Risk calculations by prescription: rituals for granting permits and land-use planning

AGS

Hazardous Substances Council
The Netherlands

Preface

In The Netherlands, the quantification of risks in external safety policy has developed into a ritual due to the prescription of an oversimplified calculation program. This prescription is referred to as unification. The present advice deals with two aspects: on the one hand, the risk calculations themselves, and on the other, the use of the outcomes of risk calculations in decision-making. The way in which calculations must now be made fails to do justice to the complexity of industrial practice, and the way in which the decision-making takes place severely limits the potential of quantitative risk analysis for understanding risks and prioritising actions. This is demonstrated and discussed in this advisory report. The Netherlands Hazardous Substances Council wishes to argue for better calculation methods and data, and moreover for reform of the decision-making process. This latter will be elaborated in a later advisory report.

Unification would seem at first glance logical to avoid differing results from the use of different models by different users, but the element of compromise and oversimplification that has been introduced makes it contestable. The principles and models that form the basis of the calculation program that it is mandatory to use in The Netherlands and the prescribed failure frequencies are ill-founded. For instance, escalation and domino effects or cumulation of industrial hazards are not taken into account. Exposure of persons is expressed in a particular measure (acute fatal injury from permanent exposure, outdoors, unprotected) while the calculation yields no information on other casualties. Further, the QRA (Quantitative Risk Assessment) instrumentarium as it is currently used provides no information about the significance for safety of measures to be taken.

It is apparent from this advisory report that the distances that have to be observed around major industrial hazards may vary enormously for minor modifications in the (most) uncertain input data and parameters. This can lead to underestimation of the risk (citizens run excessive risk) or to overestimation (unnecessary land use and societal costs).

The choice for unification should include a commitment to bring the selected QRA instrumentarium up to the state of the art and keep it there; this effort is presently insufficient. Additionally, the training that the users of the prescribed calculation method must undergo is insufficient to reach the required level of understanding.

The risk contours that result from the calculations play a determining role in the decision making for issuing of licences and for the distances from the hazard that have to be observed in land use planning. Granting permits and spatial allocation are in a certain sense irrevocable. Changes in insight may yield new risk contours. If these differ (significantly) from previous contours, this should have consequences for decision making. Through unification, policy and maintenance are in fact more closely interwoven. It has become apparent that in the interplay between the Ministry of Housing, Spatial Planning and the Environment (the Ministry of VROM) and The Netherlands National Institute for Public Health and the Environment (RIVM), parameters have been modified such that the old risk contours once again resulted from the calculations (retrofit). In other cases, parameter values appear to have been set to achieve predefined outcomes. Examples of this are presented throughout this advisory report.

Decision making based on a single number is bound to be insufficient. It is the one-dimensional use of risk analysis that contains in itself much more relevant information. This information can – certainly if the QRA instrumentarium were to link up more closely with reality – be used to better assess and possibly improve the safety of an installation and to better protect the citizen. Furthermore, other considerations may also be included in the decision making process, such as the transport to and from these establishments. In this way, the decision making in the context of external safety and land use planning can be improved. In the present advisory report directions are given for further improvement which will be addressed in a subsequent report.

Chairman of the Council,	General Secretary,	Chairman of the Working Group,
Prof. dr ir J.G.M. Kerstens	N.H.W. van Xanten, PharmD, ERT, MPA	Ir C.M. Pietersen

Contents

Summary

In Dutch external safety policy, the acceptability of risk in the area surrounding a hazard is assessed based on a limit value for individual risk (IR). Additionally, changes to societal risk (SR) must be justified, in which a less strict (with regards to the IR) so-called orientation criterion for the societal risk in practice forms an important reference point. In The Netherlands, a single software program (SAFETI-NL) with associated manual (Reference Manual Bevi Risk Assessments, Handleiding Risicoberekeningen Bevi[1]) is prescribed for the calculation of levels of individual and societal risk for establishments. This prescribed "Bevi calculation method" forms the basis for decisions with important consequences for industry, land use planning and the protection of citizens.

In the present advisory report, the Council discusses the findings of an evaluation of the prescribed calculation method and its implications for planning and decision making with regard to external safety. The evaluation focussed on the risk modelling of a BLEVE (Boiling Liquid Expanding Vapour Explosion) at an LPG filling station, an incident type that plays a significant role in external safety policy. The risk modelling of the BLEVE according to the prescribed calculation method has a number of serious deficiencies. The following was observed:

- Transparency: the basis for the modelling of a BLEVE in the software program SAFETI-NL is indeed explained in the Reference Manual Bevi Risk Assessments, but significant disadvantages are associated with the prescription of a single calculation method.
- Verifiability: the failure frequencies prove to be at least one order of magnitude (a factor of 10) lower than commonly used elsewhere (due to decisions taken at the end of the 70s at the start of activities in the field of risk analysis).
- Robustness: the robustness of the calculation method has been made artificially high due to the fact that the values of parameters and coefficients have been laid down in the calculation method. In this way it is concealed that small variations in assumptions or starting points often result in large variations in indirect land use and IR and SR. The prescriptions in the Reference Manual Bevi Risk Assessments thus conceal the large variation in the possible results of the calculations.
- Validity in terms of correctness: the incident scenarios described in the event tree for a BLEVE of LPG are not correctly modelled in a physicochemical sense. Also, human error and similar scenarios are neglected in the risk calculations.
- Validity in terms of safety relevance: use of the calculation method gives no or only limited insight in opportunities to increase safety. Using the prescribed QRA instrumentarium, it is almost impossible to gain insight that is of importance for the assessment of safety-improving measures.

1 Bevi is the Dutch abbreviation for the Decree on External Safety of Establishments (Bulletin of Acts and Decrees 2004, 250).

The AGS concludes that the prescribed calculation method yields no reliable view of the safety and the opportunities to increase this, and that it is inadequate for decision making directed at the protection of citizens against the risks associated with the production, use and storage of hazardous substances. The Council earlier made a similar observation concerning the prescribed calculation method for the risks of transport of hazardous substances (AGS, 2006). This latter method nonetheless forms at present the basis for decision making concerning the basic rail, road and waterway networks.

It is the Council's view that the solution cannot be found only by focusing on the quantification of risks. Improving the safety-relevance of the prescribed calculation method requires an increase of the number of dimensions of the outcome of risk calculations in order to make feedback possible to practical situations. The Council recommends incorporating additional, safety-relevant information into planning and decision-making processes, along with the results from quantitative risk analyses (short term). Apart from this, the Council envisages a more far-reaching change of The Netherlands' QRA practice to be necessary (medium to long term). In this context, the AGS lists a number of interesting elements in decision-making procedures in other EU Member States which also implement the Seveso II Directive. The AGS will consider the possibilities for adapting The Netherlands' QRA practice in a subsequent advisory report.

Finally in this report, an argument is made for a strict separation of policy on the one side and, on the other, research and development in the field of quantitative risk analysis. The current close relationship between policy and R&D sometimes leads to representations of risk that have little relationship with reality. In this respect, the Council recommends organising an independent research and development programme, the results of which should be used to periodically (for example every five years) evaluate the prescribed calculation methodology on the basis of new insights and practical experience. Knowledge must be not only developed but also preserved.

Introduction

In the densily populated Netherlands, it is practically impossible to separate the population and activities with hazardous substances in such a way that in case of an accident, no harm will be done to the area surrounding the hazard. Certainly, handling hazardous substances implies risks, but their magnitude can be limited. The Seveso II Directive provides a framework to European Union Member States to control major-accident hazards involving dangerous substances[2]. In The Netherlands, the assessment of the acceptability of risks to the surrounding area primarily takes place based on limit values for individual risk[3] (IR) and a less strict (with regards to the IR) evaluation criterion for societal risk[4] (SR). The (local or provincial) competent authority must justify changes in the level of societal risk, for example if new land use developments are planned in the vicinity of an already-existing establishment.

For the determination of the individual risk and societal risk from establishments, a calculation method is prescribed in The Netherlands, the "Bevi calculation method", consisting of the SAFETI-NL calculation package in combination with the Reference Manual Bevi Risk Assessments (RIVM, 2009). Thereby, this calculation methodology plays an important role in the justification of decisions concerning external safety and so has consequences for land use planning, industry and public safety. Due to the interests at stake and the reliance of decision makers on the outcomes of risk calculations, the Hazardous Substances Council conducted an evaluation. The technical evaluation was carried out based on an example: the risk modelling of a BLEVE (Boiling Liquid Expanding Vapour Explosion) at an LPG filling station. A BLEVE is an incident type with great implications for the claims for indirect land use around hazardous establishments (see also page 13). The Council considers the findings with respect to the BLEVE to be characteristic of the deficiencies in the calculation methodology.

---

2 The Seveso II Directive 96/82/EU aims at prevention of major accident hazards involving dangerous substances and at limitation of consequences when an accident occurs.

3 Individual risk is the probability per year that a person who remains in a certain place in the open air, continuously and unprotected, will die within 24 hours as the direct result of an unusual incident within an establishment in which a hazardous substance or hazardous waste is involved. The exposure is considered to take place at a height of one metre. No information about other casualties is included in the concept of individual risk.

4 Societal risk is a measure for the cumulative probabilities per year that at least 10, 100 or 1000 people will die as the direct consequence of their presence in the area of influence of an establishment and an unusual incident within said establishment in which a hazardous substance or hazardous waste is involved.

The evaluation carried out is part of a wider investigation programme of the Hazardous Substances Council concerning QRA practices in The Netherlands (QRA = Quantitative Risk Analysis). In its advisory report ‘QRA modelling for the transport of hazardous substances’ (QRA-modellering voor vervoer van gevaarlijke stoffen, AGS, 2006), the Council has already criticized the modelling of risks related to the transport of hazardous substances by road, rail and water.[5] In the present report, on risk assessment for establishments, the Council looks beyond just modelling, and draws attention to the utility of the QRA results for planning and decision making as well. This report is mainly intended to set the agenda: the Council is drawing attention to the limited possibilities to obtain a reliable view of safety of an establishment or land-use plan when using the prescribed calculation method. Further, the prescribed method provides hardly any insight to evaluate safety provisions and thus to limit risks.[6]

Critical observations made by the Council about the prescribed calculation of risks to the area surrounding hazards should not be confused with criticism of quantitative risk analysis as such. The prescribed calculation method is only the *implementation* that has been given in The Netherlands’ external safety policy to an otherwise valuable analysis *methodology*. The Netherlands’ present approach is restricted to generating risk contours and estimating the societal risk. With the prescribed risk calculation method, the evaluation of the effectiveness of safety measures is either difficult or impossible. This evaluation could however be attained via different methods (vide infra).

5 The risk modelling of the transport of hazardous substances through pipelines has not yet been evaluated by the Council.
6 In a previous report (AGS, 2008a), the Council already indicated that the results of the present QRA provide little help for analyses of the possibilities of self-rescue or emergency aid.

Quantitative risk analysis

A VALUABLE METHOD FOR RISK ASSESSMENT

In quantitative risk analyses (QRAs), probabilities and consequences of (known and quantifiable) unwanted events are systematically mapped out, and are expressed numerically. With such analyses, insight can be gained into the severity of risks and the effectiveness of (counter)measures. Quantitative risk analysis is being used in many sectors to improve safety, optimise processes and support decision-making processes, from the chemical sector, the air transportation and aerospace sector to logistics and the medical sector.

A QRA method is in principle intended to map the many possible (accident) scenarios, the probabilities and consequences. The analysis renders insight in identification of scenarios with important contributions to the overall level of risk, and also enables comparative evaluation of risk-reducing measures. When developing a QRA instrumentarium for a specific application, the intended use of the instrumentarium is of paramount importance: for it determines the required level of detail and the aspects that may or may not be left out of consideration. With the QRA *instrumentarium* that is used in The Netherlands' external safety policy, the potential of the QRA *method* is only utilized to a limited extent. As is argued in this advisory report, the legally-prescribed method for carrying out risk calculations for establishments has limited value for obtaining a reliable view of the severity of risks and the possibilities to reduce these.

Important topics in the development of a QRA instrumentarium are the theoretical models used and the implementation of these models in software. Yet the quality of a quantitative risk analysis is not solely determined by the quality of the QRA instrumentarium employed, but also by the knowledge and expertise of the user: for the schematic representation of an establishment and the assessment of the value of the results of calculations demand knowledge and experience. Each model is a simplification that is only valid within certain limits.

Therefore, expertise is required to avoid a model being used unremarkedly outside its boundaries of application. A risk calculation should never be just box-ticking, even if the available QRA instrumentarium is very simple to use. In making the Bevi calculation method mandatory, the government has assumed the standpoint that "anyone" should be able to use the calculation model. The Council considers the three day training course to learn how to use the software to be completely insufficient. Safety requires knowledge, as the Council has argued in previous advisory reports (AGS, 2004; 2007).

THE ROLE OF QUANTITATIVE RISK ANALYSIS IN EXTERNAL SAFETY POLICY

The Netherlands is densely populated. Activities with hazardous substances often take place close to population centres. For this reason, efforts are made to reduce the risks from hazardous substances. This may have consequences for economic activity. It might for example make the stocking and operation of (LPG) filling stations impossible, restrict (pipeline) transport of natural gas, or ultimately mean the end of chemical industry in The Netherlands. By taking safety measures, the risks may be reduced to an acceptable level, enabling both industry and land-use development. Although serious accidents with hazardous substances can never be ruled out completely, they happen very seldom. This aspect is of great importance to the societal acceptance of activities associated with the production, use, storage and transport of hazardous substances. Quantitative risk analysis is a valuable tool to evaluate the probability aspects in decisions concerning the acceptability of risks. A precondition is that the calculated risk is an adequate representation of the actual risk. As of present, this is not sufficiently the case.

In The Netherlands, the acceptability of the risks of chemical establishments to the surrounding area is primarily evaluated based on the limit value for the individual risk (IR) and the orientation criterion for the societal risk (SR), which are laid down in the Decree on External Safety of Establishments.[7] The calculation of the IR and SR requires a quantitative risk analysis.[8]

The Netherlands has played an important role in the past in the development of knowledge in the field of the modelling of risks of chemical plants for the surrounding area. It was one of the first countries where decisions with regard to the acceptability of such risks were (partly) based on the results of quantitative risk analyses. The Netherlands' expertise in the field of modelling risks to the surrounding area is embodied in a series of internationally-reknown publications, referred to as the 'coloured books'.[9] The coloured books have – however – not been updated for some years. The calculation models behind various calculation packages that have been developed since, including the one prescribed in The Netherlands, SAFETI-NL, deviate from the coloured books. As a result, the relationship with the coloured books has faded in recent years.

Various models to calculate the individual and societal risks have been developed based on the coloured books. A benchmark study demonstrated that the results from these models could differ dramatically, despite their shared basis (RIVM, 2001). This may partly be explained by the space left for interpretation that the coloured books left for the development of calculation models, and partly by the space left for interpretation these models offered in the schematic representation of an installation and the selection of parameter values.

---

7 A similar approach is used in The Netherlands' policy with regard to the transport of hazardous substances.

8 For the establishments known as categorial, the IR and SR are not calculated, but the required distances are deducted from tables in the Regulation on External Safety of Establishments (Regeling externe veiligheid inrichtingen, Revi). These distances are based on the results of risk calculations, in which various of assumptions are made about so-called "standard" installations.

9 An overview of scenarios (possible forms of loss of containment) and the probabilities assigned to these scenarios is included in the Purple Book (PGS3, 1999). Appraisals of the physical effects for each scenario are listed in the Yellow Book (PGS2, 1997) and evaluations of the relationships between exposure and damage are described in the Green Book (PGS1, 2005).

Although it is impossible in practice to identify one single correct calculation result, the legislature considered it undesirable from the viewpoint of legal certainty that the question of whether a certain limit value was reached should be strongly dependent on choice of model or on expert judgement (Explanatory Memorandum with Bevi[10]). In 2006 therefore, a switch was made to the system referred to as unification, which means that a single calculation package was selected that must be used within the Bevi framework for calculation of IR and SR for establishments: SAFETI-NL.[11] In this calculation package, the parameter values to be used are to a large extent fixed in order to make the calculation results less dependent on assessments made by the risk analyst (see also Uijt de Haag et al., 2008). In this way, the complex reality has been heavily simplified. The prescribed risk modelling, including parameter values and scenarios, is described in the Reference Manual Bevi Risk Assessments (RIVM, 2009). In this advisory report, the calculation package in combination with the Manual is referred to as 'the prescribed calculation method'.

The prescribed calculation method plays an important role in the planning and decision making due to the threshold value for the individual risk and the orientation criterion for the societal risk. Thus, construction of houses within the SR 10^{-6} contour is prohibited, and changes to the societal risk must be justified[12], in which the orientation criterion forms an important reference in practice. Using the prescribed calculation method, the location of the 10^{-6} risk contours is determined and the societal risk is quantified. The prescribed calculation methodology thus forms the basis of administrative decisions with important consequences for industry, land use planning and the safety of citizens.

---

10 Bulletin of Acts and Decrees 2004, 250.

11 In the risk modelling of the transport of hazardous substances by road and rail and also by pipeline, other calculation packages are used. The Council has previously published an advisory report on risk modelling of the transport of hazardous substances (AGS, 2006).

12 This justification is the responsibility of the competent government authority.

Plan for evaluation of the prescribed calculation method

The Council has carried out an evaluation of the legally prescribed calculation method – the Bevi calculation method, comprising the SAFETI-NL software program and the Reference Manual Bevi Risk Assessments – for the calculation of the risks from establishments to the surrounding area. The aim of this evaluation was to investigate the limitations of the prescribed calculation method and to assess the consequences for decisions based on the results of calculations. A complete validation of the prescribed calculation method would be wide-ranging. For this reason, the Council decided to use a case study to highlite some remarkable findings. The Council considers its findings characteristic of the method in a wider sense, as will be explained in the next section.

Figure 1. BLEVE with fireball at Crescent City, 21 June 1970.

THE CASE: BLEVE OF LPG

Serious accidents may happen with flammable gases stored as pressurized liquid, such as LPG. An important incident type for LPG and other gases stored in this way is the BLEVE (Boiling Liquid Expanding Vapour Explosion). In such an explosion, the contents of a pressure vessel are released forcefully (see Appendix II for a more detailed explanation of a BLEVE). Due to the high explosion pressure, fragments of the tank or the tank itself may be ejected over great distances. If, moreover, the released liquid-gas mixture can be ignited, as is the case for LPG, a huge fireball may result (Figure 1). A BLEVE of an LPG road tanker is the scenario that is determining for the safety distances to be respected around an LPG filling station. Besides this, a BLEVE is an important scenario in transport.

BLEVEs may have catastrophic consequences. It is estimated that 500 people lost their lives on 19 November 1984 during a series of BLEVEs at the PEMEX LPG terminal at San Juan Ixhuatepec in Mexico City[13]. On 11 July 1978 at least 215 people died at Los Alfaques campsite in Spain due to a BLEVE from an LPG road tanker. Although the probability of a disaster of such proportions in The Netherlands of 2010 is low, the BLEVE plays an important role in external safety policy: for BLEVEs can never be completely ruled out, yet they can cause damage over an extensive area.

The results of the Chain Studies (Ketenstudies, TNO et al., 2004) give an indication of the risks and land-use consequences related to (policy with respect to) BLEVEs. The costs and benefits of a large number of safety measures were investigated in the Chain Studies. Several of these measures regarded reduction of the probability of a hot BLEVE. In a hot BLEVE, the tank contents are heated up by a fire before total failure of the pressure vessel occurs (for detailed explanation, see Appendix II). In the Chain Studies, the starting point was the hypothesis that the application of a heat-resisting coating to LPG road tankers would reduce the risk of a hot BLEVE by 95%.[14] The idea behind this is that the fire brigade would then have more time to extinguish a fire near the pressure vessel, before the risk of a BLEVE arose. In this context, it is assumed that the fire brigade arrives within a certain time, and that the fire brigade will extinguish every fire completely and in time (95% of cases; see also Appendix IV, page 56). If the fire brigade is not present within the time stipulated, the risk of a hot BLEVE is not reduced as a result of the thermal insulation coating (5% of cases).

Based on these assumptions, the introduction of a thermal insulation coating could significantly reduce the probability of an accident with at least ten fatalities, causing the indirect land use[15] in the vicinity of LPG filling stations and transport routes to be lower.

13 See, among others, Pietersen CM. 25 Years Later – The two greatest industrial disasters with industrial substances (*25 Jaar later – De twee grootste industriële rampen met gevaarlijke stoffen*). Nieuwerkerk aan den IJssel, 2009.

14 Originally, a coating that could be applied as a foam layer to the tank wall was assumed. Due to warnings from inspection agencies such as KIWA that the quality of the tank wall would thus not be so easy to check, it was opted in 2009 for a covering that could be removed again, for example for inspections. When reference is made in this report to a ‘coating’ then a source from the past is being cited. If reference is to a ‘covering’ then the thermal insulation covering to be introduced is meant. See also page 24 for further explication on the introduction of the thermal insulation covering.

15 Defined in the Chain Studies as usage restrictions of land due to external safety risks.

The probability of an accident with at least ten fatalities could reduce by 70% according to the assumptions in the Chain Studies, and the land use by 90% (Figure 2). In other words, reduction of the probability by over two thirds through the introduction of a coating implies an order of magnitude (a factor ten) in terms of reduction in indirect land use.

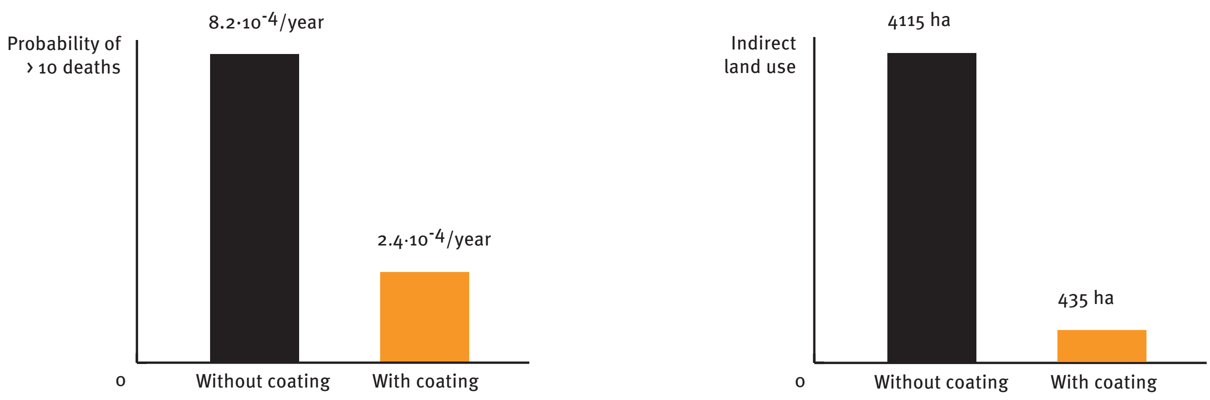

Figure 2. The probability of death and the indirect land use without and with a thermal insulation coating on LPG road tankers (based on the assumptions in the Chain Studies[16]).

It is the prominent role of the BLEVE within external safety policy that made the Council decide to carry out the evaluation of the prescribed calculation method using this type of accident. The prescribed risk modelling of the BLEVE provides the basis for decisions by competent authorities that have important consequences for the utilisation of scarce space, industrial activity and the safety of citizens.

ASSESSMENT FRAMEWORK

Possible functions of the QRA instrumentarium

In order to assess the prescribed calculation method, first the functions of the instrumentarium must be defined: for the accuracy and the potential use of the instrumentarium must link up with the functions it must be able to perform (see also page 9).

16 The figures are based on the assumptions in the Chain Studies for LPG filling stations and LPG road transport. For LPG filling stations a reduction is assumed in the probability of at least 10 fatalities from $5.1 \cdot 10^{-4}$ per year to $0.91 \cdot 10^{-4}$ per year; for LPG road transport from $3.1 \cdot 10^{-4}$ per year to $1.5 \cdot 10^{-4}$ per year (TNO et al., 2004). In total, with the assumptions made, the probability of at least 10 fatalities reduces from ($5.1 \cdot 10^{-4} + 3.1 \cdot 10^{-4} =$) $8.2 \cdot 10^{-4}$ per year to ($0.91 \cdot 10^{-4} + 1.5 \cdot 10^{-4} =$) $2.4 \cdot 10^{-4}$ per year. According to KPMG et al. (2004), for LPG filling stations, and using the assumptions made, the number of hectares where the orientation value of the SR is exceeded reduces from 3800 to 340, and for transport from 315 ha to 95 ha. In total, the number of hectares where the orientation value of the SR is exceeded then reduces from (3800 + 315 =) 4115 to (340 + 95 =) 435. In the main report on the Chain Studies (KPMG et al., 2004), the designation ‘indirect land use’ is used for land area where the orientation value of the SR is exceeded.

The Council discerns two functions for a QRA instrumentarium:

- The calculation of the individual risk (IR) and the societal risk (SR) for assessing permit applications.[17]
- The provision of insight into measures that may increase safety in the specific situation to be evaluated.

For the first function, the Council considers it important that the instrumentarium is transparent, verifiable and robust and contains no deficiencies, considering the role of the IR and SR calculated according to the Decree on External Safety of Establishments (Bevi) in planning and decision making. Further, the Council considers it important that, using the instrumentarium, an assessment of the IR and SR may be obtained that is consistent with the view of experienced risk analysts based on state-of-the-art methods.

For the second function, it is important that the QRA instrumentarium can be used to gain insight on how to reduce risks and increase safety. In the Explanatory Memorandum in the Decree on External Safety of Establishments, this objective has already been formulated implicitly, but it has not been put into practice (sec. 5.3): "In this Decree, environmental quality requirements are laid down for the protection of people in vulnerable and moderately vulnerable objects against the risk of decease as a result of the release of hazardous substances during an accident in an establishment." To actually provide this protection against fatalities in practical situations, information for the evaluation of safety measures is needed. The AGS has already referred to this in the advisory reports 'Risk policy and disaster control' (Risicobeleid en rampenbestrijding) and 'Advice of fire brigades' (Brandweeradvisering).

Criteria for the assessment

In the evaluation of the prescribed calculation method, the Council focused on the underlying scenarios, consequences and probabilities, and the implementation of the models in software, as well as on the role of expert judgement in the use of the instrumentarium. A link was made with the framework previously used in the assessment of the risk modelling of the transport of hazardous substances (AGS, 2006).[18] The following assessment criteria were considered:

- **Transparency**: to what extent transparency exists about the theoretical models that are implemented in the software? Is it clear what processes are being carried out by the software? The criterion applies to the calculation package in itself.
- **Verifiability**: to what extent are sources for coefficients or (fixed) input data still accessible? Is it possible to see what the arguments have been in the past for the choice of a specific scenario, a model or an input variable? What is basis of the value of the input data, and/or where can the derivation from specific source data been found? The criterion applies to the inputs in the risk calculation.

---

17 This concerns both licences for establishments (Environmental Management Act or Wm licences) and those for land-use developments in the vicinity of establishments (Spatial Planning Act or Wro licences). Ultimately, the granting permits process always has two possible outcomes: the licence is either granted or not. Additional requirements for either the establishment or the spatial plan may well be stipulated in Wm or Wro decrees.

18 In the present report, the assessment framework is elaborated farther than in the report about QRA modelling for transport. In that, only the criteria transparency, verifiability and robustness were employed.

- **Robustness:** are results sensitive to the choice of input parameters? The Council therefore carried out a sensitivity analysis.[19]
- **Validity:** the extent to which the model describes reality. Because major accidents with hazardous substances seldomly occur and because they all have their own background, the investigation of one or even several accidents of the same type may be instructive, but is statistically insufficient. Therefore, the validity criterion has been subdivided into two more restricted criteria:
  - **Correctness:** are the assumptions and starting points for the system description correct? Have (partial) models been validated e.g. using field trials or after accidents? If important omissions are present, calculation results fail to provide an impression of the safety level and of the possibilities to increase safety.
  - **Safety relevance:** to what extent can safety provisions and safety-increasing (or decreasing) circumstances be entered into risk calculations? To what extent do the results of the risk calculations provide insight into the magnitude of risks and the possibilities to reduce risks?

19 Results must be sensitive to parameters when a physical/chemical dependency exists (see also the validity criterion).

Evaluation of the prescribed calculation method

In this chapter, the results of the evaluation of the risk modelling of a BLEVE at an LPG filling station are described. The prescribed calculation method is evaluated on each of the criteria in the previous chapter. The results are reflected upon in the next chapter.

The fact that results of risk analyses have uncertainty margins is a matter of common knowledge for risk analysts. For competent authority managers, this is actually often not true. In this chapter, in order to picture the practical implications of these uncertainties, various calculations are made for a standard LPG filling station. The calculations were made with the prescribed calculation method and also with slightly modified assumptions and starting points (sensitivity analysis). The different results show how the indirect land use would change if other assumptions and starting points were to be used in the risk calculations. In this chapter, inaccuracies that the AGS observed in the prescribed risk modelling of a BLEVE are also noted. It should be emphasised that no exhaustive evaluation of the prescribed calculation method has been conducted: the main objective of the evaluation was to provide insight into the limitations that the prescribed method has. The chapter concludes with a discussion about the general applicability of the findings.

TRANSPARENCY

The theoretical models that are incorporated into the calculation package that is prescribed in The Netherlands, SAFETI-NL, are largely described in the Reference Manual Bevi Risk Assessments (RIVM, 2009). The Manual provides an overview of the BLEVE models implemented in SAFETI-NL and thus fulfils the transparency criterion. Still there are disadvantages associated with the obligation to use the Bevi calculation method (see below).

VERIFIABILITY

The BLEVE fireball model that is used in the prescribed method is presented comprehensively in the Yellow Book (PGS2, 1997). The same applies to the probit (measure of probability) in the Green Book (PGS1, 2005) that is used to make the connection between the radiation from fires and lethality. The verifiability is in this regard sufficient.

The verifiability of the failure frequencies is however limited. It is not straightforward and is sometimes even impossible to derive how the failure frequencies have been established. The Reference Manual Bevi Risk Assessments (RIVM, 2009) is of no help here either. As an example, without any motivation, the probability of total failure of a pressure vessel has been reduced in the past by an order of magnitude (factor of ten) or more. This has serious consequences for the calculation of the probability of a BLEVE.

The starting points and assumptions that form the basis of the probability of a BLEVE as used in The Netherlands are not clear. It required an extensive investigation by the AGS to determine what these are based on. It finally became apparent that the origin of the probability of a BLEVE as used in The Netherlands may be traced back to three studies into the safety of pressure vessels: Philips and Warwick (1969), Smith and Warwick (1974) and Bush (1975). These old studies primarily concerned steam vessels.[20] Although the many reports that have been issued in The Netherlands since then may give a different impression, the present failure frequencies for pressure vessels are not based on more recent case histories. Such information is indeed available: in the United Kingdom, the failure frequencies used are based on data for pressure vessels of more recent date (see also Appendix III). Further, it became apparent from the investigation by the Council that the failure frequencies of pressure vessels currently used in The Netherlands were reduced on vague grounds at the very start of activities in the field of risk analysis at the end of the 70s. The failure frequency of a pressure vessel derived from the studies of Philips and Warwick (1969), Smith and Warwick (1974) and Bush (1975) was reduced by a factor of at least 10 in the COVO study.[21] Thorough argumentation for this reduction is absent (see also Appendix III). This unjustified reduction directly influences the failure frequencies listed in the Reference Manual Bevi Risk Assessments (RIVM, 2009).

The probability prescribed in The Netherlands for instantaneous failure of a pressure vessel is relatively low, just as is the probability of a BLEVE calculated from this (0.7 to $2.5 \cdot 10^{-7}$ per year; see Appendix III, page 46, for further explanation). In the United Kingdom the BLEVE probability applied for stationary installations is a factor of 40 to 140 higher.[22]

ROBUSTNESS

Various comparative studies have demonstrated that the results of risk calculations are strongly dependent on expert judgement (Amendola, 1992; RIVM, 2001; Lauridsen, 2002). The user of a calculation program may select a model and modify the parameter values and coefficients. The results of calculations may thus differ. The robustness of the risk modelling of a BLEVE according to the prescribed calculation method is actually very high. This high robustness has been achieved by excluding (further) expert judgement by defining parameter values, coefficients and models in the prescribed calculation method (referred to as unification). In the risk analyses thus, fixed failure frequencies are imposed, and in the modelling of the fireball, only the setting of the safety valve (i.e. the pressure) and the volume of the fireball can be varied. The robustness is thus constructed on a policy decision. It is

---

20 Steam vessels have been in use for more than 150 years to date. It should be observed that there are differences between steam vessels and vessels in chemistry and also that new techniques and standards are used. E.g., for the different types of vessels, the load (pressure) is neither equal nor constant. Vessels used in chemistry often suffer more from contamination and may be subject to corrosion. For this reason, special materials and manufacturing and welding techniques are used. In the past decades, standards for manufacture, maintenance and inspection have also changed.

21 In the COVO study, the risks to the surrounding area from six establishments in the Rijnmond area were mapped out (COVO Commission, 1982). A more detailed discussion of the COVO study is included in Appendix III.

22 In HSE (2004) a BLEVE probability of 10^{-5} per year is used.

not a characteristic of the calculation method in itself, as is demonstrated below in some examples.

The pursuit of robustness should not degenerate into insensitivity to essential parameters. After all, reality is almost always different from a "standard" installation. Risk analysis should be tailored to the situation. The Council carried out various risk calculations to picture the sensitivity of calculation results to assumptions and starting points (The calculations are included in Appendix IV; a summary of the results follows below). In the calculations, an LPG filling station with a throughput of 1000 m^3 per year is taken as an example.[23]

This sensitivity analysis reveals that relatively small deviations from the assumptions and starting points listed in the Reference Manual Bevi Risk Assessments (RIVM, 2009) may lead to large changes in the indirect land use around LPG filling stations. This means that the risk calculations are (very) sensitive to such deviations. The Risk Calculation Manual masks the great variation of possible results from the calculations.

If the model, the parameter values and coefficients were not fixed as a matter of policy in the prescribed calculation method, the results of the risk analyses could vary greatly. This may be illustrated by the following examples:

1 Variations in the probability of a BLEVE during the unloading of an LPG road tanker

The position of the 10^{-6} risk contour is strongly dependent on relatively small variations in the probability of a BLEVE during unloading of an LPG road tanker. This probability is determined by the number of transfers, the duration of unloading and the (very uncertain) probability of a BLEVE during each transfer. In a standard LPG filling station[24], according to the calculation method to be used, two accident types determine the level of the individual risk: (close to the filling connection) failure of the pump and outlet hose of a transferring LPG road tanker and (at a greater distance) a BLEVE from a transferring LPG road tanker. According to calculations with the prescribed calculation method, the failure of the outlet hose makes a negligible contribution to the IR at a distance of more than about 40 m. An IR greater than 10^{-6} at a distance of over 40 m is only possible if the BLEVE plays an important role in the risk analysis (Geerts, 2006). The various partial contributions to the IR are compared to the distance in Appendix IV, Figure 8, page 53.

If unloading LPG road tankers are not provided with a thermal insulation covering, the distance from the 10^{-6} risk contour to the filling connection is 50 m (LPG filling station with a throughput of 1000 m^3 per year, see Appendix IV, Figure 10, page 55).

---

23 According to a survey, there are 544 filling stations with an LPG throughput of less than 500 m^3 per year, 1119 with a throughput of between 500 and 1000 m^3 per year and 324 filling stations with a throughput of over 1500 m^3 per year (RIVM communication, 14 December 2009).

24 According to the prescribed calculation method, by standard LPG filling station should be understood an LPG filling station that complies with the requirements applicable in The Netherlands and of which the layout corresponds to the assumptions used in the derivation of the distances listed in the Regulation on external safety of establishments (Regeling externe veiligheid inrichtingen, Revi). In the policy currently in force (since 2007 (Amendment to Revi, Staatscourant, Govt Gazette 2007, 66)) the presence of a thermal insulation covering on the LPG road tanker is assumed. Such a covering has only been applied to a few LPG road tankers by the start of 2010 (see also page 24).

For only a 50% higher probability of a BLEVE during transfer, this distance increases to 100 m. And for a not unimaginable ten-fold increase in the risk of a BLEVE – see also the verifiability of failure frequencies in the previous section – to 190 m (Figure 3 and Appendix IV, Figure 13, page 58).

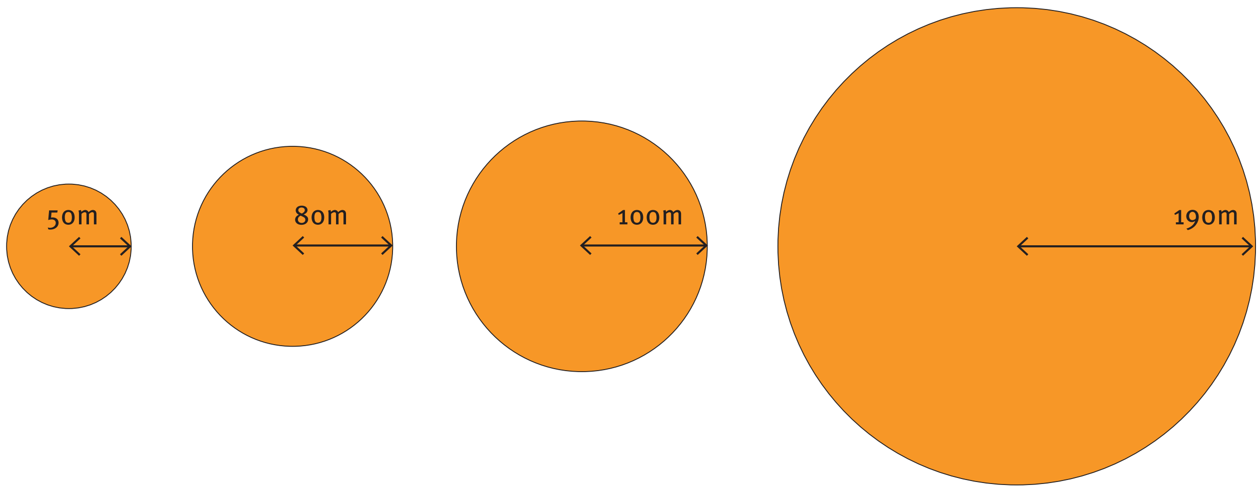

Figure 3. The influence of small variations in the probability of a BLEVE during unloading of an LPG road tanker (product of the number of transfers, unloading time and BLEVE probability per time unit during transfer) for a standard LPG filling station with a throughput of 1000 m^3 per year and unloading LPG road tankers not provided with a thermal insulation covering.

2 Variations in the dose-response relationships

In lethality calculations, relationships are described between exposures on the one hand and probabilities of fatality on the other, using dose-response relationships (known as probit functions). Differences exist between the various probit functions mentioned in the literature; this has to do with the experiments they have been derived from. There is a considerable variation between the different probits. The choice of probit thus influences the results of calculations. The AGS calculated lethality for a hot BLEVE with a 26.7 ton LPG road tanker using different probit functions. Besides the TNO probit that is implemented in SAFETI-NL, other probits have also been used in this evaluation, including the one used by the HSE in the United Kingdom. In Figure 4 it is indicated how large the area would be in which lethality is over 50% using calculations with the various probits.

In a diagram in Appendix IV, distances are also shown for other percentages of lethality and a more detailed description is included (Figure 15, page 59). From the comparison, it is apparent that the approach used in The Netherlands is relatively pessimistic.[25]

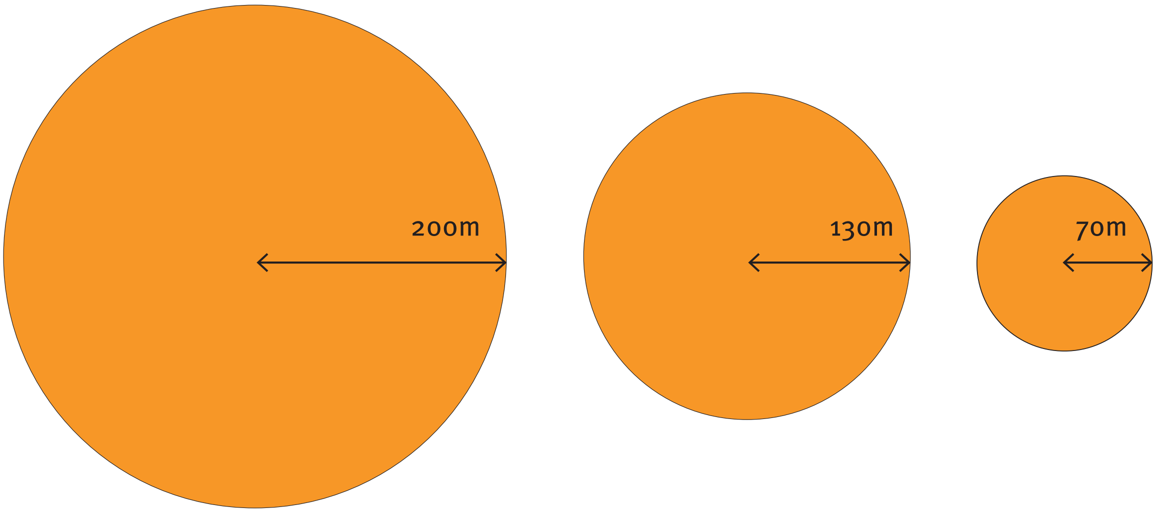

Figure 4. The area around a 26.7 ton LPG road tanker in which the lethality for a hot BLEVE is more than 50% according to the TNO probit, the probit as used in the United Kingdom (UK HSE) and the Lees probit.

VALIDITY: CORRECTNESS

The Council has observed various points for improvement of the BLEVE risk modelling. These mainly concern the scenarios and (the backgrounds of) the failure frequencies used:

1 **Leaving out human error and other scenarios**

A frequency of 5.10^{-7} per year is used in The Netherlands for the failure of a pressure vessel. It is striking that in the Purple Book (PGS3, 2005: page 3.3) it is stated that this probability must be increased by a factor of ten – by 5.10^{-6} per year – if standard safety provisions[26] are missing or external impacts (such as collisions for example) and human errors (such as overfilling) cannot be excluded. Conversely, in the Reference Manual Bevi Risk Assessments (RIVM, 2009), the failure frequency contributions of external impacts and human errors are left out on the presumption that standard safety provisions are present: if they were to be absent, they should be implemented immediately. The Council is of the opinion that the failure frequency contribution of external impacts, corrosion and human actions may not be dismissed just like that, even if standard safety provisions are present. The British Health and

25 The failure frequencies used in The Netherlands for pressure vessels are relatively optimistic. The proposition that differences in pessimism and optimism in the different steps of the risk calculation compensate for each other is not defensible. For each separate step, reasonable assumptions must be made to prevent the creation of a hopeless tangle of optimistic and pessimistic assumptions.

26 What provisions should be understood by standard safety provisions is not further explained in the Purple Book.

Safety Executive (HSE) shares this judgement. A higher probability must be used if there is reason to do so (HSE, 2004). If the increase by 5.10^{-6} per year mentioned in the Purple Book were used, the probability of catastrophic rupture would increase by around a factor of ten (see also Appendix III, page 49 et seq.).

2 **Probability of ignition incorrect**

The probability of a BLEVE being accompanied by a fireball is dependent on the probability that the BLEVE is followed by a direct ignition (if the tank contents are flammable, as with LPG). In The Netherlands' prescribed calculation method, this probability is assumed to be dependent on the release quantity. Physically, this is incorrect. The probability of direct ignition is i.a. dependent on the initial causes of the BLEVE. The probability of direct ignition from a mechanical impact is less than from a fire near the tank. In case of a hot BLEVE, the fire will always cause direct ignition (see also Figure 7 in Appendix III, page 50).

In the Reference Manual Bevi Risk Assessments[27], this incorrectness is justified as follows: "It has been opted to retain the distinction in the volume in order to remain in agreement with previous QRAs as much as possible". The Council deduces from this that the physically incorrect modelling was already recognised, but that it was decided for policy reasons not to allow the final results of the calculation to deviate too far from earlier calculations. On page 28, the interwovenness of policy and calculation is elaborated further.

3 **Incorrect assumption of the presence of safety provisions**

In estimating the probability of a BLEVE in the presence of fire, the question whether the vapour space or the liquid space of the tank is subject to heat radiation by the fire, is of great importance. If the vapour space is irradiated, the tank wall is not cooled by liquid there, causing serious local weakening of the wall. In the prescribed risk modelling, the probability of a BLEVE when the vapour space is irradiated is set equal to one. If the liquid space is irradiated, the probability of a BLEVE is set equal to 0.1, because it is assumed that in 90% of cases a BLEVE will be prevented because safety (over-pressure) valves would ensure a blow-off of the contents (RIVM-CEV, 2008, page 8). In the decision making process whether an LPG filling station may be licensed or should be removed, this safety provision is presumed to be present. This is striking because over-pressure valves are not mandated by international directives[28] and, in practice, not all LPG road tankers are fitted with an over-pressure valve (OVV, 2006). The Liquid Gas Association (Vereniging Vloeibaar Gas, VVG) has communicated that its members' LPG road tankers are indeed fitted with over-pressure valves.[29] This provision is not mandatory, however. In calculating the risk at an LPG filling station, the risk from unloading LPG road tankers without over-pressure valve may thus be underestimated.

4 **Incorrect scenario**

The scenarios included in the event tree are incorrect. In the direct ignition branch, events are included that only happen with delayed ignition (see Figure 7, page 50 in Appendix III). Moreover, for bunded LPG pressure tanks, the hot BLEVE scenario has

---

27 RIVM, 2009. Module C, page 103.
28 The ADR (Accord Européen relatif au transport international des marchandises Dangereuses par Route, European Agreement concerning the international carriage of Dangerous goods by Road) and Directive 94/55/EC (Directive 94/55/EC of the Council of 21 November 1994 on the approximation of the laws of the Member States with regard to the transport of dangerous goods by road).
29 Communication from Mr F. Melcher de Leeuw (VVG director) on 8 March 2010.

been excluded in the prescribed calculation method because the tank cannot be irradiated by a fire under the tank, nor by a jet fire.[30] A cold BLEVE remains possible however, for example due to corrosion or overfilling (see also page 50 in Appendix III). Finally, the probability of a BLEVE from bunded pressure tanks is indeed included, but the consequences are then ignored (see also pages 50 and 51 in Appendix III). This modelling method consequently underestimates the probability of an explosion or flash fire, because the assumed (conditional) probability of a BLEVE is at the cost of the probability of these other phenomena.

Finally

With regard to the effect modelling, the Council has not observed any deficiencies in its evaluation of the risk modelling of a BLEVE. The TNO model used for the fireball in the prescribed method is an empirical model. This model gives the best description of the fireball diameter, duration and radiation in experiments with up to 2 tons of LPG – the largest experiments conducted to date (Bagster & Pittblado, 1989; Cowley & Johnson, 1991). It should be noted that the TNO model for the fireball has a good fit describing the experiments at small scale (up to 2 tons), but there still are significant uncertainties with respect to the scaling up to storage volumes currently used in practice.

VALIDITY: SAFETY RELEVANCE

The safety relevance of the prescribed Bevi calculation method is low: insight cannot be gained (or only very limitedly) into the influence of safety provisions. This applies both to mandatory provisions (that are assumed to be present) and to those that could possibly be taken. The relationship between the safety (or danger) of a specific establishment and the calculated individual and societal risks is thus weak:

1 **Safety measures not recognised**

The generic nature of the failure frequencies used implies that safety measures are not recognised or conversely are recognised as standard (and possibly wrongfully) in risk calculations. The prescribed failure frequencies for pressure vessels regard situations without corrosion, fatigue due to vibration, human error or external impacts. This implicitly presupposes the presence of measures, maintenance, inspection and management systems that may well be absent in practice.

2 **No tailor-made assessment for an establishment**

The modelling according to the Reference Manual Bevi Risk Assessments takes no account of differences in for example the expertise, safety management systems or emergency measures present at different (types of) establishments. The probability of a BLEVE with fireball is thus modelled in the same way for an industrial process plant as for an LPG filling station.

3 **No tailor-made assessment of exposure**

In calculating the consequences of heat radiation it is assumed as standard that a person gets away from direct heat radiation after no more than 20 seconds by escaping, for example behind a barrier. This standard escape time does not reflect the possibilities for self-rescue actually present. These may differ greatly from case to case, depending on the characteristics of the population exposed (older people are less able to rescue themselves than young people) and on the characteristics of

30 RIVM, 2009. Module C, page 102.

the surrounding area, such as building density and the presence of escape routes. The Council has already observed in a previous report that the prescribed calculation method is of little or no help for analysing the possibilities of self-rescue and emergency aid (AGS, 2008a).

4 Anticipating safety gain since 2007

The distances for safety clearances around LPG filling stations were reduced in 2007 from 110 m to 40 m for filling stations with a throughput over 1000 m^3 per year.[31] This reduction is founded on agreements with the LPG sector to increase safety: the LPG autogas covenant (VROM and VVG, 2005). In this, particularly the application of a thermal insulation coating to LPG road tankers is of importance. Although the competent authorities have indicated that problems exist in practice regarding enforcement of applying a coating to transferring LPG road tankers (Association of Netherlands Municipalities, 2009), the Ministry of Housing, Spatial Planning and the Environment expects that the great majority of LPG road tankers in The Netherlands will have been provided with a thermal insulation covering by August 2010.[32] At the start of 2010, a quarter of the roughly 30 LPG road tankers of Liquid Gas Association members had been provided with a covering.[33,34] Indeed, for LPG filling stations with a throughput of 1000 m^3 per year, the question of whether transferring LPG road tankers are provided with a thermal insulation covering hardly affects the position of the 10^{-6} risk contour (the distance from the filling connection would decrease, according to calculations using the prescribed calculation method, from 50 m to around 40 m, if all LPG road tankers were provided with a covering; see also page 56 in Appendix IV, Figure 10).

For filling stations with a greater throughput, the influence of the thermal insulation covering on the position of the 10^{-6} risk contour is in fact important. The Council observed in a sensitivity analysis that reducing the clearance distance in Revi from 110 m to 40 m for LPG filling stations with a throughput of 1500 m^3 per year can only be justified if a large proportion of the transferring tankers are provided with a thermal insulation covering (see Figure 5; the individual risk for different distances is shown in Appendix IV in Figure 12 on page 57). It is therefore important that the change to the clearance distance in the Revi is reconsidered if it should prove that it is not feasible to provide all LPG tankers in The Netherlands with a thermal insulation covering.

31 Revi amendment (Staatscourant, Govt Gazette 2007, 66).
32 Communication from Mr J. van Staalduine (Ministry of Housing, Spatial Planning and the Environment) during the Feedback group meeting for this advisory report, held on 16 November 2009.
33 Communication from Mr F. Melcher de Leeuw (Liquid Gas Association) on 8 March 2010.
34 Due to the problems about introducing the thermal insulation coating, The Netherlands Environmental Assessment Agency (PBL) significantly increased the estimated number of houses situated within the 10^{-6} risk contour for LPG filling stations to around 4,500 (PBL, 2009). In 2008, the Agency was still assuming a number of 1,800 homes, due to the LPG autogas covenant (PBL, 2008).

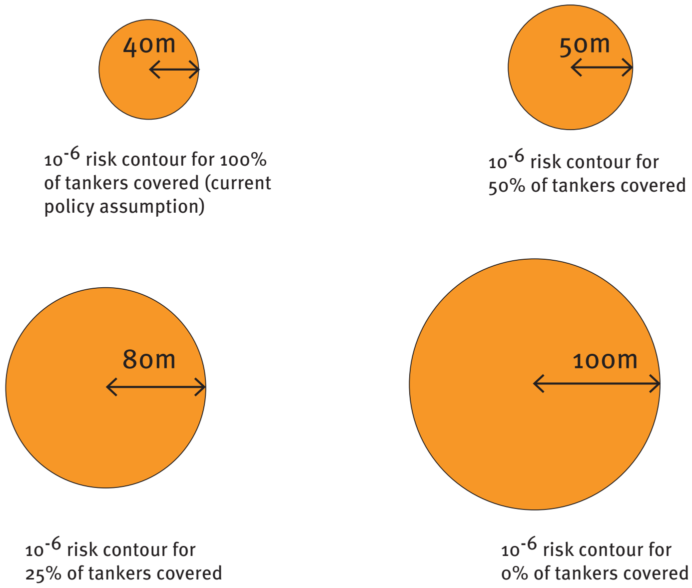

Figure 5. Position of the 10^{-6} risk contour for a standard LPG filling station with a throughput of 1500 m^3 per year for different percentages of the transferring tankers that are provided with a thermal insulation covering.

It should be noted that the QRA results for an LPG filling station with a throughput of 1500 m^3 per year are identical to the results for one with a throughput of 1000 m^3 per year if, for the latter filling station, the assumption of a 50% longer duration of stay is made (45 minutes rather than the 30 minutes necessary according to the prescribed calculation method to unload the LPG[35]). Deviations from the standard duration of stay may have nothing to do with the unloading of LPG, but do influence the level of the risk.

THE GENERAL APPLICABILITY OF THE FINDINGS FOR THE BLEVE

Although the evaluation was focused on the risk modelling of a BLEVE at LPG filling stations, the Council considers its findings to be typical for the calculation method prescribed in The Netherlands in a broad sense. The backgrounds and levels of the failure frequencies used in The Netherlands are independent of the question of whether a pressure vessel contains LPG or for example chlorine. The mandatory-to-use calculation method is unsuitable for the assessment of safety measures for a specific establishment or for analysing possibilities for self-rescue and emergency aid. The risk modelling (scenario definition, estimation of frequencies, and effect and consequence modelling) for different incident types and types of hazardous properties (flammable, explosive, toxic) features similar difficulties. The uncertainties in each part of the risk modelling are considerable, and this is not only the case for a BLEVE. E.g., the dose-response relationships that define the relation between exposure levels and victim probabilities for toxic substances are at least as uncertain as those for thermal radiation, and the dispersion of toxic substances in a built-up area is very difficult to model.

35 The 30 minutes' duration of stay assumed in the prescribed calculation method is necessary to pump over (an average of) 15 m^3 LPG. Besides this, around thirty actions have to be carried out by the driver of the LPG road tanker. No time is added for this in the prescribed calculation method. The use of only the transfer time and not the duration of stay of the tanker at the LPG filling station would lead to an underestimation of the risk.

Reflections

In the evaluation described in the previous chapter, the Council observed that the present, prescribed calculation method for carrying out a quantitative risk analysis for a BLEVE of LPG is sufficiently transparent (page 17). Robustness is not in fact locked into the calculation method itself, but has been introduced artificially by means of a policy-driven intervention (unification) in order to compensate for the large range of possible results in the use of the methodology (see pages 18-19). Moreover, the calculation method features limitations and deficiencies as regards the verifiability, correctness and safety relevance (see pages 17, 21 and 23 respectively). In this chapter, the considerations are presented that form the basis for the conclusions and recommendations in the present advisory report.

THE TENSION BETWEEN ROBUSTNESS AND SAFETY RELEVANCE

As discussed on page 14 et seq., in external safety policy, a QRA (ideally) fulfils two functions:

- Calculation of the individual risk and the societal risk for assessing permit applications.
- Provision of insight into measures that may increase safety in the specific situation to be evaluated.

For the first function, a QRA instrumentarium of high robustness is desirable. This is connected to the role of QRA results in The Netherlands' external safety policy: for, through the limit value for the individual risk, QRA results directly influence decisions concerning external safety. High robustness may prevent every decision being challenged by disputing the results of the underlying QRA.

For the second function, the safety relevance of the QRA instrumentarium is important. For a clear insight into the risks of an establishment for the surrounding area, it is important that the risk analysis does justice both to the characteristics of the establishment under consideration and to those of the surrounding area (see also page 23). A single number as the outcome of a calculation is bound to be insufficient for decision making. Increasing the safety relevance of the calculation methodology demands an increase of the number of dimensions of the outcome of risk calculations in order to make feedback into practice possible. The drawback of performing tailor-made work – rather than assuming standard installations – however is that it has a negative influence on the robustness of risk calculations. Robustness and safety relevance are thus difficult to unite in a single calculation methodology.

Through unification, the robustness of the QRA instrumentarium has been increased. This was done particularly to smoothen the process of granting permits. A side effect of the unification is that the safety relevance of the QRA instrumentarium has been reduced. Yet, in a solid external safety policy, safety-relevant information is essential: otherwise QRA practice degenerates into a ritual for granting permits. Various companies (and sector associations) have indicated that, except for permit application, they make no use of the QRAs prepared with the presently prescribed calculation method. That fact that companies use other methods and models to assess and increase the safety of their establishments is illustrative of the limited safety relevance of the presently prescribed calculation method.

No simple technical solution exists for the tension between robustness and safety relevance of the QRA instrumentarium. The observed lack of safety relevance does not primarily require model amendments. In the Council's view, the solution is in modifying policy: the second function of the QRA, gaining of insight, must also be realised. For this, the following two options exist in broad terms.

Firstly, a step-by-step approach is possible, in which the results from a very robust (but not very safety-relevant) quantitative risk analysis are introduced into planning and decision making, along with the results of a very safety-relevant (but not very robust) analysis. The results from calculations with the robust QRA instrumentarium, together with the limit value of the individual risk and the orientation criterion for the societal risk, can then be considered as a first coarse filter in the assessment of permit applications and land-use plans. The results of the location-specific analysis may then be submitted to the competent authority in the form of an advisory report about the societal costs and benefits of measures. This is considered to be possible within the present framework of accounting for the societal risk and would not require any important policy modifications. Location-specific analyses should then be included into the Decree on external safety of establishments (Bevi). In order to increase safety it is necessary that the input of expertise is at the appropriate point in time (if possible as early as the planning stage).

Secondly, a more far-reaching approach is possible, in which the solution is in a modification of how permit applications and land-use plans are being assessed. By putting less emphasis on numerical values (limit value for IR and orientation criterion for SR) in the assessment of QRA results in planning and decision making, the importance of the robustness of the QRA instrumentarium may be reduced. This would make the introduction of a more safety-relevant QRA instrumentarium possible. The risk could be subdivided into classes, or frequency and consequence classes could be assessed separately. Also, the transport to and from an establishment could be considered in combination with the safety assessment of the establishment. In this way, a procedure for preparing spatial planning visions that puts more emphasis on the dialogue among the stakeholders could be developed. QRA results would then be used mainly in a relative sense, to gain more insight into the differences between alternatives. In the next chapter, examples are given of experiences with this approach in other EU member states. As disputes are not unimaginable with a method that puts the emphasis on dialogue, the approach would require an independent authoritative body that could – if necessary – act as arbiter. This arbiter could be a body like the Health and Safety Executive in the United Kingdom.

THE INTERWOVENNESS OF RISK MODELLING AND POLICY

Calculations carried out with the prescribed QRA instrumentarium are linked to numerical criteria in policy in the field of external safety (IR and SR). Model modifications may thus have important consequences for land-use planning and industry. In the current official practice for modification within the prescribed QRA instrumentarium, the emphasis is put not so much on the scientific merits of modification proposals and the relationship with reality, but mainly on policy consequences. The responsibility for model modifications has been assigned to the Centre for External Safety (Centrum voor Externe Veiligheid, CEV), part of the RIVM. In this, the CEV has to deal with the technical contribution from the group referred to as the Experts' Consultation on Risk Analysis (Deskundigenoverleg Risicoanalyse, DORA) and with the policy-related contribution from the Directors' Consultation on External Safety (Directeurenoverleg Externe Veiligheid).

The Council is of the opinion that the existing policy is impeding research and development. The practical consequences of changes in starting points, assumptions and modelling are blocking (discussion about) fundamental renewal of the QRA instrumentarium. Via DORA, indeed the possibility exists to pay attention to flaws in the prescribed risk modelling, but the discussion on this is limited to details of the prescribed calculation method. Although incremental improvement in the prescribed QRA instrumentarium is theoretically possible via DORA, there is little room for (the discussion of) fundamental model modifications within the framework of existing policy.

The limited resources for research and development are exemplary of the notion that the QRA instrumentarium has been finalized and that it now only has to be administered. The Council strongly opposes this notion and so considers it of importance that old assumptions and new approaches can be freely discussed, without this being directed by a prescribed risk modelling method or by consequences of new insights for policy. This requires a looser connection between policy and calculation methodology. This is not only conducive to the ability to purposefully invest in safety improvements, but also to retain knowledge. The Council fears that the background of the current risk modelling, which is already only known to few, will be completely lost from sight when those who have been involved in the current risk modelling leave the field. This tendency is meanwhile apparent, as is demonstrated in this advisory report (pages 17 and 21). In previous reports (AGS, 2004; 2007), the Council has already argued in a general sense that knowledge is crucial for safety.

If a clear distinction were to be made between state of the art in the field of risk analysis and the prescribed calculation method in The Netherlands, it could be avoided that policy considerations hinder the development of insight and knowledge, without causing serious disadvantages for the execution of policy from continuously changing insight. In practice however, the emphasis is almost completely on the maintenance of the prescribed calculation method.

With a clear separation between research and development on the one hand and the maintenance of the prescribed package on the other, it would be possible to have a 'development track' and a 'maintenance and management track'. In the development track research the focus would be on improvements in risk modelling, and in the maintenance and management track on the maintenance of the prescribed calculation method. While the first track would be characterised by dynamics and an emphasis on validity (correctness and safety relevance), the second would be characterised by stability.

Both tracks would need to be interconnected periodically to assess if the prescribed instrumentarium still is in concert with improved insights and approaches, or whether more important improvements or even replacement of the instrumentarium is desirable. Maintenance and management of the instrumentarium would feature a relatively short timeschedule (consultation with intervals in the order of months).[36] Adaptation of the prescribed method to the results of research and development would take place on a longer timeschedule (in the order of five years) and might lead to policy modifications.

In the present situation in fact, only maintenance and management of the QRA instrumentarium are in place. No provision is made in current policy for periodic evaluations in which the foundations of the QRA instrumentarium are assessed with respect to newly-gained knowledge and practical experience.[37] The resources for research and development on which such periodic evaluations could be based are also absent at present. Given the limitations noted in this advisory report, there is a great need for these.

A PARALLEL WITH THE TRANSPORT OF HAZARDOUS SUBSTANCES

In 2006, the Council published the results of an investigation into the prescribed method for calculating the risks of transport of hazardous substances for the surroundings (AGS, 2006). The Council concluded then that this calculation method (Risk Calculation Method II, Dutch abbreviation RBM II) was insufficiently transparent, verifiable and robust.[38] It was also observed that RBM II was only very limitedly useful to weigh up the possibilities to improve safety. This is still the case.

The limitations of the prescribed method for calculating the risks of transportation of hazardous substances are currently relevant, considering the role the results of risk calculations play in defining the basic road, rail and waterway networks[39]. As a consequence, the definition of these basic networks relies heavily upon a numerical exercise, which at first glance provides clarity to the various parties concerned, but upon more detailed consideration opens up to a wide range of possible outcomes.

The Council sees parallels between policy developments in the field of the transport of hazardous substances and those in the field of stationary establishments. In both cases, attention is increasingly drawn to bottlenecks in decision-making processes by competent authorities and processes of granting permits. With that, the

36 The timeschedule at present is in fact longer. Between putting a certain bottleneck on the DORA agenda and its processing into the prescribed calculation method a period of one to two years often passes.
37 At the end of 2009, the Minister for Housing, Spatial Planning and the Environment specified in the 'Ninth progress report regarding external safety policy' what should be understood by the promised evaluation of societal risk policy (see Parliamentary Document 27801, no. 70): an investigation into the municipal translation of national policy in the implementation practice. The Council argues for a more basic evaluation: the underlying technical-scientific insights should also be assessed based upon the assessment criteria specified by the AGS.
38 Criteria for correctness and safety relevance are added in the present advisory report.
39 The Dutch government considers the development of a policy to define a network for transportation (road, rail and water), with more or less dedicated tracks for transportation of dangerous goods.

relationship with safety seems secondary. The Council certainly does not wish to trivialise the problems of decision making and granting permits, but does consider it alarming that the second objective of the use of a QRA instrumentarium, the improvement of safety through evaluating safety-increasing measures, is not taking place adequately. This may well be explained by the fact that disasters and serious accidents with hazardous substances seldom happen, while issues with regard to policy execution are experienced every day, but it does not advance safety.

The QRA practice in international perspective

This chapter describes how some other European Member States implement the Seveso II Directive: the United Kingdom, France and Germany. There are various alternatives to (parts of) The Netherlands' QRA practice, in which decisions regarding external safety are to a large extent based on a single number obtained from an oversimplified, prescribed calculation method.

QRA and external safety in the United Kingdom: COMAH and PADHI

In the United Kingdom, the Health and Safety Executive (HSE) plays an advisory role in establishing land-use plans and the granting of permits. In the context of COMAH,[40] the competent authority must ask HSE for advice when assessing permit applications for establishments. Although HSE only has an advisory role, its position is such that recommendations are generally adopted by the competent authority. PADHI (Planning Advice for Developments near Hazardous Installations) is the name of the method used by HSE in advising on land-use plans (HSE, 2009; this method is described in more detail in Appendix VI). Interesting aspects of the external safety policy in the UK concern HSE's autonomous position, the importance of knowledge and experience in the assessment of the safety of establishments, and the separate evaluation of the vulnerability of the surrounding area.

1 In evaluating the safety of establishments in the United Kingdom, in contrast to continental Europe, no assumption is made of an exact definition of acceptable risk or rules derived from this. Instead, the ALARP (As Low as Reasonably Practicable) principle is the starting point for evaluating permit applications for establishments. The ALARP principle obliges the operator to demonstrate that he or she has done everything within reason to restrict the risk (HSE, 2001). In the risk analyses, which are carried out tailored to the establishment, the effectiveness and costs of provisions must be shown explicitly. The Council particularly considers the role of quantitative risk analysis in the debate between operator and HSE interesting, as well as the possibilities this role offers to better better make use of the potential of the QRA method.

2 Because HSE has an advisory role, it does not suffer any restraint on innovation in the development of methods for the analysis of risks through the policy-related consequences of changed insights. After accidents, HSE conducts investigations to determine if there are reasons to amend the existing methods. HSE indicates that it uses the most recent insights in drafting advisory reports in a COMAH

40 The Control of Major Accident Hazards Regulations 1999. The COMAH Regulations 1999 were amended on 30 June 2005 (Control of Major Accident Hazards (Amendment) Regulations 2005).

context (HSE, 2009). The method HSE uses in evaluating land-use plans (PADHI) is described in various publications.

3 In assessing the acceptability of risks to the surrounding area, HSE takes explicit account of the vulnerability of the surroundings. The elaboration of the vulnerability concept as used by HSE cannot be applied just like that to The Netherlands' context (see also Appendix VI, page 62).

QRA AND EXTERNAL SAFETY IN FRANCE: PPRT

After the accident in Toulouse in 2009, in which 29 people were killed and more than 2400 injured, the French external safety policy was fundamentally revised and PPRTs (Plans de Prévention des Risques Technologiques or Plans to Prevent Technological Risks) were introduced. A more detailed explanation of the preparation of a PPRT may be found in Appendix VI. Interesting aspects of the PPRT are the site-specific character of the risk analyses, the relevance of the risk analyses for the analysis of the possibilities for self-rescue and emergency aid, the method of working with frequency, effect and consequence classes, the separate consideration of the vulnerability of the surrounding area, the emphasis on dialogue with the stakeholders, and the area-oriented approach.

1 A PPRT is prepared based on the results of EDDs (Études de Dangers). An EDD is comparable to The Netherlands' external safety report, although the risk analysis that forms the basis of an EDD has a more site-specific character. The results of the EDDs form the basis for evaluation of external safety in the context of a PPRT. This means that the assessment of external safety rests on site-specific risk analyses that form the basis for the assessment of the safety of establishments.

2 Distinction is made in the scenario definition between rapid and slow accident progressions. A scenario is characterised as slow if, in case of an accident, there are sufficient opportunities for self-rescue and emergency aid. The area within which, in case of a slow scenario, irreversible effects are possible is indicated on a map; this concerns thermal, toxic and as well as over-pressure effects. Through this procedure, the results of the risk analysis are immediately usable for analysing the possibilities for self-rescue and disaster control. As the Council stated in a previous advisory report, the current QRA in The Netherlands is insufficiently useful for this purpose (AGS, 2008a).

3 In the risk analysis forming the basis of the PPRT frequency, effect and consequence classes are used. In the classification of frequencies, effects and consequences, quantitative and also semi-quantitative or qualitative approaches may be used. Besides this, the probabilities and consequences of scenarios are each separately presented to the stakeholders.

4 In drafting a PPRT, the vulnerability of the surrounding area is evaluated by experts of the DDE (Direction Départementale de l'Équipement), in collaboration with local authorities and other local partners. In this, local inhabitants, employees, cultural heritage and nature are considered. The results of the evaluation are projected on a map and are used in preparing land-use plans.

5 In preparing a PPRT, the emphasis is on consultation and dialogue.[41] The national government, industry and local government bodies are all actively involved in the preparation of a PPRT and contribute financially to its realisation. The results of QRAs serve as input to the dialogue among the various stakeholders, including also employees and neighbours. QRA results are also included in decision making in a relative sense, in considering alternatives and setting priorities.

6 The preparation of a PPRT is a labour-intensive process. To minimize the necessary effort, in principle only the establishments known as Seveso top tier are included in the analyses. In this way, it is avoided that large numbers of establishments must be considered for each PPRT.

7 A PPRT is not prepared for each single establishment but for a certain area. There may be multiple establishments in this area. Some precautions, such as the provision of an installation of water for fire extinguishing or expansion of emergency aid capacity, may be of benefit for different risk sources. Their cost-effectiveness may only become apparent when studying the problem at a higher scale level. This aspect was also apparent in an earlier report by the Council directed at the coherence between risk policy and disaster control (AGS, 2008b).[42]

EXTERNAL SAFETY WITHOUT QRA IN GERMANY: TAA

In federal Germany, the external safety policy is vested at different administrative levels. The Technischer Ausschuss für Anlagensicherheid (TAA) of the Störfall-Kommission (2005) makes recommendations for the distances to be maintained between establishments and vulnerable objects (for more detailed explanation, see Appendix VI). In contrast to The Netherlands, the UK and France, the distances prescribed by the Störfall-Kommission are not based on an explicit evaluation of accident probabilities. The distances indicate the size of the area within which irreversible health effects would occur.[43] The Council is of the opinion that an approach in which the probabilities of accident scenarios are also included provides a better perspective to balance economy, land-use planning and safety than a deterministic approach, certainly in the densely-populated Netherlands.
Nonetheless, the German approach includes interesting elements.

41 The informing of and consulting with citizens about risks to the surrounding area and safety provisions is also an important part of the Seveso II Directive (art. 11, 12), European Council Directive 96/82/EC of the Council of 9 December 1996 on the control of major-accident hazards involving dangerous substances, after amendment by Directive 2003/105/EC of the European Parliament and Council.

42 After publication of this report, it was observed during a series of interviews by the Council in December 2008 - January 2009 that experiments are already underway in some safety regions, such as the Twente Region, with area-linked (fire brigade) advice. Competent authorities are also experimenting with spatial planning visions with regard to external safety.

43 The distances are determined based on accident scenarios in which the maximum leak size is given based on (German) historical grounds. A more detailed explanation is given in Appendix VI.

These concern the great attention for the safety of installations and the possibility – in case there is more information available – to deviate from standard distances, and to apply a more detailed method to determine the distances:

1 In German external safety policy, the emphasis is placed strongly on the BAT principle (Best Available Technology): it is investigated to what extent the safety of an establishment can be increased by applying the best available technologies. Special attention is paid to the fact that the application of a new best available technology may be very costly. In practice, a balance therefore must be found between the costs and the safety benefits of measures. Application of the BAT principle does mean that extensive consideration is given to the extent the safety of a specific establishment can be increased.

2 The TAA indicates that it is possible to carry out a systematic hazard analysis if land-use developments are being considered in the vicinity of an existing establishment, for which purpose the characteristics of the specific installations are known. Although this comprehensive analysis is still deterministic (no explicit consideration of accident probabilities), the Council considers it a valuable notion that it should be possible to deviate from a standard working method if the necessary data are available.

Conclusions

The evaluation of the prescribed calculation method was carried out based on a number of criteria. The resulting observations are summarised briefly below. Besides this, it is observed that the policy must become more safety-relevant, and the organization of the way in which modifications are made to the prescribed calculation methodology must be improved, in order to remove the existing hindrances.

1 Serious deficiencies in the prescribed method

In external safety policy, a single calculation method – the BEVI calculation method – is prescribed for carrying out risk calculations for the purposes of Wm (environmental) and Wro (planning) permit granting. The results from these calculations play a significant role in planning and decision making because of the legally stipulated limit value for individual risk and the orientation criterion for societal risk. Summarising, the Council concludes the following with regard to the prescribed calculation method:

- Transparency: the basis for the models for BLEVE in the software program SAFETI-NL is indeed explained in the Reference Manual Bevi Risk Assessments, but significant disadvantages are associated with the prescription of a single calculation method.
- Verifiability: the failure frequencies prove to be at least one order of magnitude (a factor of 10) lower than commonly used elsewhere (due to decisions taken at the end of the 70s at the start of activities in the field of risk analysis).
- Robustness: this has been made artificially high due to the fact that the values of parameters and coefficients have been laid down in the prescribed calculation method. In this way it is concealed that small variations in assumptions or starting points often result in large variations in indirect land use and IR and SR. The prescriptions in the Reference Manual Bevi Risk Assessments thus conceal the large variation in the possible results of the calculations.
- Validity in terms of correctness: the incident scenarios described in the event tree for a BLEVE of LPG are not correctly modelled in a physicochemical sense. Also, human error and similar scenarios are neglected in the risk calculations.
- Validity in terms of safety relevance: use of the calculation method gives no or only limited insight in opportunities to increase safety. Using the prescribed QRA instrumentarium, it is almost impossible to gain insight that is of importance for the assessment of safety-increasing measures.[44, 45]

---

44 Neither is the prescribed QRA instrumentarium of much help in analysing the possibilities of self-rescue or emergency aid, as the Council already indicated in a previous advisory report (AGS, 2008a).

45 Besides the QRA, businesses subject to Brzo (Decree on Risks of Serious Incidents) must also prepare a safety report. The information in a safety report is actually only usable to a very limited extent to supplement the insight in an establishment's safety as acquired using the prescribed calculation method.

The above observations correspond with the results of an earlier investigation into the prescribed method of calculating the risks of transport of hazardous substances (AGS, 2006). There, likewise, risk calculations fail to provide a realistic image of safety and the possibilities to increase it. Nevertheless, decisions regarding the basic rail, road and waterway networks are made based on these calculations. In the external safety policy for both establishments and transport, the emphasis is placed increasingly on bottlenecks in the process of granting permits. The original objective of the policy, ensuring the safety of citizens, seems to disappear from sight.

2 **Policy insufficiently safety-relevant**

In the current external safety policy, QRA results are used in an absolute manner for comparison with the limit value of the individual risk and the orientation criterion for the societal risk. The artificially high robustness of the QRA instrumentarium in fact limits the possibility of taking uncertainty and local circumstances into account in risk analyses. Robustness and safety relevance are thus difficult to unite in a single QRA instrumentarium.

The limited safety relevance of the QRA instrumentarium does not primarily require further technical development, but rather adaptation of policy. For this, in braod terms, there are two possibilities: (i) supplementing the results from a robust QRA with safety-relevant information obtained via another route, or (ii) altering the way in which planning and decision making concerning external safety is conducted (less emphasis on an absolute use of QRA results, as is more common practice abroad), in which case a less robust but more safety-relevant QRA instrumentarium can be used. At the same time, more attention should be paid to the consequences of the choice of a certain location on for example transport (inwards and outwards).

3 **Organisation not focused on employing knowledge and insight**

The current organisation and working method hinder modifications into the prescribed calculation method based on new insights. The policy consequences of changes to the prescribed risk calculation model stand in the way of (discussion about) improvement to the QRA instrumentarium. Attention is restricted particularly to the execution aspects of national policy by municipalities and provinces. Besides this, safety gains have been prematurely booked before the safety provisions are actually implemented (thermal insulation coverings on LPG road tankers).

In this context, the Council is still concerned about the development of insight and knowledge and about its retention. There is a real problem that the background of the prescribed QRA instrumentarium, such as the basis for the failure frequencies and other parameters used, will be completely lost from sight.

Recommendations

Based on these findings, it is considered necessary to increase the attention to safety in policy, to improve the mathematical basis for decision making with regard to granting permits and in land-use planning, to make a strict separation between policy in the field of external safety and the maintenance of the calculation instrumentarium, and to safeguard the development of knowledge.

1 **Increase attention to safety in policy and decision making (strategic level)**
With respect to the issues observed, the Council requests the government ministers involved to increase attention to safety in policy (strategic level). The balance has tipped over to calculations using the prescribed calculation method, in which a single number has become leading. A problem rises when the results of calculating the individual risk and societal risk are confused with absolute truths. The calculation results are in fact surrounded by great uncertainties and are based on assumptions and starting points that are not always verifiable or valid. Risk calculations carried out by prescription will often fail to give a reliable view of safety.

The Council moreover considers it important that, in evaluating permits and land-use plans, the (local and provincial) competent authorities look beyond the mere results of a calculation: the limit value for the individual risk and the orientation criterion for the societal risk. A situation or a plan that meets limit and orientation values is not always sensible. This issue arises not only in the risks from stationary installations and land-use developments near them, but also in the transport of hazardous substances (see also AGS, 2006). Additionally, granting permits is considered separately from transport. No integral evaluation takes place. Regarding the production, storage and also transport of hazardous substances, policy seems to be primarily focused on bottlenecks in the process of granting permits, rather than on a thorough weighing up of economy, land-use planning and citizens' safety.

Via accounting for the societal risk, theoretically there is a possibility to include safety-relevant information in planning and decision making. The 'Guide to the societal risk duty of accountability' (which is the translation the Ministry of VROM uses for 'Handreiking verantwoordingsplicht groepsrisico', VROM, 2007) in fact fails to provide any concrete help or proposal on this subject. The Council therefore recommends that methods be developed and made available with which safety-relevant information can indeed be obtained. This information must be such that it provides competent authorities with insight into the possibilities to increase safety. Several possibilities that may be considered for improvement of decision making and the justification thereof are given below.

2 Improve instrumentarium for founding of decision making (tactical level)

To improve the mathematical founding of decision making, the Council recommends a fundamental review of the calculation methodology (tactical level). The variation in the results of calculations – even with small variations in the assumptions – is large, and the relationship between the results of risk calculations and the safety of establishments is weak. The QRA instrumentarium prescribed in The Netherlands is thus insufficiently suitable to obtain insight into the magnitude of risks and the possibilities to reduce them.

To achieve a good balance between economic activity on the one hand and the safety of employee and citizen on the other, the Council envisages a more far-reaching change of decision making with regard to industrial safety in relation to hazardous substances and of The Netherlands' QRA practice to be necessary in due course. For this, the Council – inspired by decision making procedures in other EU Member States that also implement the Seveso II Directive – sees various possibilities, including:

- By putting the emphasis on the dialogue among the stakeholders during planning processes, the results of risk analyses may be used more in a relative sense, to weigh up options and set priorities. In this way, opportunities may be created to remove the limitations of the present QRA instrumentarium, which are associated with the absolute use of QRA results in decision making by competent authorities. In order to avoid impasses, an authoritative arbiter should be introduced. Besides this, the introduction of an area-oriented approach could be considered, which in the opinion of the Council would offer opportunities to take safety provisions that are possibly not feasible on a smaller scale.
- By applying separate probability, effect and consequence classes, more justice can be done to the great uncertainties with which the results of quantitative risk analyses are surrounded. Currently, an accuracy is often attributed to numerical values that they do not possess.
- By making a distinction in the risk analysis between rapid and slow accident progressions, information can be provided to the emergency services that is useful for preparing advisory reports concerning the possibilities for self-rescue and disaster control. The results from QRAs would then also be relevant to the documents referred to as fire brigade advisory reports that are prepared in the context of accounting for the SR by competent authorities (see also AGS, 2008a).
- By showing the vulnerability of the surrounding area on maps, planners will be better able to take account of external safety when preparing land-use plans.
- By also presenting the probabilities and consequences of serious accidents separately, and not combining them directly into a risk measure (such as an individual risk or societal risk curve), valuable information can be provided to planners to reduce the risk to the surrounding area. It is important, however, to assess whether certain information needs to be handled confidentially from a viewpoint of security and malevolence.
- With a Bayesian approach, uncertainties of knowledge and statistics can be incorporated into estimates of the individual and the societal risk. In this way, fruitless discussions about "the true figure" can be avoided, and the great sensitivity of the position of 10^{-6} risk contours to the choice of certain calculation parameters can be reduced.

It is emphasised that the above summary is in no sense exhaustive. The Council will consider the possibilities for adapting The Netherlands' QRA practice in more detail in a subsequent advisory report.

3 Strictly separate policy and maintenance of the calculation instrumentarium (implementation level) and safeguard knowledge development

The Council wishes to draw attention to the organisation around the review of the calculation methodology (implementation level). The Council is of the opinion that the current way in which the maintenance of the prescribed calculation method is done – in which the RIVM sets priorities based on the technical proposals from DORA and policy input from the Directors' Consultation on External Safety (in Dutch: Directeurenoverleg Externe Veiligheid) – indeed provides space for incremental model modifications, but offers insufficient opportunities for periodic and, where necessary, fundamental change to the calculation methodology based on new insights. The Council also observes that safety gains have been booked prematurely in a policy context. On these grounds, a clearer separation should be introduced between the maintenance of the prescribed calculation method on the one hand and research and development on the other. Besides the daily management and maintenance of the prescribed instrumentarium, a periodic (for example five-yearly) evaluation of the instrumentarium should be introduced in which the calculation methodology is evaluated based on new insights and practical experience. For this, a research and development programme must be realised first of all, in which the necessary knowledge is not only reinforced, but can also be preserved.

Literature

Abbasi T, Abbasi SA (2007). The boiling liquid expanding vapour explosion (BLEVE): Mechanism, consequence assessment, management. Journal of Hazardous Materials, 141: 489-519.

Abbasi T, Abbasi SA (2008). The boiling liquid expanding vapour explosion (BLEVE) is fifty ... and lives on! Journal of Loss Prevention in the Process Industries, 21: 485–487.

AGS (2004). Space for expertise (Ruimte voor expertise). Hazardous Substances Council (AGS), The Hague.

AGS (2006). QRA modelling of transport of hazardous substances (QRA-modellering vervoer van gevaarlijke stoffen). Hazardous Substances Council (AGS), The Hague.

AGS (2007). Safety requires knowledge (Veiligheid vereist kennis). Hazardous Substances Council (AGS), The Hague.

AGS (2008a). Advise of fire brigades in the context of the accounting for societal risk: state of affairs (Brandweeradvisering in het kader van de verantwoordingsplicht groepsrisico: stand van zaken). Hazardous Substances Council (AGS), The Hague.

AGS (2008b). Risk policy and disaster control: towards more coherence (Risicobeleid en rampenbestrijding: op weg naar meer samenhang). Hazardous Substances Council (AGS), The Hague.

Amendola A, Contini S, Ziomas I (1992). Uncertainties in chemical risk assessment: Results of a European benchmark exercise. Journal of Hazardous Materials, 29, 347-363.

Bagster DG, Pittblado RM (1989). Thermal Hazards in the Process Industry, Chemical Engineering Progress , 85(7): 69-75.

Beerens HI, Post JG, Uijt de Haag PAM (2006). The use of generic failure frequencies in QRA: the quality and use of failure frequencies and how to bring them up-to-date. Journal of Hazardous Materials, 130: 265-270.

Bush SH (1975). Pressure Vessel Reliability. Transactions of the AMSE, Journal of Pressure Vessel Technology.

Cowley LT, Johnson AD (1991). Blast and Fire Engineering Project for Topside Structures. F11. Oil and Gas Fires: Characteristics and Impact.

COVO Commission (1982). Risk analysis of six potentially hazardous industrial objects in the Rijnmond area, a pilot study; A report to the Rijnmond public authority.

Geerts R (2006). What is the basis for the risk zoning for LPG filling stations? The quantitative basis of external safety legislation (Waarop berust de risicozonering voor LPG-tankstations? Het kwantitatieve fundament van de externe veiligheidsregelgeving), External Safety Journal (Tijdschrift Externe Veiligheid). Volume 3, no. 1.

HSE (2001). Reducing risks protecting people, HSE's decision making process.

HSE (2004). Planning Case Assessment Guide. Chapter 6K: Failure Rate and Event data for use within Risk Assessments.

HSE (2009). PADHI – HSE's Land Use Planning Methodology. Version August 2009.

Hurst NW, Hankin RKS, Wilkinson JA, Nussey C and Williams JC (1992). Failure Rate and Incident Databases for Major Hazards, 7th International Symposium on Loss Prevention and Safety Promotion in the Process Industries, Vol. 3, 143, 1-22, Taormina, Italy, 4-8 May.

IPO (1994). Manual for preparing and assessing an external safety report (Handleiding voor het opstellen en beoordelen van een extern veiligheidsrapport). Project A73.

KPMG, TNO, ECORYS (2004). Chain studies on ammonia, chlorine and LPG. Shared risks: External safety of ammonia, chlorine and LPG production chains (Ketenstudies ammoniak, chloor en LPG. Gedeelde risico's: Externe veiligheid productieketens ammoniak, chloor en LPG). Main report.

Lauridsen K, Kozine I, Markert F, Amendola A, Christou M, Fiori M (2002). Assessment of uncertainties in risk analysis of chemical establishments, The ASSURANCE project, Final summary report. Risø National Laboratory.

Lees FP (1996). Loss prevention in the Process Industries-Hazard Identification, Assessment, and Control. Volumes 1-3, Butterworth-Heinemann, Oxford: 12/94-98.

Logtenberg T (1998). Derivation of failure frequencies for loss of containment cases. TNO Report MEP-R98/501.

NIBRA (2004). Coatings for LPG road tankers (Coatings voor LPG-tankauto's). Verhallen P, Aubel P (authors). Netherlands Institute for Fire Fighting and Disaster Control (NIBRA) – now Netherlands Institute for Physical Safety (NIFV). Project number 441N0055.

Nussey C (2006). Failure frequencies for major failures of high pressure storage vessels at COMAH sites: A comparison of data used by HSE and The Netherlands.

OVV (2006). Road tanker fires with hazardous substances. Safety study (Tankautobranden met gevaarlijke stoffen. Veiligheidsstudie). Dutch Safety Board (OVV). The Hague, 17 November 2006.

PBL (2008). Environmental balance 2008 (Milieubalans 2008). Netherlands Environmental Assessment Agency (PBL).

PBL (2009). Environmental balance 2009 (Milieubalans 2009). Netherlands Environmental Assessment Agency (PBL).

PGS1 (2005). Methods for determining possible harm to people and objects due to release of hazardous substances (Methoden voor het bepalen van mogelijke schade aan mensen en objecten door het vrijkomen van gevaarlijke stoffen). Green Book. Formerly CPR 16.

PGS2 (1997). Methods for the calculation of physical effects. Yellow Book. Formerly CPR 14 E. Version 3.

PGS3 (2005). Publication Series on Dangerous Substances (PGS3). Guidelines for quantitative risk assessment. Purple Book. CPR18e. Part I: establishments. Version 3.

Phillips CAG, Warwick RG. (1969). A survey of defects in pressure vessels built to high standards of construction and its relevance to nuclear primary circuits. UKAEA AHSB(S) R162.

RIVM (2001). Benchmark risk analysis models. RIVM report 610066015.

RIVM-CEV (2006). Justification of effectiveness of thermal insulation coating; Influence of coating on location of individual risk contour (Onderbouwing effectiviteit van hittewerende coating; Invloed coating op ligging van plaatsgebonden risicocontour). Letter from RIVM-CEV (CM van Luijk) to Ministry of Housing, Spatial Planning and the Environment. 452/06 CEV Mah/sij-1329, 20 December 2006.

RIVM-CEV (2008). QRA calculations for LPG filling stations (QRA-berekening LPG-tankstations), version 1.1, dated 29 May 2008.

RIVM-CEV (2008a). Step-by-step plan for societal risk calculations for LPG filling station (LPG road tanker not provided with thermal insulation coating) (Stappenplan groepsrisicoberekening LPG-tankstation (LPG-tankauto niet voorzien van hittewerende coating)), version of 6 June 2008.

RIVM (2009). Reference Manual Bevi Risk Assessments (Handleiding Risicoberekeningen Bevi), version 3.2, dated 1 July 2009.

Smith TA, Warwick RG (1974). The second survey of defects in pressure vessels built to high standards of construction and its relevance to nuclear primary circuits. UKAE Safety and Reliability Directorate, SRD R30.

Smith TA, Warwick RG (1981). A survey of defects in pressure vessels in the UK for the period 1962-78, and its relevance to nuclear primary circuits. UKAE Safety and Reliability Directorate, SRD R203.

Störfall-Kommission (2005). Technischer Ausschuss für Anlagensicherheit (TAA). Leitfaden. Empfehlungen für Abstände zwischen Betreibsbereichen nach der Störfall-Verordnung und schutzbedürftigen Gebieten im Rahmen der Bauleitplanung – Umsetzung § 50 BmlSchG der SFK/TAA-Arbeitsgruppe "Überwachung der Ansiedlung". SFK/TAA-GS-1.

Taylor JR (1998). Review of failure data for risk analyses, Version 1 Issue 1, Neste and Taylor Associates ApS, Glumsoe.

TKO (1996). RE-95-1. Version 02-02-1996. KO-95, KO-96, KO-100.

TNO, ECORYS, KPMG (2004). Chain studies on ammonia, chlorine and LPG. Elaboration of solution directions, phase 3 (Ketenstudies ammoniak, chloor en LPG. Uitwerking oplossingsrichtingen fase 3). Final report.

Uijt de Haag PAM, Gooijer L and Frijns PJMG (2008). Quantitative risk calculation for land use decisions: the validity and the need for unification. In: TM Kao, M Zio en V Ho (Eds.). International Conference on Probabilistic Safety Assessment and Management PSAM9, Hong Kong.

VNG (2009). Agreements for LPG autogas covenant. Letter from VNG (S. Pijpstra) to VROM (P. Torbijn), BAMM/U200900283, 17 February 2009.

VROM and VVG (2005). LPG autogas covenant, 22 June 2005.

VROM (2007). Guide to the societal risk duty of accountability (Handreiking verantwoordingsplicht groepsrisico). Version 1.0.

Walls WL (1978). Just what is a BLEVE? Fire Journal: 46-47.

Bevi	Decree on external safety of establishments (Besluit externe veiligheid inrichtingen)
BLEVE	Boiling Liquid Expanding Vapour Explosion
CLIC	Comité Local d'Information et de Concertation
DRIRE	Directions Régionales de l'Industrie, de la Recherche et de l'Environnement
EDD	Étude de Dangers
DDE	Direction Départementale de l'Équipement
HSE	Health and Safety Executive
IPO	Association of Provincial Authorities (Inter Provinciaal Overleg)
LPG	Liquefied Petroleum Gas
PADHI	Planning Advice for Developments near Hazardous Installations
PPRT	Plan de Prévention des Risques Technologiques
IR	Individual Risk
QRA	Quantitative Risk Analysis
Revi	Regulation on external safety of establishments (Regeling externe veiligheid inrichtingen)
RIVM-CEV	National Institute for Public Health and the Environment, Centre for External Safety (Rijksinstituut voor Volksgezondheid en Milieu, Centrum voor Externe Veiligheid)
SR	Societal Risk
STIIIC	Service Technique Interdépartemental d'Inspection des Installations Classées
TAA	Technischer Ausschuss für Anlagensicherheit
VNG	Association of Netherlands Municipalities (Vereniging van Nederlandse Gemeenten)
VVG	Liquid Gas Association (Vereniging Vloeibaar Gas)
Wm	Environmental Management Act (Wet milieubeheer)
Wro	Spatial Planning Act (Wet ruimtelijke ordening)

BLEVE: Boiling Liquid Expanding Vapour Explosion

Definition

A BLEVE arises when a pressure vessel with (pressurized) liquefied gas collapses. The pressure in the vessel is determined by the vapour pressure of the substance, associated with the temperature of the liquid. If pressure at a given tank temperature is above atmospheric pressure – and if the tank wall fails – the liquid phase present in the tank will be "overheated" and expand almost instantaneously to atmospheric pressure (see also Walls, 1978; Abbasi & Abbasi, 2007, 2008). The energy necessary to partially vaporise the liquid causes cooling of the remaining liquid. The almost instantaneous expansion will carry the non-vaporised liquid with it as small droplets and form a cloud of a mixture of liquid and vapour.

In the context of modelling risks of hazardous substances (see also the coloured books), the term BLEVE is used more specifically for the failure of a pressure tank with a flammable (pressurized) liquefied gas. It is noticed that a BLEVE thus cannot arise for flammable liquids below their boiling point. Neither can there be a BLEVE with flammable gases.

Causes

In the storage or transport of gases compressed to a liquid, two causes may lead to a BLEVE. The first possible cause is fire/flames in contact with the tank. Due to this, the tank contents is heated and pressure will increase (according to the vapour/liquid equilibrium). At the same time, locally the strength of the tank wall may be reduced as a result of the temperature increase. The combination of increased pressure and (local) reduction of strength will finally lead to failure of the tank wall. The second possible cause of a BLEVE is a mechanical impact (for example collision), due to which the tank wall collapses. The pressure in the tank from which the substance is released may in that case be lower than in case of a fire. This distinction leads to what is referred to as a cold or hot BLEVE respectively.

Consequences

In a BLEVE, three mechanisms can be distinguished, which may lead to damage and injury:

1 Firstly, there is a pressure wave that mainly causes damage near to the hazard (physical explosion).
2 In case the tank contains flammable substances and there is a (direct) ignition, a fireball follows. This is the damage-determining phenomenon with very great heat radiation – fatal to people – over a significant distance, depending on the magnitude.
3 The third mechanism regards the of fragmentation effect. Fragments of the pressure tank may be blown away over considerable distances.

Of course, the fire effects only happen if the BLEVE involves a flammable liquid, such as LPG in this case. The damage may lead to domino effects if other vessels with the same or another hazardous substance are present. It should be observed that in the case of a BLEVE due to a fire, this is not a gas cloud (known as a free) explosion. For a mechanically-induced BLEVE this could well be the case: flammable gases then disperse in the atmosphere and form a flammable and explosive mixture that, upon ignition, may lead to a gas cloud fire and an explosion. The latter is dependent on the extent to which the gas cloud is enclosed. This is the accident scenario that happened in Viareggio, resulting in more than 30 deaths (railway accident on 29 June 2009).

Background to The Netherlands' figure for the probability of a BLEVE

In this Appendix, an overview is presented of the background to the BLEVE probabilities used in The Netherlands. First of all there is a description of the way in which the probability of a BLEVE should be determined according to the Reference Manual Bevi Risk Assessments (RIVM, 2009). Next, the appendix contains a description of the origin of the failure frequencies used in The Netherlands for pressure vessels. This historical sketch indicates that the failure frequencies rest on relatively old casuistics, and that the level of the failure frequencies was reduced in the past, without thorough foundation, by an order of magnitude (factor 10) or more. Abroad, different, often higher, failure frequencies are being used. The Appendix concludes with a discussion of several errors in the event tree used in The Netherlands for determining the probability of a BLEVE.

The probability of a BLEVE as applied in The Netherlands

According to the Reference Manual Bevi Risk Assessments (RIVM, 2009), the probability of a BLEVE with fireball in a stationary installation should be determined by multiplying the probability of the instantaneous release of a flammable gas compressed to a liquid, by the probability of direct ignition (see also Figure 7, at the end of this Appendix). For stationary establishments, the frequency for instantaneous failure of a pressure vessel is assumed to be $5 \cdot 10^{-7}$ per year. For the subsequent probability of direct ignition a value is between 0.2 (release quantity < 1000 kg) to 0.7 (release quantity > 10,000 kg) is used. The fraction that is modelled as BLEVE with fireball comes to 0.7. The probability of a BLEVE with fireball as used in The Netherlands thus varies from $0.7 \cdot 10^{-7}$ per year (< 1000 kg) to $2.5 \cdot 10^{-7}$ per year (> 10,000 kg) for stationary establishments.[46]

For transport vehicles (e.g. LPG road tankers) at an establishment, also a frequency of $5 \cdot 10^{-7}$ per year is used for the instantaneous release of the full tank contents (with correction for duration of stay). If a fire in the vicinity and/or mechanical impact cannot be excluded, such as for an LPG filling station, an additional BLEVE scenario is added (RIVM-CEV, 2008). For transport units, a value of 0.4 (for a road tanker) to 0.8 (for a railway tank wagon) is used for the probability of direct ignition after instantaneous release of the tank contents. The fraction modelled as a BLEVE is set equal to 1 (RIVM, 2009). Finally, the probability of a BLEVE caused by loading or unloading an LPG road tanker depends according to RIVM-CEV (2008) upon the amount to be discharged and the duration of stay at the LPG filling station.

The origin of the failure frequencies used in The Netherlands for pressure vessels

The failure frequencies used in The Netherlands are based to a significant degree on relatively old casuistics (see also Logtenberg, 1998; Beerens et al., 2006). The failure frequencies may be traced back via the Purple Book (PGS3, 1999), the IPO-A73 (IPO, 1994) and RE-95-1 (TKO, 1996) documents and the COVO study (COVO Commission, 1982) to studies of Philips and Warwick (1969), Smith and

46 The frequency of $0.7 \cdot 10^{-7}$ per year follows from multiplication of $5 \cdot 10^{-7}$ (instantaneous release), 0.2 (direct ignition) and 0.7 (fraction modelled as BLEVE). In an analogous way, the frequency of $2.5 \cdot 10^{-7}$ per year is calculated: $5 \cdot 10^{-7} \times 0.7 \times 0.7 = 2.5 \cdot 10^{-7}$. The modelling for industrial process installations takes place in the same way as for LPG filling stations, despite differences in expertise, safety management and emergency facilities (see also page 46).

Warwick (1974) and Bush (1975). In Figure 6, the origin of the failure frequencies used in The Netherlands for pressure vessels is shown schematically. In the subsequent text, the origin and level of these frequencies and their poor foundation are further elucidated.

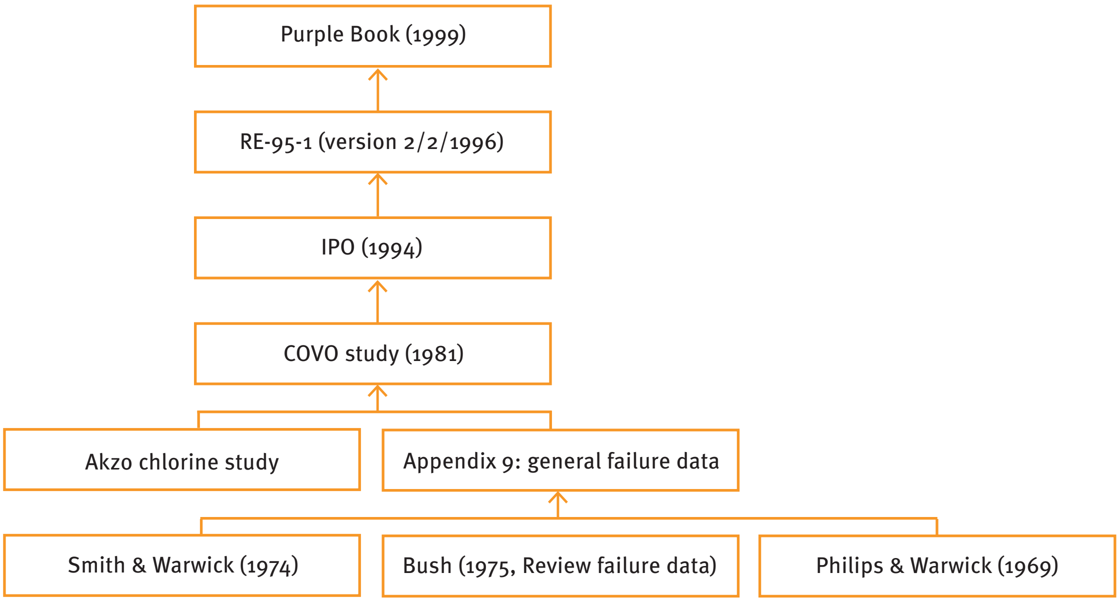

Figure 6. The history of the failure frequencies used in The Netherlands for pressure vessels (Beerens et al., 2006: 267).

The frequency of catastrophic failure in the COVO study (10^{-6} per year) is based on the studies of Philips and Warwick (1969), Smith and Warwick (1974) and Bush (1975). These studies were carried out with a view to the safety of nuclear power stations and mainly concerned steam vessels (built to Class 1 requirements) and a limited number of process vessels. In the COVO study, Cremer&Warner (who carried out the study) then assumed a failure frequency by reducing the values in the studies concerned by more than an order of magnitude. No thorough justification for this reduction is presented. The chairman of COVO[47], who was also the representative of DCMR (the central Rotterdam-Rijnmond environmental agency), criticized this fact at the time, as is explained below.

The AGS has attempted to carry out a reconstruction of the derivation of the failure frequencies in the COVO study, based on the available literature. This produces a confusing view. Appendix IX of the COVO study contains a failure frequency table in

47 COVO, the 'contact group on safety of local inhabitants', was a working group set up at the end of the 70s to carry out a pilot risk analysis on six plants in the Rijnmond area. The commission was initiated by the 'Rijnmond Public Body' (a cooperative body of the municipalities around Rotterdam, in Dutch: Openbaar Lichaam Rijnmond). The steering group consisted of three representatives from government departments and ten from industry. Also, the Disaster Prevention Committee (Commissie Preventie van Rampen), TNO (independent research agency) and later the Province of South Holland and the RIVM were represented. The chairman was a representative of DCMR. The commission was carried out by the British consultant Cremer&Warner, with second opinions from a German and an American consultant.

which the base failure rates for pressure vessels are listed for a static situation without increasing influences from vibration, corrosion, temperature variations or human error. Apart from two values of 10^{-6} per year for “catastrophic failure” and 10^{-5} per year for “serious leakage”, ranges are also mentioned of $6.3 \cdot 10^{-7}$ to $4.6 \cdot 10^{-5}$ per year and $6 \cdot 10^{-6}$ to $2.6 \cdot 10^{-3}$ per year respectively. These originate from the studies mentioned but no derivation is given. Lees (1996) provides some information about the British references mentioned in the COVO study. Particularly the study of Phillips and Warwick (1969) is discussed. This study assessed 12,700 manufactured vessels with a total use of 103,000 vessel-years. Of these, 132 vessels failed, seven of which catastrophically and of them four due to erroneous process handling, one slipped through the inspection after manufacture as regards quality, and only two failed through fatigue and thus formed the basis of the frequency determination for catastrophic failure. For “potentially dangerous” through fatigue, 62 cases were relevant. These data led to the resulting values for failure frequencies of $2 \cdot 10^{-5}$/year and $6 \cdot 10^{-4}$/year respectively. Although Smith and Warwick (1974) present higher values, a later study by the same authors (1981 SRD R203) returns to roughly the older values of Phillips and Warwick (1969). Also, the terms for the various manners of failure are not used unambiguously throughout the different studies. While the meaning of the term “catastrophic” is comparable to the concept used in the COVO study, this is not the case for “potentially dangerous” (defects/cracks, often no leak) versus “serious leakage” (hole of 50 mm). In the COVO study, the frequencies mentioned are set considerably downwards. The observed frequency for “catastrophic” is reduced by a factor of 20 to 10^{-6}/year and for “serious leakage” by a factor of 60 to 10^{-5}/year. This thus appears to be a very rough estimate. The factor 20 for catastrophic failure is explained by Cremer&Warner (COVO study, p. 2-356) by the fact that catastrophic failure only occurs in 10-25% of failure cases. This once however fails to match Lees’ description that leads to a much lower percentage (2/132). At the same time, for use in the risk analysis, the value for “serious leakage” is lowered still further by a factor of 3 due to the large hole size of 50 mm. Indeed, the DCMR representative indicated in a comment (Covo study pp 5-44, 5-45), based on a German analysis, that he considered the failure frequencies used by Cremer&Warner to be certainly a factor of 3 too low.

The failure frequencies in the IPO-A73 document are based on the results of the COVO study. The catastrophic failure of the pressure vessel in IPO-A73 is partly modelled as instantaneous release, as the release of the full tank contents in 10 minutes and as release through a hole with an effective diameter of 50 mm. For these events, frequencies of $5 \cdot 10^{-7}$, $2.5 \cdot 10^{-7}$ and $2.5 \cdot 10^{-7}$ per year respectively are used (together 10^{-6} per year). For leakages, a distinction is made between a leak with an effective diameter of 50 mm (10^{-5} per year per pipeline connection) and leakage through a leak with a diameter of 10 mm (10^{-5} per year per pipeline connection).

RE-95-1 is an overview of commentary and proposals to do with IPO-A73, dealt with in a consultation referred to as the Technical Bottleneck Consultation (Technisch Knelpunten Overleg, TKO), of the Ministry of Housing, Spatial Planning and the Environment. In RE-95-1, catastrophic failure is presented as two scenarios: instantaneous failure ($5 \cdot 10^{-7}$ per year) and the release of the entire tank contents through a hole with an effective diameter of 50 mm, or a continuous release with a duration of 10 minutes ($5 \cdot 10^{-7}$ per year). In RE-95-1, it is assumed that leakage due to connections breaking off from flanges and pipelines on the tank is already included as standard in the failure frequency of the vessel's filling and emptying connecting pipelines. The scenario mentioned in IPO-A73 with a frequency of 10^{-5} per year per pipeline connection for a leak with an effective diameter of 50 mm has thus been dropped.

The Purple Book is based on RE-95-1. For simplification, the two scenarios for catastrophic failure are defined as instantaneous release ($5 \cdot 10^{-7}$ per year) and as complete, continuous release in 10 minutes ($5 \cdot 10^{-7}$ per year). Striking is the statement in the Purple Book (PGS3, 2005: 3.3) that the failure frequencies listed must be increased by $5 \cdot 10^{-6}$ per year if external impacts (such as flooding) and human error (such as overfilling) cannot be excluded. In SAFETI-NL, this correction is ignored as standard. Conversely, external impacts form an explicit part of the failure frequencies used by the British HSE (Table 1, below). The Council is also of the opinion that the failure frequency contributions of external impacts and corrosion should not be disregarded just like that. Indeed, experience shows that the failure frequency is significantly increased due to erroneous human actions (see also page 21).

A comprehensive literature study by Logtenberg (1998) demonstrates that the failure frequencies of pressure vessels are surrounded by great uncertainties: for instantaneous failure, the variation in reported failure frequencies comes to a factor of 1000 (13 sources). Logtenberg proposes to use the median for the probability of instantaneous failure, i.e. 10^{-5} per year. This value is a factor of 20 higher than the frequency that is currently used in risk calculations in The Netherlands ($5 \cdot 10^{-7}$ per year).

Parallel to the developments in The Netherlands, a database has been built up by HSE in the United Kingdom for failures of vessels containing LPG. The first publication of these data was in 1992 by Hurst et al. The value for catastrophic failure is based on a study of the LPG Transport Authority from 1983 from which it was apparent that an estimated 280,000 vessel-years had passed without catastrophic failure (HSE, 2004). Based on this, a failure frequency of $< 2.5 \cdot 10^{-6}$ per year was determined. An update of the study in 1992 presented a failure frequency of $< 9.4 \cdot 10^{-7}$ per year. However, in the population considered, mainly LPG tanks with contents of less than 1000 kg were represented. Therefore, HSE continued using the generic failure frequency of $2 \cdot 10^{-6}$ per year for the catastrophic failure of LPG pressure tanks.

Recently, a comparative study was conducted by Nussey (2006) into the British and Netherlands failure frequencies for pressure vessels (Purple Book). These frequencies are a factor 10 higher in the United Kingdom. Nussey concludes that apparently not the failure frequencies used by HSE seem high, but that The Netherlands' failure frequencies are low. Based on figures from experience, Taylor (1998) proposed even higher failure frequencies than those used by HSE.

Type of failure	PB99 default	PB99 'complete'	HSE
Catastrophic	0.5	5.5	2 - 6
Large hole	0.5	5.5	5
Small hole	10	10	55
All types	11	21	62 - 66

Table 1. PB = Purple Book, 'complete' is including increase of the failure frequency by $5 \cdot 10^{-6}$ as a result of external impacts (such as flooding) and human error (such as overfilling). Nussey, 2006.

Summarising, the Council concludes that the failure frequencies prescribed in The Netherlands by means of the Reference Manual Bevi Risk Assessments were reduced on unclear grounds in the past and – in line with the United Kingdom – should be at least a factor of 10 higher.

The event tree used in The Netherlands is incorrect

In order to determine the probability of a BLEVE with fireball, the Reference Manual Bevi Risk Assessments uses the event tree below (Figure 7). The starting point in this event tree is the frequency of instantaneous failure of a pressure vessel containing a (pressurized) liquefied gas. In the Manual the probability of direct ignition is assumed to be dependent on the quantity released: the direct ignition probability is 0.2 for release quantities less than 1000 kg, 0.5 for release quantities between 1000 and 10,000 kg, and 0.7 for release quantities over 10,000 kg.

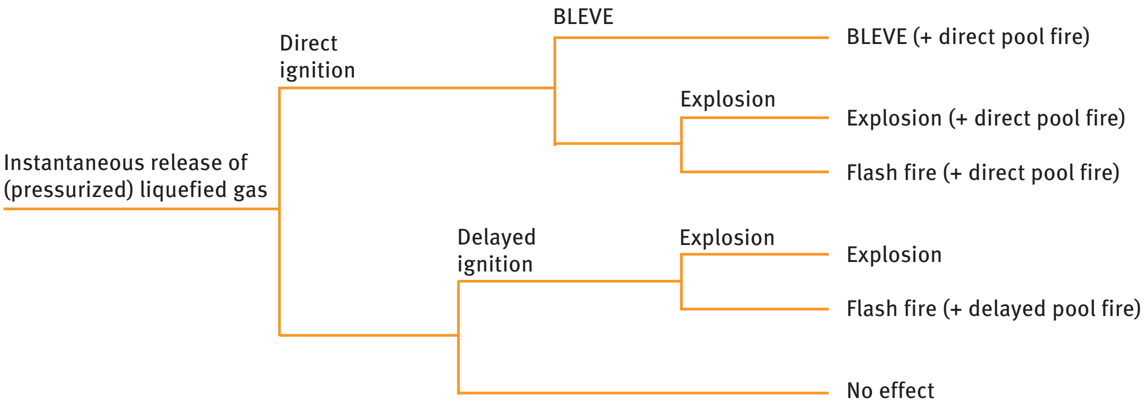

Figure 7. Event tree for the instantaneous release of a flammable (pressurized) liquefied gas according to the Reference Manual Bevi Risk Assessments (RIVM, 2009, page 17, figure 4). This event tree is incorrect.

The event tree (Figure 7) and the probabilities of ignition used in the Reference Manual Bevi Risk Assessments are incorrect. There are two fundamental inaccuracies:

- A hot BLEVE arises by bursting of the vessel with instantaneous release. In case of a fire near the tank, there is by definition direct ignition. This is not dependent on the quantity released, as is stated.[48]
- An explosion and a flash fire are also included in the direct ignition branch. This is impossible: there is no mixing with air in case of direct ignition. This applies to both a hot and a cold BLEVE.

Both inaccuracies lead to an erroneously reduced frequency of a BLEVE.

Moreover, it is assumed for underground LPG pressure tanks that a BLEVE cannot arise[49], because irradiation by a fire in the vicinity is almost impossible. A cold BLEVE is in fact also possible for a bunded tank, due for example to corrosion or overfilling.

48 This is known, but is denied for policy reasons (see also page 22).

49 RIVM, 2009. Module C, page 102.

Finally, the way in which a BLEVE for bunded LPG pressure tanks is left out of consideration[50] is incorrect: the conditional probability is not presumed to be equal to zero, but the effect of the BLEVE is ignored. This leads to the conditional probabilities being assumed to be too low for the other incident types (explosion and flash fire) that follow from an instantaneous release with direct ignition. For, if a BLEVE is considered to be impossible, the sum of the probabilities of incident types different from a BLEVE is equal to one after an instantaneous release with direct ignition.

50 RIVM, 2009 pages 15 and 18.

In this Appendix, a description is presented of risk calculations for the probability of a BLEVE for a "standard LPG filling station" according to the prescribed calculation method.[51] Subsequently, the sensitivity analysis carried out by the Council is described. The results demonstrate that the position of the 10^{-6} risk contour for LPG filling stations has a wide variation: the distance of the 10^{-6} risk contour from the filling connection may vary from tens of metres upto a few hundred, depending on the (plausible) assumptions made in the risk calculation.

Risk calculations for a "standard LPG filling station"
The Council carried out sensitivity analyses for a standard Netherlands LPG filling station with a throughput of 1000 m^3 per year. The schematic representation data were derived from the RIVM website.[52] Checking the results of the risk calculations for different throughputs (500, 1000 and 1500 m^3/year) with the distances in the Revi only revealed very slight differences (2-5 m). The assumptions in the risk calculations thus appear to be in agreement with the assumptions forming the basis of the distances table in the Revi.

In Table 2, an overview of the scenarios and probabilities is presented. The LPG filling station includes a storage tank (accident type O) with piping, a pump with excess flow valve (accident type P) and a unloading hose (accident type L), the last two of which are only in use while unloading. Besides this, an unloading road tanker is considered (accident types T and B). All these components are presumed to be at the same location. The unloading time is assumed to be 0.5 hours. The presence time is assumed by RIVM to be equal to the unloading time. As input for the calculations it is assumed there are 70 transfers per year.

Scenario	Scenario description	Probability	unit	Scenario probability after corrections and conversion (per year)
O1	instantaneous complete failure of the storage vessel 9.2 tons	$5.0 \cdot 10^{-7}$	per year	$5.0 \cdot 10^{-7}$
O2	release of the complete contents in ten minutes	$5.0 \cdot 10^{-7}$	per year	$5.0 \cdot 10^{-7}$
O3	release from vessel (hole with effective diameter of 10 mm)	$1.0 \cdot 10^{-5}$	per year	$1.0 \cdot 10^{-5}$
O4	full bore rupture of pipeline 1.25"	$5.0 \cdot 10^{-7}$	per year per m	$5.0 \cdot 10^{-6}$
O5	pipeline – leak 0.125"	$1.5 \cdot 10^{-6}$	per year per m	$1.5 \cdot 10^{-5}$
O6	full bore rupture of loading/unloading hose 1.25"	$5.0 \cdot 10^{-7}$	per year per m	$3.8 \cdot 10^{-5}$
O7	loading/unloading hose – leak 0.125"	1.5·10-6	per year per m	$1.1 \cdot 10^{-4}$
P1	pump failure with excess flow valve operational – 104 kg	$9.4 \cdot 10^{-5}$	per year	$3.8 \cdot 10^{-7}$
P2	pump failure with excess flow valve failure – 3"	$6.0 \cdot 10^{-6}$	per year	2.4·10-8
P3	pump leakage – 0.3"	$4.4 \cdot 10^{-3}$	per year	$1.8 \cdot 10^{-5}$
L1	unloading hose failure with excess flow valve operational – 65 kg	$3.5 \cdot 10^{-6}$	per hour	$1.2 \cdot 10^{-5}$
L2	unloading hose failure with excess flow valve failure – 2"	$4.8 \cdot 10^{-7}$	per hour	$1.7 \cdot 10^{-6}$
L3	unloading hose leak – 0.2"	$4.0 \cdot 10^{-5}$	per hour	$1.4 \cdot 10^{-3}$

51 QRA calculations for LPG filling stations (QRA-berekening LPG-tankstations), RIVM-CEV, 29 May 2008.
52 PSU file of 29/2/2008, description of 29/05/08.

Scenario	Scenario description	Probability	unit	Scenario probability after corrections and conversion (per year)
T1	instantaneous failure of 100% filled road tanker (RT)	$5.0 \cdot 10^{-7}$	per year	$2.0 \cdot 10^{-9}$
T2	RT 100% failure of largest connection	$5.0 \cdot 10^{-7}$	per year	$2.0 \cdot 10^{-9}$
B1	RT 100% leakage during unloading - BLEVE	$5.8 \cdot 10^{-10}$	per hour	$1.0 \cdot 10^{-9}$
B2	RT 100% other fire – 26.7 ton BLEVE	$2.0 \cdot 10^{-8}$	per transfer	$4.4 \cdot 10^{-9}$
B3	RT 67% other fire - BLEVE	$2.0 \cdot 10^{-8}$	per transfer	$1.1 \cdot 10^{-8}$
B4	RT 33% other fire - BLEVE	$2.0 \cdot 10^{-8}$	per transfer	$1.7 \cdot 10^{-8}$
B5	RT 100% external impact – 26.7 ton BLEVE	$2.3 \cdot 10^{-9}$	per transfer	$5.4 \cdot 10^{-8}$
B6	RT 67% external impact - BLEVE	$2.3 \cdot 10^{-9}$	per transfer	$5.4 \cdot 10^{-8}$
B7	RT 33% external impact - BLEVE	$2.3 \cdot 10^{-9}$	per transfer	$5.4 \cdot 10^{-8}$

Table 2. Assumptions in LPG filling station risk calculations according to RIVM (RIVM-CEV, 2008). (RT = LPG road tanker).

Figure 8 shows the contributions to the individual risk (IR) of the different components of the LPG filling station. At a short distance, the pump and unloading hose make a dominant contribution to the IR. The probability of an accident with pump or unloading hose is in fact greater than the probability of an accident with storage tank or road tanker; for the effect distances the opposite applies. At a greater distance, mainly the contributions of the storage tank and road tanker are important. In the initial situation, the 10^{-6} risk contour is about 35 –40 m from the filling connection.

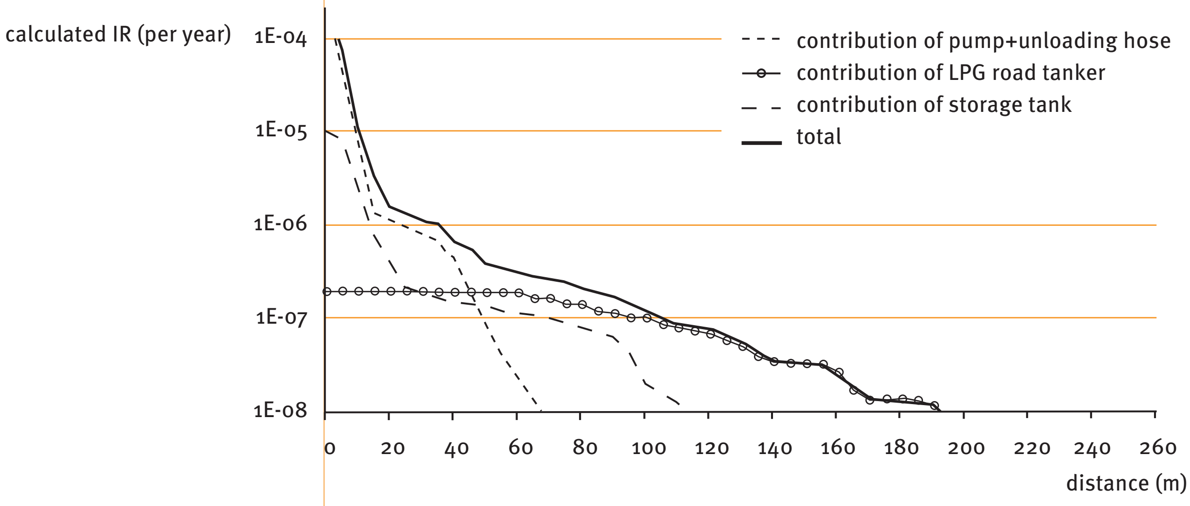

Figure 8. The build-up of the IR using the calculation method for an LPG filling station with a throughput of 1000 m^3, in which it is assumed – and since 2007 taken for reality in policy[53] – that 100% of the discharging LPG road tankers have a thermal insulation coating (expected by the Ministry for Housing, Spatial Planning and the Environment to be realised in the course of 2010).

53 Revi amendment (Staatscourant, Govt Gazette 2007, 66).

Sensitivity analysis

The sensitivity of the results to uncertainties was investigated by carrying out a sensitivity analysis. For this, the value of one variable was altered each time and all other parameter values were maintained equal to the initial situation as presented above. The following variables were considered:

1. The probability of catastrophic failure
2. The presence of a themal insulation coating
3. The number of transfers and the BLEVE probability per transfer
4. The relationship between exposure and lethality (probit)

1 The probability of catastrophic failure

The term catastrophic failure is used to describe instantaneous release (standard frequency $5 \cdot 10^{-7}$ per year) and complete, continuous release in 10 minutes (standard frequency $5 \cdot 10^{-7}$ per year).[54] Figure 9 shows the effect on the individual risk of an increase of the probability of catastrophic failure by a factor 10 (to a value of $5 \cdot 10^{-6}$ per year for instantaneous release and $5 \cdot 10^{-6}$ per year for continuous release in 10 minutes).

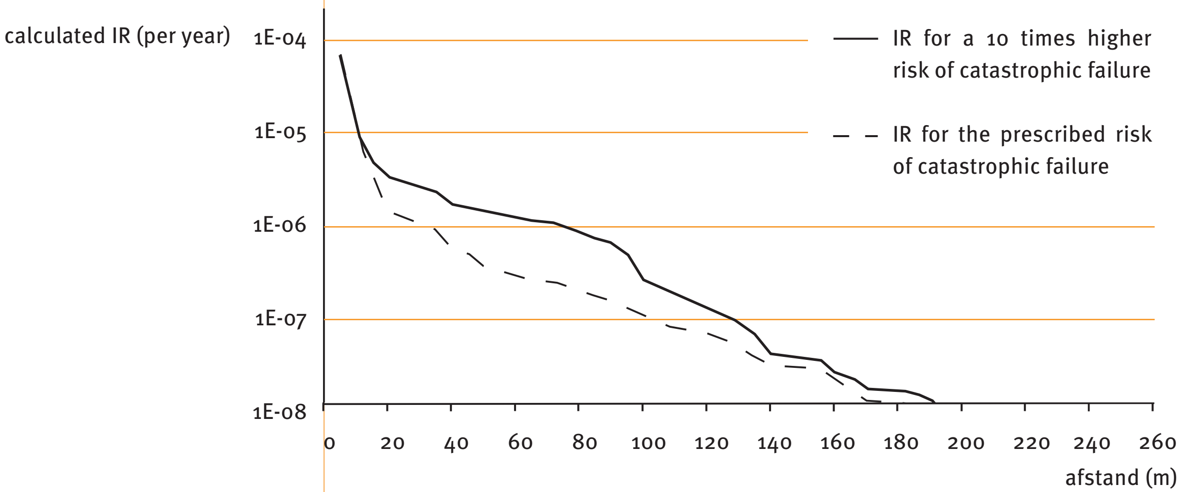

Figure 9. The effect of variation of the risk of catastrophic failure on individual risk.

For a factor 10 higher risk of catastrophic failure, the distance of the 10^{-6} risk contour to the filling connection increases from around 35-40 m to around 80 m. This increase is caused to a large extent by the increase in the probability of an accident with the storage tank (scenarios O1 and O2). The influence of the modification of the contribution of the road tanker to the IR is very limited (scenarios T1 and T2). This is the result of the correction that is applied for the duration of stay of the LPG road tanker at the LPG filling station.

2 The presence of a thermal insulation coating

In 2007, the Minister for Housing, Spatial Planning and the Environment radically reduced the safety clearances: the distance for compliance with the limit value for the individual risk of 10^{-6} per year was reduced in that year from 110 m to 40 m for LPG filling stations with a throughput of over 1000 m^3 per year.[55] This radical

54 RIVM, 2009. Module C, page 28.
55 Revi amendment (Staatscourant, Govt Gazette 2007, 66).

reduction rests on the assumption that, in the future, transferring road tankers would be provided with a thermal insulation coating, as was agreed in the LPG Autogas Covenant (VROM & VVG, 2005). A recent letter from the competent authorities (VNG, 2009) in fact indicates that in practice major problems exist regarding the realisation of the coating on LPG road tankers. At the start of 2010, a covering[56] had been fitted to six to eight of the around thirty LPG road tankers of members of the Liquid Gas Association (VVG). It is the intention that before the end of 2010 all LPG road tankers will be fitted with this covering, including road tankers of non-members. From January 1, 2011 it will be mandatory to use covered road tankers for unloading at LPG filling stations. This requires an amendment to the LPG Filling Station Decree (Besluit LPG-tankstations).[57] In the sensitivity analysis, the AGS investigated what the influence of variations in the probability of the presence of a coating is on the individual risk.

The effect of the covering in the initial situation splits into two parts in the prescribed modelling: a probability of 0.05 that a tank fails despite the thermal insulation covering (in case the fire brigade arrives too late) and a probability of 0.19-0.73 that the tank is irradiated on the liquid space of the pressure tank (depending on the filling level of the tank; if in fact the liquid space of the tank is irradiated the tank contents will cool the wall and prevent local weakening of the wall). In the sensitivity analysis, the Council considered the individual risk if 0% or 100% of the transferring tankers were provided with a thermal insulation covering. For an LPG filling station with a throughput of 1000 m^3 per year it is apparent that, according to the prescribed calculation method, the thermal insulation covering only has a very limited effect on the position of the 10^{-6} risk contour: the distance from the contour to the filling connection without covering is around 50 m, rather than around 35-40 m (Figure 10). This limited sensitivity is associated with the probability of an accident with an LPG road tanker at a filling station with a throughput of 1000 m^3 per year.

It is apparent that the sensitivity to the presence of a thermal insulation covering increases significantly with higher throughputs, when calculations are done according to the prescribed method. Therefore, the effect of the thermal insulation covering on the position of the 10^{-6} risk contour was also mapped out for an LPG filling station with a throughput of 1500 m^3 per year. In Figure 11, the contributions of the different parts of an LPG filling station on the individual risk are shown, starting with a standard LPG filling station with a throughput of 1500 m^3 per year where none of the unloading LPG road tankers is fitted with a thermal insulation covering, as until now often is the case. The distance of the 10^{-6} risk contour to the filling connection in this case is around 100 m. The figure also shows that a limited reduction in the risk of an accident with an LPG road tanker would markedly affect the position of the 10^{-6} risk contour.

56 In 2009, tests were conducted by TNO with a thermal insulation covering of silica blankets in place of the epoxy coating of the tank wall envisaged earlier (TNO project number 034.74471/01.02). TNO concluded that this coating provides protection against fire for 75 minutes.

57 Filling stations that possess a very large sprinkler system may be exempted from this (communication from Liquid Gas Association, VVG).

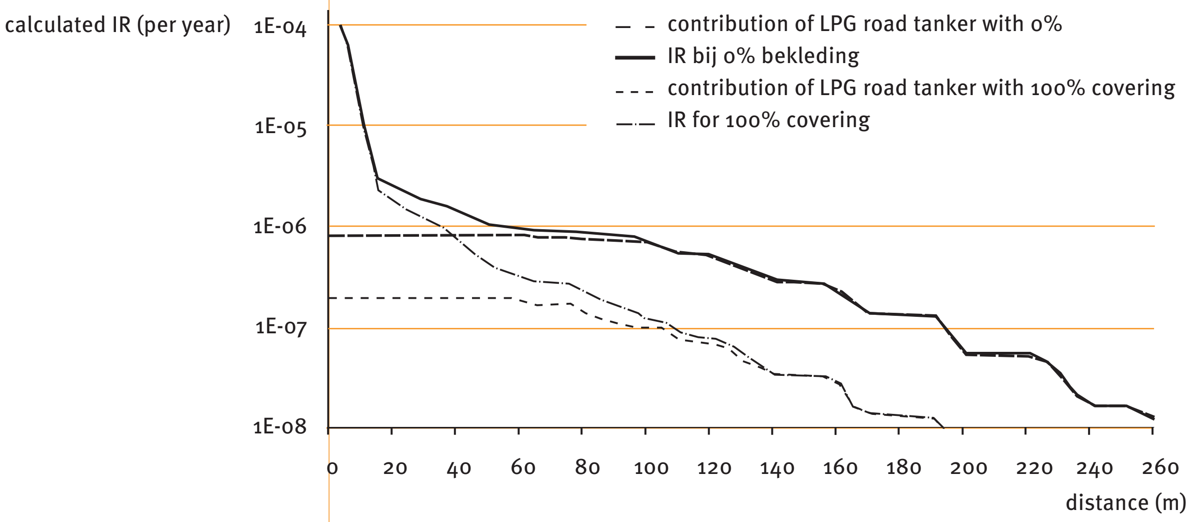

Figure 10. The contribution of unloading LPG road tankers with and without thermal insulation covering to the individual risk around an LPG filling station with a throughput of 1000 m^3 per year.

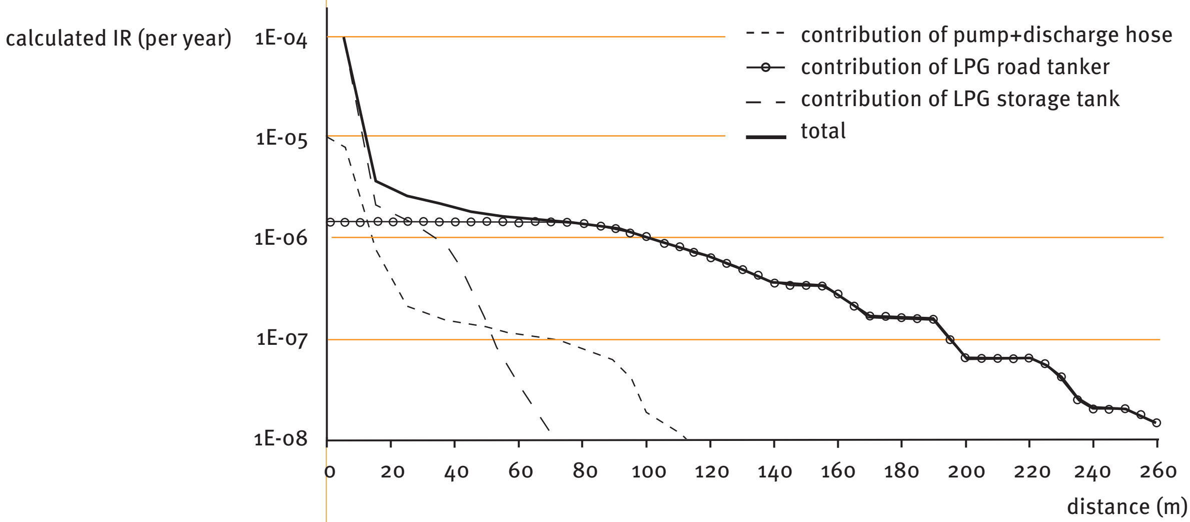

Figure 11. The build-up of the IR for a standard LPG filling station with a throughput of 1500 m^3 per year and LPG road tankers that are not fitted with a thermal insulation covering. In Figure 12, the situation where the covering either is or is not fitted to a proportion of the LPG road tankers is illustrated. In Figure 8, a standard LPG filling station with a throughput of 1000 m^3 per year is illustrated.

Figure 12 (see page 57) shows the influence of the percentage of covered tankers on the level of the individual risk as a function of the distance to the filling connection for an LPG filling station with a throughput of 1500 m^3 per year. If all unloading LPG road tankers were fitted with a thermal insulation covering, the distance to the 10^{-6} risk contour from the filling connection would be around 40 m. If 50% of the unloading LPG road tankers were fitted with a thermal insulation covering, this distance would be around 50 m. If 25% were fitted with a covering, the distance from the 10^{-6} risk contour to the filling connection would be around 80 m. For 0% covered LPG road tankers, this would be around 100 m.

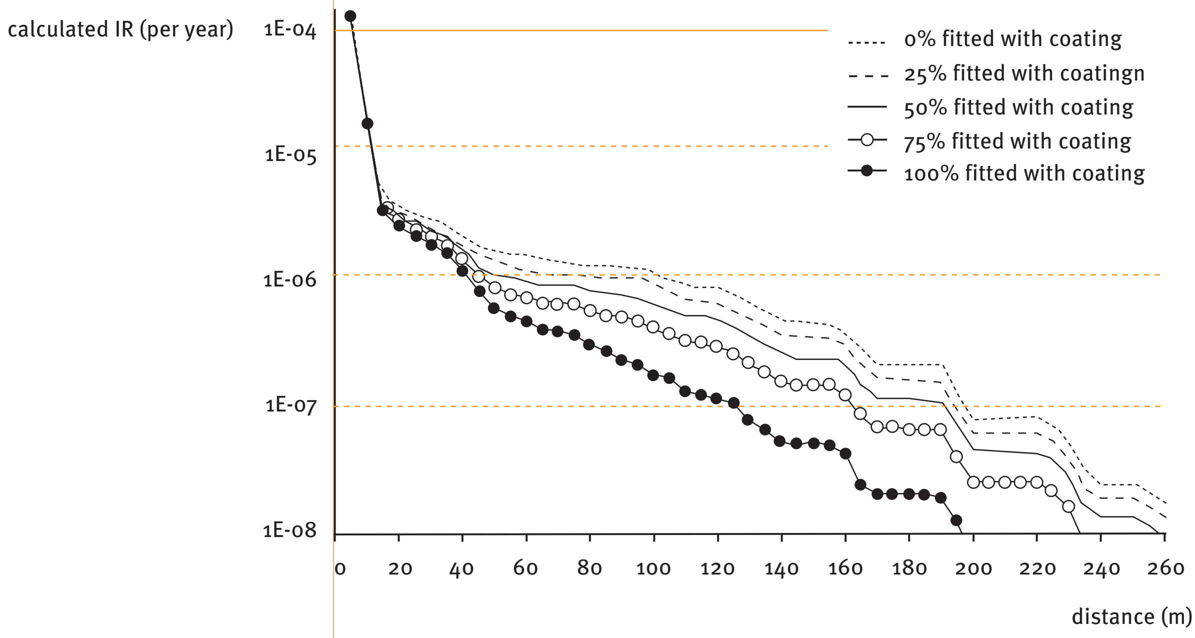

Figure 12. The individual risk around an LPG filling station with a throughput of 1500 m^3 per year for different percentages of LPG road tankers that are fitted with a thermal insulation coating.

The probability of 5% that is used in the prescribed calculation method for failure of the thermal insulation covering of an LPG road tanker exposed to fire is only based on the probability of long-term heating in case the fire brigade fails to arrive in due time (RIVM-CEV, 2006). It in fact remains the question whether the fire brigade would actually start extinguishing if the exact outbrake time of the fire were unclear. Besides this, the covering could also be damaged through mechanical impact. After an accident it may thus be unclear whether the covering has been damaged in the accident. In such cases, the fire brigade might be unable to prepare an adequate plan of attack (NIBRA, 2004).

3 The number of transfers and the BLEVE probability per transfer

Figures 8 and 11 illustrate that, close to the filling connection, the contribution of unloading LPG road tankers to the IR runs almost horizontally. A very limited increase in the probability of a BLEVE per transfer (for non-covered LPG road tankers), the number of transfers and/or the duration of stay could in this way lead to a large increase in the distance from the 10^{-6} risk contour to the filling connection. A halving or doubling of the BLEVE probability could cause a shift of more than 50 m to the 10^{-6} risk contour, depending on the initial situation (the throughput of the LPG filling station under consideration and the unloading time assumed). It should be emphasised that an increase or decrease by a factor of 2 in the failure frequency is only a very slight variation, taking account of the uncertainties regarding the failure frequencies (see also Appendix III). In Figures 13 and 14, the sensitivity of the distance between the 10^{-6} risk contour and the filling connection to the BLEVE probability for unloading is shown for LPG filling stations with throughputs of 1000 m^3 and 1500 m^3 per year.

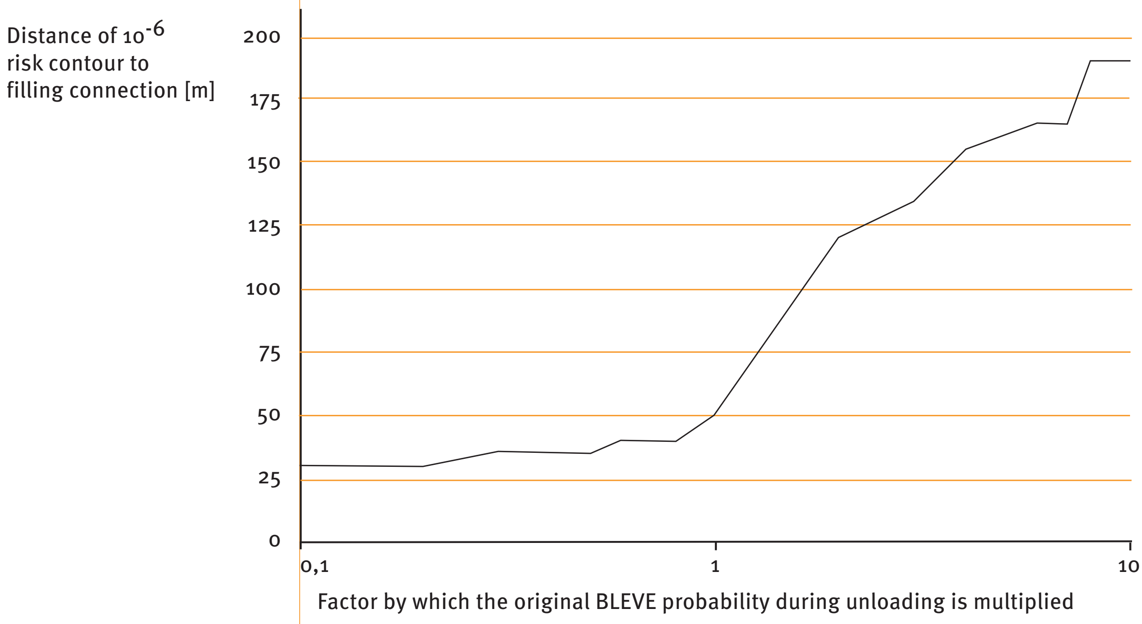

Figure 13. Relationship between the position of the 10^{-6} risk contour and the probability of a BLEVE for an unloading LPG road tanker, considering a standard LPG filling station with a throughput of 1000 m^3 per year, 70 unloadings per year, a duration of stay of 30 minutes, and LPG road tankers that are not fitted with a thermal insulation covering.

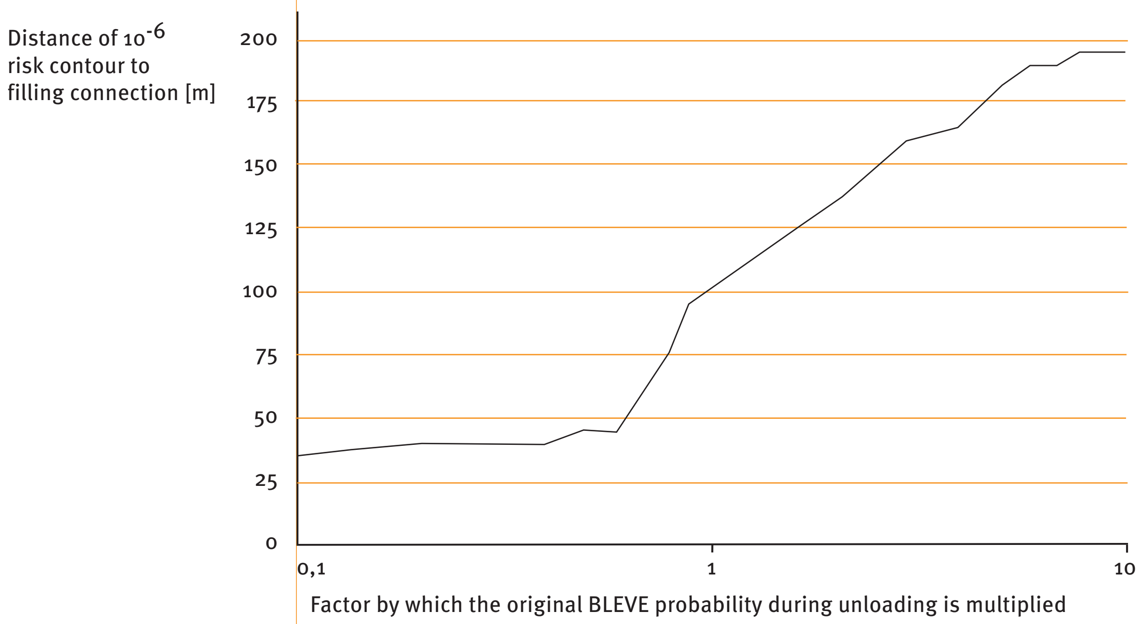

Figure 14. Relationship between the position of the 10^{-6} risk contour and the probability of a BLEVE for an unloading LPG road tanker, considering a standard LPG filling station with a throughput of 1500 m^3 per year, 105 unloadings per year, a duration of stay of 30 minutes, and LPG road tankers that are not fitted with a thermal insulation covering.

4 The relationship between exposure and lethality (probit)

The relationship between effects and consequences (lethality) may be expressed with probits. In SAFETI-NL, the probit known as the 'TNO probit for exposure of people to thermal radiation' has been implemented. In this, above 35 kW/m^2, a lethality of 100% is assumed, and zero lethality for an exposure causing less than 1% of the exposed persons to die. The maximum exposure time according to the prescribed calculation method is 20 seconds. With these assumptions, the influence of self-ignition of clothing on lethality is negligible. The TNO probit is based on data on the lethality of UV radiation from nuclear weapons with a conversion factor to convert the results to thermal radiation as a result of hydrocarbon fires. According to the documentation for the prescribed calculation method, it is apparent from experimental data that the 1% limit value for the dose for first degree burns from hydrocarbon fires is a factor of 2.23 lower than for UV radiation related to nuclear weapons. In the TNO probit, this factor of 2.23 is then used to convert the lethality probit for UV radiation from nuclear weapons to one for thermal radiation from hydrocarbon fires. The Green Book (PGS1, 2005), discusses also other models, based on fires and incidents from the past; in these models the relationship between lethality and the percentage of third degree burns is given (Prugh, Lees). These probits lead to a notably lower lethality for the same radiation load.

In a sensitivity analysis, the influence of the choice of the probit for the consequences of a hot BLEVE with fireball was considered. For this, the lethality was calculated as a function of distance using different probits for a 26.7 ton LPG road tanker and the thermal radiation according to SAFETI-NL (Figure 15). An exposure time of twenty seconds was chosen for the various probits, with the exception of the 'TNO probit including a correction for escape behaviour' (TNO+escape), where 5 seconds reaction time was assumed and an escape velocity of 4 m/s, as suggested in the Green Book (PGS1, 2005)[58]. It was also assumed that the lethality within the radius of the fireball is 100%.

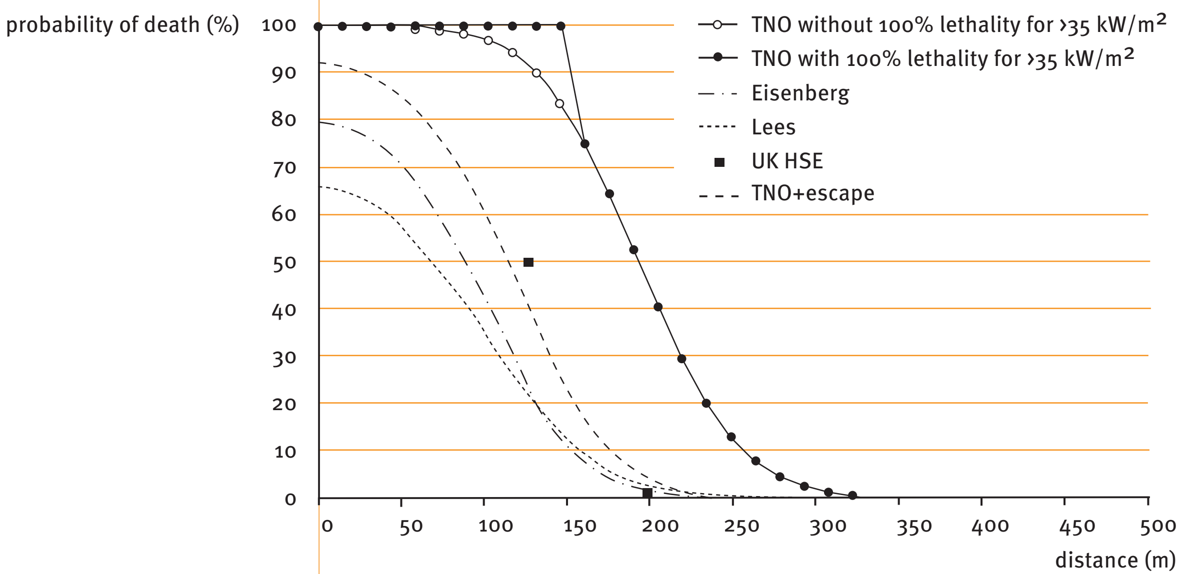

Figure 15. Lethality as function of distance for different probits for a hot BLEVE with fireball and an LPG road tanker filled with 26.7 tons of LPG.

58 In this context the terms escape behaviour and escape velocity are used for small area evacuation.

From Figure 15, it is apparent that the TNO probit is relatively pessimistic. The lethality at the same distance is noticeably lower with the probits according to Eisenberg, Lees, the HSE in the United Kingdom (2 points) and the TNO probit including a correction for escape behaviour. The Council did not conduct any investigation into the correctness of the different probits. It is indeed clear that a significant variation exists. This underlines the importance of regular validation and of keeping the underlying data up to date.

Appendix V Safety provisions for storage and transfer of LPG

Safety is an important aspect in the design of storage or transfer of LPG. In the overview below, a number of safety provisions are listed (the overview is not exhaustive). The definitive choice of measures is dependent in practice upon legislation and internal company guidelines. Only a limited number of these measures is allowed to be included using the prescribed calculation method. It is therefore not possible to optimise a design for safety.

Using the prescribed calculation method, the following can be included:

- Location of filling station with respect to possible fires or causes of mechanical impact
- Volume of reservoir
- Above-ground or underground storage tank
- Thermal insulation covering of pressure tank

Using the prescribed calculation method, the following cannot be included:

- Sprinkler system for parked LPG road tanker
- Back-flow protection in filling pipe (simple or high-grade version)
- Excess flow valve (mechanical or high-grade version)
- Cathodic protection, corrosion protection on piping and tank
- Choice of material in connection with corrosion
- Grounding
- Emergency valves in loading and unloading piping connected to the emergency blocking system
- Gas detection
- Inspection of piping and valves
- Testing of piping and valves
- Position indicators for critical valves
- (Automatic) overfill protection
- Automatic depressuring facilities to prevent fire escalation
- Blow off relief valve, single or double version
- Thermal expansion relief valve for enclosed liquid piping
- High-grade pump seals
- Classification of possible (electrical) ignition sources
- Presence of qualified and trained personnel
- Proper instructions/protocols for operations
- Protection against driving away without disconnecting
- Break-off coupling at safe place for driving off without disconnecting

This Appendix gives a description of the implementation of the Seveso II Directive in some other European Member States. The Council notices interesting starting points for improvement to The Netherlands' QRA practice in the United Kingdom (PADHI), France (PPRT) and Germany (TAA) (see also page 31 et seq.).

PADHI: Planning Advice for Developments near Hazardous Installations
HSE advises competent authorities ("planning authorities") on permit applications for land-use developments in the vicinity of establishments and pipelines with major hazards. The original advisory procedure was lengthy, expensive and placed heavy demands on a central team of specialised risk analysts. After a review of its advisory practice, HSE developed a method, PADHI, that made it possible to deal with all advice requests at local level and to accelerate the advisory procedure:

1 When assessing the safety of an establishment in the context of COMAH, HSE defines a "consultation zone" around the establishment (or pipeline). The safety assessment and definition of the consultation zone is based on a site-specific risk analysis. In this analysis, the opportunities for risk reduction are mapped out and evaluated.

2 If a land-use development lies within the "consultation distance" defined by HSE, the competent authority (known as the "planning authority") must request advice from HSE. The competent authority indicates where the development is planned and provides sufficient details about the type of development to allow the vulnerability ("level of sensitivity") to be determined.

3 Within the consultation zone, HSE has defined three zones: the inner zone (IZ), middle zone (MZ) and outer zone (OZ) (Figure 16). The risk to people diminishes as they are located in a zone further removed from the hazard. The boundary between the inner and middle zones (IZ and MZ) corresponds to a probability of 10^{-5} per year that a permanently-present individual is exposed to a hazardous dose that results in an overall lethality of 1%. For the boundary between the middle and outer zones (MZ and OZ), this probability is 10^{-6} per year, and for the edge of the outer zone (OZ) $3 \cdot 10^{-7}$ per year.

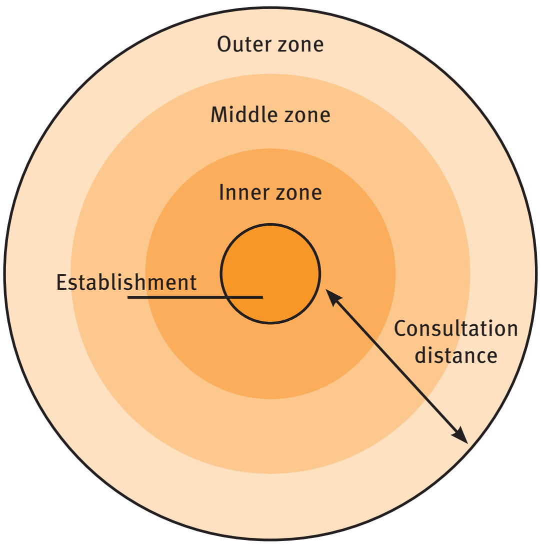

Figure 16. The zone layout around an establishment within the consultation distance.

4 Based on a matrix, it is evaluated what types of development are considered acceptable within each zone. The vulnerability of the surrounding area is taken into account. Regarding the vulnerability, four levels are distinguished (Table 3). For each level, there are exceptions to the standard allocation. Thus, 1 or 2 houses are not considered as level 2 but level 1. The distinction that is made in The Netherlands between risks at individual level (individual risk) and risks at population level (societal risk), is not made explicitly in the United Kingdom, but is included implicitly in the level of sensitivity.

Level	Description	Inner zone	Middle Zone	Outer zone
1	Based on normal working population	DAA	DAA	DAA
2	Based on general public (at home, involved in normal activities)	AA	DAA	DAA
3	Based on vulnerable members of the public (children, those with mobility difficulties or those unable to recognise physical danger)	AA	AA	DAA
4	Large number of people in level 3, or large number of level 2 people in the open air	AA	AA	AA

AA Advise against
DAA Don't advise against

Table 3. Level of sensitivity and risk assessment matrix for surrounding areas used by HSE.

5 The advice of HSE consists only of "advise against" and "don't advise against". The assessment is based on a matrix which indicates for each zone and level of sensitivity whether a positive or a negative judgement will be issued (Table 3). The competent authority includes this advice in its assessment of a permit application for a land-use development. In general, HSE's advice is followed.

PPRT: Plan de Prévention des Risques Technologiques
In Toulouse in 2001, 29 people lost their lives in an explosion, and more than 2400 were injured. The accident led to a large-scale review of French external safety policy. PPRTs (Plans de Prévention des Risques Technologiques) form an important part of current policy for the "top tier" Seveso establishments. Around 420 PPRTs will be prepared, for 622 establishments and around 900 communities. The Plan de Prévention des Risques Technologiques obtained a legal basis in 2003 through the Risks Act 2003-699.[59] Décret no. 2005-1130 of 7 September 2005[60] stipulates the implementation that must be given to the PPRT.

59 Loi no 2003-699 du 31 juillet 2003 relative à la prévention des risques technologiques et naturels et à la réparation des dommages. NOR DEVX0200176L.
60 Décret no 2005-1330 du 7 septembre 2005 relatif aux plans de prévention des risques technologiques. Ministère de l'Écologie et du Développement Durable. NOR DEVP0530023D.

The realisation of a Plan de Prévention des Risques Technologiques includes the following steps:

1 **Preparation of safety report**
The operator drafts a safety report (Étude de Dangers, EDD). In the EDD, for each incident, the probability, consequences and kinetics of the incident are mapped out. With the aid of a matrix, the acceptability of the risks is assessed (5 probability and 5 consequence classes). Based on this, it is decided whether or not further analysis and additional provisions are needed. The EDD is focused on the particular establishment and includes both technical and organisational aspects.

2 **Analysing risks for the surrounding area**

Probabilities and effects
The prefect defines the study area. The inspectorate (DRIRE or STIIIC) conducts the analysis based on the EDDs for the establishments within the study area. The probabilities of effects of a certain intensity are mapped out. In this, distinction is made between radiation, toxic and mechanical (overpressure) effects.

In determining the surrounding area risks ("aléas"), only phenomena with effects outside the establishment are included. Phenomena with a frequency of $<10^{-5}$ per year remain out of consideration under the following conditions: the probability classification is based on passive protection for each scenario, or is based on at least two technical safety provisions for each scenario, and the retention of the safety classification even if one safety provision fails.

Based on kinetics, distinction is made among the scenarios. If there is sufficient time for emergency aid and self-rescue, a scenario is classified as slow, in other cases as rapid. For the slowly-developing scenarios, the extent of the areas within which irreversible consequences are possible are projected on a map. For the rapidly-developing scenarios, surrounding area risk levels are determined for each location, based on the (cumulative) probabilities and the intensity of effects. Seven surrounding area risk levels are distinguished, based on four effect classes (first filter) and five probability classes (second filter). For toxic, radiation and overpressure effects, separate maps are prepared.

Vulnerability of the surrounding area
The vulnerability of the surrounding area is mapped out by the DDE, in collaboration with local authorities and other local partners. In this, not only inhabitants are being considered, but also working population, cultural heritage and nature. The location of vulnerable objects and their types are shown on a map.

Rough zoning and further analysis
The maps of the "aléas" and vulnerable objects are superimposed. Based on this, a rough zoning is carried out and decisions are made on additional analyses to be conducted. The rough zoning is based on the aléa levels. In this, it is first indicated roughly where there will be a prohibition on new buildings (or new buildings allowed conditionally), then it is indicated roughly where there will be a safety clearance zone or the possibility of sale of property to local authorities.

Further analyses focus on the question whether the vulnerability of objects can be reduced and on the question whether there are costs associated with clearance, sale, reduction of vulnerability and provisions to be taken at the risk source.[61] The local context is included in further analyses.

3 **Strategy determination**
Based on the rough zoning and the further analyses, the options to reduce risk are evaluated and choices are made. In matrices, it is defined for each effect (toxic, thermal, overpressure) what types of measures must be taken for each combination of "aléa" and object. The result of this phase is a detailed proposal for the PPRT.

4 **Elaboration and enactment**
Advice is obtained from the CLIC (Comité Local d'Information et de Concertation). The CLIC is an independent committee aimed at creating a framework for the exchange of information and ideas among the various stakeholders. Besides this, the CLIC contributes at a detailed level to the PPRT by evaluating it critically and by presenting an advice. After public consultation the PPRT is enacted (unless modifications are necessary).

TAA: Technischer Ausschuss für Anlagensicherheit
Article 12 of the Seveso II Directive, the article that concerns spatial planning in the vicinity of hazardous establishments, has been implemented in Germany in the Baugesetzbuch (BauGB), together with the Baunutzungsverordnung (BauNVO) and section 50 of the Bundes-Immissionsschutzgesetz (BImSchG). The Technischer Ausschuss für Anlagensicherheit (TAA) contains recommendations for the distances to be maintained around establishments where hazardous substances are produced and/or stored. In this, the TAA makes a distinction between two situations (Störfall-Kommission, 2005):

1 Zoning without detailed knowledge: if the detailed layout of an industrial or commercial zone is not yet known, fixed distances may be used for each hazardous substance. The recommended standard distances are based on the principle that establishments are both designed and managed according to the state of the art. The scenarios considered are a fire or gas cloud explosion with direct ignition and a release of a toxic substance. The distances are based in general[62] on a release due to a leak with an area of 490 mm^2. In exceptional cases, deviations from these fixed distances are allowed, if based on the specific installation design or specific operational experience.

---

61 A declaration of the societal necessity for compulsory purchase is drafted by the local authorities. The costs of clearance and purchase are shared among the national government, the local authorities and the operator. Building measures are for the account of the property owner but are compensated up to 10% of the property value.

62 In Germany during the last fifteen years, data have been collected about accidents in the chemical industry. Based on experience, numerical values for different failure frequencies and leak sizes are stipulated that can be used to determine what distances have to be respected.

2 Zoning with detailed knowledge: in case of existing industrial or commercial zones, in which the specific substances, licensed quantities and process installations are known, deviation from the standard recommended distances is allowed, and a systematic hazards analysis may be conducted. For this, the following recommendations are made:

- If the distance to the vulnerable object is less than the recommended distance without detailed knowledge, an individual case study must be conducted.
- If other regulations stipulate a minimum distance (e.g. legislation with respect to explosive substances), this distance must be respected.
- For the individual case study, technical recommendations are made with respect to the scenarios to be considered. The probability aspect is not mentioned.

APPENDIX VII Parties involved

For the preparation of this advisory report, a Council Working Group and a Committee with external members were formed, both under the chairmanship of ir C.M. Pietersen and supported by dr ir drs R.B. Jongejan, secretary. Intermediate results from the Council Working Group and Committee were discussed in the overarching QRM Steering Group, in which the subsequent advisory report addressing potential improvements for the QRA practice in The Netherlands is currently being prepared. The intermediate results were also presented to a feedback group.

QRM Steering Group
Prof. dr ir J.G.M. Kerstens
Ir C.M. Pietersen
Prof. ir drs J.K. Vrijling
N.H.W. van Xanten, PharmD, ERT, MPA
Dr ir drs R.B. Jongejan, secretary

QRA Council Working Group
Ir C.M. Pietersen
Prof. dr A.J. van der Wal
P. van der Torn, MD, D.Env.
Prof. dr ir H. Pasman

QRA Committee
Ir C.M. Pietersen
Ir M. de Groot
Ir J.C. de Knijff
Ir A. Valk

Feedback Group

Dr P.H. Bottelberghs	DHV
H.J. Bril	Sabic
Ir R. Geerts	AVIV
T. Gielkens	Sabic
C.J.M. van Gils	Du Pont
Ir L. Gooijer	RIVM
B.J. Haitsma	Arcadis Vectra
W.J. Klijn	Ministry of the Interior and Kingdom Relations
M. Korteweg Maris	VNCI
Dr N. Rosmuller, M.Sc.	TNO
Drs J.A. van Staalduine	Ministry of Housing, Spatial Planning and the Environment
Dr P.A.M. Uijt de Haag	RIVM
Mrs ir A. van der Rest	Shell
Ing. J.G.A.M. Verbakel	Ministry of Housing, Spatial Planning and the Environment
V. van der Vlies	VNG
E.J. Wijdeveld, LLM	Deltalinqs
P.G. Wildschut, LLM	CTGG

IMPRINT

ISBN/EAN: 978-90-77710-17-3 (translation into English)

Design: Taluut, Utrecht.

Adviesraad Gevaarlijke Stoffen

Oranjebuitensingel 6
Postbus 20951 - IPC 770
2500 EZ Den Haag
www.adviesraadgevaarlijkestoffen.nl