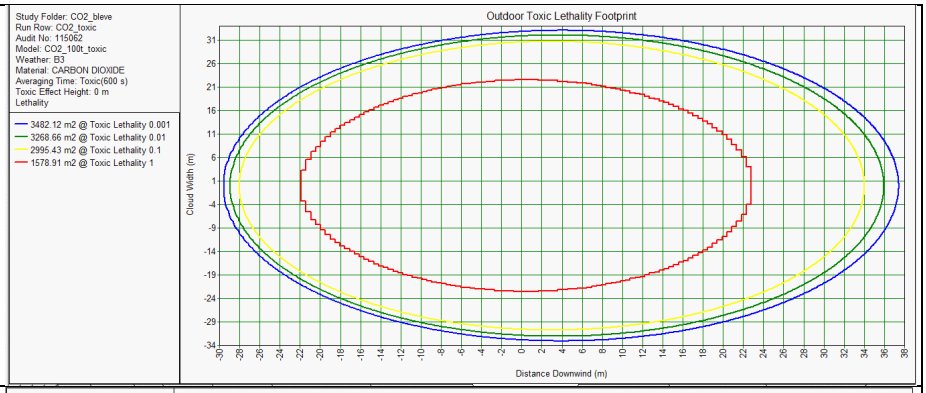
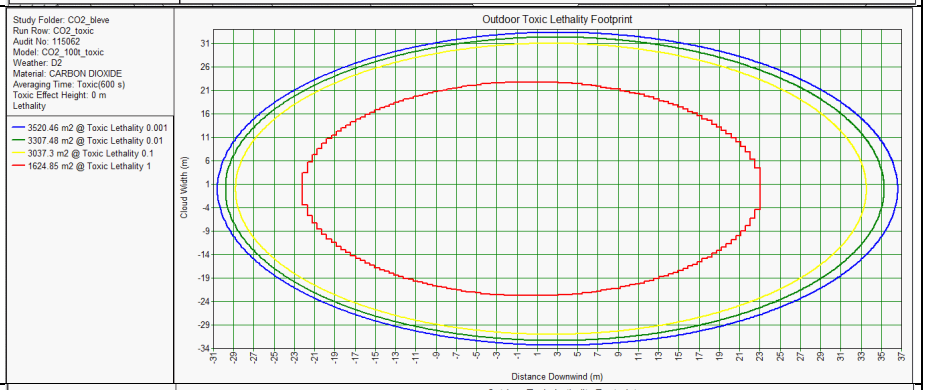
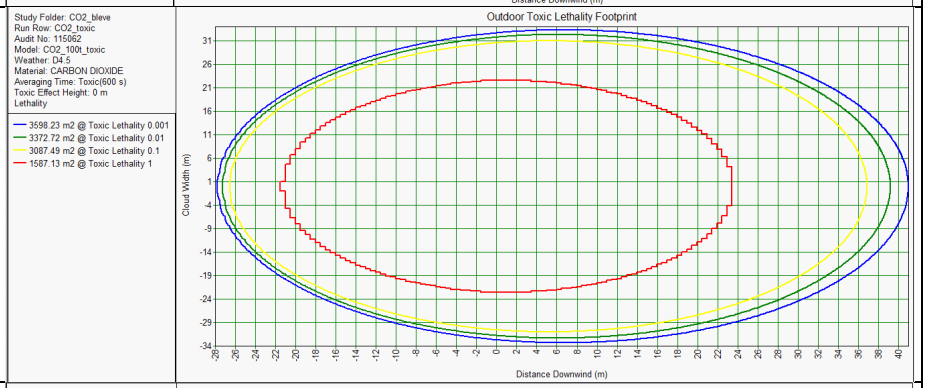
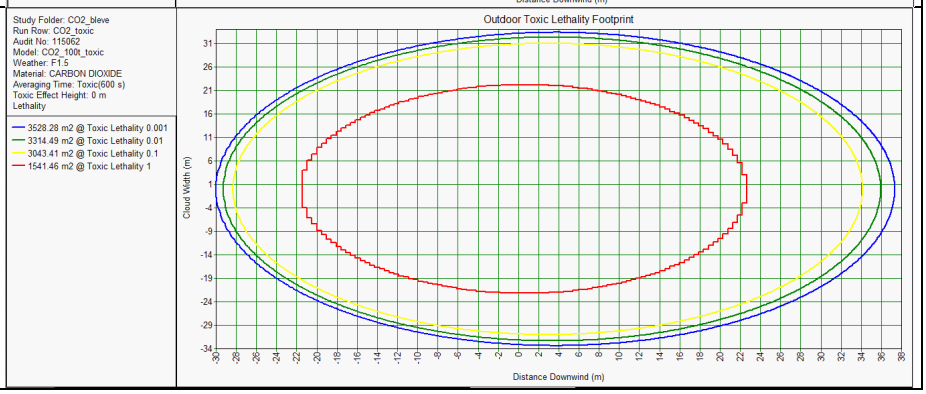
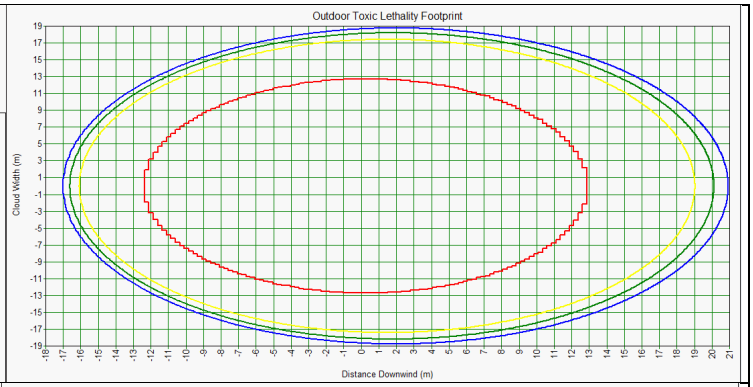
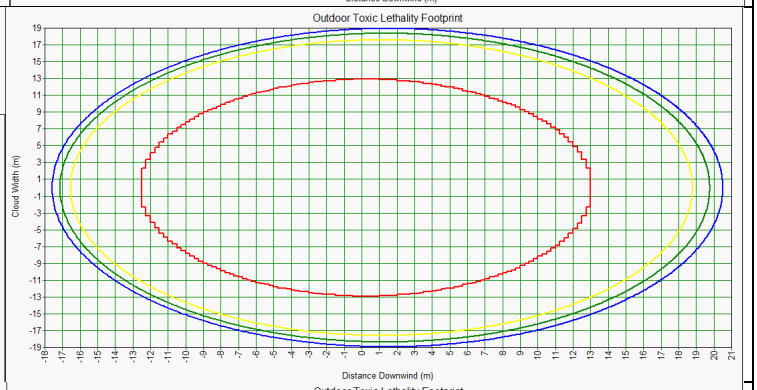
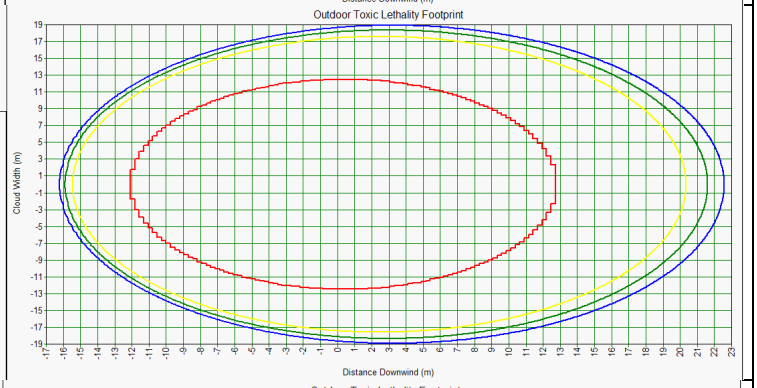
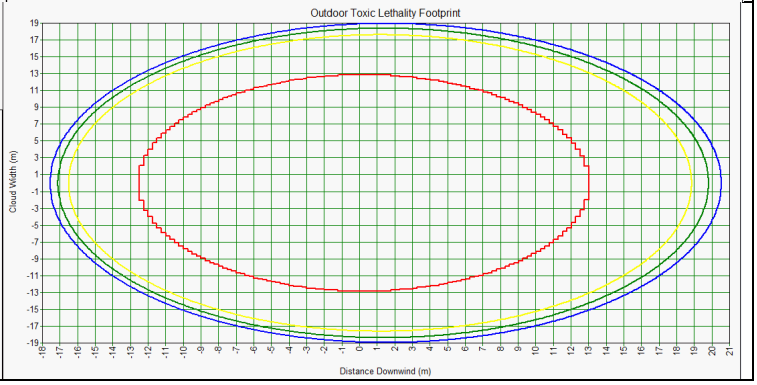
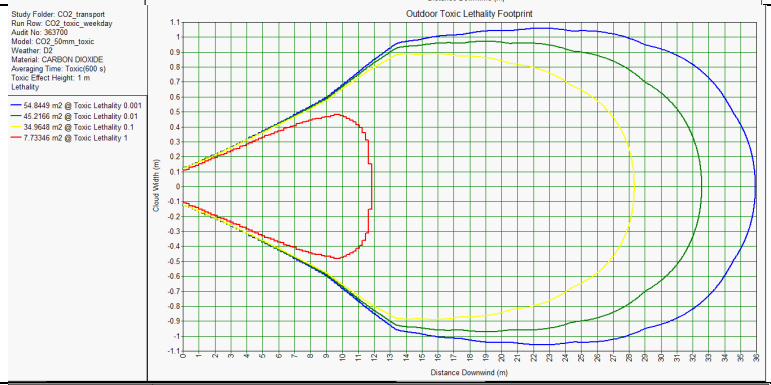
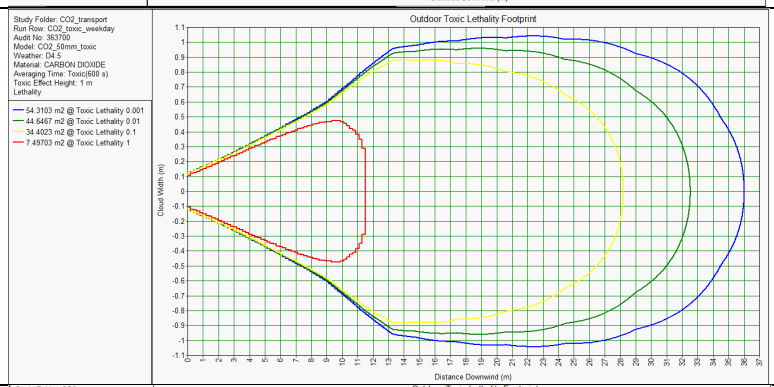
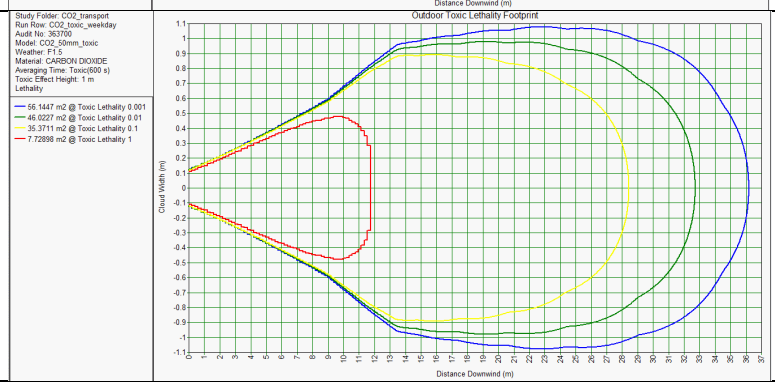
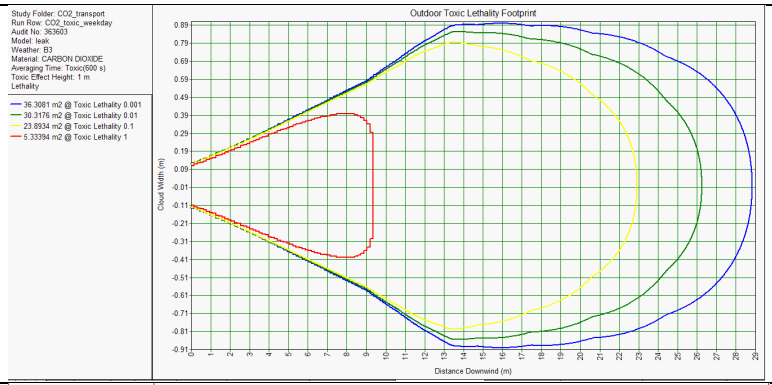
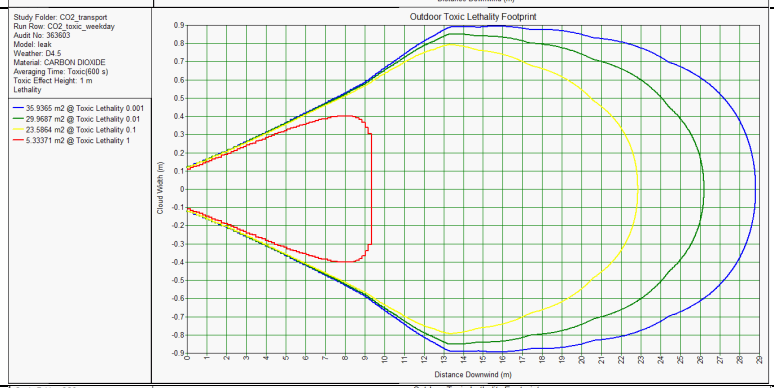
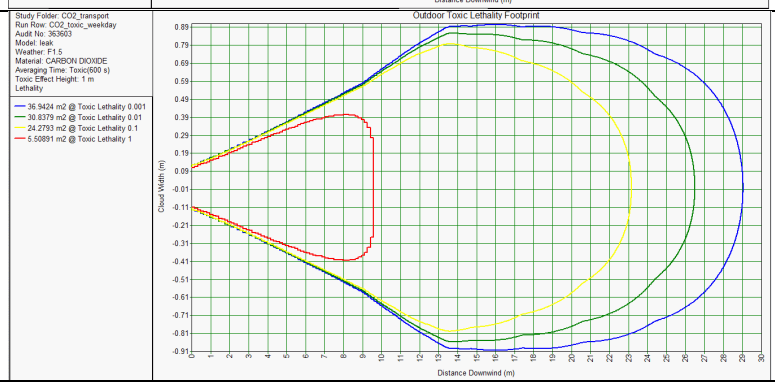
Figure 1 Lethality Footprints for Toxic Impact

Rupture (100-tonne) - B3	
Rupture (100-tonne) – D2	
Rupture (100-tonne) – D4.5	
Rupture (100-tonne) – F1.5	

Rupture (20-tonne) – B3	Study Folder: CO2_bleve Run Row: CO2_toxic Audit No: 115062 Model: CO2_20t_toxic Weather: B3 Material: CARBON DIOXIDE Averaging Time: Toxic(600 s) Toxic Effect Height: 0 m Lethality 1118.23 m2 @ Toxic Lethality 0.001 1049.43 m2 @ Toxic Lethality 0.01 960.622 m2 @ Toxic Lethality 0.1 504.823 m2 @ Toxic Lethality 1 
Rupture (20-tonne) – D2	Study Folder: CO2_bleve Run Row: CO2_toxic Audit No: 115062 Model: CO2_20t_toxic Weather: D2 Material: CARBON DIOXIDE Averaging Time: Toxic(600 s) Toxic Effect Height: 0 m Lethality 1133.42 m2 @ Toxic Lethality 0.001 1064.84 m2 @ Toxic Lethality 0.01 976.42 m2 @ Toxic Lethality 0.1 518.468 m2 @ Toxic Lethality 1 
Rupture (20-tonne) – D4.5	Study Folder: CO2_bleve Run Row: CO2_toxic Audit No: 115062 Model: CO2_20t_toxic Weather: D4.5 Material: CARBON DIOXIDE Averaging Time: Toxic(600 s) Toxic Effect Height: 0 m Lethality 1152.33 m2 @ Toxic Lethality 0.001 1080.83 m2 @ Toxic Lethality 0.01 988.855 m2 @ Toxic Lethality 0.1 487.483 m2 @ Toxic Lethality 1 
Rupture (20-tonne) – F1.5	Study Folder: CO2_bleve Run Row: CO2_toxic Audit No: 115062 Model: CO2_20t_toxic Weather: F1.5 Material: CARBON DIOXIDE Averaging Time: Toxic(600 s) Toxic Effect Height: 0 m Lethality 1134.36 m2 @ Toxic Lethality 0.001 1066 m2 @ Toxic Lethality 0.01 977.853 m2 @ Toxic Lethality 0.1 515.636 m2 @ Toxic Lethality 1 

Leak (100-tonne 50mm) – B3	
Leak (100-tonne 50mm) – D2	
Leak (100-tonne 50mm) – D4.5	
Leak (100-tonne 50mm) – F1.5	

Leak (20-tonne 50mm) – B3	
Leak (20-tonne 50mm) – D2	
Leak (20-tonne 50mm) – D4.5	
Leak (20-tonne 50mm) – F1.5	

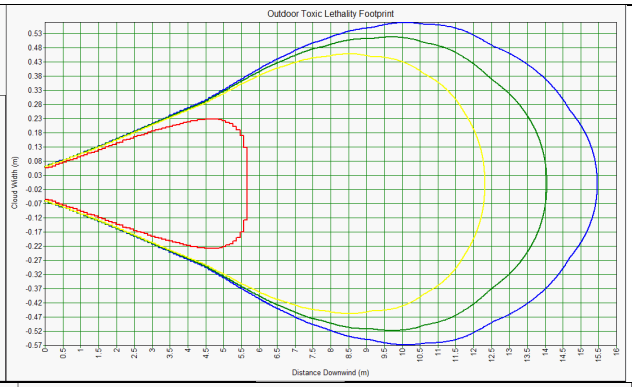
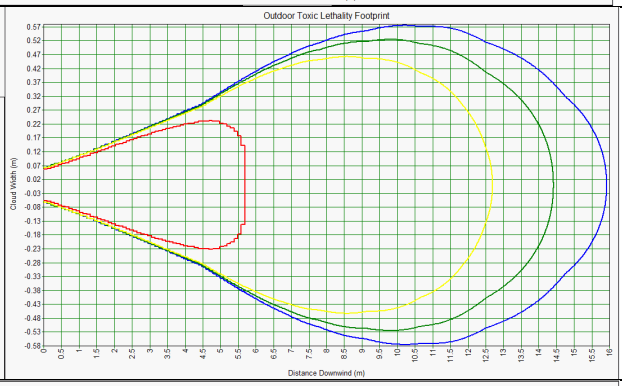
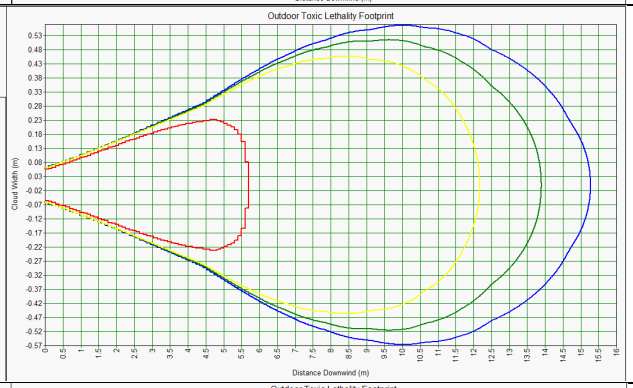
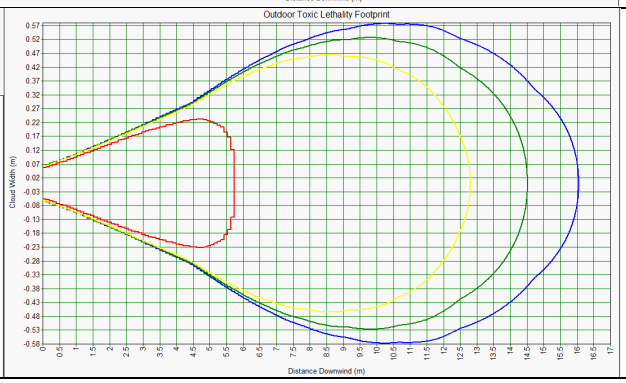
Leak (20-tonne 25mm) – B3	tudy Folder: CO2_transport un Row: CO2_toxic_weekday udit No: 363603 odel: leak eather: B3 aterial: CARBON DIOXIDE veraging Time: Toxic(600 s) xic Effect Height: 1 m thality 11.4411 m2 @ Toxic Lethality 0.001 9.55825 m2 @ Toxic Lethality 0.01 7.48658 m2 @ Toxic Lethality 0.1 1.80525 m2 @ Toxic Lethality 1 
Leak (20-tonne 25mm) – D2	Study Folder: CO2_transport Run Row: CO2_toxic_weekday Audit No: 363603 Model: leak Weather: D2 Material: CARBON DIOXIDE Averaging Time: Toxic(600 s) Toxic Effect Height: 1 m Lethality 12.0104 m2 @ Toxic Lethality 0.001 10.0018 m2 @ Toxic Lethality 0.01 7.80953 m2 @ Toxic Lethality 0.1 1.82796 m2 @ Toxic Lethality 1 
Leak (20-tonne 25mm) – D4.5	Study Folder: CO2_transport Run Row: CO2_toxic_weekday Audit No: 363603 Model: leak Weather: D4.5 Material: CARBON DIOXIDE Averaging Time: Toxic(600 s) Toxic Effect Height: 1 m Lethality 11.272 m2 @ Toxic Lethality 0.001 9.40639 m2 @ Toxic Lethality 0.01 7.36105 m2 @ Toxic Lethality 0.1 1.80271 m2 @ Toxic Lethality 1 
Leak (20-tonne 25mm) – F1.5	Study Folder: CO2_transport Run Row: CO2_toxic_weekday Audit No: 363603 Model: leak Weather: F1.5 Material: CARBON DIOXIDE Averaging Time: Toxic(600 s) Toxic Effect Height: 1 m Lethality 12.2034 m2 @ Toxic Lethality 0.001 10.1453 m2 @ Toxic Lethality 0.01 7.91914 m2 @ Toxic Lethality 0.1 1.83773 m2 @ Toxic Lethality 1 

Figure 2 Lethality Footprints for Overpressure Impact

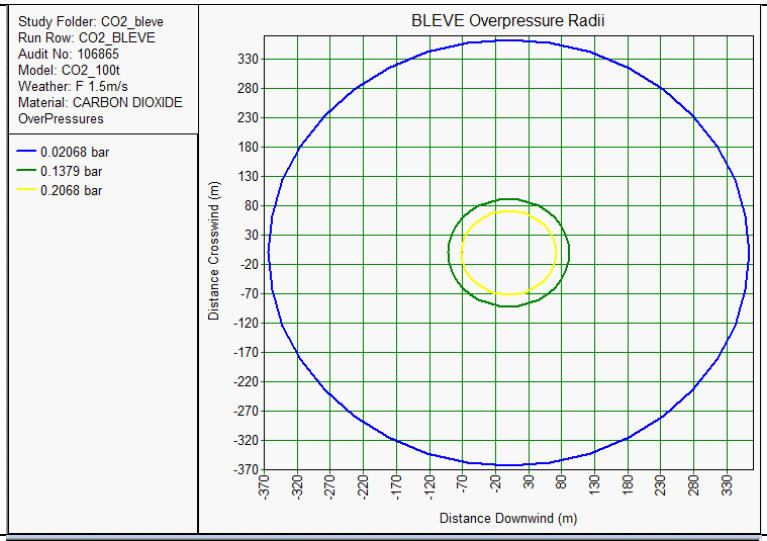
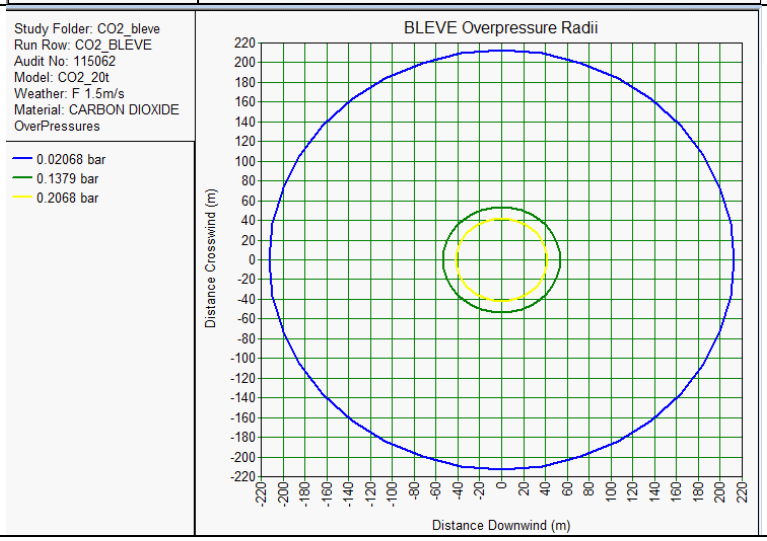
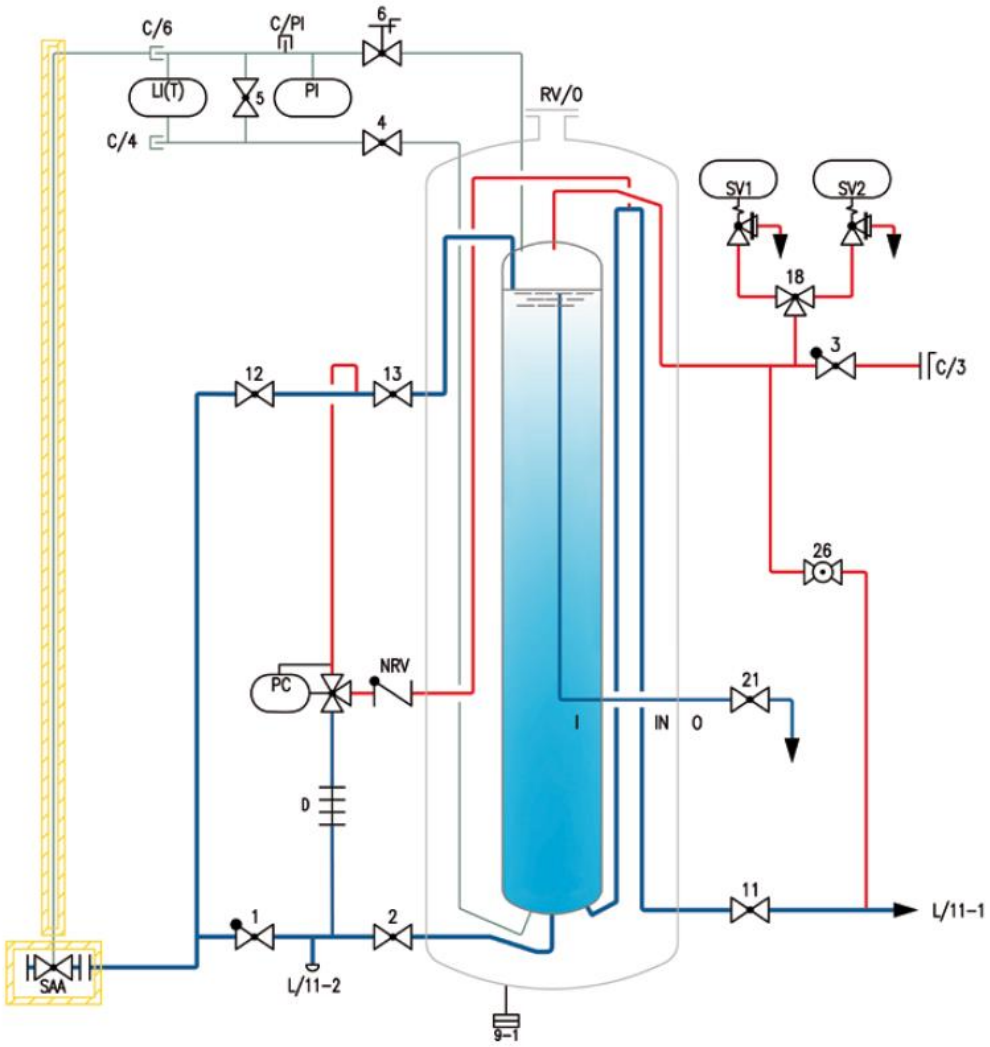
Rupture (100-tonne)	
Rupture (20-tonne)	

Figure 3 Typical Schematic of CO2 Storage Tank



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

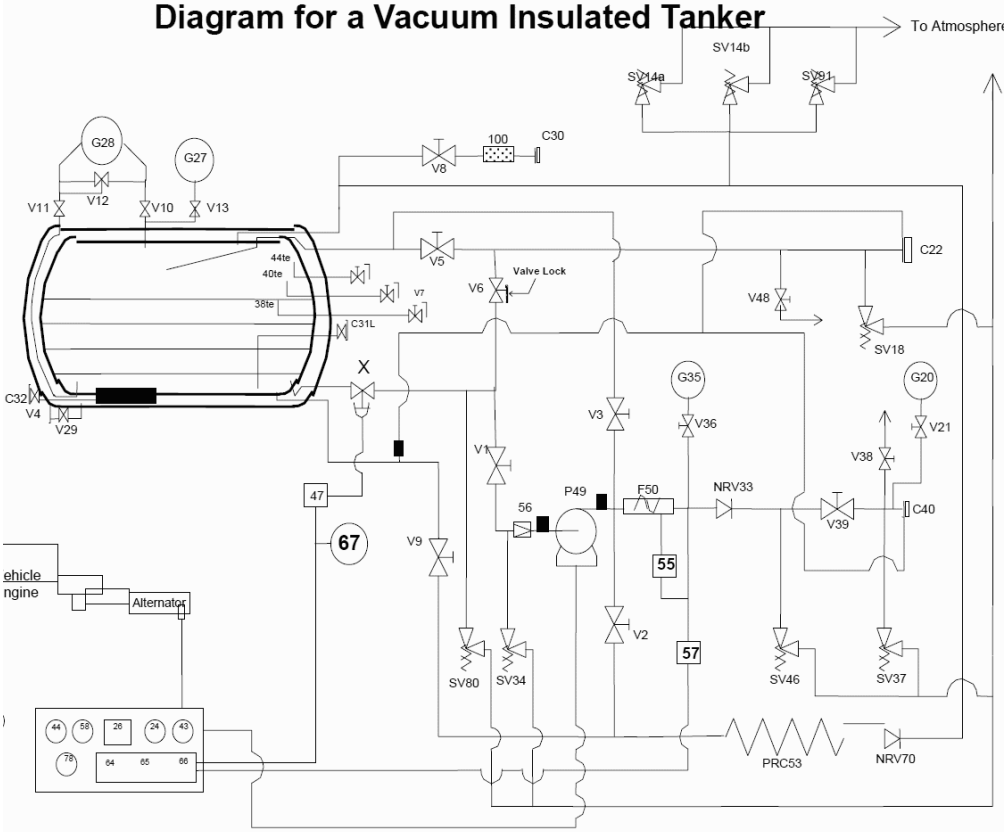
Options

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.

Figure 4 Typical Schematic of Vacuum Insulated Tanker

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

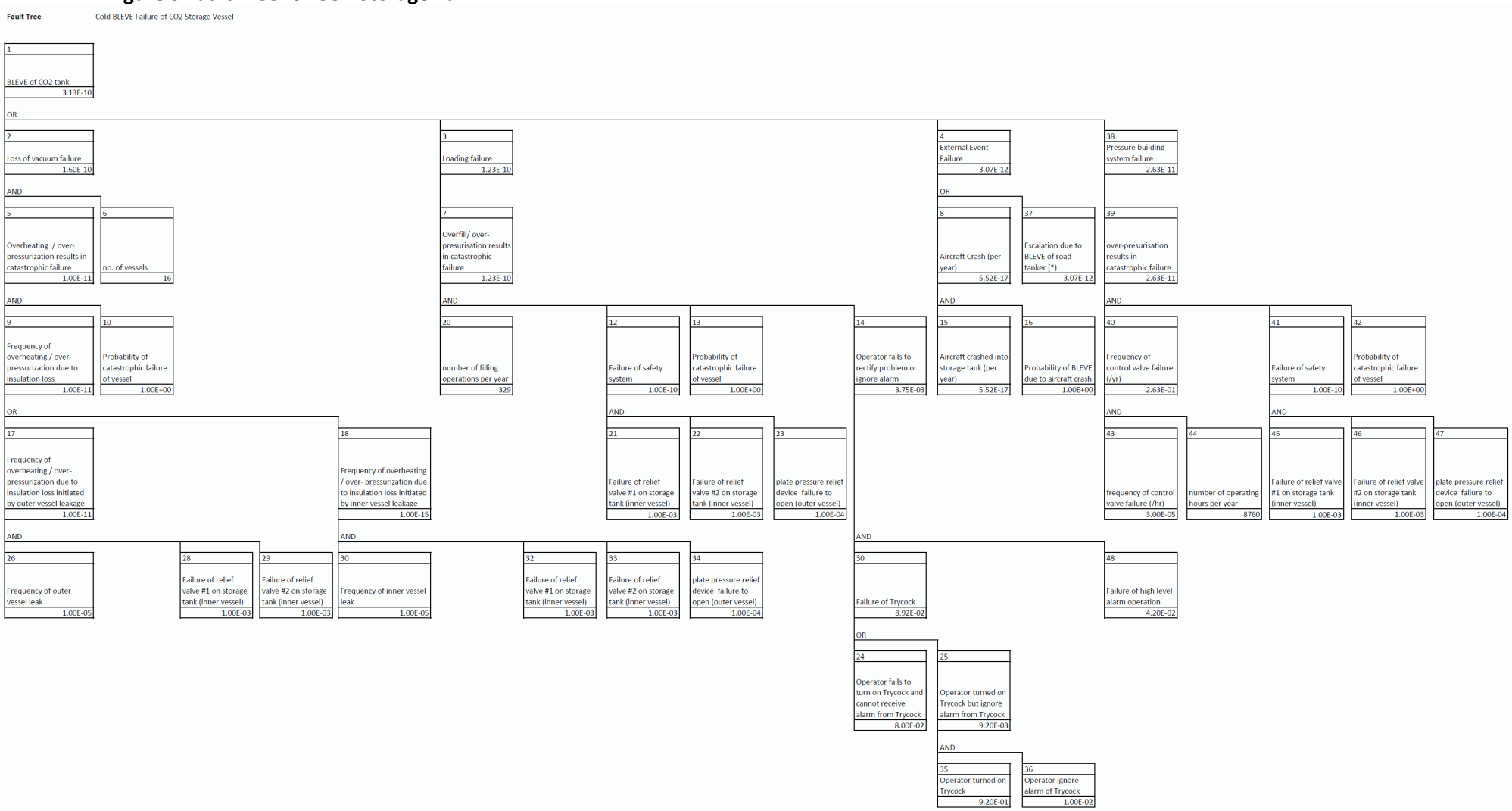


X Emergency Shut-Off Valve
1 Pump Suction Valve
2 Pump Feed to Pressure Raising Coil
3 Recycle Valve
4 Vacuum Valve
5 Top Fill Valve
6 Bottom Fill / Decant Valve
7 Trycock Valve(s)
8 Main Vent Valve
9 Pressure Raising Valve
10 Contents Gauge Isolating Valve (Gas)
11 Contents Gauge Isolating Valve (Liquid)
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 CO2 road tankers used in the Desalination Plant, there will be 2 pairs of independent pressure relief valves (PRVs) installed on inner vessel.

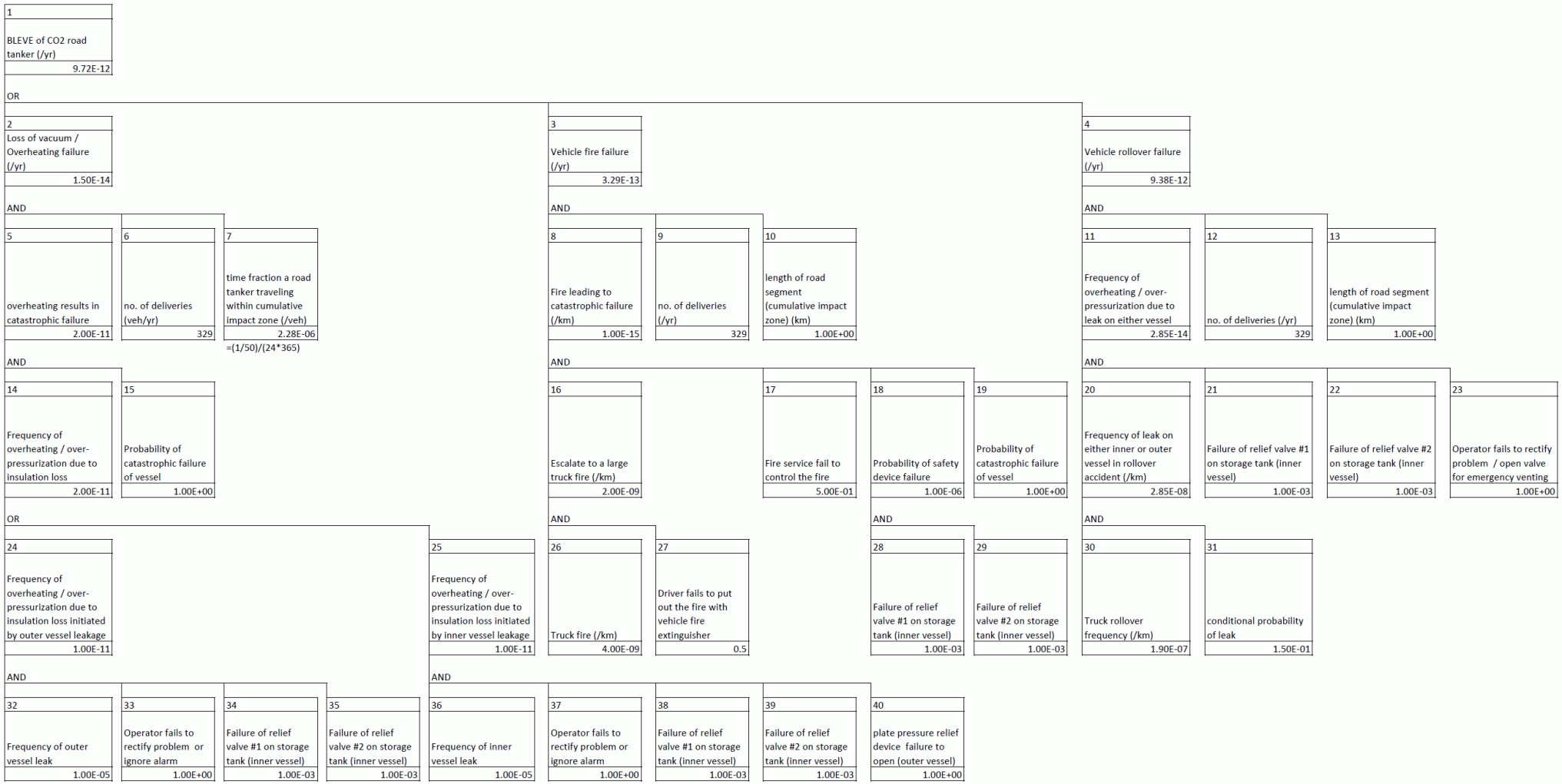
Figure 5 Fault Tree for CO2 Storage Tank BLEVE



Remarks (*)
Box 14 - For CO2 filling operation, 1 plant staff will be requested by CO2 supplier to stay with the road tanker driver during filling operation. Moreover, contents gauge is available for monitoring of liquid level although Trycock is the main indicator for full tank.
Box 48 - failure of high level alarm at control room may be caused (1) being ignored by operation staff; or (2) breakdown of high level alarm system. Probability of failure of high level alarm system refers to the example "high level alarm system for crystallisation plant" in Lees F. P., Loss Prevention in the Process Industries, Butterworth Heinemann, 4th Edition.
ignore high level alarm = (Errors of commission such as operating the wrong button or reading the wrong display. More complex task, less time available, some cues necessary, 0.001) x (Unfamiliarity with a situation which is potentially important but which only occurs infrequently or which is novel, 17) src: OGP 434-05 Table 2.7 & 2.8
Box 24 - fail to turn on Trycock = (Errors of omission where dependence is placed on situation cues and memory. Complex, unfamiliar task with little feedback and some distractions, 0.01) x (No obvious means of reversing an unintended action, 8) src: OGP 434-05 Table 2.7 & 2.8
Box 35 - operator turned on Trycock = 1 - Box 24
Box 36 - ignore Trycock alarm = (Errors of commission such as operating the wrong button or reading the wrong display. More complex task, less time available, some cues necessary, 0.001) x (A low signal-noise ratio, 10) src: OGP 434-05 Table 2.7 & 2.8
Box 32, 33 - Inner vessel leakage leads to loss of vacuum insulation. The increase in pressure in the insulation space would trigger the plate pressure relief device on the outer vessel. In case the plate pressure relief device fails to open, temperature and pressure in the inner vessel would increase.
Over-pressurization and BLEVE can only occur if pressure relief valves on the inner vessel fail to open.
Box 37 - refer to fault tree for "Cold BLEVE Failure of CO2 Road Tanker within the Desalination Plant"
Box 43, 44 - reference to Lees; conservatively assumed the valve is under operation all the time. In fact, the pressure building system operates on demand.

Figure 6 Fault Tree for CO2 Road Tanker BLEVE (offsite)

Fault Tree Cold BLEVE Failure of CO2 Road Tanker along Transport Route within the Cumulative Impact Zone



Box 23/ 33/ 37 = 1 - assume the driver does not have sufficient time to respond

Box 40 = 1 - assume plate pressure relief device is not installed

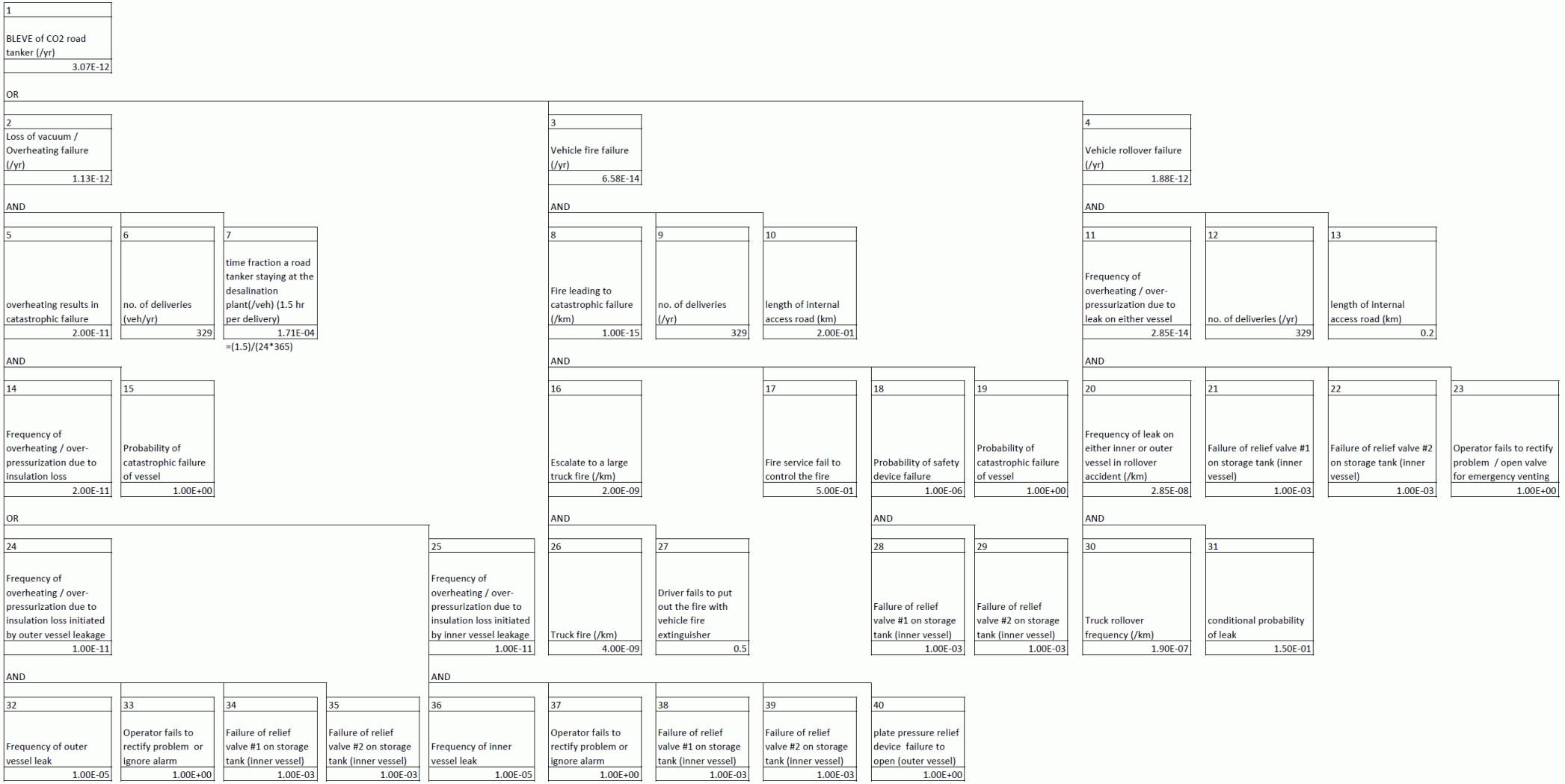
Box 4 - according to findings of the HAZID workshop, BLEVE may occurs when both inner and outer vessels are punctured in a rollover accident. However, the initial conditions are the same as or similar to the operating conditions when both vessels is ruptured or punctured at the same time. Since the initial conditions do not fall within the BLEVE zone, BLEVE is unlikely to occur. On the other hand, damage to either vessel leads to loss of vacuum and change of initial conditions. Therefore, leak failure of either vessel is considered in the fault tree.

Box 31 - refer to "QRA of transport of LPG and Naphtha, Methodology report, DNV, 1996"

Box 38, 39 - Inner vessel leakage leads to loss of vacuum insulation. The increase in pressure in the insulation space would trigger the plate pressure relief device on the outer vessel. In case the plate pressure relief device fails to open, temperature and pressure in the inner vessel would increase. Over-pressurization and BLEVE can only occur if pressure relief valves on the inner vessel fail to open.

Figure 7 Fault Tree for CO2 Road Tanker BLEVE (onsite)

Fault Tree Cold BLEVE Failure of CO2 Road Tanker within the Desalination Plant



Box 23/ 33/ 37 = 1 - assume the driver does not have sufficient time to respond

Box 40 = 1 - assume plate pressure relief device is not installed

Box 4 - according to findings of the HAZID workshop, BLEVE may occurs when both inner and outer vessels are punctured in a rollover accident. However, the initial conditions are the same as or similar to the operating conditions when both vessels is ruptured or punctured at the same time. Since the initial conditions do not fall within the BLEVE zone, BLEVE is unlikely to occur. On the other hand, damage to either vessel leads to loss of vacuum and change of initial conditions. Therefore, leak failure of either vessel is considered in the fault tree.

Box 31 - refer to "QRA of transport of LPG and Naphtha, Methodology report, DNV, 1996"

Box 38, 39 - Inner vessel leakage leads to loss of vacuum insulation. The increase in pressure in the insulation space would trigger the plate pressure relief device on the outer vessel. In case the plate pressure relief device fails to open, temperature and pressure in the inner vessel would increase. Over-pressurization and BLEVE can only occur if pressure relief valves on the inner vessel fail to open.

Figure 8 Fault Tree for CO2 Road Tanker Rupture Failure (offsite)

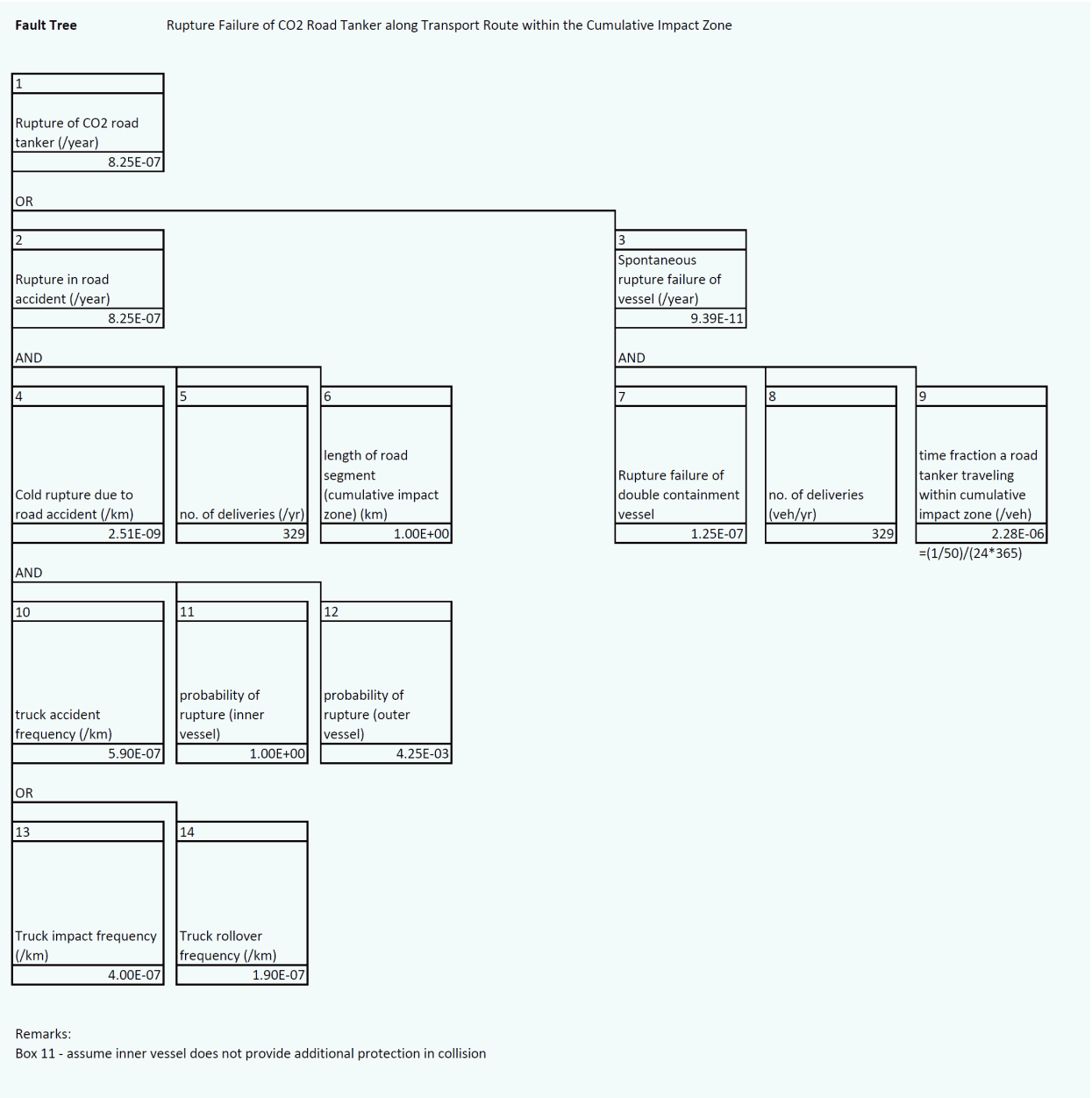
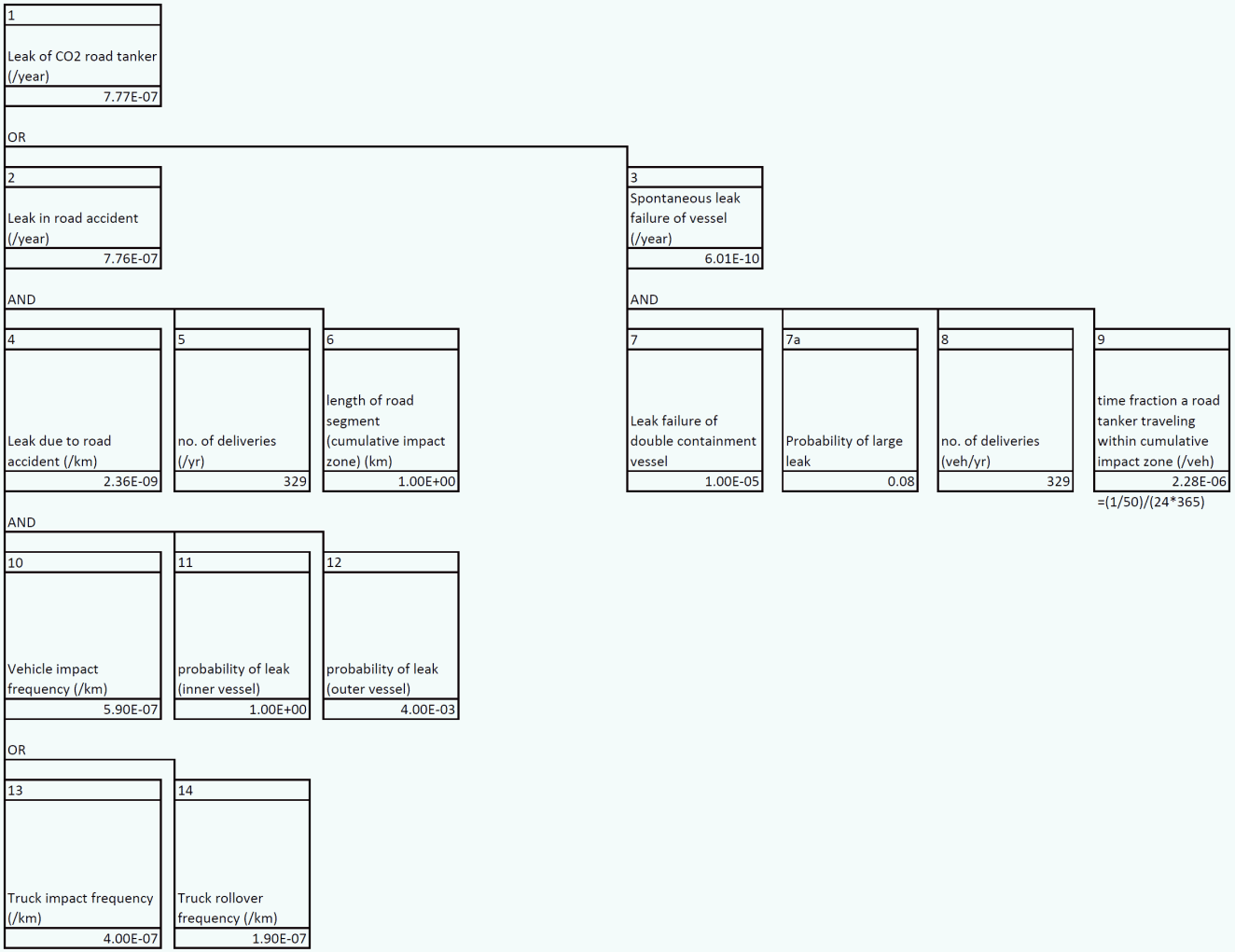


Figure 9 Fault Tree for CO2 Road Tanker Large Leak (offsite)

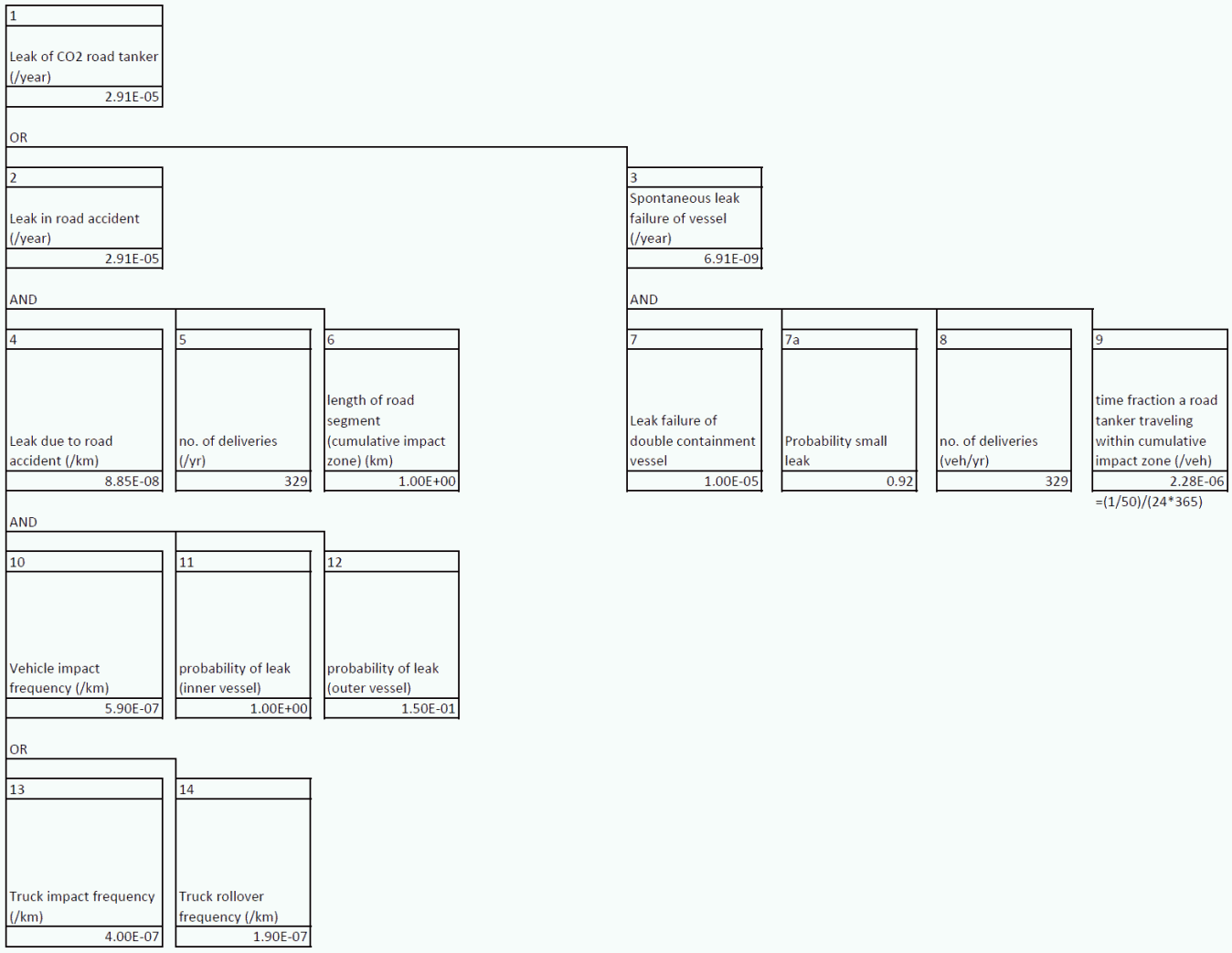
Fault Tree Large Leak Failure of CO2 Road Tanker along Transport Route within the Cumulative Impact Zone



Remarks:
Box 7a - leak failure rates for pressure vessel : major failure (50mm leak) = 5E-6 per year; minor failure (<50mm leak) = 5.5E-5 per year; major failure ~8% of leak failure
(ref. src: Failure Rate and Event Data for use within Risk Assessments (28/06/2012))
Box 11 - assume inner vessel does not provide additional protection in collision

Figure 10 Fault Tree for CO2 Road Tanker Small Leak (offsite)

Fault Tree Small Leak Failure of CO2 Road Tanker along Transport Route within the Cumulative Impact Zone



Remarks:
Box 7a - leak failure rates for pressure vessel : major failure (50mm leak) = 5E-6 per year; minor failure (<50mm leak) = 5.5E-5 per year; minor failure ~92% of leak failure
(ref. src: Failure Rate and Event Data for use within Risk Assessments (28/06/2012))
Box 11 - assume inner vessel does not provide additional protection in collision