

Representing Societal Risk as an FN Curve and Calculating the Expectation Value

Introduction

Risk management in occupational safety often requires the numerical quantification of risks. For situations such as the failure of a guard at a power press, the appropriate formulation of quantified risk is *individual risk*. For situations having the potential to harm many people, so-called major hazards, the appropriate formulation of quantified risk is *societal risk*.

Individual risk is simply the predicted frequency of the undesired outcome. Societal risk takes account of both the severity of the range of possible outcomes and the frequency at which they each are predicted to occur. It is usually presented as a two dimensional relationship between frequency and cumulative severity of outcome, called an FN curve. This is best understood from a simple example.

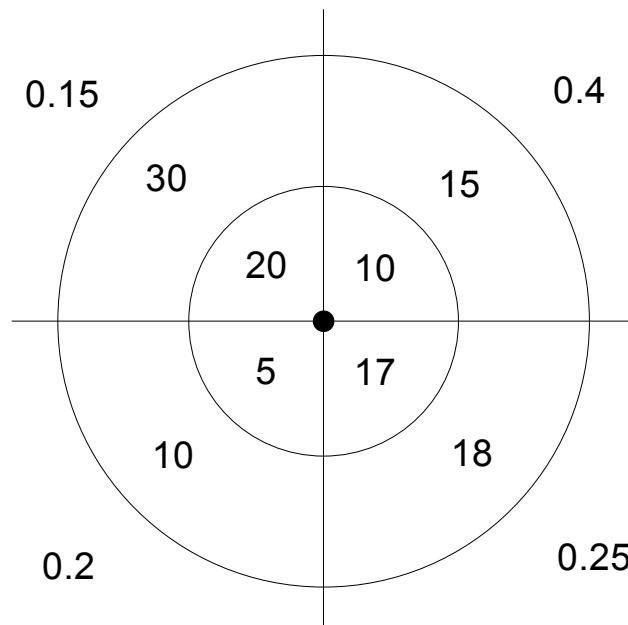
A Simple FN Curve

Consider a major hazard site storing a compressed liquefied toxic gas, such as chlorine, in a bulk tank. In a comprehensive assessment, loss of containment of the chlorine from a bulk tank might be modelled as possibly 10 idealised *scenarios*. Additional scenarios would be used to model loss of containment of the chlorine from associated pipework and vessels. For this example a single scenario will be used.

Dense gas dispersion models are used to model each release for a range of combinations of wind speed and atmospheric stability. For toxic gases the use of 4 combinations is common. For this example two combinations representing daytime and night-time conditions will be used.

Risk calculations may assume that the likelihood of the wind blowing in a particular direction is equally distributed around the compass. This is using a *uniform wind rose*. This approach is normally regarded as inadequate where suitable meteorological data is available, such as in Great Britain. Risk assessment for toxic gases would typically aggregate the meteorological data into 12 sectors. For this example meteorological data aggregated into 4 sectors will be used.

The number of fatalities are predicted for each scenario, for each direction, for each speed/stability combination. For this example the results can be represented by the following diagram.



This indicates that a wind blowing towards the NE in daytime conditions is predicted to kill 10 persons, and in night-time conditions to kill 25 persons. The wind blows in that direction for 40% of the time day and night.

If the loss of containment that leads to these outcomes is 4 chances in a million per year (4×10^{-6}) then the following table shows the calculation of the frequencies of the individual outcomes and the expectation value for each outcome.

Event	Base Frequency	Direction	Day/Night	Outcome Frequency	Outcome	Expectation Value
	(per year)	(-)	(-)	(per year)	(fatalities)	(fatalities per year)
NE-Day	4.0E-6	0.4	0.8	1.3E-6	10	1.3E-5
NE-Night	4.0E-6	0.4	0.2	3.2E-7	25	8.0E-6
SE-Day	4.0E-6	0.25	0.8	8.0E-7	17	1.4E-5
SE-Night	4.0E-6	0.25	0.2	2.0E-7	35	7.0E-6
SW-Day	4.0E-6	0.2	0.8	6.4E-7	5	3.2E-6
SW-Night	4.0E-6	0.2	0.2	1.6E-7	15	2.4E-6
NW-Day	4.0E-6	0.15	0.8	4.8E-7	20	9.6E-6
NW-Night	4.0E-6	0.15	0.2	1.2E-7	50	6.0E-6
				4.0E-6		6.3E-5

The expectation value of 6.3×10^{-5} is often used for valuing safety improvements in monetary terms. If a chemical plant is considering fitting an additional safety measure to reduce the likelihood of this loss of containment then an initial screening assumption might be that the event will be eliminated by the measure. If the plant lifetime is 30 years, and the value placed on an averted fatality is £1.2 million, then the monetary value of implementing the measure is:

$$30 \times (6.3 \times 10^{-5}) \times (1.2 \times 10^6) = \text{£}2268$$

This value would then be compared with the costs of implementing the measure and it must be implemented unless the costs are grossly disproportionate to the monetary value of the benefit. In practice, there would be more harms averted than just the fatalities used here. Some initial information in occupational safety cost benefit analysis can be found on the HSE web site⁽¹⁾. The author's views on gross disproportion can be found in a technical paper⁽²⁾.

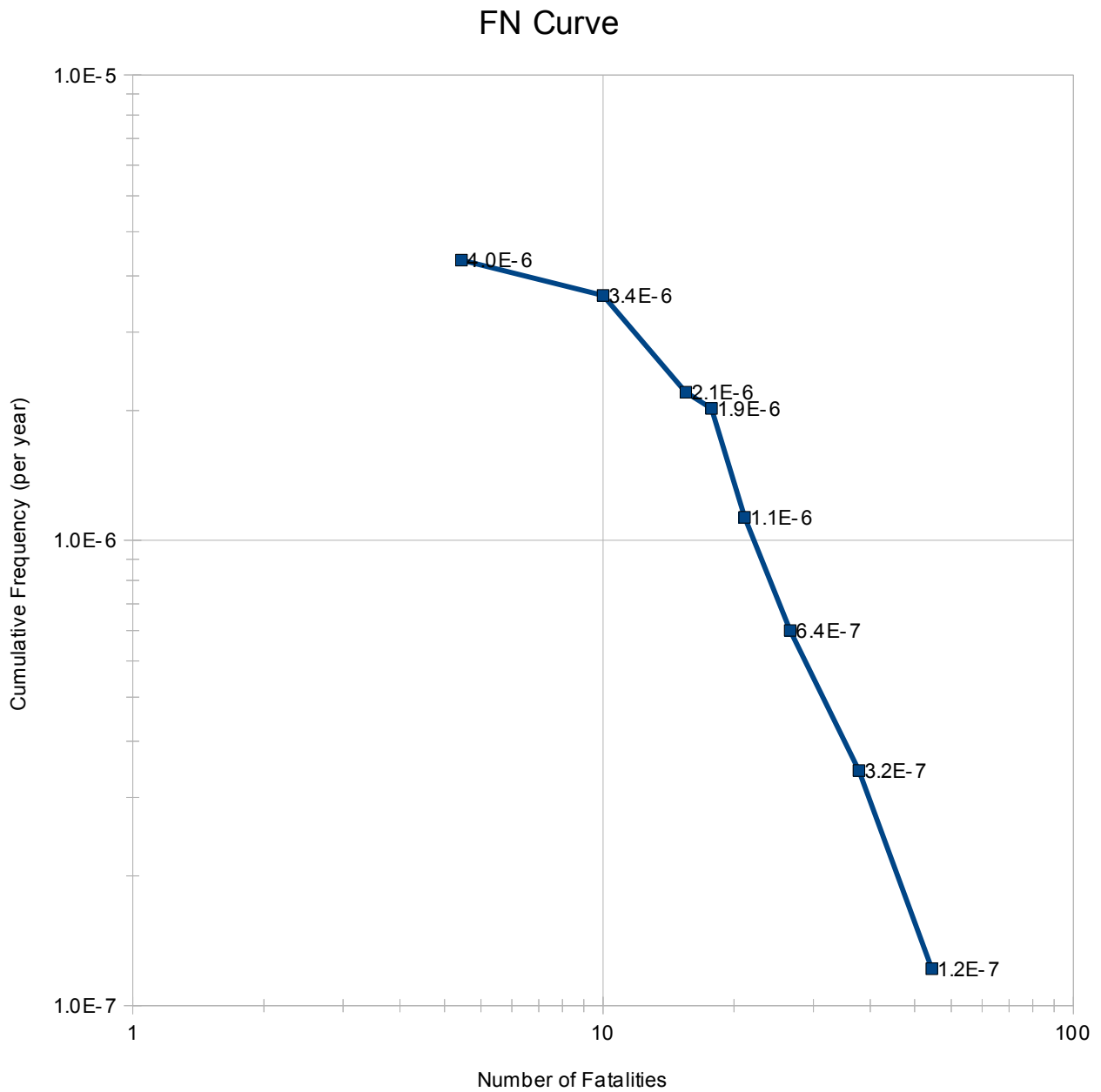
In order to produce a FN curve the table of outcomes is then sorted into decreasing number of fatalities and an additional column added for the cumulative frequency.

Event	Base Freq	Direction	Day/Night	Outcome Frequency	Outcome	Cumulative Frequency
	(per year)	(-)	(-)	(per year)	(fatalities)	(per year)
NW-Night	4.0E-6	0.15	0.2	1.2E-7	50	1.2E-7
SE-Night	4.0E-6	0.25	0.2	2.0E-7	35	3.2E-7
NE-Night	4.0E-6	0.4	0.2	3.2E-7	25	6.4E-7
NW-Day	4.0E-6	0.15	0.8	4.8E-7	20	1.1E-6
SE-Day	4.0E-6	0.25	0.8	8.0E-7	17	1.9E-6
SW-Night	4.0E-6	0.2	0.2	1.6E-7	15	2.1E-6
NE-Day	4.0E-6	0.4	0.8	1.3E-6	10	3.4E-6
SW-Day	4.0E-6	0.2	0.8	6.4E-7	5	4.0E-6

1 <http://www.hse.gov.uk/risk/theory/alarpcheck.htm>

2 "Gross Disproportion, Step by Step - A Possible Approach to Evaluating Additional Measures at COMAH Sites", by Martin H Goose, 2006 (available from the author)

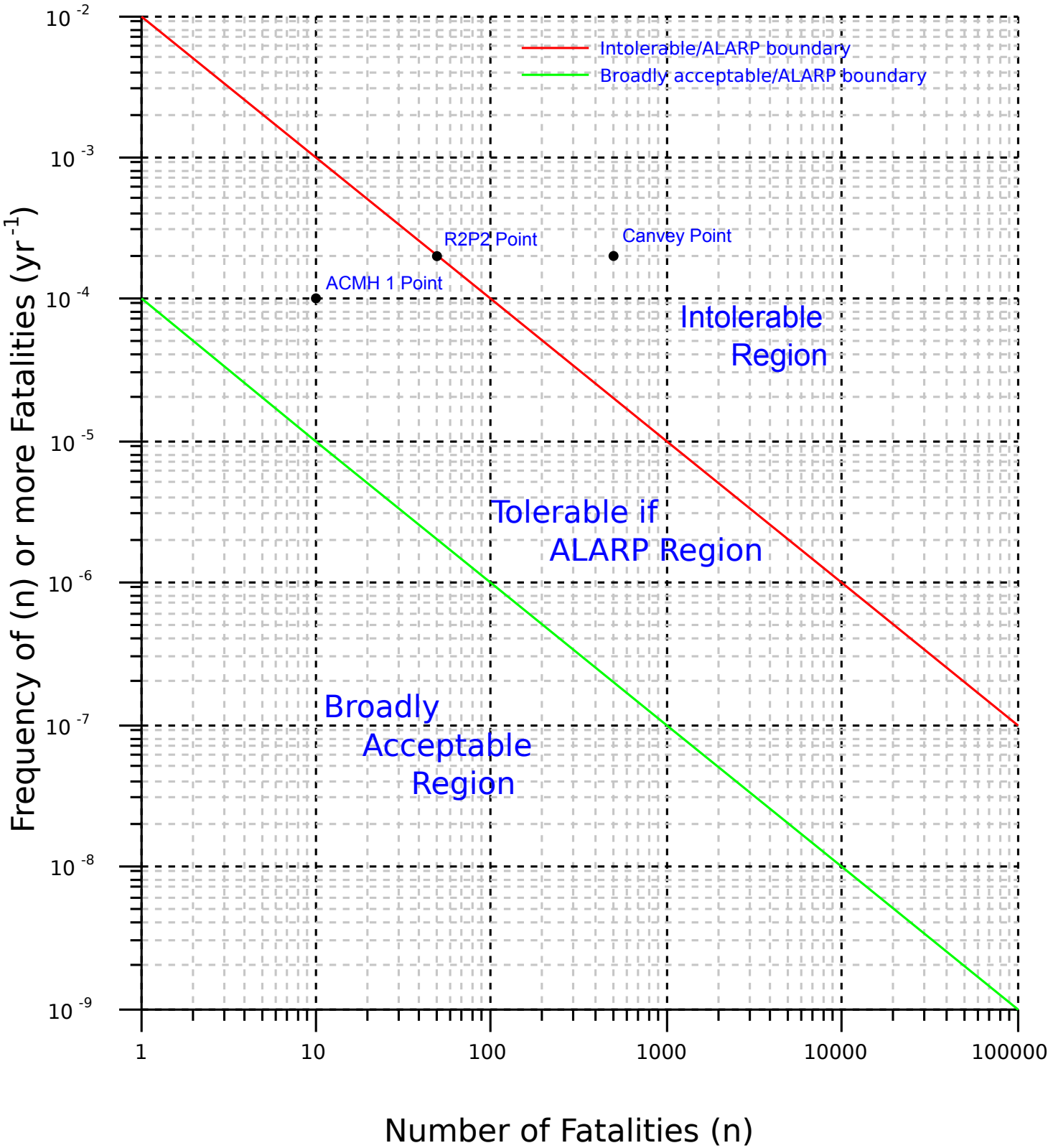
The resulting values of fatalities (N) are then plotted against cumulative frequency (F) conventionally on a log/log plot.



In a real assessment to produce an FN curve the number of outcomes analysed and plotted is likely to be hundreds and possibly thousands.

The FN plot generated would then be compared with appropriate societal risk criteria. The criteria usually take the format of a pair of straight lines similar to those shown in the next page.

Societal Risk Criterion



Note: These criterion lines are now adopted HID criteria (HID Circular SPC/Permissioning/09 - Annex)