APPENDIX Q

HAZOP Work Sheets

Table B1 HAZOP Work Sheets

DEVIATION	HAZARD	CAUSE	CONSEQUENCE	SAFEGUARDS / MITIGATING FACTORS	NOTES
1. ITEM: Fuel barge berthing/unloading					
FIRE	Barge strikes berth	1. Severe weather 2. Human error during berthing 3. Barge drifts and strikes berth.	Damage to barge and/or equipment at berth leading to spillage of fuel and fire	1. Berthing operation takes place at low speed. 2. Fenders on berth 3. Barge robust enough to with- stand all but most severe impact 4. Relatively calm area of harbour 5. Flash point of all fuels handled at jetty above ambient temperature (lowest is kerosene, flash point=38^{0}C) 6. Hazardous area classification scheme enforced at oil depot 7. Deployment of booms to contain oil spills	1. Fire unlikely to affect occupants of the Joint Departmental Depot but may affect people at the open recreation area just along the seawall from the jetty
	Fire/explosion on-board barge	1. Engine fire 2. Smoking 3. Electrical fault	Fire spreads to cargo.	1. Fire-fighting equipment on-board barge and at berth 2. Prohibition of smoking 3. Passive fire-protection features of barge	
	Ranging	1. Tidal movement	Unloading hose detaches leading to spillage of fuel and fire	1. Limited tidal range in Hong Kong which can be taken up within slack of unloading hose. 2. Constant supervision of unloading operation by CRC staff	

DEVIATION	HAZARD	CAUSE	CONSEQUENCE	SAFEGUARDS / MITIGATING FACTORS	NOTES
	Improper connection of unloading hose	1. Under or over tightening of bolts on flanged joints	Leak from connecting point leading to fire	1. 4" containment wall around connecting point 2. Constant supervision of unloading operation (instruction to barge crew to stop pumping)	
	Leak from hose or flanged joints on barge	1. Tear in hose 2. Poorly made joints on barge 3. Poor condition of hose	Fuel spillage leading to fire	1. Limited containment provided by sill around deck of barge 2. Constant supervision of unloading operation (instruction to barge crew to stop pumping) 3. Regular inspection and pressure testing of hoses	
	Dropped object	1. Improper use of hoist on barge	Unloading hose detaches	1. Little scope for dropped object to cause damage to hose 2. Constant supervision of unloading operation (instruction to barge crew to stop pumping)	
	Premature disconnection of unloading hose	1. Operator error	Leak from connecting point leading to fire	1. 4" containment wall around connecting point 2. Constant supervision of unloading operation (instruction to barge crew to stop pumping)	
	Barge breaks away from berth	1. Insecure berthing of barge 2. Severe weather	Fuel spillage leading to fire	1. Constant supervision of unloading operation (instruction to barge crew to stop pumping)	

DEVIATION	HAZARD	CAUSE	CONSEQUENCE	SAFEGUARDS / MITIGATING FACTORS	NOTES
	Incorrect connecting point chosen for the type of fuel being delivered	1. Operator error or mix-up	1. Overfilling of storage tank leading to fire	1. Connecting points are labelled for each fuel type (although diesel oil stored in 2 tanks) 2. Overfill protection	
	Leak from pipework/fittings between jetty and tank farm	1. Corrosion 2. Impact 3. Internal explosion	1. Leak or rupture of pipeline leading to fuel spillage and fire	1.Pipelines run along a relatively short length of pipe bridge across the road to the storage tanks 2. No obvious sources of impact (Cranes on the neighbouring scrap yard would not reach pipe bridge if tip over; Road not used for routine vehicular access) 3. No flammable atmosphere within pipework to cause explosion 4. Site drainage to oil interceptor	
EXPLOSION	Vapour cloud explosion	1. Accumulation of vapour from fuel spillage in confined area	1. Equipment damage 2. Window breakage 3. Injury to workers and members of the public	1. No confined areas in the vicinity of the unloading jetty 2. Types of DG carried by barge normally below flash point	
	Explosion in ullage of fuel compartment on barge	1. Local heating / ignition of flammable atmosphere in ullage 2. Contact with hot surface	1. Catastrophic failure of fuel compartment 2. Spill of fuel followed by pool fire	1. Types of DG carried by barge normally below flash point 2. Smoking prohibited	
EXTERNAL EVENTS	Barge struck by another vessel	1. Bad weather 2. Loss of Steerage	1. Damage to fuel barge leading to spill and fire	1. Low level of marine activities in that area	

DEVIATION	HAZARD	CAUSE	CONSEQUENCE	SAFEGUARDS / MITIGATING FACTORS	NOTES
2. ITEM: LPG cylinder delivery/loading , unloading and export					
FIRE	Collision with another vehicle	1. Driver error 2. mechanical failure	1. Release of LPG leading to jet fire (prolonged release immediately ignited), fireball (instantaneous release immediately ignited) or flash fire (delayed ignition)	1. Good visibility in truck manoeuvring area 2. LPG cylinder wagon is licensed vehicle conforming to GSO requirements. 3. Fire fighting equipment on board truck 4. LPG cylinders transported in protective cages	1. LPG cylinder wagon parks adjacent to bunded area. opposite LPG storage area 2. Site is congested - manoeuvring of the trucks required.
	Collision with fixed objects (e.g. bund wall, pipework running along side of bund wall at ground level)	1. Driver error 2. mechanical failure	1. Damage to truck and possible release of LPG 2. Damage to fixed equipment and release of flammable liquid	1. Truck manoeuvring takes place at slow speed 2. Fire fighting equipment on board truck 3. LPG cylinders transported in protective cages	
	Loadshedding	1. Unsecured load	1. Release of LPG leading to jet fire (prolonged release immediately ignited), fireball (instantaneous release immediately ignited) or flash fire (delayed ignition).	1. LPG cylinders transported in protective cages. 2. Historical experience indicates LPG cylinders resilient to damage in loadshedding incidents.	
	Vehicle fire	1. Cab fire 2. Engine fire 3. Tyre fire 4. Ignition of combustibles near truck	1. Flames impinge on LPG cylinders leading to BLEVE. 2. Projectile hazard due to exploding cylinders 3. Secondary fires	1. LPG cylinder wagon is licensed vehicle conforming to GSO requirements 2. Fire fighting equipment on board truck. 3. Minimal combustible items in LPG storage area	
	Damage to LPG cylinders by fork lift truck	1. Operator error	1. Possible damage to LPG cylinders and release of LPG	1. LPG cylinder valve protected 2. Operator training	1. LPG cylinders are unloaded by LPG-propelled fork lift truck.

DEVIATION	HAZARD	CAUSE	CONSEQUENCE	SAFEGUARDS / MITIGATING FACTORS	NOTES
	Dropped load	1. Mechanical failure of fork lift truck	1. Possible damage to LPG cylinders and release of LPG	1. LPG cylinders handled in protective cages 2. Minimal drop height	
	Fire on fork lift truck	1. Engine fire 2. Electrical fire 3. LPG release from rear of fork lift truck	1. Flames impinge on LPG cylinders leading to BLEVE. 2. Projectile hazard due to exploding cylinders. 3. Secondary fires		1. No license required for LPG fork lift truck
	Incorrect stacking	1. Operator error	1. LPG cylinder crates could topple over.	1. Cylinder crates are single-stacked only. 2. No requirement for double stacking	
	Incorrect placement	1. Operator error 2. LPG storage area full	1. LPG cylinder placed closer to drum filling station with consequent risk of flammable liquid fire affecting LPG cylinders	1. Current separation distance between LPG storage area and drum filling station (12m) is in excess of UK HSC and US NFPA requirements. 2. LPG storage area is clearly demarcated.	
	Collision involving fork lift truck	1. Operator error 2. Mechanical failure	1. Possible damage to LPG cylinders and release of LPG	1. No other vehicle movements or obstructions in vicinity of LPG storage area 2. LPG cylinders handled in protective cages	
EXPLOSION	Vapour cloud explosion	1. Accumulation of LPG vapour in confined space and subsequently ignition	1. Equipment damage 2. Window breakage 3. Injury to workers and members of the public	1. LPG storage area well ventilated 2. No other confined areas in vicinity of LPG storage area with possible exception of pump house and office building	

DEVIATION	HAZARD	CAUSE	CONSEQUENCE	SAFEGUARDS / MITIGATING FACTORS	NOTES
EXTERNAL EVENTS	Arson	1. Vandalism	1. Fire engulfing LPG cylinders	1. Daytime only operation but 24-hr security present 2. 2.5m-high wall around the site	
	Maintenance or modification work		1. Incorrect isolation/draining of tank leads to fuel spillage and fire. 2. Hot work causes ignition of combustible residues in tanks leading to fire/explosion	1. Permit-to-work system	
	Flooding	1. Heavy rain	1. Possible floating of LPG cylinders	1. Site drainage system	
3. ITEM: Bulk fuel storage					
FIRE	Fire on top of storage tank (e.g. rim fire on floating roof tank)	1. Local heating/ignition of flammable vapour (Vapour escapes from inadequate rim seal.) 2. Lightning strike 3. Burning embers from fire on adjacent sites	1. Thermal radiation from fire causes damage to nearby plant or injury to people. 2. Smoke penetration into nearby buildings via openings, ventilation intakes, etc.	1. Foam protection system 2. Water sprays to protect adjacent tanks 3. Routine inspection and maintenance of tanks 4. Fire hydrants for FSD use 5. Fuels handled in depot normally below flash point	
	Fire in bund	1. Fuel spillage from tank or tank connections	1. Thermal radiation from fire causes damage to nearby plant or injury to people. 2. Smoke penetration to nearby buildings	1. Water sprays to protect adjacent tanks 2. Routine inspection and maintenance of tanks 3. Fire hydrants for FSD use 4. Fuels handled in depot normally below flash point	

DEVIATION	HAZARD	CAUSE	CONSEQUENCE	SAFEGUARDS / MITIGATING FACTORS	NOTES
	Fire outside bund	1. Fuel spillage and bund overtopping, e.g. due to drain valve left open, damage to bund	1. Pool fire spreads across site.	1. Site drainage/containment system 2. Drain valve normally closed (not readily accessible)	
EXPLOSION	Explosion inside tank	1. Ignition of flammable vapour inside tank 2. Ignition of flammable vapour during tank maintenance/cleano ut	1. Catastrophic failure of tank 2. Pool fire, projectile hazard 3. Secondary fires	1. No vapour space during normal operation of floating roof tank 2. Fuels handled in depot normally below flash point	
	Vapour cloud explosion	1. Accumulation of flammable vapour in confined space and subsequently ignition	1. Equipment damage 2. Window breakage 3. Injury to workers and members of the public	1. No other confined areas in vicinity of tanks with possible exception of pump house and office building 2. Fuels are below their flash point.	
EXTERNAL EVENTS	Fire on adjacent site	1. Burning of rubbish 2. Accidental fire	1. Possible ignition of fuel spillage at oil depot	1. 2.5m-high 2-hr fire resistance wall around site	
	External impact	1. Crane on adjacent scrap yard topples over.	1. Tanks out of range		
	Earthquake / subsidence /aircrash		1. Collapse of tanks and bund leading to unconfined fuel spillage	1. Fuel stored below flash point	

DEVIATION	HAZARD	CAUSE	CONSEQUENCE	SAFEGUARDS / MITIGATING FACTORS	NOTES
4. ITEM: LPG storage					
FIRE	Leak or rupture of cylinders	1. Corrosion 2. Overfilling	1. Release of LPG leading to jet fire (prolonged release immediately ignited), fireball (instantaneous release immediately ignited) or flash fire (delayed ignition)	1. Regular inspection and testing of cylinders 2. Precautions against overfilling 3. Fixed water spray system	
EXPLOSION (see Item 2 above)					
EXTERNAL EVENTS	External fire	1. Hydrocarbon pool fire elsewhere on site 2. Fire in adjacent site	1. Fire engulfs LPG cylinders leading to BLEVE 2. Thermal radiation hazard and projectile hazard 3. Secondary fires 4. Possible knock-on effects to DG storage at Joint Departmental Depot	1. Separation of LPG storage area from other facilities conforms to relevant standards. 2. 2.5m-high 2-hr fire resistance wall around site 3. Fixed water spray system 4. Portable fire extinguisher 5. Packaged DGs (Cat 2, Cat 5) will be stored at Joint Departmental Depot but arrangements not yet determined. Unlikely that bulk Cat 5 DG storage will be provided.	
	External impact				1. No obvious source of external impact. Adjacent site is access road only.

DEVIATION	HAZARD	CAUSE	CONSEQUENCE	SAFEGUARDS / MITIGATING FACTORS	NOTES
5. ITEM: Bulk tanker loading					
FIRE	Pump fire	1. Overheating of pump	1. Spreading pool fire around pump farm area	1. Site drainage and containment system 2. Manual isolation of tank discharge line (within bund)	1. Possible knock-on impact to drum storage of red dye
	Spill from pipeline or loading arm	1. Corrosion 2. External impact 3. Fatigue	1. Fuel spillage and fire	1. Site drainage and containment system 2. Manual isolation of tank discharge line (within bund) 3. Driver and CRC staff present during tanker loading 4. Pump emergency stop on gantry.	1. Loading rate 1000 l/min 2. No automatic metering system
	Pump starts before loading are inserted or loading arm removed before pump stops.	1. Human error	1. Fuel spillage and fire	1. Site drainage and containment system 2. Driver and CRC staff present during tanker loading 3. Pump emergency stop on gantry. 4. Foam spray system beneath tanker loading canopy	
	Overfilling of tanker	1. Human error 2. Meter failure	1. Fuel spillage and fire	1. Site drainage and containment system 2. Driver and CRC staff present during tanker loading 3. Pump emergency stop on gantry. 4. Foam spray system beneath tanker loading canopy	

DEVIATION	HAZARD	CAUSE	CONSEQUENCE	SAFEGUARDS / MITIGATING FACTORS	NOTES
EXPLOSION	Explosion within tanker	1. Static discharge during loading 2. Ignition by nearby electrical equipment or vehicle engine	1. Catastrophic failure of road tanker	1. Hazardous area classification scheme 2. Road tanker conforms to FSD requirements. 3. Fuels mostly loaded are high flash point diesel oils.	
EXTERNAL EVENTS	Tanker impacted by another vehicle	1. Driver error	1. Possible puncturing of tank	1. Road tanker conforms to FSD requirements. 2. Tanker manoeuvring at slow speed	
6. ITEM: Dye marker injection / storage					
FIRE	Spill from tank / pipework	1. Corrosion 2. External impact	1. Spillage of dye marker and fire	1. Bund beneath dye marker tank	
	Drum failure	1. Corrosion 2. External impact	1. Spillage of dye marker and fire	1. Dye marker has high flash point	
EXPLOSION	External fire	1. Spillage / fire in adjacent areas	1. Dye marker tank / drums rocket in fire	1. Site fire fighting equipment	
7. ITEM: Drum filling					
FIRE	Spill from pipeline or drum filling hose	1. Corrosion 2. External impact 3. Fatigue 4. Tear in hose	1. Fuel spillage and fire 2. Fire may escalate to involve already filled drums on truck.	1. Site drainage and containment system 2. Manual isolation of tank discharge line (within bund) 3. Driver and CRC staff present during drum filling 4. Pump emergency stop on gantry	

DEVIATION	HAZARD	CAUSE	CONSEQUENCE	SAFEGUARDS / MITIGATING FACTORS	NOTES
	Spill during drum fillling	1. Human error, e.g. overfilling	1. Fuel spillage and fire 2. Fire may escalate to involve already filled drums on truck.	1. Drum filling nozzle has dead man's handle. 2. Foam spray system above drum filling station	
	Dead man's handle jams open.	1. Mechanical failure or inadequate maintenance	1. Fuel spillage and fire 2. Fire may escalate to involve already filled drums on truck.	1. Site drainage and containment system 2. Manual isolation of tank discharge line (within bund) 3. Foam spray system above drum filling station	
	Spill from drums stored on site	1. Corrosion 2. External impact 3. External fire	1. Spreading pool fire 2. Potential knock-on effects to LPG storage area	1. Drums from drum filling station exported immediately 2. Empty drums remain on truck.	
EXPLOSION	Vapour cloud explosion	1. Accumulation of flammable vapour in confined space (office building) and subsequently ignition	1. Equipment damage 2. Window breakage 3. Injury to workers and members of the public	1. Drainage around drum filling station 2. Fuels (mainly kerosene and IDO) dispensed at drum filling station are below flash point.	
	Exploding drums	1. Fire at drum filling station engulfs drums on truck.	1. Equipment damage 2. Window breakage 3. Injury to workers and members of the public 4. Projectile hazard 5. Secondary fires	1. FSD license requirements for package truck 2. Foam spray system above drum filling station	
EXTERNAL EVENTS	Package truck impacted by another vehicle	1. Driver error	1. Possible puncturing of drums	1. Package truck conforms to FSD requirements. 2. Truck manoeuvring at slow speed	

DEVIATION	HAZARD	CAUSE	CONSEQUENCE	SAFEGUARDS / MITIGATING FACTORS	NOTES
8. ITEM: Bulk fuel export					
FIRE	Collision with another vehicle	1. Driver error 2. mechanical failure	1. Possible puncturing of tank leading to fuel spillage and fire	1 Trucks enter and exit site at same location but visibility in truck manoeuvring area is good. 2. Manoeuvring takes place at slow speed. 3. Tanker conforms to FSD requirements. 4. Fire fighting equipment on site	
	Vehicle fire	1. Cab fire 2. Engine fire 3. Tyre fire	1. Possible damage to tank leading to catastrophic failure 2. Fuel spillage and fire	1. Tanker conforms to FSD requirements. 2. Fire fighting equipment on site	
EXPLOSION	Tank explosion	1. Prolonged fire beneath road tanker	1. Catastrophic failure of tank accompanied by fire ball and pool fire	1. Tanker conforms to FSD requirements. 2. Fire fighting equipment on site	
9. ITEM: Drum export					
FIRE	Vehicle fire	1. Cab fire 2. Engine fire 3. Tyre fire	1. Possible damage to drums on truck leading to fuel spillage and escalation of fire 2. Possible knock-on effects to LPG storage area	1. Truck conforms to FSD requirements. 2. Fire fighting equipment on site	