

## ***Appendix 11.5.8***

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### ***Derivation of Failure Frequencies of Petrol cum LPG Filling Stations***

# Estimated Frequencies of Significant Release of LPG (with Knock-on Effect) - Station 1

Release Description	Frequency (without Knock-on Effect) /year [A1]	Appendix	Likelihood (escalation) /year [A2]	Note	Failure Frequency (with Knock-on Effect) /year [A']
Catastrophic Failure of a Storage Vessel	3.74E-07	11.5.4-1	1.07E-11	1,2	3.74E-07
Catastrophic Failure of Road Tanker	6.32E-07	11.5.4-2	1.07E-11	1,3	6.32E-07
Partial Failure of a Storage Vessel	1.01E-05	11.5.4-3	1.07E-11	1,2	1.01E-05
Partial Failure of Road Tanker	4.66E-05	11.5.4-4	1.07E-11	1,3	4.66E-05
Guillotine Failure of Liquid Filling Line to Storage Vessel	4.52E-11	11.5.4-5	1.07E-11	1,3	4.61E-11
Guillotine Failure of Liquid Filling Line to Dispenser	1.74E-07	11.5.4-6	1.07E-11	1,3	1.74E-07
Failure of Dispenser	1.14E-03	11.5.4-7	1.07E-11	1,2	1.14E-03
Guillotine Failure of Hose during Unloading from Tanker to Storage Vessel, LPG Released from Tanker	1.47E-06	11.5.4-8a	1.07E-11	1,3	1.47E-06
Guillotine Failure of Hose during Unloading from Tanker to Storage Vessel, LPG Released from Vessel	3.83E-09	11.5.4-8b	1.07E-11	1,2	3.83E-09
Failure of Flexible Hose during Loading to LPG vehicles, LPG Released from Dispenser	5.54E-02	11.5.4-9a	1.07E-11	1,2	5.54E-02
Failure of Flexible Hose during Loading to LPG vehicles, LPG Released from vehicle	5.54E-03	11.5.4-9b	1.07E-11	1,3	5.54E-03
Release from Storage Vessel Pump Flange	4.36E-04	11.5.4-11	1.07E-11	1,2	4.36E-04
Release from Storage Vessel Drain Valve	4.80E-04	11.5.4-12	1.07E-11	1,2	4.80E-04
Failure of Vapour Return Line	1.44E-07	11.5.4-13	1.07E-11	1,2	1.44E-07
Guillotine Failure of Liquid Line from Tanker to Loading	2.32E-05	11.5.4-14	1.07E-11	1,2	2.32E-05
BLEVE of Road Tanker	5.84E-09	11.5.4-15	1.07E-11	1,3	5.84E-09

## Note 1

Failure Frequency (with Knock-on Effect) per year [A'] = (Likelihood escalation per year [A2] x portion of time onsite + Frequency (without Knock-on Effect) per year [A1])  
e.g. Catastrophic Failure of Road Tanker [A'] = 1.07 E-11 x 343 x (1.5 / 24 / 365) + 6.32E-7

## Note 2

Likelihood escalation per year [A2] is obtained from petrol rupture failure frequency without knock-on effect,  
i.e. Likelihood (escalation) [A2] = (freq for petrol rupture) x (ignition probability) x (failure of vessel's protection)  
= 2.14E-9 x 0.05 x 0.1 = 1.07 E-11

## Note 3

Likelihood escalation per year [A2] is obtained from petrol rupture failure frequency without knock-on effect,  
i.e. Likelihood (escalation) [A2] = (freq for petrol rupture) x (ignition probability) x (probability of failure to drive away)  
= 2.14E-9 x 0.05 x 0.1 = 1.07 E-11

## Estimated Frequencies of Significant Release of LPG (with Knock-on Effect) - Station 2

Release Description	Frequency (without Knock-on Effect) /year [A1]	Appendix	Likelihood (escalation) /year [A2]	Note	Failure Frequency (with Knock-on Effect) /year [A']
Catastrophic Failure of a Storage Vessel	1.88E-07	11.5.4-1	4.22E-11	1,2	1.88E-07
Catastrophic Failure of Road Tanker	3.81E-07	11.5.4-2	4.22E-11	1,3	3.81E-07
Partial Failure of a Storage Vessel	5.11E-06	11.5.4-3	4.22E-11	1,2	5.11E-06
Partial Failure of Road Tanker	2.81E-05	11.5.4-4	4.22E-11	1,3	2.81E-05
Guillotine Failure of Liquid Filling Line to Storage Vessel	1.07E-10	11.5.4-5	4.22E-11	1,3	1.09E-10
Guillotine Failure of Liquid Filling Line to Dispenser	4.11E-07	11.5.4-6	4.22E-11	1,3	4.11E-07
Failure of Dispenser	1.14E-03	11.5.4-7	4.22E-11	1,2	1.14E-03
Guillotine Failure of Hose during Unloading from Tanker to Storage Vessel, LPG Released from Tanker	8.93E-07	11.5.4-8a	4.22E-11	1,3	8.93E-07
Guillotine Failure of Hose during Unloading from Tanker to Storage Vessel, LPG Released from Vessel	2.32E-09	11.5.4-8b	4.22E-11	1,2	2.32E-09
Failure of Flexible Hose during Loading to LPG vehicles, LPG Released from Dispenser	4.86E-02	11.5.4-9a	4.22E-11	1,2	4.86E-02
Failure of Flexible Hose during Loading to LPG vehicles, LPG Released from vehicle	4.86E-03	11.5.4-9b	4.22E-11	1,3	4.86E-03
Release from Storage Vessel Pump Flange	2.18E-04	11.5.4-11	4.22E-11	1,2	2.18E-04
Release from Storage Vessel Drain Valve	2.40E-04	11.5.4-12	4.22E-11	1,2	2.40E-04
Failure of Vapour Return Line	1.52E-07	11.5.4-13	4.22E-11	1,2	1.52E-07
Guillotine Failure of Liquid Line from Tanker to Loading	1.40E-05	11.5.4-14	4.22E-11	1,2	1.40E-05
BLEVE of Road Tanker	3.53E-09	11.5.4-15	4.22E-11	1,3	3.53E-09

### Note 1

Failure Frequency (with Knock-on Effect) per year [A'] = (Likelihood escalation per year [A2] x portion of time onsite + Frequency (without Knock-on Effect) per )  
e.g. Catastrophic Failure of Road Tanker [A'] = 4.22 E-11 x 207 x (1.5 / 24 / 365) + 3.81E-7 = 3.81E-7

### Note 2

Likelihood escalation per year [A2] is obtained from petrol rupture failure frequency without knock-on effect,  
i.e. Likelihood (escalation) = (freq for petrol rupture) x (ignition probability) x (failure of vessel's protection)  
= 8.43E-9 x 0.05 x 0.1 = 4.22 E-11

### Note 3

Likelihood escalation per year [A2] is obtained from petrol rupture failure frequency without knock-on effect,  
i.e. Likelihood (escalation) = (freq for petrol rupture) x (ignition probability) x (probability of failure to drive away)  
= 8.43E-9 x 0.05 x 0.1 = 4.22 E-11

### Estimated Frequencies of Significant Release of LPG (with Knock-on Effect) - Station 3

Release Description	Frequency (without Knock-on Effect) /year [A1]	Appendix	Likelihood (escalation) /year [A2]	Note	Failure Frequency (with Knock-on Effect) /year [A']
Catastrophic Failure of a Storage Vessel	1.92E-07	11.5.4-1	1.86E-11	1,2	1.92E-07
Catastrophic Failure of Road Tanker	5.55E-07	11.5.4-2	1.86E-11	1,3	5.55E-07
Partial Failure of a Storage Vessel	5.11E-06	11.5.4-3	1.86E-11	1,2	5.11E-06
Partial Failure of Road Tanker	4.09E-05	11.5.4-4	1.86E-11	1,3	4.09E-05
Guillotine Failure of Liquid Filling Line to Storage Vessel	6.32E-11	11.5.4-5	1.86E-11	1,3	6.45E-11
Guillotine Failure of Liquid Filling Line to Dispenser	2.43E-07	11.5.4-6	1.86E-11	1,3	2.43E-07
Failure of Dispenser	1.14E-03	11.5.4-7	1.86E-11	1,2	1.14E-03
Guillotine Failure of Hose during Unloading from Tanker to Storage Vessel, LPG Released from Tanker	1.29E-06	11.5.4-8a	1.86E-11	1,3	1.29E-06
Guillotine Failure of Hose during Unloading from Tanker to Storage Vessel, LPG Released from Vessel	3.37E-09	11.5.4-8b	1.86E-11	1,2	3.37E-09
Failure of Flexible Hose during Loading to LPG vehicles, LPG Released from Dispenser	4.86E-02	11.5.4-9a	1.86E-11	1,2	4.86E-02
Failure of Flexible Hose during Loading to LPG vehicles, LPG Released from vehicle	4.86E-03	11.5.4-9b	1.86E-11	1,3	4.86E-03
Release from Storage Vessel Pump Flange	2.18E-04	11.5.4-11	1.86E-11	1,2	2.18E-04
Release from Storage Vessel Drain Valve	2.40E-04	11.5.4-12	1.86E-11	1,2	2.40E-04
Failure of Vapour Return Line	1.78E-07	11.5.4-13	1.86E-11	1,2	1.78E-07
Guillotine Failure of Liquid Line from Tanker to Loading	2.03E-05	11.5.4-14	1.86E-11	1,2	2.03E-05
BLEVE of Road Tanker	5.13E-09	11.5.4-15	1.86E-11	1,3	5.13E-09

#### Note 1

Failure Frequency (with Knock-on Effect) per year [A'] = (Likelihood escalation per year [A2] x portion of time onsite + Frequency (without Knock-on Effect) per year)  
e.g. Catastrophic Failure of Road Tanker [A'] = 1.86 E-11 x 301 x (1.5 / 24 / 365) + 5.55E-7

#### Note 2

Likelihood escalation per year [A2] is obtained from petrol rupture failure frequency without knock-on effect,  
i.e. Likelihood (escalation) = (freq for petrol rupture) x (ignition probability) x (failure of vessel's protection)  
= 3.72E-9 x 0.05 x 0.1 = 1.86 E-11

#### Note 3

Likelihood escalation per year [A2] is obtained from petrol rupture failure frequency without knock-on effect,  
i.e. Likelihood (escalation) = (freq for petrol rupture) x (ignition probability) x (probability of failure to drive away)  
= 3.72E-9 x 0.05 x 0.1 = 1.86 E-11

# Estimated Frequencies of Significant Release of LPG (with Knock-on Effect) - Station 4

Release Description	Frequency (without Knock-on Effect) /year [A1]	Appendix	Likelihood (escalation) /year [A2]	Note	Failure Frequency (with Knock-on Effect) /year [A']
Catastrophic Failure of a Storage Vessel	1.91E-07	11.5.4-1	4.36E-11	1,2	1.91E-07
Catastrophic Failure of Road Tanker	5.25E-07	11.5.4-2	4.36E-11	1,3	5.25E-07
Partial Failure of a Storage Vessel	5.11E-06	11.5.4-3	4.36E-11	1,2	5.11E-06
Partial Failure of Road Tanker	3.87E-05	11.5.4-4	4.36E-11	1,3	3.87E-05
Guillotine Failure of Liquid Filling Line to Storage Vessel	1.14E-10	11.5.4-5	4.36E-11	1,3	1.17E-10
Guillotine Failure of Liquid Filling Line to Dispenser	4.39E-07	11.5.4-6	4.36E-11	1,3	4.39E-07
Failure of Dispenser	1.14E-03	11.5.4-7	4.36E-11	1,2	1.14E-03
Guillotine Failure of Hose during Unloading from Tanker to Storage Vessel, LPG Released from Tanker	1.23E-06	11.5.4-8a	4.36E-11	1,3	1.23E-06
Guillotine Failure of Hose during Unloading from Tanker to Storage Vessel, LPG Released from Vessel	3.20E-09	11.5.4-8b	4.36E-11	1,2	3.20E-09
Failure of Flexible Hose during Loading to LPG vehicles, LPG Released from Dispenser	6.48E-02	11.5.4-9a	4.36E-11	1,2	6.48E-02
Failure of Flexible Hose during Loading to LPG vehicles, LPG Released from vehicle	6.48E-03	11.5.4-9b	4.36E-11	1,3	6.48E-03
Release from Storage Vessel Pump Flange	2.18E-04	11.5.4-11	4.36E-11	1,2	2.18E-04
Release from Storage Vessel Drain Valve	2.40E-04	11.5.4-12	4.36E-11	1,2	2.40E-04
Failure of Vapour Return Line	1.47E-07	11.5.4-13	4.36E-11	1,2	1.47E-07
Guillotine Failure of Liquid Line from Tanker to Loading	1.93E-05	11.5.4-14	4.36E-11	1,2	1.93E-05
BLEVE of Road Tanker	4.86E-09	11.5.4-15	4.36E-11	1,3	4.86E-09

## Note 1

Failure Frequency (with Knock-on Effect) per year [A'] = (Likelihood escalation per year [A2] x portion of time onsite + Frequency (without Knock-on Effect) per year) e.g. Catastrophic Failure of Road Tanker [A'] = 4.36 E-11 x 285 x (1.5 / 24 / 365) + 5.25E-7

## Note 2

Likelihood escalation per year [A2] is obtained from petrol rupture failure frequency without knock-on effect, i.e. Likelihood (escalation) = (freq for petrol rupture) x (ignition probability) x (failure of vessel's protection) = 8.72E-9 x 0.05 x 0.1 = 4.36 E-11

## Note 3

Likelihood escalation per year [A2] is obtained from petrol rupture failure frequency without knock-on effect, i.e. Likelihood (escalation) = (freq for petrol rupture) x (ignition probability) x (probability of failure to drive away) = 8.72E-9 x 0.05 x 0.1 = 4.36 E-11

# Estimated Frequencies of Significant Release of LPG (with Knock-on Effect) - Station 5

Release Description	Frequency (without Knock-on Effect) /year [A1]	Appendix	Likelihood (escalation) /year [A2]	Note	Failure Frequency (with Knock-on Effect) /year [A']
Catastrophic Failure of a Storage Vessel	2.01E-07	11.5.4-1	3.57E-11	1,2	2.01E-07
Catastrophic Failure of Road Tanker	9.56E-07	11.5.4-2	3.57E-11	1,3	9.56E-07
Partial Failure of a Storage Vessel	5.12E-06	11.5.4-3	3.57E-11	1,2	5.12E-06
Partial Failure of Road Tanker	7.05E-05	11.5.4-4	3.57E-11	1,3	7.05E-05
Guillotine Failure of Liquid Filling Line to Storage Vessel	1.15E-10	11.5.4-5	3.57E-11	1,3	1.19E-10
Guillotine Failure of Liquid Filling Line to Dispenser	4.42E-07	11.5.4-6	3.57E-11	1,3	4.42E-07
Failure of Dispenser	1.14E-03	11.5.4-7	3.57E-11	1,2	1.14E-03
Guillotine Failure of Hose during Unloading from Tanker to Storage Vessel, LPG Released from Tanker	2.24E-06	11.5.4-8a	3.57E-11	1,3	2.24E-06
Guillotine Failure of Hose during Unloading from Tanker to Storage Vessel, LPG Released from Vessel	5.82E-09	11.5.4-8b	3.57E-11	1,2	5.82E-09
Failure of Flexible Hose during Loading to LPG vehicles, LPG Released from Dispenser	8.37E-02	11.5.4-9a	3.57E-11	1,2	8.37E-02
Failure of Flexible Hose during Loading to LPG vehicles, LPG Released from vehicle	8.37E-03	11.5.4-9b	3.57E-11	1,3	8.37E-03
Release from Storage Vessel Pump Flange	2.18E-04	11.5.4-11	3.57E-11	1,2	2.18E-04
Release from Storage Vessel Drain Valve	2.40E-04	11.5.4-12	3.57E-11	1,2	2.40E-04
Failure of Vapour Return Line	2.25E-07	11.5.4-13	3.57E-11	1,2	2.25E-07
Guillotine Failure of Liquid Line from Tanker to Loading	3.51E-05	11.5.4-14	3.57E-11	1,2	3.51E-05
BLEVE of Road Tanker	8.85E-09	11.5.4-15	3.57E-11	1,3	8.85E-09

## Note 1

Failure Frequency (with Knock-on Effect) per year [A'] = (Likelihood escalation per year [A2] x portion of time onsite + Frequency (without Knock-on Effect) per year [A1])  
e.g. Catastrophic Failure of Road Tanker [A'] = 3.57 E-11 x 519 x (1.5 / 24 / 365) + 9.56E-7 = 9.57E-7

## Note 2

Likelihood escalation per year [A2] is obtained from petrol rupture failure frequency without knock-on effect,  
i.e. Likelihood (escalation) = (freq for petrol rupture) x (ignition probability) x (failure of vessel's protection)  
= 7.14E-9 x 0.05 x 0.1 = 3.57 E-11

## Note 3

Likelihood escalation per year [A2] is obtained from petrol rupture failure frequency without knock-on effect,  
i.e. Likelihood (escalation) = (freq for petrol rupture) x (ignition probability) x (probability of failure to drive away)  
= 7.14E-9 x 0.05 x 0.1 = 3.57 E-11

# Estimated Frequencies of Significant Release of Petrol with Knock-on Effect

Likelihood (base) /veh.yr (A1)		Likelihood (escalation) (A2)	Likelihood (A') = (A1+A2)	Station No.	No. of vehicles per year (D)	Time presence (hr) (F)	Time fraction for presence Note 2	Failure freq. per year
Tanker Rupture	4.00E-08	1.26E-06	1.30E-06	1	313	2	2.28E-04	9.30E-08
		7.27E-07	7.67E-07	2	1231	2	2.28E-04	2.16E-07
		9.85E-07	1.02E-06	3	543	2	2.28E-04	1.27E-07
		9.41E-07	9.81E-07	4	1273	2	2.28E-04	2.85E-07
		1.58E-06	1.62E-06	5	1043	2	2.28E-04	3.86E-07
Tanker Large Leak (liquid)	3.60E-08	1.26E-06	1.30E-06	1	313	2	2.28E-04	9.27E-08
		7.27E-07	7.63E-07	2	1231	2	2.28E-04	2.14E-07
		9.85E-07	1.02E-06	3	543	2	2.28E-04	1.27E-07
		9.41E-07	9.77E-07	4	1273	2	2.28E-04	2.84E-07
		1.58E-06	1.62E-06	5	1043	2	2.28E-04	3.85E-07
Tanker Medium Leak (liquid)	3.60E-08	1.26E-06	1.30E-06	1	313	2	2.28E-04	9.27E-08
		7.27E-07	7.63E-07	2	1231	2	2.28E-04	2.14E-07
		9.85E-07	1.02E-06	3	543	2	2.28E-04	1.27E-07
		9.41E-07	9.77E-07	4	1273	2	2.28E-04	2.84E-07
		1.58E-06	1.62E-06	5	1043	2	2.28E-04	3.85E-07

## Note 1

Likelihood (escalation) (A2)

= LPG BLEVE Freq. without knock-on effect \* Ignition Prob. \* Prob. of failure to drive away  
+ LPG Rupture Freq. without knock-on effect \* Ignition Prob. \* Prob. of failure to drive away  
+ LPG aboveground Continuous Freq. without knock-on effect \* Ignition Prob. \* Prob. of failure to drive away

Example Calculation for

Station 1:

$$= 5.84E-9*1*1 + (3.74E-7+6.32E-7)*0.9*1 + (4.66E-5+4.52E-11+1.47E-6+2.32E-5)*0.05*0.1$$

$$= 1.26E-06$$

## Note 2

Time fraction for presence (G)

$$= (F)/(365*24)$$