-tank is available.

Explanation of type designation:

L = air heated
40 = max. permissible working overpressure: 40 bar
8 F = number of Finned tubes: 8
2,5 = length of single finned tube: 2,5 m

Type L 40 - 4 F 2,5

Mounting kit



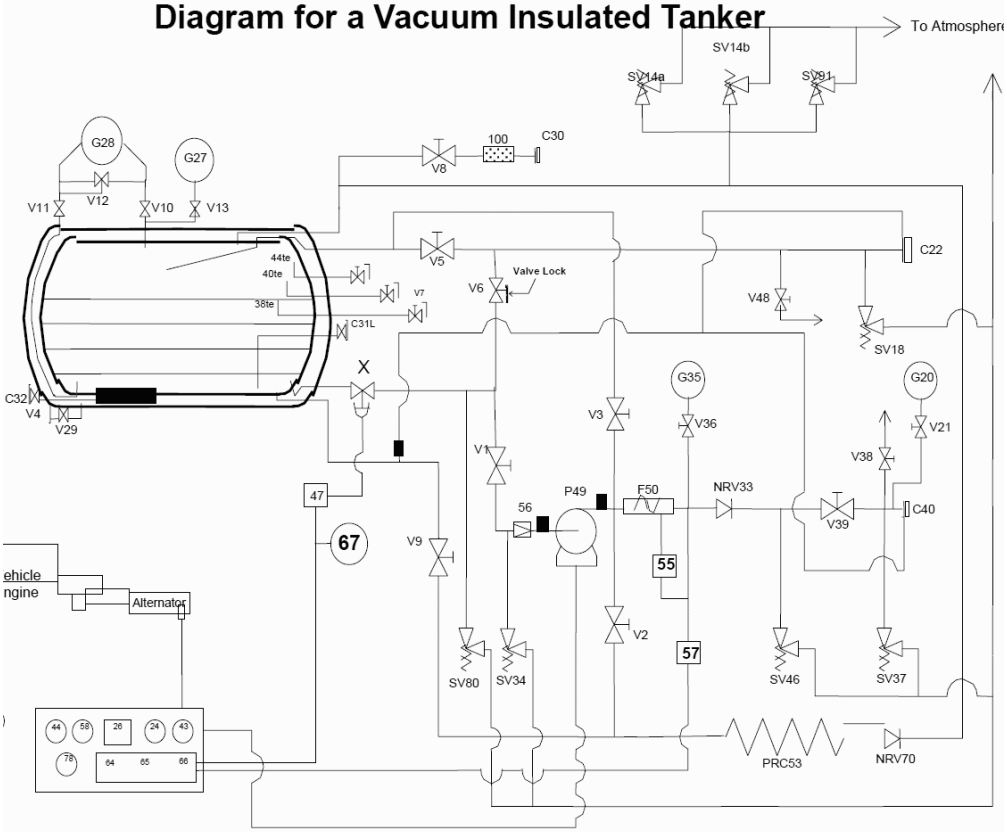
Type L 40 - 2 F 2,5

vaporiser type	dimensions approx.			weight empty	nominal capacity*)	connections (inlet/outlet)	Linde ident-no.
	depth [m]	widht [m]	height[m]	[kg]	N_2 [Nm³/h]	[mm]	
L 40 - 8 F 2,5	1,67	0,516	2,733	140	120	screwed: M40 x 2 pipe: DN 15 (21,3 x 1,5) socket welding end: ø18,2 material: stainless steel	J34895
L 40 - 4 F 2,5	1,67	0,276	2,733	74	60		I32740
L 40 - 2 F 2,5	0,69	0,276	2,709	37	30		I32631

*) The capacity is based on an ambient temperature of 20°C, 70 % rel. humidity, 15°C temperature difference between ambient and gas outlet temperature at a continuous 8-hours-operation

Dwg 6 Typical Process Diagram for Road Tanker

Appendix A – Example of a Process and Instrumentation Diagram for a Vacuum Insulated Tanker



X Emergency Shut-Off Valve
1 Pump Suction Valve
2 Pump Feed to Pressure Raising Coil
3 Recycle Valve
4 Vacuum Valve
5 Top Fill Valve
6 Bottom Fill / Decant Valve
7 Trycock Valve(s)
8 Main Vent Valve
9 Pressure Raising Valve
10 Contents Gauge Isolating Valve (Gas)
11 Contents Gauge Isolating Valve (Liquid)
12 Contents Gauge Equalising Valve
13 Vessel Pressure Gauge Isolating Valve
14 Vessel Relief Valve
18 Top Fill / Decant Hose Relief Valve
20 Back Pressure Gauge
21 Back Pressure Gauge Isolating Valve
22 Top Fill / Decant Line Coupling
24 Earth Leakage Protection Trip Button
26 Pump Start / Stop Unit
27 Vessel Pressure Gauge
28 Liquid Level Contents Gauge
29 Vacuum Gauge Head Isolating Valve
30 Main Vent Coupling
31 Analysis Valve
32 Vacuum Gauge Head
33 Non-Return Valve
34 Pump Suction Relief Valve
35 Pump Delivery Pressure Gauge
36 Pump Delivery Gauge Isolating Valve
37 Delivery Hose Relief Valve
38 Delivery Hose Vent Valve
39 Pump Delivery Valve
40 Delivery Line Coupling
43 Canopy Light / Working Light Switch
44 Ammeter
45 Engine Speed Tachometer
46 Delivery Line Relief Valve
47 Emergency Valve Actuator
48 Top Fill / Decant Hose Vent Valve
49 Pump and Motor
50 Flowmeter
53 Pressure Raising Coil
55 Metering Pressure Switch
56 Pump Suction Filter
57 Off-Prime Pressure Switch
58 Hours Run Meter
64 Emergency Shut-Off Button
65 Emergency Shut-Off Valve Operating Button
66 Emergency Shut-Off Valve “Open” Indicator
67 Remote Emergency Shut-Off Buttons (2)
70 Pressure Raising Coil Gas Phase Non-Return Valve
78 Earth Leakage Protection Warning Light
80 Closed Circuit Relief Valve
91 Vessel Secondary Relief Valve
100 Main Vent Silencer

Source: EIGA, Road Vehicle Emergency and Recovery, IGC Doc 81/06/E

Remarks:
This is only a typical schematic figure of vacuum insulated tanker. For CO_2 road tankers used in the Desalination Plant, there will be 2 pairs of independent pressure relief valves (PRVs) installed on inner vessel.