Risk acceptance criteria for Hydrogen Refuelling Stations

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By Norsk Hydro ASA and DNV
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1 INTRODUCTION

Quantitative risk acceptance criteria must be established before performing quantitative risk analyses (QRA). Acceptance criteria for use in EIHP2 when performing QRA on H_2 refuelling stations are proposed in this document. Further this report documents and describes the approach and methodology used to establish the criteria.

Quantitative risk acceptance criteria are an important part of an enterprises risk or safety management system. Acceptance criteria are based on the established safety goals and quantification of these. Risk results from QRA of installations, plants, procedures etc. are compared with these criteria to determine whether the risk level is acceptable or not. If the estimated risk level is too high compared to the acceptance criteria, risk reducing measures must be identified and implemented. The criteria will also be used for establishing safety distances.

2 ESTABLISHMENT OF RISK ACCEPTANCE CRITERIA

2.1 Risk exposed persons

Risk acceptance criteria must be established for all groups of people that are exposed to accidents originating from a refuelling station. Different types of criterion are used for these groups.

Third party

Third party risk will consider how events on the refuelling station can affect areas outside the refuelling station boundaries and include people living and working in the vicinity of the refuelling station or visiting/travelling through the neighbourhood of the refuelling station. Both societal and individual (or geographical) risk measures should be considered (e.g. FN curves and risk contours).

Refuelling station customers (second party)

This will assess people visiting the refuelling station area to use the facilities. These people will be exposed to the risks at the refuelling station for a limited period of time, while visiting the facilities. Therefore, the risk contribution to each individual will be very low. However, it would be unreasonable to use this as an argument for not considering this risk.

Hydrogen refuelling station personnel (first party)

This includes personnel involved in operation, inspection and maintenance of the hydrogen and/or the conventional re-fuelling station. Generally, a higher risk level will be considered acceptable for this group than for Third party. An individual risk criterion, setting limits to the risk of each individual working at the station, is the most relevant.

2.2 Alternative strategies for establishing criteria

The acceptable risk for hydrogen filling stations could be related to existing risk levels for conventional and natural gas refuelling infrastructure. The existing risk level might be documented as either of:

- Average risk level for a refuelling station, based on statistical information for refuelling infrastructure or comparable activities in a country or area, or for a supplier (e.g. BP, Norsk Hydro, Shell or Esso)
- Estimated risk for "typical" conventional/natural gas refuelling stations, considering that these today represent a spectrum of risk levels.

If comparable risk statistics and analyses for conventional and natural gas refuelling stations are lacking, the acceptable risk could also be related to general risks in society. This approach could be selected based on an overall safety target for introduction of hydrogen refuelling stations, - for example that such installations should not increase the general risk level in society.

This means that we have three alternative strategies for developing risk acceptance criteria:

1. Comparing with statistics from existing stations, giving average risk level
2. Comparing with estimated risk levels from risk analyses
3. Comparing with general risks in society.

The results of the discussion can be summarized as follows:

Comparing with statistics from existing petrol/gas stations

Defining risk acceptance criteria based on strategy 1 is problematic since it is difficult to find relevant data/statistics. Accident data from conventional filling stations are not easily available, and the results include both accidental releases of fuel together with other accidents, such as "road rage", collisions etc. Since the intention is to compare the risk of the fuels, such data may not give a representative risk level related to accidental releases of the fuel. Strategy 1 was therefore rejected as a main methodology.

Comparing with estimated risk levels based on results from risk analyses of existing petrol/gas filling stations

Strategy 2 is also problematic since it is difficult to find a "typical" conventional petrol station that can be used for comparison. Using this strategy, it would be important to ensure that the assumptions as far as possible stay constant for the different fuel types (capacity, location, etc.). Comparison would also have to consider that while hydrogen might be produced at the facility, conventional fuels are transported over long distances. A comparison just considering the station would therefore be "unfair". Considering also the amount of work and resources required to perform a full quantitative risk analysis of a conventional fuel station, including supply this strategy was also rejected.

On this basis, it was decided that criteria based on comparison with general risk in society (strategy 3) is the best choice, and that the QRAs should be undertaken based on the acceptance criteria described under strategy 3.

2.3 Suggested detailed risk acceptance criteria

When comparing with the general risk in everyday life it is normal to use the natural fatality risk for the age group with the lowest individual fatality risk. This is for the age group between 5 and 15 years. Dutch data suggest a base death rate of $1*10^{-4}$ per annum for the age group 10 to 14 years. UK data suggest a base death rate of $2.8*10^{-4}$ per annum for the age group 5 to 14 years. These data are from ref./1/. Based on this a base death rate is set at $1*10^{-4}$.

Further process plants should not lead to more than a 1% increase in the natural fatality rate, i.e. $1*10^{-6}$. This risk level is used as acceptance criteria by Dutch authorities, VROM, for process industry in general, see ref./2/ and by Australian authorities for LPG refuelling stations, see ref./3/.

The following risk acceptance criteria are related to process related hazards only, and not other types of hazards such as robberies, collisions, sliding on ice, occupational hazards etc.

Third party (based on general societal risk comparison):

No residential area, third party working premises or public assembly area outside the station shall be exposed to fatal exposure levels caused by major accidents at the station of probability greater than 10^{-6} per year. If there are buildings surrounding the facility, fatal exposure due to collapse of these shall be taken into account.

And:

For the societal risk it is proposed to use the Dutch VROM criteria, ref./2/. This is a FN curve (Frequency of N or more fatalities, as function of N) as shown in Figure 1. If the calculated risk is above the curve the risk <u>must</u> be reduced.

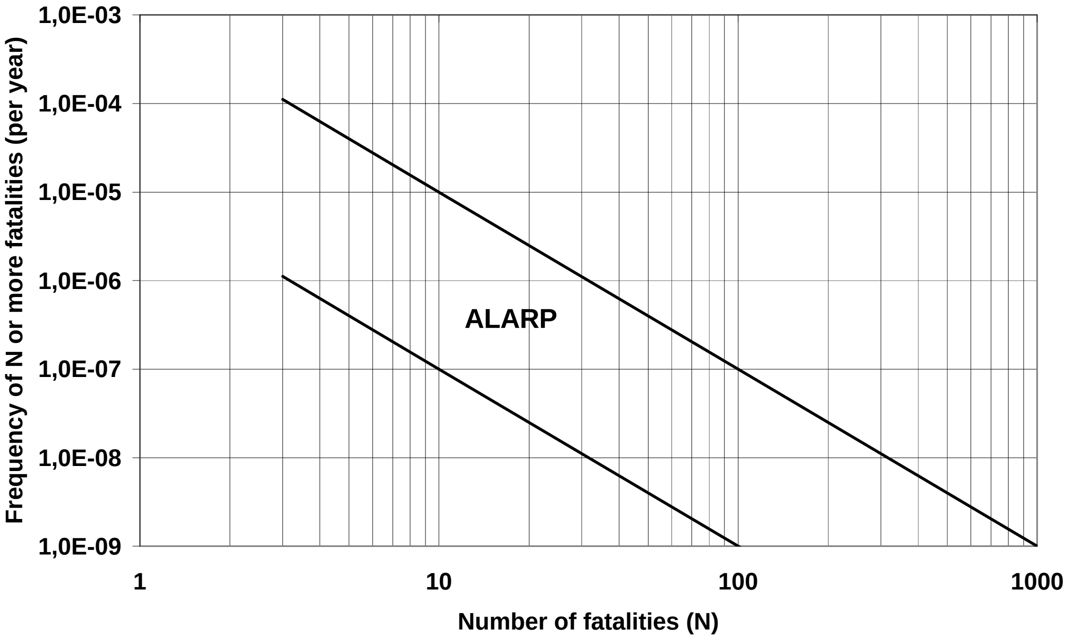

Figure 1 Societal risk curve, FN curve with ALARP region

The upper line in Figure 1 represents the risk acceptance curve. The region between this line and the lower line denotes the ALARP area (As Low As Reasonable Practical). For scenarios with risk levels that lay between these lines the risk should be reduced if practical, typically subject to cost benefit analysis. For scenarios with risk levels above the upper curve, measures to reduce the risk must be implemented.

The slope of the FN curve is designed to reflect the society's aversion to single accidents with multiple fatalities as opposed to several accidents with few fatalities.

Refuelling station customers

The probability of a major accident causing one or more fatalities among customers shall not exceed 10^{-4} per year.

Hydrogen refuelling station personnel

The *individual* probability of fatality should not exceed 10^{-4} per year.

2.4 Risk matrix

In the concept phase of e.g. refuelling stations it is more practical to use Rapid Risk Ranking (RRR) or a more coarse risk analysis than QRA. In this case a risk matrix is used instead of FN curves. A risk matrix is based on the numbers in a FN curve but allows for the uncertainty incorporated in RRR. The proposed risk matrix for H_2 refuelling stations is shown in Table 1.

Table 1 Risk Matrix

		PROBABILITY (per year)				
		A (<0.001)	B (0.01-0.001)	C (0.1-0.01)	D (1-0.1)	E (10-1)
Consequence severitty	1 (Catastrophic)	H	H	H	H	H
	2(Severe loss)	M	H	H	H	H
	3 (Major damage)	M	M	H	H	H
	4 (Damage)	L	L	M	M	H
	5 (Minor damage)	L	L	L	L	M

The consequence severity levels shown in the table above are defined in Table 2.

Table 2 Consequence severity levels

Level	Description	Definition		
		People	**Environment**	**Material**
1	CATASTROPHIC	Several fatalities	Time for restitution of ecological resource such as recreation areas, ground water >5 years	Total loss of station and major structural damages outside station area
2	SEVERE LOSS	One fatality	Time for restitution of ecological resource 2 - 5 years	Loss of main part of station. Production interrupted for months.
3	MAJOR DAMAGE	Permanent disability Prolonged hospital treatment	Time for restitution of ecological resource < 2 years	Considerable structural damage Production interrupted for weeks
4	DAMAGE	Medical treatment Lost time injury	Local environmental damage of short duration < 1 month??	Minor structural damage Minor production influence
5	MINOR DAMAGE	Minor injury Annoyance Disturbance	Minor environmental damage	Minor material damage

The probability levels are defined as shown in Table 3.

Table 3 Probability levels

Level	Description	Definition	Frequency
A	IMPROBABLE	Possible, but may not be heard of, or maybe experienced world wide.	About 1 per 1000 years or less
B	REMOTE	Unlikely to occur during lifetime/operation of one filling station	About 1 per 100 years
C	OCCASIONAL	Likely to occur during lifetime/operation of one filling station	About 1 per 10 years
D	PROBABLY	May occur several times at the filling station	About 1 per year
E	FREQUENT	Will occur frequently at the filling station	About 10 per year or more.

In the risk matrix in Table 1 there are three risk levels and the following acceptance criterion is proposed, (Table 4):

Table 4 Risk levels

Level	Level name	Description
H	High	High risk, not acceptable. Further analysis should be performed to give a better estimate of the risk. If this analysis still shows unacceptable or medium risk redesign or other changes should be introduced to reduce the criticality.
M	Medium	The risk may be acceptable but redesign or other changes should be considered if reasonably practical. Further analysis should be performed to give a better estimate of the risk. When assessing the need of remedial actions, the number of events of this risk level should be taken into consideration. ALARP.
L	Low	The risk is low and further risk reducing measures are not necessary

3 REFERENCES

/1/ European Industrial Gases Association: “Determination of Safety Distances” IGC Doc 75/01/E/rev, 2001, Internet http://www.eiga.org

/2/ "ESRA" newsletter April 1997. European Safety and Reliability Association (ESRA)

/3/ "Risk assessment of LPG automotive refuelling facilities", Robert E. Melchers and William R. Feutrill, Reliability Engineering and System Safety 74 (2001) p.283-290

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