Tank lorry fires involving dangerous goods

Safety study

The Hague, 17 November 2006 (project number T 2005 WV 0312 01)

THE DUTCH SAFETY BOARD

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CONSIDERATION

Reason for the thematic study on tank lorry fires involving dangerous goods
This report discusses a) the risk assessment that the fire service will have to perform in the event of a tank lorry[1] fire that involves dangerous goods, and b) the overall approach to risks in the underlying policy for the transport of dangerous goods. The road transport of dangerous goods is a source of safety concerns – not in the first place because there are frequent incidents but rather because the consequences of an incident, when it does occur, can be very substantial. It is estimated that there have been six tank lorry fires involving dangerous goods in the Netherlands since 1999. In each of these cases, the consequences were limited.

The thematic study on 'Tank Lorry Fires involving Dangerous goods' was launched in response to two major tank lorry fires, one near Ewijk in May 2001 and the other one near Eindhoven in July 2003. The drivers of the tank lorry and the two other lorries involved in the accident in Ewijk were able to run away from the scene unharmed, but in the Eindhoven case the driver of the lorry was trapped in the burning cabin and died. In the course of the investigation (August 2005) another major tank lorry fire took place, this time on the A28 motorway near 't Harde. In this accident, the drivers of the tank lorry and the other lorry involved were slightly injured. In all three cases, the tank lorries carried flammable substances and were involved in a road accident. One further, notable similarity was that in each of these cases the fuel tanks under the lorries were damaged, leaked large quantities of diesel, and caught fire. As a result, in each of these cases the motorway had to be closed off for hours. In one case, moreover, a nearby industrial estate had to be evacuated because of the risk of an explosion. The motorway blockades and the evacuation of the surrounding area caused considerable disruption and economic damage. As a result, the need for those precautions was called into question afterwards.

a. Risk assessment by the fire department
In the event of a tank lorry fire, the fire department can either decide to take immediate action or to await a possible explosion at some distance. On the one hand, swift ("offensive") action to extinguish the fire may help to prevent an explosion and far-reaching consequences for the surrounding area. On the other hand, offensive action may have fatal consequences for the fire fighters involved; for them, a more expectant ("defensive") approach is obviously the safer option. The decision about the course of action also depends on the presence of people in the area or trapped inside the burning vehicle.

It appears that there is no clear (administrative) framework to guide the decisions that the fire department needs to take. There are various examples in which the actions taken by the fire department were judged after the event, while no clear expectations had been formulated in advance. The only thing the fire department is expressly expected to do in this context is "protect its own safety". In practice, that guideline is not sufficient to go by.

This is illustrated by the following examples. When, in the Ewijk incident, the fire department decided to play it safe and sealed off and evacuated the whole area surrounding the burning tank lorry, there were doubts whether that measure was justified in view of the congestion that it caused. In 1995, when Amsterdam fire fighters entered a burning storage shed because there might be people inside, this was called an unnecessary risk afterwards. Conversely, in the case of the Hercules[2] crash the fire department was blamed afterwards for not having made any attempt to open the burning aircraft, because it initially (erroneously) believed there were no passengers inside.

In the absence of an administrative assessment framework, the fire department uses its 'own' assessment instruments. There appear to be several factors that the fire department takes into account when deciding about the course of action to take: i) *the dangerous good involved*, ii) *the nature, size and expected development of the incident* and iii) *the nature and size of the area under threat*. The investigation has revealed that in practice fire fighters do not have enough information at their disposal to assess these factors effectively, and that the information they do have is insufficient as a basis for a clear course of action. In this connection, the Safety Board has identified the following issues:

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[1] In the rest of this document, the term 'tank lorry' is understood to include articulated tank lorries.
[2] A military transport aircraft that crashed at Eindhoven Airport on 15 July 1996. As a result of the crash, 34 people died.

- It sometimes proves problematic – and occasionally even impossible – to identify the dangerous good involved. For example, the orange plates stating the code of the relevant substance (category) are not always visible in thick smoke or on lorries that have overturned and that are carrying different types of materials. In addition, the fire department does not always have access to the transport documents with data about the substances concerned.
- There are not enough enforcement data available to assess the reliability of substance specifications on the orange plates and transport documents.
- The operational fire fighters that were interviewed make incorrect assumptions, and have insufficient knowledge, about the behaviour of articulated tank lorries with dangerous goods in the event of an accident.
- The development of a tank lorry fire and the extent to which it can be extinguished are largely determined by the accessibility of the site and the availability of water.

Some of the problems mentioned by the Safety Board in this report were already identified on earlier occasions. For example, after studying the acrylonitrile leak at the Amersfoort railway station in 2002, the Dutch Transport Safety Board arrived at a number of similar conclusions, stating that the fire department was supposed to do its job with limited information about the dangerous good involved. The Rail Accident Investigation Board had identified the same problem back in 1990, in a preliminary investigation of an incident involving a transport of dangerous goods near the town of Boxtel. In those days, the only document that used to be available was a consignment note kept by the engine driver (which was usually difficult to read). After that particular incident it was decided that for each high-risk transport the waybill should be faxed to the relevant fire department, stating the risk levels involved and the code of the substance being transported.

b. Dealing with risks in the safety policy for the transport of dangerous goods
The Dutch Safety Board has identified the following regulatory and policy-related context that influences the difficult decisions the fire department needs to make. The aim of the authorities is to minimise obstruction to the transport of dangerous goods and to spatial planning (e.g. newly built areas), as both are regarded as factors with a high societal value. The idea is that safety should be optimised within those given values. The Safety Board has noticed that a great deal of attention within this policy area focuses on external safety and the underlying risk calculations, i.e. on the consequences of accidents in the transport of dangerous goods for people that live, work or engage in leisure activities in the surrounding area. At the same time, the Safety Board found that due to the absence of a systematic accident registration system, insight into the number, nature and causes of road accidents involving dangerous goods is inadequate.

The following examples show that accident analysis can yield important insights that may help to further improve safety. In a Safety Board investigation into three tank lorry fires, one specific risk factor that emerged was the vulnerability of the fuel tank. In fact, the fires at Ewijk (2001), Eindhoven (2003) and ’t Harde (2005) were all caused by a ruptured fuel tank. Lorry fuel tanks are mounted on the outside of the chassis and are made of thin steel plate sheet or aluminium, which makes them particularly vulnerable in practice. Given the fact that the road accident registration system does not yield sufficient insight into the scope of the problem, the Safety Board analysed the recommendations issued by recovery experts in connection with motorway accidents involving lorries. On the basis of that analysis, the Safety Board estimates that every year some fifty to one hundred accidents take place in which the fuel tanks of the lorries involved are damaged to such an extent that several hundreds of litres of fuel leak out. In view of the consequences (the leakage of dangerous goods), the measures (including transport guidelines and incentive schemes) focus particularly on the trailer. For example, in the LPG Service Stations Covenant of June 2005, the parties agreed that articulated LPG tank lorries that are used to provision service stations must be fitted with heat-resistant cladding (this measure applies to approximately half of all LPG tank lorries in the Netherlands). The lorry itself has so far been left out of the equation.

The fuel tanks of lorries are supposed to meet only a limited set of requirements, none of which concerns the prevention of leaks due to damage, for example in the event of an accident. Nor do lorries that carry dangerous goods have to meet any supplementary safety requirements in this respect compared with regular lorries. In addition, there is a trend to increase the capacity levels of fuel tanks. In view of the potential consequences of a tank lorry fire, the Safety Board believes measures should be taken to reduce the vulnerability of fuel tanks. The first category that qualifies for such measures is that of lorries carrying dangerous goods, but the measures should eventually be made to apply to all lorries, as a flammable load that does not itself qualify as hazardous (such as paper, wood or butter) may become very dangerous if the lorry catches fire. And even if there is no fire, a leak of hundreds of litres of fuel poses a hazard for motor cyclists, as well as causing traffic congestion and environmental damage.

Final conclusions
On the basis of the thematic study, the Safety Board has drawn the following conclusions:

1. Tank lorry fires for which the fire department must be called in are a regular occurrence. The potential consequences of such fires for emergency services workers, road users and/or other people in and around the site of the accident appear to be substantial.
2. There is no system in place for the collection, analysis and sharing of information about accidents involving the transport of dangerous goods by road. As a result, there is a lack of insight into the actual risks and risk-determining factors involved in such transports.
3. In the case of a large tank lorry fire, the fire department will not always be able to carefully assess the risks to support its decision to either actively fight the fire or watch its development from a distance and contain the (potential) consequences.
4. The vulnerability of the fuel tanks of lorries, combined with the increasing capacity of those tanks, leads not only to nuisance (after an accident the asphalt will have to be cleaned) but also to increased safety risks in the road transport of dangerous goods.

Recommendations
On the basis of the study results, the Safety Board has formulated a number of recommendations for the parties involved in fighting tank lorry fires and, in a more general sense, in promoting the safety of the transport of dangerous goods by road. The Board recommends:

1. that the Ministers of the Interior and of Transport, Public Works & Water Management set up an information system, in consultation with the fire department (via the NVBR[3] and/or the *Veiligheidskoepel*), to ensure the fast provision of information to fire fighters about the load (such as the type and quantity of the substance involved) and the vehicle (such as the type of tank and presence of a pressure relief valve).
2. that the Minister of the Interior investigate the extent to which the knowledge available within the fire department (in addition to vehicle know-how) could be enhanced and/or put to use more effectively in order to help the fire department choose between defensive and offensive action in fighting tank lorry fires, and recommends that the Minister take measures accordingly.
3. that the Ministers of the Interior and of Transport, Public Works & Water Management investigate the extent to which the timely availability of sufficient quantities of extinguishing water can be guaranteed at bottlenecks along dangerous good transport routes (and stretches of motorway nearby residential areas), and recommends that they take measures accordingly.
4. that the Minister of Transport, Public Works and Water Management implement an effective supervision and enforcement policy to gain more insight into the reliability of the substance data on the orange plates and transport documents, and take all the necessary measures to that effect.
5. that the Minister of Transport, Public Works and Water Management call for tighter international regulations to prevent leaks in the fuel tanks of lorries – especially, to begin with, lorries used in the transport of dangerous goods. Such measures could include devices to screen off or reinforce the fuel tanks.
6. that the Minister of Transport, Public Works and Water Management and the carriers (through their umbrella associations) take measures to promote the systematic reporting, registration and analysis of accidents and near accidents (incidents) in the transport of dangerous goods, learn the lessons and share that knowledge in a national and international context.
7. that the Ministers of Housing, Spatial Planning & the Environment, Transport, Public Works and Water Management, the Interior, and Social Affairs & Employment see to it that safety measures relating to the transport of dangerous goods are formulated with due regard not only for the effects on external safety, but also for the safety of road users, emergency services workers and bystanders.

The Hague, November 2006

[3] Netherlands Association for Fire Departments and Disaster Relief

P. van Vollenhoven	M. Visser
Chairman of the Safety Board	General Secretary

GLOSSARY

accident frequency	Number of accidents per unit of exposure (e.g., the mileage covered).
actions at source	Actions that need to be taken at or near the site of the accident in order to stabilise the source.
AGS	Dangerous goods Advisor (*Adviseur Gevaarlijke Stoffen*).
appendage	An accessory that serves to complete a machine or plant. Examples of appendages in the case of a tank include a filling pipe or a pressure gauge.
Basic Network	Road category system aimed to reconcile priorities in spatial planning on the one hand, and the transport of dangerous goods on the other.
BLEVE	Boiling liquid, expanding-vapour explosion. See Appendix 5 for further details.
boiling line	In a phase diagram (pT diagram), pressure (p) is plotted against temperature (T) and the various phases (solid, liquid, gas) and phase changes of a substance are shown. In a phase diagram, the boiling line indicates the transition between vapour and liquid (and the boiling point as a function of pressure).
boiling point	The boiling point of a pure substance is the temperature at which that substance changes from the liquid into the gas phase. As long as the substance is heated, the temperature of the liquid will remain at the boiling point and the process will continue until all the liquid has evaporated. The temperature required for the phase change depends on the pressure.
cabotage	The transport of a load by a Dutch enterprise between two locations outside the Netherlands, with the goods being loaded and unloaded in the *same* country.
cloud fire	Combustion of a free gas cloud emitted into the atmosphere for example as a result of a leak; under special conditions, the combustion can be explosive.
CPR	The Committee to Prevent Disasters Caused by Dangerous goods (CPR) no longer exists. It was replaced by the (independent) Dangerous goods Advisory Board in 2004. The effort to convert the CPR guidelines to the Dangerous goods Publication Series (PGS) began in 2005. The PGS guidelines have come in the place of the frequently used CPR guidelines.
defensive action	A fire fighting strategy in which protection of the area around the accident takes priority over elimination of the source of the danger.
deflagration	A heterogeneous explosion (q.v.) in which the combustion process is fuelled by heat transfer. Explanation: The speed at which an explosive combustion process propagates itself is called the linear combustion rate. In explosive gas mixtures that rate is between 0.1 and 200 m/s, and in solid substances and liquids between 0.001 and 1 m/s. An explosive combustion process in the open air will not produce a bang. In a fully or partly confined space, deflagration produces a muffled bang (‘boom’).

detonation	A heterogeneous explosion (q.v.) in which the combustion process travels at supersonic speed in the form of a shock wave. Explanation: A shock wave is a moving ridge of increased pressure that compresses the medium when it passes, causing the medium to react. The speed at which a shock wave travels is called the detonation speed. In explosive gas mixtures the detonation speed is between 1500 and 3000 m/s, and in solid substances and liquids between 2000 and 8000 m/s. A detonation always produces a loud and sharp 'bang'.
ERICards	Emergency Response Intervention Cards (ERICards) issued by CEFIC[4] provide information about the risks of particular substances and about the actions to be taken in the event of an accident. The information is intended to ensure that the first relief workers to arrive on the site have access to specific and reliable information about the substance involved. The ERICards have been designed by experts from the various emergency services and the chemical industry, with support from the European Commission, and can be obtained via the Internet (www.ericards.net).
Fire Fighting Squad	Back-up technical team only called in to fight fires in the most extreme cases. A Fire Fighting Squad comprises a command unit and four articulated fire engines.
flash point	The lowest temperature at which a liquid gives off sufficient vapour, under controlled test conditions, to create a flammable mixture in combination with the air above the liquid. At the flash point itself, there is not yet sufficient vapour to sustain a combustion process.
gas phase	The phase in which a substance appears as a gas. Most (though not all) substances have a solid, liquid and gaseous phase.
group risk (GR)	The chance per year that a group of a specific minimum number of people die as a result of an accident.
HBM	Chief Fireman (*hoofdbrandmeester*, post at officer's rank, known as *brandweercommandant* [Fire Officer] in municipalities of up to 40,000 inhabitants).
heat-sensitive camera	A camera that registers the heat (infrared) rays instead of the optical rays emitted by an object. The infrared image represents the thermal condition of the outside of an object.
heterogeneous explosion	A chemical explosion in which the combustion process starts at one point from where it travels as a narrow band through the flammable medium (also see Flame front). Heterogeneous explosions can be divided into two processes according to travel speed: - deflagration (q.v.): travels at subsonic speed - detonation (q.v.): travels at supersonic speed
impact reduction	Actions that need to be taken to limit the effects of an accident beyond the immediate environment (e.g., charting the spread of the dangerous good, warning and alerting the public and, if required, decontaminating the environment).

[4] CEFIC = European Chemical Industry Council

irradiation[5]	The transmission of heat rays to an object.
liquid phase	The phase in which a substance appears as a liquid.
local risk (PR)	The risk that a fictitious person bound to one and the same spot without protective measures for one year, dies as a result of an accident associated with a certain activity (e.g., the transport of dangerous goods by road).
LOGS	Dangerous goods Accident Relief Guide (*Leidraad Ongevalsbestrijding Gevaarlijke Stoffen*).
multidisciplinary aid	Fire department, police and GHOR (Medical Assistance in the case of Accidents and Disasters).
offensive action	A fire fighting strategy in which the main priority is to eliminate the source of danger and/or to rescue victims near to that source.
OGS Squad	Technical unit called in to fight accidents involving dangerous goods. The OGS Squad includes gas suit teams and is fitted out with a decontamination container, an OGS swap body or an OGS assistance vehicle.
OGS	Dangerous goods Accident Relief (*Ongevalsbestrijding Gevaarlijke Stoffen*).
OVD	Specialist Officer of the fire department (*Officier van Dienst*).
PGS	Dangerous goods Publication Series (*Publicatiereeks Gevaarlijke Stoffen*, see CPR).
pool fire	A leaked quantity of liquid (in the form of a pool) that has caught fire.
preparation	The preparation for the response to fires, accidents and disasters that have not yet taken place.
prevention	The prevention or containment of fires, accidents and disasters.
RAC	Regional Emergency Centre (*Regionale Alarm Centrale*)
RBM II	Standardised calculation method designated by the Ministry of Transport, Public Works and Water Management to determine external safety risks associated with the transport of dangerous goods.
repression	(In the Netherlands:) The actual fight against fires, accidents and disasters that have taken place.
risk	Chance * effect: the adverse consequences of an activity in relation to the chance that they occur.
RNVGS	Risk Standards for the Transport of Dangerous goods (*Risiconormering Vervoer Gevaarlijke Stoffen*).
ROGS	Regional Dangerous goods Supervision Officer (*Regionaal Officier Gevaarlijke Stoffen*).

[5] This term has nothing to do with radiation therapy as used in medical contexts. It refers to the fact that an object that is on fire or otherwise excessively hot, emits heat rays in all directions and ‘irradiates’ any object that receives those rays. For example, an LPG tank can be irradiated by a pool fire, and an sunbather is irradiated by the sun.

ROT	Regional Operating Team (*Regionaal Operationeel Team*).
tank lorry	Lorry with a tank trailer.
third countries transport	The transport of a load by a Dutch enterprise between two locations outside the Netherlands without crossing the Dutch border, with the goods being loaded and unloaded in *different* countries.
vulnerable objects / locations	In policy[6], objects qualify as vulnerable or partially vulnerable in relation to the assumption that certain groups in society need more protection than others. This primarily concerns homes, as they can be expected to accommodate many people over longer periods of time. Then there are certain groups of people who merit special protection on account of their development or physical/mental condition, such as children, the elderly or the sick. Other factors that determine the difference between vulnerable and partially vulnerable objects include the chance that certain groups are present in an object, the size of such groups, the functional relationship between objects and the high-risk activity, and the presence of adequate means of escape.

[6] Source: Ministry of Transport, Public Works and Water Management, *Circulaire Risiconormering vervoer gevaarlijke stoffen* (Risk Standards for the Transport of Dangerous goods Circular) (2004)

1 INTRODUCTION

1.1 REASON FOR THE THEMATIC INVESTIGATION – THREE TANK LORRY FIRES INVOLVING DANGEROUS GOODS

This investigation was launched in response to three tank lorry fires in 2001, 2003 and 2005 (the 2005 accident was the subject of a concise exploration and is only referred to in this introduction). A brief summary of the events is given below. Appendix 1 offers an extensive description of the accidents that took place in 2001 and 2003 and of the way they were handled by the fire department.

The first fire took place in May 2001 after a tank lorry filled with ethyl acetate crashed into a traffic jam on the A50 motorway near the Ewijk junction. The diesel leaking out of the damaged fuel tank caused a fire that spread to two other lorries. In its response the fire department took into account that the tank might explode, and opted for a defensive approach, which meant that the fire fighters kept a distance and did not actively fight the fire.

In July 2003, around two years after the Ewijk accident, there was an accident with an LPG lorry on the A2 motorway in the municipality of Eindhoven. In this case, too, the fuel tank of the lorry was damaged and the leaking diesel caught fire. The driver was trapped inside the cabin. The fire department opted for an offensive approach and immediately began extinguishing the fire, but the driver of the tank lorry could not be rescued.

In both these accidents, the tank lorries were carrying flammable substances and were involved in a road accident. In both cases, the fire was the result of fuel leaking out of the damaged fuel tank. In both cases, moreover, the motorway was closed off and the area around the site of the accident was evacuated. In the Eindhoven case this also meant evacuating homes and several businesses (shops, office buildings and restaurants) in the neighbourhood.

Afterwards, as in similar cases, members of the public were critical of the fire department's response. As regards the Ewijk accident, people wondered whether the measures taken were really necessary and why the fire department had not finalised its relief operations sooner than it did. The evacuation and the traffic jams had caused considerable inconvenience and economic damage.

After the second accident, near Eindhoven, the Dutch Safety Board decided to launch a thematic inquiry in order to provide more insight into the safety risks for fire fighters and the local area associated with the transport of dangerous goods by road, with a special emphasis on the fuel tanks of articulated (tank) lorries, because in both accidents the fire (and the resulting risk of an explosion) was caused by a leak in the fuel tank. Fuel tanks are an important aspect in the prevention of fire in the transport of dangerous goods, and have so far not received the attention they deserve in policy and regulations.

In the course of the inquiry, in August 2005 a third tank lorry fire occurred on the A28 motorway in the direction of Zwolle, near 't Harde. In this accident a tank lorry filled with diesel and petrol crashed into a lorry parked on the hard shoulder. The fuel tank of the articulated lorry was damaged, and the fuel leaking out of it caught fire. The fire spread under the trailer, aided by fuel residues in the filing openings of the tank on the trailer. The drivers of the tank lorry and the lorry parked on the shoulder were slightly injured and had a lucky escape. The fire department decided to take an offensive approach because initially it feared, among other things, that a private car with the driver still inside had got stuck under the tank lorry or was standing in the smoke cloud generated by the fire. The motorway was closed off in both directions. Later on it appeared that the tank on the trailer had burst in three places[7].

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[7] The fire department initially suspected that one of the holes had been caused by the impact of the collision and was the place where the fire had started. However, an investigation by the Road Transport Agency of the tank on the trailer later revealed that in that particular spot the wall of the trailer had probably ruptured as a result of temperature differences and discontinuities caused by the fire. This is because the hole was located above the liquid line (which marks the transition between the liquid and the air/vapour mixture). In addition, no traces of the impact were found near the hole. As regards the other holes, it was clear from the start that they could not have been caused by the impact.

1.2 RESEARCH QUESTIONS

During the investigation an attempt was made to answer questions concerning:

1. the actions taken by the fire department in fighting tank lorry fires
2. the risks associated with the transport of dangerous goods by road (for emergency services workers, road users and the surrounding area)
3. the vulnerability of fuel tanks as a specific risk factor.

Sub 1
As regards the actions taken by the fire department in fighting tank lorry fires, the following questions were formulated:

- What are the factors that determine whether the fire department takes an offensive or defensive approach to tackle a major tank lorry fire?
- Is it possible to carefully weigh the risks in the event of a tank lorry fire?
- How can the risk assessment and the supply of information to support that assessment in the event of a tank lorry fire be improved?

Sub 2
The research questions about the risk associated with the transport of dangerous goods by road are as follows:

- What is known about the risks (of accidents) associated with the transport of dangerous goods by road (in tank lorries) and the related safety policy?
- What are the prospects in relation to the risk level? Is that level expected to increase or decrease?

Sub 3
The following research questions concern the vulnerability of fuel tanks:

- How vulnerable are the fuel tanks of trailers in the event of an accident?
- What are the potential consequences?
- What is the anticipated trend regarding the chance and consequences of leaks in fuel tanks?
- Are there any measures that might reduce the risk and consequences of damage to fuel tanks?

1.3 PARTIES INVOLVED AND THEIR RESPONSIBILITIES

The most important parties involved in this connection are:

- the Ministry of Transport, Public Works and Water Management, with:
  - the Directorate-General for Civil Aviation and Freight Transport (DGTL) being responsible for policy development and (further) regulations concerning the Carriage of Dangerous Goods Act (*Wet vervoer gevaarlijke stoffen*);
  - the Transport, Public Works and Water Management Inspectorate (IVW) being responsible for compliance with laws and regulations on the transport of dangerous goods
- the Ministry of the Interior and Kingdom Relations, which is responsible for policy development, (further) regulations and supervision in connection with disaster and accident relief operations involving the transport of dangerous goods
- the Ministry of Housing, Spatial Planning and the Environment, which acts as the policy coordinator and supervisor in the field of external safety
- the municipalities, which bear direct administrative and operational responsibility for the development and implementation of disaster and accident relief plans
- the fire department, which, under the auspices of the mayor, acts as the operational service in the response to tank lorry fires
- the Netherlands institute for Physical Safety (Nibra), which is responsible for the training of fire fighters
- drivers, carriers and producers of dangerous goods, who are responsible for the safe transport of those substances
- the Road Transport Agency (RDW), which is responsible for the testing and admission to the Dutch and European markets of vehicles used for the transport of dangerous goods on the basis of technical regulations.

We refer to Appendix 2 for further details about these and other parties involved and their respective responsibilities in (the response to accidents during) the transport of dangerous goods.

1.4 JUSTIFICATION AND SCOPE OF THE INVESTIGATION

The task of the Dutch Safety Board is to investigate accidents and make recommendations to prevent future accidents and/or reduce their consequences. This is also the purpose of the present study, which the Safety Board has carried out in the hope to be able to contribute to further improvements in the safety of the transport of dangerous goods by road.

The Safety Board performed the investigation in the form of a thematic study. For that reason, the incidents discussed have been subjected only to a partial analysis. In order to generate real added value, the Safety Board decided to limit the scope of the investigation to the following components:

- The assessment of risks and the decisions taken by the fire department when fighting tank lorry fires.
- The risks of (accidents associated with) the transport of dangerous goods and the related safety policy.
- The vulnerability of fuel tanks, the potential consequences and remedial measures.

According to the Safety Board, so far these topics have not received the attention that they deserve in the current policy and regulations for the transport of dangerous goods. See Appendix 3 for a more detailed justification of the present investigation.

The scope of the inquiry was further defined by the nature of the accidents under review. The tank lorries concerned were carrying flammable substances and liquefied gases. This is why the discussion of tank lorry fires in this report is limited to these categories of substances. However, some of the study findings are also relevant to other categories of dangerous goods and indeed to the transportation of goods by road in general. Appendix 4 presents a list of other categories of substances and loads – and the potential consequences of transport-related accidents – to which the findings apply (in part).

1.5 READING GUIDE

The abbreviations and concepts used in this report are explained in the Glossary. Chapter 2 discusses the general assessment framework, including a summary of existing relevant laws and regulations on the transport of dangerous goods and on relief operations for accidents involving such substances. Chapter 3 deals with the assessment process for the fire department in responding to accidents involving dangerous goods in general, and tank lorry fires in particular. This includes an analysis of the factors that determine the choice for offensive or defensive action, and a discussion of the extent to which a careful assessment of the risks involved is at all possible. In Chapter 4 that decision is put in a broader perspective. This chapter discusses the policy-related approach to the risks for the local neighbourhood, and the extent of the insight into the actual situation as regards the transport of dangerous goods and the associated incidents and accidents. Chapter 4 also includes an analysis of the vulnerability of fuel tanks in lorries. Chapter 5 presents a number of conclusions and provides answers to the research questions. Chapter 6, finally, presents the relevant recommendations.

2 ASSESSMENT FRAMEWORK

The assessment framework is the framework within which assessments are carried out and has three constituent parts, namely:

- a description of the current laws and regulations in the relevant sector in which the event occurred
- a description of supplementary standards, guidelines and views from the industry itself, and
- a description of the Safety Board's expectations, the general assessment framework for safety management, and the implementation in practice of the principle of own responsibility.

The first two parts of the assessment framework are sector-specific, with their content relating to the type of event. The third part is a general section that describes the Safety Board's expectations in respect of the way in which the stakeholders implement their own responsibility for safety in practice. The three parts will now be gone into in more detail.

2.1 LAWS AND REGULATIONS

This section provides a description of the laws and regulations relating to:

- the transport of dangerous goods
- the relief effort for accidents that involve dangerous goods.

2.1.1 Transport of dangerous goods

WVGS - Carriage of Dangerous Goods Act
The Netherlands Carriage of Dangerous Goods Act (Wet *vervoer gevaarlijke stoffen*, WVGS) came into force on 1 August 1996. The WVGS is a framework Act that regulates responsibilities and sets general requirements. The detailed requirements, such as packaging requirements including for substances, are set out in three ministerial regulations:

- one for road transportation (the VLG)
- one for transportation by rail (the VSG), and
- one for transportation by inland waterways (the VBG).

Only the first of these is relevant for this report.

Regulation of the overland transport of dangerous goods
The VLG regulation pertaining to the overland transport of dangerous goods regulates the implementation of EC Directive 94/55/EC relating to the transport of dangerous goods by road, and also adds supplementary provisions at a national level. EC Directive 94/55/EC incorporates the schedules from the ADR treaty on the international transportation of dangerous goods by road. 'ADR' stands for European Agreement concerning the Carriage of Dangerous Goods by Road. This treaty was signed at a meeting of the United Nations Economic Commission for Europe (UNECE) in Geneva, Switzerland on 30 September 1957 and came into force on 29 January 1968. Since then, 39 countries have signed up to the treaty, including the Netherlands. The European Union implemented the ADR in Directive 94/55/EC dated 21 November 1994. The ADR is updated every two years to bring it into line with the latest thinking on safety.

The VLG incorporates requirements that apply to all vehicles used in the transport of dangerous goods. In the case of certain categories of substances, including explosives and flammable liquids, supplementary structural requirements have been set for electrical installation, fire safety, the linking mechanism for trailers, and fire prevention. In addition, there are supplementary requirements specifically for vehicles in respect of the transport of packed dangerous goods, bulk transportation and for substances that are transported at specific temperatures. Finally, there are supplementary requirements for the transport of dangerous goods in tanks and tank lorries. These concern both the tank itself (including on the use of the tank, fill factor, wall thickness, filling openings, pressure relief valves) and the tank lorry (including on stability, rear protection, heating and electrical equipment).

In addition to requirements set for vehicles, the VLG also sets out the client's responsibilities (including organising the classification and authorisation of the dangerous goods to be transported in accordance with the ADR, providing correct information and documentation for the carrier, and suitable packaging) and those of the carrier (including checking the authorisation in accordance with the ADR, checking that vehicles have no damage or defects, and have valid certification), as well as setting out the required training standard for the drivers transporting dangerous goods. In addition, any business involved in the transport of dangerous goods and/or related activities must appoint a safety advisor. This safety advisor must concentrate on the prevention of safety risks, for example by monitoring compliance with the rules, making safety recommendations and reporting annually to the management. The safety advisor is also expected to investigate and report on accidents and incidents.

2.1.2 Relief effort for accidents involving dangerous goods

1985 Fire Services Act
The Netherlands Fire Services Act (*Brandweerwet*) regulates the organisation of the fire fighting services. In accordance with Section 1 of this Act, each municipality must have its own fire department, with the Municipal Executive regulating the organisation, management and duties of the municipal fire department and also being responsible for the prevention, limiting and fighting of fire, fire risks and other risks to people and animals. In Section 3, the Act assigns the municipalities to particular regions. Section 4 lays down the responsibilities of the regional fire department, which include drafting the organisational and management plan, preparing the coordination and operational direction of the relief effort for disasters and major accidents, setting up the organisation needed to enable the fire department to take action in exceptional circumstances, and advising fellow Municipal Executives on fire prevention, fire fighting and limiting fires in certain properties, and on the purchasing of equipment.

Disasters and Major Accidents Act
The Netherlands Disasters and Major Accidents Act (*Wet rampen en zware ongevallen*, WRZO) sets the responsibilities for the relief effort for disasters and major accidents and for the preparation for such work. Section 11 of this Act stipulates that the mayor has supreme authority in the event of a disaster, major accident or serious risk of one arising. The person in charge of the fire department is charged with the operational direction of the relief effort for a disaster or major accident, unless the mayor makes other provision for this. Section 2 of the Act states that the Municipal Executive is charged with the preparation of the relief effort for disasters and major accidents within its municipality, this to include in particular exercises and the organisation of suitable arrangements. To this end, and in accordance with Section 3, the Municipal Executive must draw up a disaster relief plan at least once every four years. This disaster relief plan includes such items as an overview of risks, the organisation, responsibilities, duties and powers within the framework of the disaster relief effort, and the policy on drafting and agreeing relief plans. At least once every four years, the mayor must approve relief effort plans for disasters and major accidents as laid down in the disaster relief plan. This disaster relief plan contains all measures to be taken in connection with a disaster or major accident.

Act to improve the quality of the disaster relief effort
This Act (*Wet kwaliteitsbevordering rampenbestrijding*) regulates efforts to improve the quality of disaster relief efforts by promoting ‘territorial congruence’ (i.e. by setting up safety regions), improving the systematic approach and tightening provincial supervision.

2.2 SUPPLEMENTARY STANDARDS AND GUIDELINES

This section describes the supplementary standards and guidelines applicable, which relate to:
- the transport of dangerous goods, and to
- the relief effort for accidents that involve dangerous goods.

2.2.1 Transport of dangerous goods

Policy document on the transportation of dangerous goods
The NVGS (Policy Memorandum on the Transport of Dangerous goods), which was adopted in March 2006, deals with the transport of dangerous goods by road, water, air (excluding so-called ‘external safety’ airports) and rail. The memorandum does not cover the transport of dangerous goods through pipelines. It has a two-pronged approach: first it looks at maintaining a balance between the various interests involved in transportation, spatial planning and safety, by drafting a

statutory Basic Network (‘*Basisnet*’) for the transport of dangerous goods. The second ‘prong’ is geared towards achieving permanent improvements in safety.

The Basic Network consists of a usage zone for transport plus safety zones that incorporate spatial planning restrictions. Under the NVGS, the Basic Network must also take into account the options and consequences for accident and disaster relief efforts. The primary responsibility for accident and disaster relief efforts in respect of the Basic Network lies with the municipalities. According to the Ministry of Transport, Public Works and Water Management, consultation and the setting up of the safety regions can help to ensure that the relief effort in respect of the Basic Network is coordinated at a national level. Municipalities and other stakeholders can ensure the accessibility of the routes used to transport dangerous goods and provide sufficient fire extinguishing equipment and escape routes, by taking these requirements into account from the very start of their spatial planning processes. Another action item for the Ministry is the ability of citizens to cope by themselves in the event of accidents involving dangerous goods. The Ministry undertakes to commission research on ways to improve this.

Risk Standards for the Transport of Dangerous goods
An important standard for the transport of dangerous goods is set out in the RNVGS (Policy Memorandum on Risk Standards for the Transport of Dangerous goods) dated 15 February 1996. This memorandum was a first attempt to apply a risk-based approach to the transport of dangerous goods. It also introduces definitions of such terms as individual risk[8] and group risk, in order to indicate the level of risk inherent in the transport of dangerous goods for the environment (also known as ‘external safety’). The aim of the ministerial circular *Risk Standards for the Transport of Dangerous goods* was to further clarify and implement this policy. This proved to be necessary because the RNVGS policy memorandum was not being interpreted and applied unambiguously in all cases. An evaluation of the RNVGS policy memorandum - which evaluation was not published until February 2006 - revealed that the policy memorandum had failed to assign an unambiguous legal status to the local authorities, given that:

- there was no clear allocation of administrative responsibilities or powers, and
- there was no uniformly approved calculation method.

The Minister of Transport, Public Works and Water Management is considering embedding the requirements for external safety for the transport of dangerous goods in a statutory regulation, which is why the ANKER project was initiated to look at the options for and consequences of such action[9]. In addition to the above-mentioned evaluation of the RNVGS, ANKER included an inventory of the risks inherent in the transport of dangerous goods in the context of external safety for both the current situation and for 2010, with possible solutions for these problems being looked at too.

Industry initiatives
Many chemical businesses in the Netherlands have signed up to the Responsible Care programme. This means that they will endeavour to continuously improve and publish their performance in the fields of safety, health and (in particular) the environment. In this context, in 1990 the European Chemical Industry (CEFIC) set up the so-called ICE (International Chemical Environment) programme. The purpose of the ICE programme is to prevent accidents involving dangerous goods where possible and, when such accidents do occur, to provide assistance when asked.

In addition, CEFIC, with financial assistance of the European Commission and in collaboration with the emergency services, has developed so-called ERICards (Emergency Response Intervention Cards). The ERICards provide information on the different categories of substances, including on their hazards and on the action to be taken by those emergency service workers who are the first to arrive on the scene and do not immediately have at their disposal specific, reliable information on the product involved in the accident.

[8] The current term is ‘local risk’.

[9] Source: *‘Bouwstenen voor een wettelijke verankering van het externe veiligheidsbeleid inzake het vervoer van gevaarlijke stoffen’* (Building blocks for the statutory integration of external safety policy concerning the transport of dangerous goods). Ministry of Transport, Public Works and Water Management (2006)

2.2.2 *Relief efforts for accidents that involve dangerous goods*

The HVR (Manual for the preparation of disaster relief efforts)
The action that the fire department has to take in the event of disasters and major accidents is described in the HVR manual (*Handboek Voorbereiding Rampenbestrijding*), published by the Dutch Ministry of the Interior and Kingdom Relations. Its content is based both on legislation and practical experiences. The manual defines fire department subprocesses. One subprocess that is part of the disaster relief effort – and relevant for this report – is 'actions at source and impact reduction'. Actions at source and impact reduction activities include fire fighting and measures to limit the emission of dangerous goods. This in turn comprises the following subactivities:

- analysis of the situation (source, impact zone, relevant circumstances)
- deciding on and announcement of plan of action
- planned and actual deployment
- monitoring progress made on fighting the fire.

Guidelines and rules of thumb for the fire department
There are a number of publications that cover the action to be taken by the fire department in the specific category 'accidents involving dangerous goods', including guidelines and rules of thumb (which have no legal status) that are set out in various source documents. The following table contains a brief overview.

Source document	**Guidelines and rules of thumb**
LOGS – *Leidraad Ongevalsbestrijding Gevaarlijke Stoffen* (Dangerous goods Accident Relief Guide (Nibra, 2001)	• Arrival times
Nibra training material: (i) *Onderbrandmeester Verbranding en blussing, Gevaarlijke Stoffen en Petrochemie en Tankincidenten* (Deputy Chief Fireman for combustion and fire extinguishing, dangerous goods, petrochemicals and tanker incidents) *(ii) Hoofdbrandmeester ROGS-officer (Chief Fireman* – ROGS (Regional Dangerous goods Supervision Officer) *and (iii) 'Adjunct hoofdbrandmeester repressie* (Assistant Chief Fireman – repressive action)	• Factors that determine the likelihood of a BLEVE • Impact zones
Leidraad incident management bij verkeersongevallen met gevaarlijke stoffen (Guide for incident management of traffic accidents involving dangerous goods') (Nibra, 2001)	• Impact zones
Bestrijding van ongevallen, waarbij tot vloeistof verdicht, brandbaar gas betrokken is (Relief efforts for accidents involving flammable liquefied gases), (Fire Department Inspectorate, 1985)	• Factors that determine whether repressive action is justified
Operationeel handboek ongevalsbestrijding gevaarlijke stoffen (Operational Manual for Dangerous goods Accident Relief) (NVBR (Netherlands Association for Fire Departments and Disaster Relief), 2003/2005)	• Impact zones

Table 1: Overview of relevant source documents

2.3 PRACTICAL IMPLEMENTATION OF OWN RESPONSIBILITY OF SAFETY MANAGEMENT

Safety measures for the transport of dangerous goods are largely based on national and international regulations which the relevant parties are deemed to observe. The Safety Board is aware that the various organisations involved in the transport of dangerous goods are working to update and improve these regulations. Mere compliance with these regulations offers no guarantee in itself that safety will be managed, maintained and continuously improved; to achieve this, a more substantial effort is needed that is the responsibility of the stakeholder organisations.

This is why - in addition to the laws and regulations (Section 2.1) and the supplementary sector-specific standards and guidelines (Section 2.2) - the Safety Board is incorporating a third component into the assessment framework. This third component sets out the Safety Board's expectations in respect of the way in which the stakeholders implement their own responsibility for safety and safety management in practice.

In principle, the way in which an organisation implements its own responsibility for safety in practice can be assessed in several different ways. Accordingly, there is no universal manual that can be used in all situations. This is why the Safety Board has itself selected five safety issues which indicate the factors that can - to a greater or lesser degree - play a role here. According to the Board, this decision is justified given that these safety issues are set out in a host of national and international legislative instruments and regulations and in a wide range of widely accepted and implemented standards and norms. One example is the Dutch Working Conditions Act (*Arbowet*), which contains basic principles such as having a risk inventory and evaluation system in place. The basic principles selected by the Safety Board are a further detailing of these.

Experiences gained from accidents in the past have shown that the structure of the safety management system and the way in which stakeholders implement it in practice play a crucial role in the management and maintenance of, and continuous improvements in, safety. Safety management relates to the way in which organisations implement safety in practice, in addition to their compliance with current laws and regulations. For example, this is about the way that the risks are mapped out and systematically managed. A suitable structure will have to be set up within an organisation in order to carry out this process, make it transparent, and to create options for achieving continuous improvement. This structure is called the 'safety management system'.

The Safety Board has informed the Minister of the Interior and Kingdom Relations about this by letter[10]. The following issues are considered by the Board in all its investigations.

1. Achieving demonstrable insight into safety-related risks to create a basis for the safety plan:
The starting points for achieving the required level of safety are:
- exploring the entire system, and
- listing the associated risks.

These findings are then used to determine which hazards need to be managed and which preventive and repressive measures are needed to achieve this.

2. Demonstrable and realistic safety plan:
In order to prevent and manage undesirable events, a realistic and practical safety plan (or safety policy) must be drafted and agreed. This safety plan is based on:
- relevant current laws and regulations (Section 2.1)
- applicable standards, guidelines and "best practices" from the industry, the organisation's own views and experiences, and the safety targets drawn up specifically for that organisation.

3. Implementing and enforcing the safety plan:
The safety plan is implemented and enforced, and the identified risks are managed, by:
- drawing up a description of the way in which the safety plan is implemented in practice, with attention paid to the specific objectives and including the resulting preventive and repressive measures
- a transparent, clearly-defined assignment of responsibilities relating to safety on the 'shop floor' in respect of the implementation and enforcement of safety plans and measures, which information is available to all
- clear definition of the personnel required and necessary expertise in the various roles
- a clearly-defined and active centralised coordination of safety activities
- realistic exercises and testing of the safety plan.

4. Tightening up the safety plan:
The safety plan must be continually assessed and tightened up, based on:
- a safety-related (risk) assessment carried out periodically and after each change in the basic principles, and on observations, inspections and audits (proactive approach)
- a system of monitoring, investigating and expert analysis of all aspects of near accidents and actual accidents (reactive approach).

The above are then used as a basis for evaluations and to uncover areas of potential improvement, which subsequently are actively focused on.

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[10] dated 17 November 2005, reference OVV2005-010999

5. Management guidance, involvement and communication:

The management of the stakeholders/organisation must:

- ensure internally that expectations regarding the safety objectives are clearly defined and realistic, and must ensure that the 'shop floor' is receptive to the idea of making continuous improvements to safety
- issue clear external communications regarding the general procedures, the way of assessing them, procedures to be used in the event of deviations etc., based on clearly defined and documented arrangements with the local neighbourhood.

3 FIGHTING TANK LORRY FIRES – ACTION TAKEN BY THE FIRE DEPARTMENT

This section describes (the organisation of) the fire department's accident relief process for tank lorry fires that involve dangerous goods. In addition, we will look at the factors that play a role in practice in the risk assessment that the fire department must perform. On the basis of its risk assessment, the fire department decides whether to first concentrate on fighting the fire (i.e. taking offensive action) or wait at a distance for a possible explosion and concentrate on evacuating the neighbourhood (i.e. taking defensive action).

The aim of this chapter is to answer the following research questions:

- What determines whether the fire department takes offensive or defensive action for a major tank lorry fire?
- Is it possible to make a balanced risk assessment in the case of a tank lorry fire?
- How can the risk assessment for the accident relief effort for a tank lorry fire and the related information provision be improved?

3.1 ORGANISATION AND RELIEF PROCESS FOR ACCIDENTS INVOLVING DANGEROUS GOODS

The (regional) organisation of the fire fighting services in the response to accidents involving dangerous goods, and the preparatory work for this, are described in the LOGS (*Leidraad Ongevalsbestrijding Gevaarlijke Stoffen* /Dangerous goods Accident Relief Guide). This Guide was drawn up by the Netherlands Institute for Physical Safety (Nibra) at the request of the Fire Department Directorate of the Ministry for the Interior and Kingdom Relations. The Guide gives details of the quantitative and qualitative resources that the emergency services can be expected to have at their disposal in the case of accidents involving dangerous goods, including tank lorry fires.

The terminology in this chapter is based on the terms used in the Guide and by the fire department itself. In some cases, these terms deviate from those used within other domains. In this context, the term 'accident' relates to an event involving dangerous goods where there is a risk of a hazard and/or nuisance to the local neighbourhood (for example from a leaking tank or tank lorry fire), and does not relate specifically to a traffic accident (although this is one of the potential causes of such an event). Check the Glossary in this report for explanations of the terms and abbreviations used.

The Guide makes an important distinction between 'actions at source' on the one hand and 'impact reduction' on the other (see table below). The term 'actions at source' is deemed to mean the actions that need to be taken at and around the site of the accident which serve to stabilise the accident situation, e.g. rescuing third parties, stopping the leak or bringing the fire under control. 'Impact reduction' is deemed to mean the actions that need to be taken to limit the effects of the accident outside its immediate vicinity, e.g. evacuating the local neighbourhood. Providing information, sounding the alarm and evacuating the area are multi-disciplinary activities carried out in collaboration with the municipal services and the police. This investigation only looks at the 'actions at source' aspect.

	Actions at source	**Impact reduction**
Basic organisational principle	Local responsibility with regional support	Regional responsibility with local support
Operational characteristics	Hazard assessment Rescue operations Stabilising the situation Measurements Personnel protection advice Coordination Decontamination	Hazard assessment Investigation/measuring Warning Large-scale decontamination

Table 2: Difference between actions at source and impact reduction (Source: LOGS)

The illustration below is an organisational chart that outlines the way in which the fire department's relief effort is organised in the event of an accident involving dangerous goods. Further down, the tasks and responsibilities are described for each section.

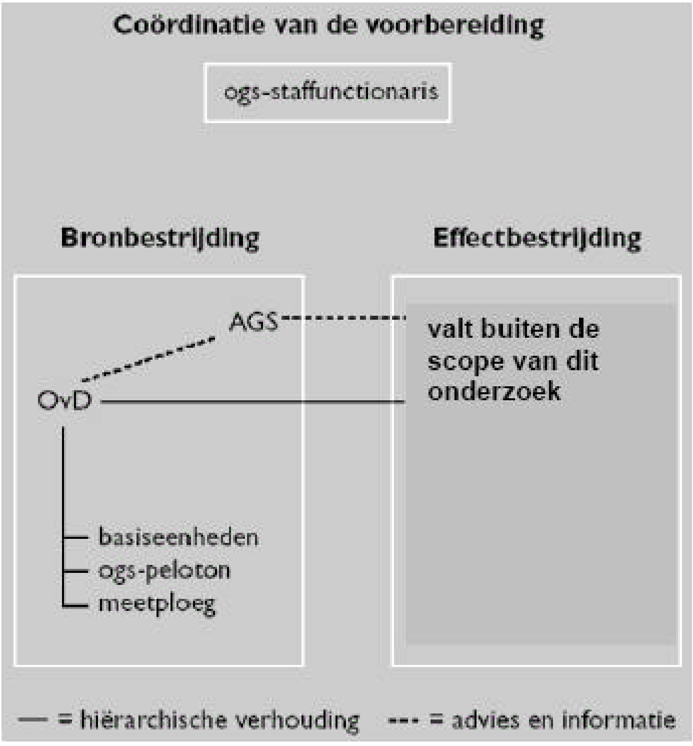

Illustration 1: Organisational chart of regional OGS (Dangerous goods Accident Relief) organisation (based on the LOGS)

Legend:
Coördinatie van de voorbereiding = Coordination of preparations
OGS-staffunctionaris = Dangerous goods Accident Relief staff officer
Bronbestrijding = Actions at source
Effectbestrijding = Impact reduction
AGS = Dangerous goods Advisor
OvD ('Officier van Dienst') = Specialist Officer of the fire department
basiseenheden = Basic units
OGS peloton = OGS Squad
meetploeg = Measuring team
valt buiten de scope van dit onderzoek = Not covered by this investigation
hiërarchische verhouding = Hierarchical relationship
advies en information = Advice and information

The first step in the accident relief process is the reporting of an accident involving dangerous goods. The regional emergency centre is then notified, whereupon the first fire department units are dispatched to the scene of the accident. Once the alarm has been sounded, the process of providing accident relief is basically as follows:

1. Arrival of basic unit at scene of accident and examination thereof (including possible commencement of rescue operations).
2. Arrival of the Specialist Officer of the fire department, who:
   a. assesses the situation and discuss it with the squad leader of the basic unit
   b. carries out a risk assessment, possibly after consulting with the AGS (Dangerous goods Advisor) / ROGS (Regional Dangerous goods Supervision Officer), and
   c. decides whether offensive or defensive action is to be taken.
3. Action taken:
   a. first of all: fight the fire (offensive action).
   b. or possibly: first wait to see if there is an explosion and evacuate the neighbourhood (defensive action).

Basic units
Once the fire department has been notified, the procedure for an accident involving dangerous goods is that a basic unit arrives at the accident site. There are guidelines for the time within which

the first fire department unit should arrive at the site, which may vary according to the actual location[11]. However, no standard arrival times are set for motorways. Accordingly, the speed with which the first basic units can reach the accident site will depend on (i) the distance from the fire station to the accident site and (ii) the accident site's accessibility (traffic situation, availability of hard shoulder etc.). In some regions, it has been decided for this reason to approach motorway incidents from two directions, in order to reach the accident site as soon as possible. At junctions and interchanges this means that on occasion four fire department units will turn out.

The first fire department unit to arrive will be under the command of a commanding officer. This officer is responsible for an initial assessment of the hazard, which can then be used to decide whether to examine the site or make an urgent rescue. The Ministry of the Interior stipulates that for this work they must be issued with fire fighting clothing, two to four chemical-resistant suits, and other items of equipment. They may also have informative material (ERICards) on them. Initially, defensive tactics must be deployed until it is possible to obtain advice from the Specialist Officer and/or the Dangerous goods Advisor, the latter advising on the specific aspects of dangerous goods in relation to the accident relief effort.

Specialist Officer of the fire department

The Specialist officer of the fire department is the operational commander of the fire department's relief effort at the site of the accident. He initiates the Dangerous goods Accident Relief procedure that sets out the general procedures and safety issues. Normally, the Specialist Officer will arrive soon after the basic unit arrives. After his arrival he will assess the hazard, if possible and necessary with the help of specialist advice (given by phone) by the Dangerous goods Advisor, and use this information to decide on the deployment strategy. The factors that play a role in the decision whether to take defensive or offensive action are discussed in the next section. The Specialist Officer also takes the initiative in coordinating the multidisciplinary relief effort at the site of the accident. In general, this coordination will take place in the form of a team discussion between the commanders of the various departments, which team is called the CTPI (Incident Site Coordination Team).

The Regional Dangerous goods Supervision Officer / Dangerous goods Advisor

In the event of an accident involving dangerous goods, the Regional Dangerous goods Supervision Officer or the Dangerous goods Advisor will advise the Specialist Officer. A Regional Officer or Advisor must be on call 24 hours a day in order to be able to give advice (by phone) to the local fire department. The standard arrival time for the Dangerous goods Advisor is 30 minutes. The Guide also states that in regions with a low risk profile it may be decided to appoint a supra-regional Dangerous goods Advisor instead, for whom there is a target arrival time of 60 minutes. Initial support for the Specialist Officer during the first 30 minutes can then be provided by an 'OGS-qualified' officer (ROGS). The Regional Officer and the Advisor have the following duties:

- hazard assessment
- advice on actions at source to local fire department
- acting as intermediary between local fire department and external (operational) expert.

Initially, the Dangerous goods Advisor or Regional Dangerous goods Officer will advise the Specialist Officer by phone on the relief effort for the accident involving dangerous goods. After all, the Specialist Officer cannot be expected to possess this specialist knowledge about the dangerous good involved. The Advisor or the Regional Officer can also advise on ways of protecting and decontaminating emergency services workers and members of the public exposed to the hazard.

Training to become a Dangerous goods Advisor demands a different level of knowledge than that required to become a Regional Dangerous goods Officer. The intake criterion for the Advisor training course is defined as follows: having an HBO (Dutch Higher Vocational Education) qualification in chemistry or physics to ready knowledge standard. A course in fire fighting or background in this field is not a requirement for following this course and passing it[12]. The Regional Dangerous Goods Officer must have a HBM (Chief Fireman) diploma in repression tactics / Specialist Officer) to level 'VWO (pre-university education) exact sciences' and an optional module in Dangerous goods Accident Relief to the above HBM level. In order to maintain quality, the

[11] These standards are guideline values, not standards required by law, and may vary depending on the type of district. In urban areas the standard is 8 minutes, but this may increase to 15 minutes in rural areas.

[12] Source: Information on the Dangerous goods Advisor study course on the website of the NIFV *Brandweeracademie* (NIFV/Nibra fire department academy) http://www.nifv.nl/web/show/id=48089

Dangerous goods Accident Relief Guide stipulates that at least twice a year the Regional Officer must take part in a national (two-day) exercise for Advisors, must visit the regional properties/objects at risk and must participate in large-scale regional exercises.

Yet more forms of (remote) support are available too, including the LIOGS (National Information Centre for Accidents Involving Dangerous goods) and the BOT-mi (Policy Support Team for Environmental Incidents) (see Appendix 2 for a description of these organisations).

Regional Dangerous goods Accident Relief (OGS) Squad
In the event of an actual or potential risk of release of very poisonous or corrosive substances, it may be necessary to operate in a protective respiratory suit. In these cases, the regional Dangerous goods Accident Relief (OGS) Squad is called in. This squad has at its disposal:

- respiratory suit teams
- a decontamination container, and a
- swap body or assistance vehicle for use in accidents involving dangerous goods.

Fire department respiratory suit teams will mainly be deployed for general impact reduction work, such as the closing of cut-off valves or connecting up hosepipe connections for the pumping over of dangerous goods. These teams are not involved in the actual rescue work, as it takes too long for them to get to the site and be operational. When fighting a tank lorry fire, the Squad will not be deployed; instead, a standard Fire Fighting Squad bolstered by a Dangerous goods Advisor and water tanks will be used.

3.2 PRACTICAL FACTORS THAT INFLUENCE THE DECISION TO TAKE OFFENSIVE OR DEFENSIVE ACTION

The decision to take defensive or offensive action depends on the assessment of the situation. The study and exercise materials for the fire department on tackling accidents involving dangerous goods (including tank lorry fires) describe the information that the Specialist Officer must use to assess the situation and weigh up the options of taking offensive and defensive action.

In the case of a tank lorry fire, the fire department must assess the situation by determining:

1. which dangerous good is involved
2. the nature, size and expected development of the tank lorry fire, and
3. the nature and size of the area under threat (i.e. persons involved in the accident, other road users, emergency services workers and local residents).

In the following sections, these three factors will be looked at one by one. For each factor we will state which (theoretical) options the fire department has to obtain the information it needs. In addition, we will use two real-life examples of tank lorry fires (detailed in Appendix 1) to look at the role these factors played in the fire department's decision-making process. At the end of each section, the Safety Board's findings are presented.

3.2.1 Factor 1: Identification of the substance involved

Sources of information

Together with the type of accident and local neighbourhood, it is the properties of the dangerous good involved that largely determine the safety risk for the surrounding area and the likelihood of an explosion. This is why it is important to find out as quickly as possible what substance is involved in the accident. In principle, the fire department can call on the following sources to find out the nature and properties of the substance:

a. the orange plate and warning sticker on the vehicle
b. the transport document and the Tremcard (Transport Emergency card) in the driver's possession
c. the driver, transportation company, sender, shipping company and/or recipient
d. the Regional Dangerous goods Supervision Officer or Dangerous goods Advisor (see Section 3.1).

In addition, 'remote' information sources such as databases and experts from the LIOGS and BOT-mi (see above) can be consulted.

a. Orange plate and warning sticker

The VLG regulation stipulates that the outside of a vehicle must bear clear information on the dangerous goods that the vehicle is transporting. The chosen means of doing this is the orange plate (see illustration below). This plate bears two numbers. A standard international four-digit number - the so-called UN number[13] - is used to identify the substance. A further stipulation is that each tank must bear a so-called 'GEVI' (hazard identification) number. This number indicates the hazards associated with the substance in question. In addition, each vehicle must carry a warning sticker bearing a symbolic illustration of the hazards associated with the dangerous good in question.

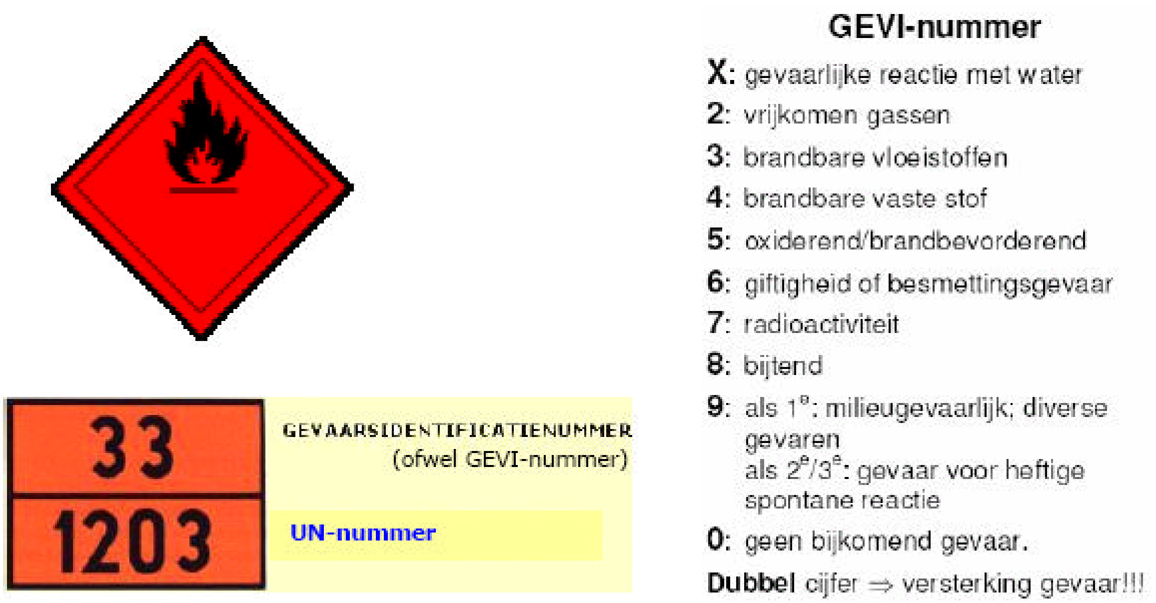

Illustration 2: Example of an orange plate (bottom left), warning sticker (top left) and explanation of the Hazard Identification (GEVI) numbering system (right). This illustration depicts an orange plate for the highly flammable liquid petrol (Hazard Identification number 33/UN number 1203) and a warning sticker denoting a flammable liquid.

Legend:
Gevaarsidentificatienummer (ofwel GEVI-nummer) = Hazard Identification number
UN-nummer = UN number
X = dangerous reaction with water
2 = release of gases
3 = flammable liquids
4 = flammable solid substance
5 = oxidising/fire-inducing
6 = toxicity or risk of infection
7 = radioactivity
8 = corrosive
9 = as 1st digit: environmentally hazardous - range of hazards
= as 2nd/3rd digit: danger of violent spontaneous reaction
0 = no additional risk
Dubbel cijfer => versterking gevaar = **Double** digit => hazard intensifies!

When a tank lorry is transporting multiple substances (in different compartments), the rules of international transport state that the lorry only has to carry an orange plate on its front and rear sides. In this case, these will not contain any substance information (UN numbers), but the side of

[13] Approx. 3,400 chemical substances have been assigned a so-called 'UN number' by an expert committee of the United Nations. In addition, a unique Chemical Abstracts Service registry number (CAS number) has been assigned to about 26 million substances. The difference between the two is that the UN number can refer to a group of related substances, each of which has its own CAS number.

the tank lorry will state the substance in each compartment. Note that if the tank lorry tips over, this data can only be read on the top side of the lorry, which means the fire department will not be able to see which substances the tank lorry is carrying.

b. Transport document and Tremcard

The VLG stipulates that when transporting dangerous goods the driver must carry the transport document and Tremcard on his person. The transport document contains the official name of the substance including the UN number and the cargo quantity (volume) or gross weight in kilograms of the substance (i.e., it is similar to the waybill for the transportation of other goods). Since 1 July 2001, the transport documentation also classifies cargo into packaging/container categories I, II or III, according to the level of the hazard. This is then used to set requirements for the packaging or, in the case of tank lorries, for the tank (such as calculated pressure).

The Tremcard is intended for the driver and contains all important data on the substance, namely:

- the hazard category
- the UN number
- the name of the substance
- protective measures (if any)
- the measures to be taken in the case of disasters
- first aid instructions, and
- the phone number of the manufacturer or sender (consignor).

Systems for passing information on to emergency services

Within the road traffic system and other transport systems there are systems available or in development that should make it possible to make information on vehicles and loads available to the emergency services quickly. The shipping industry has had its IVS90 information and tracking system for ten years now. The information contained therein includes data on the ship, cargo, journey and number of persons on board. *Rijkswaterstaat* (the Dutch Directorate-General for Public Works and Water Management) asks shipmasters to provide this information when they use one of the major Dutch waterways. The system is designed to streamline shipping traffic and also assists in the event of disasters and accidents. Since the data on the ship, cargo, journey and number of persons on board is available quickly to the emergency services, they can use it to help them decide on the action they are going to take. The system is currently being further modernised with the help of GPS technology, which will mean not only that the position of a vessel or vehicle can be determined but also that specific information can be passed on to government departments.

The Dutch Ministry of Transport, Public Works and Water Management has launched a joint research project with the road transport industry to look at options for the introduction of a digital waybill[14] and a 'tracking & tracing system for the transportation of dangerous goods by road'[15], for the enforcement of working time rules, the routing of dangerous goods cargoes, and for information provision to the emergency services. An eCall system (part of the European eSafety programme) is being developed for (luxury) cars. This system will make it possible for specific data to be sent automatically to an emergency centre after an incident, such information to include type of vehicle, features of the incident, whether the vehicle is lying upside down, seriousness of the impact etc. This system can be expanded to provide facilities for the emergency services so that they can find out the necessary information when at the accident site.

[14] Ministry of Transport, Public Works and Water Management (2004), '*Minder lastig voor bedrijven: Programme reductie administratieve lasten met 25% in the periode 2003-2006'* ('Less inconvenience for businesses: programme to reduce the administrative burden by 25% during the period 2003-2006'). Ministry's own publication, The Hague.

[15] Ministry of Transport, Public Works and Water Management, '*Nota mobiliteit'* (Mobility Memorandum) (2004) and Ministry of Transport, Public Works and Water Management (2006), '*Nota vervoer gevaarlijke stoffen'* (Transport of Dangerous goods Memorandum) (2006)

c. The driver, transportation company, sender, shipper and/or recipient involved

In the case of an accident during the road transportation of dangerous goods, the driver, the transportation company and/or the shipper can be important sources of information for the emergency services. Apart from handing over the waybill papers and providing information about the substance, the driver can provide the fire department with additional information about the load (including any compartmentalisation) and fill factor of the tank lorry, the presence of any safety devices, and about the structure of and materials used in the tank. The driver cannot always be expected to provide the necessary information after an accident, especially if he was injured. Another possibility is that the driver may be well but unavailable to the emergency services (for example if the neighbourhood has been evacuated). The safety of the driver, especially in relation to actual or potential cargo leaks, is an important issue too.

The transportation company can verify the data on the substance and will also know the identity of the sender and/or shipper of the cargo. The sender/shipper can provide specific product information (for example in the case of mixtures and combined loads) and may be able to advise the relief effort. For example, the European chemical industry has helped to develop the so-called 'ERICards' (Emergency Response Information Cards).

One factor that may limit the provision of information to the fire department is the accessibility of the transportation company, sender and shipper when it comes to obtaining expert information and advice. For instance, companies may not be accessible by phone outside office hours and an expert may not be available at that company all the time. The question is also whether the fire department actually knows about this information source and/or whether it uses it in practice. For example, the LOGS Guide does provide details of government assistance for the accident relief effort, but there is no mention of possible assistance from the industry.

Ewijk and Eindhoven

In the case of the two accidents in Eindhoven and Ewijk, it could not be immediately ascertained which substance was involved. The investigation of these two events revealed that the above sources of information were not available to the fire department.

In the case of the Ewijk event, the relevant documents were left behind in the tank lorry cabin as the driver forgot to take them with him whilst he got to safety. Whilst the accident relief effort was underway, the driver was located about 200 m to the south-west of the accident site. The emergency services workers had their base about 300 m north-east of the accident site. This was one reason why for some time the fire department was proceeding on the basis of an incorrect substance number. This incorrect substance number had been communicated by a passer-by and was difficult to check at the site, because the orange plates were not visible due to the huge amount of smoke. The properties of the substance identified by the incorrect number (namely UN-1171, i.e. ethylene glycol monoethyl ether) differ from the properties of the actual load, which was ethyl acetate (UN-1173). This incorrect information led to the fire department concluding that it was dealing with a flammable substance with a relatively high boiling point of 135 ºC. However, the actual load (ethyl acetate) had a much lower boiling point (77 ºC) and was classified as highly flammable due to its relatively low flashpoint. There are differences between the two substances in respect of their toxicity too: the substance incorrectly believed to be in the tank was somewhat more toxic than the actual cargo. Luckily, the action taken in Ewijk on the basis of the incorrect substance number had no serious consequences. However, a single different digit in this number sometimes indicates a substance that has completely different properties. In other words, in order to ensure correct and safe deployment of relief operations, it is very important for the fire department immediately to have access to the correct substance number.

As regards the two Regional Dangerous goods Relief Officers - who in both cases arrived at the sites after about half an hour - the danger was already considerable by the time they arrived. In both cases, the fire department had already decided on its initial strategy. The Regional Officers had already been able to advise the fire department by phone on that strategy. In the case of Ewijk, moreover, the Specialist Officer of the fire department in charge of the operation only received important information at a relatively late stage.

In the Eindhoven case, the cabin was burnt out, during which fire the driver died. This meant that the driver and the transport documents could play no role in identifying the substance involved. According to the fire department, the presence of isobutane or other hydrocarbon gases such as

LPG is in principle easily determined by the shape of the tank. A quick examination of the orange plate confirmed that it was indeed isobutane.

Findings
The Board has established that for the tank lorry fires investigated, the process to identify the dangerous good involved did not proceed optimally. The fire department could not get hold of the transport documents, and in the Ewijk case the orange plates could hardly be glimpsed, nor could the driver give the fire department any information. This meant that the fire department was in fact acting on the basis of incorrect information regarding the substance involved. The driver can take action himself after an accident to get in touch with the fire department[16] to provide useful information. The emergency services who are at the scene must also bear in mind the important role that the driver can play in giving important information to the fire department, especially if the area around the accident site has been sealed off. The carrier, shipper and sender can also provide useful information; the limiting factor here is the accessibility to these companies and the level of expertise that the emergency services can call on at short notice. There are systems available and in development that can optimise information provision to the emergency services in the case of accidents involving dangerous goods.

3.2.2 Factor 2: Nature, size and development of the tank lorry fire

Nature and size of the fire
In the case of small, brief fires and fires where the cargo tank is not directly irradiated, the likelihood that the tank will rupture is not great. This means that these fires can be extinguished relatively easily and without too much risk. However, in the case of major fires and/or fires where the cargo tank is irradiated, the temperature can rise so much that the tank wall bursts.

Development of the fire
A major fire in a tank lorry carrying dangerous goods can lead to a dangerous situation for emergency services workers, road users and the local neighbourhood. Various different scenarios are possible here[17]: for instance, the transportation of flammable liquids in an atmospheric tank can lead to a pool fire in which the burning pool spreads out. There are examples of pool fires that caused serious accidents when petrol flowed into buildings. If a flammable liquid or gas is being transported in a pressurised tank, then a rapid so-called ‘flash off’ (comparable to a jet of flame) of a fraction in the substance can occur. In the case of tank lorry fires in tunnels, there are other potential scenarios, as flammable gases and vapours of flammable liquids can accumulate there before igniting, creating a gas cloud explosion[18]. A BLEVE[19] can occur when a liquefied gas suddenly expands explosively into a multiple of its original volume (in the case of LPG, this is twenty times the volume of the liquid). This so-called physical explosion unleashes considerable forces.

In addition to the nature and size of the fire that the fire department initially has to deal with, the following factors play an important role in the further development of a tank lorry fire:

a. tank properties and internal pressure
b. the intensity, duration and location of the heat source in relation to the fill factor
c. the options for extinguishing or cooling.

a. Tank properties and internal pressure
We can distinguish between atmospheric and pressure tanks by means of a number of structural and design details. For instance, pressure tanks for the transport of compressed liquefied gases are always cylindrical, whereas atmospheric tanks carrying fossil fuels are usually suitcase-shaped. However, not all cylindrical tanks are pressure tanks, as cylindrical tanks are also used to carry

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[16] Depending on the nature of the accident and the associated physical and mental state of the driver, there are naturally limits to the information that you can expect from a driver after an accident.
[17] For a list of possible consequences of a fire in or near to a vehicle that is transporting dangerous goods, see Appendix 4.
[18] TNO (Netherlands Institute for Applied Scientific Research (2003), *Toepasbaarheid fysische effectmodellen t.b.v. ongevalsscenario’s in tunnels* (Applicability of physical effect models to accident scenarios in tunnels) (commissioned by the Centre for Tunnel Safety at the Civil Engineering Department of the Dutch Directorate-General for Public Works and Water Management)
[19] BLEVE = Boiling Liquid Expanding Vapour Explosion. For further information, see Appendix 5.

fuels. Apart from the shape, there are other external characteristics that can be used to identify the type of tank and whether safety devices have been fitted. The safety devices may indicate the speed with which a scenario can develop (see also paragraph c below: 'Intensity, duration and location of the heat irradiation').

You need the relevant knowledge and experience to identify the type of tank involved in the accident. The study and exercise materials on relief efforts for accidents involving dangerous goods deal with this to a limited extent, on top of which each fire department unit will only have had experience of dealing with a few such accidents. This is why all fire departments need to learn from the experiences gained from the fighting of other tank lorry fires at home and abroad. Here too there is an option for developing tools for the fire department (e.g. by using a flowchart with photos) so that when at the accident site fire fighters can be sufficiently certain that they have identified the right type of tank and the safety devices present (if any). It is important to keep this information up-to-date, given the continual developments in this field.

If the fire causes the tank wall to rupture, this can lead to a pool fire, jet of flame, gas cloud explosion or BLEVE (see subsection above: accident scenarios for tank lorry fires). The tank wall will burst when the maximum permissible pressure is exceeded and/or the strength of the tank wall decreases (including localised weakening) due to excessive temperatures. In other words, the likelihood that the tank wall will rupture depends on the pressure in the tank and the strength of the tank wall. The strength of the tank wall may be lower than the original design strength, due to it being damaged by the fire and/or other factors before, during or after the accident.

In practice, it is difficult to establish the pressure in the tank. Not all tanks have fitted manometers (pressure gauges), and even if one has been fitted, it is very unlikely that fire fighters will be able to get close enough to read it. In practice, the fire department attaches great importance to the question whether any pressure relief valve has been heard to blow off. Interviews revealed that some fire fighters were not aware that it is *not* obligatory to fit a pressure relief valve under international guidelines and thus they are not always fitted to tank lorries. In other words, just because fire fighters do not hear a valve blow off gas, they may assume that the pressure in the tank is lower than the valve's design pressure, whereas in reality no pressure relief valve was present in the first place, so the actual pressure in the tank could be much higher than assumed and could indeed be approaching the point at which the tank ruptures[20]. In addition, case studies and tests of LPG tanks have shown that in many cases where pressure relief valves are the only safety measure, they fail to prevent a BLEVE, as not all LPG is blown off before the temperature at which the tank wall ruptures is reached. They do delay the BLEVE but not by long enough to permit safe cooling and extinguishing[21].

Note too that in most cases the tank wall is more likely to rupture due to its strength being reduced by the heat of the fire than by any increase in the pressure. This occurs at the site of the vapour phase (see next paragraph on the intensity, duration and location of heat irradiation) and at places where the tank wall is damaged or where there are discontinuities (such as wall seams or dividing walls). Discontinuities are not usually visible from the outside and the fire department cannot always gauge the extent of the tank wall damage. This relates both to the damage caused by the accident itself and the original condition of the tank wall. A special department of the Road transport Agency tests the density of the tank wall every three years and the tank strength every six years. The annual vehicle inspection checks that this has been done. If it has not, no roadworthiness certificate will be issued at the regular inspection. The parties involved must check that each shipment's certificates are in order. In addition, the owners of the vehicles must report any damage or modifications to the Road Transport Agency.

b. Intensity, duration and location of the heat irradiation, and the fill factor
When the fire department arrives at the scene, it is important that they can assess the size of the fire and how long it has already been burning. This is because it is the intensity and duration of the fire that determine the temperature and hence the pressure in the tank lorry (see previous subsection) and the rupturing of the tank wall by the heat.

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[20] For further information on pressure relief valve technology and the warning function for the fire department, see Appendix 6.
[21] TNO (2005), *BLEVE prevention for a LPG tank vehicle or LPG tank wagon* (commissioned by the Ministry of Transport, Public Works and Water Management)

If the tank wall temperature is too high (500-600 °C), the level of pressure that it can cope with will fall because its material strength has declined. This is why it is important to get an indication of the temperature of the tank wall itself. Accordingly, the location of the heat irradiation and the tank's fill factor need to be ascertained: in that part of the tank where the cargo is not liquid but is in its vapour phase, there will only be limited conduction of the heat to the liquid part of the cargo. This means that it is more likely that the tank will rupture at this spot, as it will be softening due to the heat irradiation from the fire. In order to determine whether the tank is being irradiated in the liquid or vapour phases, fire fighters need to know the tank's fill factor. The location of the heat irradiation is also relevant in connection with possible weak spots in the tank wall (see also the paragraph on tank wall pressure and strength).

Heat-sensitive cameras can be used to determine the temperature. The basic version of such cameras only provides a general heat image based on differences in colour, but even that can be helpful, for example if the image shows that the load (the liquid) is much cooler than the vapour above it. More advanced cameras give a better resolution and also indicate the temperature of the tank wall[22]. Not all fire department vehicles are equipped with such cameras. Most units have bought cameras for the vehicles used by the Special Officer or by the fire department's tanker sprayers (the tanker sprayer is the first vehicle to arrive at the accident site). The heat-sensitive camera is non-compulsory but can supplement the equipment set out in the Ministry of the Interior's list of standard equipment for tanker sprayers.

In June 2005, the Ministry of Spatial Planning, Housing and the Environment signed a covenant with the LPG sector that aims to reduce LPG-related risks. One of the possible measures is to fit the tank lorry with heat-resistant cladding, which would make the liquid in the tank heat up less quickly, giving the fire department more time either to arrive at the scene with all the right equipment it needs and possibly with fire-extinguishing water too and fight the fire, or alternatively to evacuate the scene before the conditions are such that a BLEVE is imminent. The aim is to achieve a protection period of at least 75 minutes. Fire tests will shortly be carried out to check whether this protection period can be achieved.

A disadvantage of heat-resistant cladding is that it covers the outside of the vehicle, making it difficult to spot anomalies in the tank just by looking at it. The Road Transport Agency expects that this will make the inspections, which are largely visual in nature, very difficult. In addition, it is unclear whether the cladding actually remains intact after an accident and how long such it continues to be sufficiently effective. The covenant provides for further investigation into the protection time offered by the heat-resistant cladding, the physical effects of an accident on the cladding, and the options for inspecting the tank wall and cladding. The Dutch government aims to get a (target) provision included in the ADR (for the road) and RID (for rail), whereby a hot BLEVE should be delayed for a specific minimum period of time. However, even if this provision is adopted, it will still take several years before it comes into force.

Some tank lorries have been fitted with awnings, which reduce the heating of the tank's contents by the sun's rays. If an awning is fitted, a lower theoretical pressure figure may be used. This usually leads to a thinner tank wall being fitted, which makes the whole tank lighter and offers obvious commercial benefits. Awnings are fitted about five centimetres above the tank wall, and only to the upper side of the tank. The disadvantage of an awning is that the fire department will have difficulty cooling the tank from above. An example of an incident where such an awning hampered fire fighting efforts was the accident in 2000 in Norway, when a train collision narrowly failed to result in an explosion or BLEVE. The Norwegian fire department found it difficult to cool the trains due to the fitted awnings, and has recently reported on this.[23]

[22] If the fire has already been burning for some time, and the irradiation affects the liquid phase, then it may be assumed that the temperature of the load is approaching the temperature of the tank wall. As long as the fire is still burning, the load will always have a somewhat lower temperature than the wall. An insulated tank wall and an intact insulation system make it more difficult for the load to heat up, but also for the fire department to ascertain the temperature of the load.

[23] Source: 'Proposal from Norway for the amendment of international guidelines for the transportation of dangerous goods by rail (RID) and road (ADR)' (reference TRANS/WP.15/AC.1/2005/43, June 2005)

c. Extinguishing and cooling options
Any warming of the tank contents and damage to the tank wall by a fire's heat can be restricted by extinguishing the fire and/or cooling the tank lorry. Cooling slows down the rate at which the tank's contents heat up and at which the tank wall is damaged, and delays and/or prevents any BLEVE or other accident scenario. In many cases, it is possible to use water to cool the tank lorry. In order to be able to cool the tank lorry sufficiently quickly, a certain extinguishing capacity per minute is needed. This depends on the size of the tank lorry and - for a tank carrying liquid substances – whether they have leaked or whether the tank wall has ruptured, allowing the substance to flow out and catch fire (a pool fire). The necessary capacity depends on such factors as the intensity of the fire, the size of the tanker and the properties of the substance involved. In order to cool a tank containing dangerous goods, each 100 m2 tank wall is assumed to require a capacity of 1000 litres/minute[24]. The distance from where the water etc. can be sprayed can be relevant too, as the type of fire or risk of an explosion may mean that a certain distance has to be maintained, to extinguish or cool safely.

Water to extinguish and/or cool can be drawn from the following sources:

- The contents of a tanker sprayer (1500-2000 litre capacity): All (25) regional fire departments possess dozens of these tanker sprayers. These will not all turn out at the same time, but the content of a single tanker sprayer is usually not enough to extinguish a tank lorry fire. They allow water to be sprayed from a maximum distance of about 20 metres.
- Foam and dry chemical fire extinguishing vehicle or foam extinguishing vehicle (approx. 8000 litre capacity). The number of foam (and dry chemical) extinguishing vehicles tends to be limited to just a few per region. These vehicles' tank capacities are usually large enough for an initial attack on the burning tank lorry. Spraying can be done from a maximum distance of about 40 metres. In 1975, the Ministry of the Interior provided six foam extinguishing vehicles to various municipalities to be deployed from strategically located stations to fight fires on motorways, and especially for accidents involving the transportation of dangerous goods in busy traffic[25]. This equipment is now reaching the end of its life, and a discussion is currently underway on whether they need to be replaced, and if so, with what.
- Fire department tanker: a motor vehicle designed to transport water alone. The tank structure and contents depend on the risks prevalent in the region in question.
- Water extraction from areas of open water by means of a submerged pump and hoses to fill tanker sprayers. Note, however, that there is often a lack of such open water alongside motorways.
- Large-scale water transportation: involves extracting water over large distances from open water. The construction of large-scale water transportation facilities takes a lot of time and depends on the distance to the fire, presence of traffic jams and the time it takes for the necessary equipment to arrive.
- Fire cocks (up to 2000 litres a minute): fire cocks are found in built-up areas in particular.
- Fire wells (located on fire drains) or bored wells that draw groundwater from the ground.

In addition to these extinguishing and cooling options, facilities can be fitted in the vehicles themselves (such as hand fire extinguishers).

Sources of information
The tank properties (especially the tank shape) can be used as a first step to rule out several accident scenarios: if the tank is not cylindrical in shape then it is not a pressure tank, which means there is no chance of a BLEVE occurring. If the tank is cylindrical, then we cannot be sure whether it is a pressure tank or atmospheric tank. To find out more about this and about the presence of any pressure relief valve and/or the tank's fill factor, the fire department should question the driver, transportation company, sender, shipper and/or recipient (see Section 3.2.2). The remaining factors relate to any information that the fire department has itself.

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[24] Source: 'Operationeel handboek ongevalsbestrijding gevaarlijke stoffen' ('Operational Manual for Dangerous goods Accident Relief') (NVBR, 2003/2005).
[25] Source: Koppers, G.P., *'Vijftig jaar inspectie voor het brandweerwezen'* (Fifty years of inspection for the fire fighting services). Ministry of the Interior, 1990.

Ewijk and Eindhoven

In both the above cases, the fire department in question had no information on the pressure in the tank and was unable to use measuring instruments to ascertain the pressure. The fire fighters were unable to get close enough to the vehicles to read the manometer (and in any case a manometer is not always present). In the Eindhoven case, the tank's fill factor was known after about half an hour, once the fire department had contacted the transportation company. This information did not influence the decision to actively tackle the fire. In the Ewijk case, the fill factor was not known, because the driver left the cargo papers behind in the vehicle and the fire department was unable to find out this information another way. The driver knew what the fill factor was,, but this information did not reach the fire department. In other words, in both cases the fire department had little to go by to help it ascertain the risk of explosion (and changes to the level of this risk) resulting from rising pressure/temperature levels.

If the tank wall is damaged, the likelihood that it will rupture is obviously greater than if it is still intact. Accordingly, the fire department tried in both cases to find out the state of the tank wall, but there were few visual clues: in Eindhoven, the vehicle had overturned, and in both cases smoke and fire hindered visibility.

In the case of Ewijk, it was noted that one side of the tank lorry's trailer had been entirely covered in flames for some time. During the cooling process, a heat-sensitive camera measured the temperature of the tank. In the Eindhoven case, no temperatures were measured.

In the case of both Ewijk and Eindhoven, there were no fire-cocks, just as there aren't along many motorways. In Ewijk, the closest water extraction source was over 500 metres away. It would have taken too long (i.e. more than 30 minutes) to organise large-scale water transportation from a ditch or canal. Reasons for this include the heavy congestion that day and the need to bring in the large-scale transportation units. The fire department depended on the water in the tanker sprayers that had been driven to the scene. The South-East Brabant fire department, which is responsible for Eindhoven, had two foam and dry chemical extinguishing vehicles that were both driven to the accident site. The fire department declared that the availability of foam and dry chemical fire extinguishing vehicles that could spray a lot of water quickly played an important role in the decision to take offensive action in the Eindhoven case.

Findings

The Safety Board has established that there is no hazard only in the case of small, brief fires and fires where the cargo tank is not directly irradiated and no damage has been caused. In the case of major fires where the cargo tank is directly irradiated, there is certainly a risk of an explosion or major pool fire or jet of flame. Factors influencing the possible outcome are the type of tank involved (atmospheric or pressure tank), the pressure on and the strength of the tank wall, the location of the heat irradiation in relation to the fill factor, and the substance in question (see Section 3.2.1), all of which determine which scenario will occur. There is not always any contact between the driver and the fire department that would allow this information to be passed on (see Section 3.2.1). Recognising which tank type (atmospheric or pressure tank) is involved requires the fire department to have the necessary knowledge and experience. One option is to develop tools for the fire department that would allow them to identify the tank type with sufficient accuracy at the site.

In the case of tank lorry fires that involve a potential risk of a BLEVE, it is not possible to predict when that risk is real. In addition to the fact that information may be lacking, there is no clear relationship between the relevant factors (including type of substance, pressure in tank, strength of tank wall, size of fire, presence of heat-resistant cladding and/or pressure relief valve) and the moment when the BLEVE occurs.

The accidents investigated have revealed that having sufficient reserves of water available that can be deployed quickly enough plays a role in the fire department's decision whether to take offensive action or to wait at a safe distance until the tank lorry is burnt out or a BLEVE or other type of accident scenario has occurred.

3.2.3 Factor 3: Nature and size of the area under threat

Sources of information

The more people find themselves in the vicinity of a burning tank lorry, the greater the number of likely victims in the event of an explosion. In the immediate vicinity of the accident, this refers to the occupants of the vehicles involved, other road users, and the emergency services workers present (including fire department, police, and ambulance staff). If there are homes or office buildings in the immediate vicinity of the tank lorry fire, the persons that are in or close to them could be injured by an explosion or BLEVE. The distance at which an explosion or BLEVE can still cause death or serious injury as a result of heat irradiation and fragmentation is about 200-500 metres, although the death range can be much further if toxic clouds are emitted. This is why it is important that buildings, areas etc. that lie within the evacuation area be cleared.

The major issues relating to evacuation are the assessment of the risk, the decision-making process and the time available. It takes time to carry out the risk assessment, to decide whether to evacuate, and to carry out the actual evacuation. The time needed depends on the local conditions. The fire department staff interviewed as part of this investigation said that it is impossible to carry out the evacuation before a potential explosion actually occurs. Another problem experienced by the fire department is the level of resources needed to carry out the evacuation. The capacity of the fire department is restricted, which is why the police would have to be involved too. However, policemen and policewomen have no protective clothing and are deemed to have insufficient knowledge when it comes to assessing the risks associated with accidents involving dangerous goods.

A dangerous good that can both cause an explosion and is poisonous (i.e. toxic) can makes things even more complicated for the fire department[26]. In such a case, the instruction 'Close all doors and windows' is inadequate, although it would be sufficient for a toxic cloud where there is no risk of explosion. Now, however, the only solution is to evacuate. This could naturally be problematic, as the evacuation itself will expose the people concerned to elevated risks when they leave their homes and offices.

Ewijk and Eindhoven

In the Ewijk case, bystanders were pushed back to a distance of 300 metres. There was a risk that toxic combustion products would be released, which is why the evacuation of a small part of the Beuningen municipality was considered, although eventually it was not carried out. All the same, siren trucks did drive through the municipality warning the residents to close their windows and doors.

The driver of the tank lorry was able to exit his vehicle himself. For this reason, the fire department saw no need to take offensive action. According to the fire department, the resulting traffic jam increased the pressure on the local fire brigade to rectify the situation quickly. However, this factor did not affect the decision to take defensive action.

In the Eindhoven case, an industrial estate lay in the immediate vicinity of the accident site (see photo below). The fire department's assessment was that the area could not be evacuated in time. Another factor was that the driver was still in his cabin. According to the fire fighters involved who were interviewed as part of this investigation, both factors played a role in the fire department's decision to start fighting the fire immediately.

[26] In the case of substances with both flammable and toxic properties, if there are broken windows it cannot be assumed that people will be adequately protected by remaining indoors (NB. Standard protection factor is set at 90%).

Illustration 3: Buildings directly alongside the A2 motorway near Eindhoven.

Findings

The Safety Board has established that in the cases investigated, the nature and size of the area under threat plays a significant role in the decision to take offensive action. If rapid rescue or evacuation is necessary, then the fire department needs to decide quickly whether to take offensive action.

3.3 CONCLUSIONS CHAPTER 3

This section answers the research questions posed at the beginning of this section.

Which factors determine whether the fire department takes offensive or defensive action when fighting a major tank lorry fire?
Before deciding how to tackle a major tank lorry fire, the fire department performs a risk assessment. The following factors (and the relationship between them) play a role in this assessment:

- Identification of the dangerous good involved
- the nature, size and expected development of the accident
- the nature and size of the area under threat in relation to the safety of those involved in the accident, other road users, emergency services workers and local residents.

In the case of a tank lorry fire, is it possible to make a balanced risk assessment?
The Safety Board has established that in the event of major tank lorry fires, a balanced risk assessment by the fire department is not always possible. The identification of the dangerous good involved is not always an easy task and is in some cases impossible. In the case of the accidents investigated, the fire department could not get hold of the transport documents and it was difficult to see the orange plates on the tank lorries. In addition, the driver does not (or cannot) always pass on relevant information to the fire department. This means the fire department may be acting on the basis of incorrect information or may be unable to obtain any information at all on the dangerous good involved.

Even if the substance involved is known, it can be difficult to assess the actual risk when implementing the accident relief effort. Recognising the type of tank and assessing the potential development scenarios for the accident requires the necessary knowledge and understanding, which is not always on hand. It was also established that in the case of tank lorry fires that could lead to a BLEVE, it is impossible to predict when the risk of a BLEVE becomes real. External observations of damage to the tank lorry and the location of the heat irradiation in relation to the fill factor should help to indicate the likelihood of an explosion, but this is often difficult or impossible to do, and will not help to determine exactly when an explosion may occur.

Despite these uncertainties, the fire department has sometimes decided to take action at the source, in particular in the case of life-threatening danger in the immediate vicinity of the fire (as the result of the traffic accident) or if there are buildings within the impact zone of a possible explosion. In such a case, the fire department will basically go by the availability of enough extinguishing water. The question is whether such an assessment will mean that a safe course of action is taken. The fire department must be properly informed in order to be able to make a proper risk assessment during the accident relief effort, and certainly - given the small number of accidents of this type in each region - must learn from other accidents and experiences at home and abroad.

How can the risk assessment as part of the accident relief effort for a tank lorry fire, and the information provision for this, be improved?
There are options for improving this risk assessment, although a certain degree of uncertainty will always remain.
This Chapter has mentioned various options for improving the availability and reliability of the information needed for the accident relief effort. If the driver of the lorry involved is uninjured, he can help give the accident relief organisation the necessary information on the cargo and vehicle. In practice, however, this information is not always passed on. There are systems already available and in development that can optimise information provision to the emergency services for accidents involving dangerous goods. There is also the option of providing better support for the fire department by gathering knowledge and past experiences of fighting tank lorry fires. This can be done by learning from tank lorry fires at home and abroad and by developing tools to enable the fire department at the scene to identify with sufficient accuracy the type of tank involved.
In addition, it makes sense to have reserves of extinguishing water available along roads that are frequently used to transport dangerous goods.

4 RISKS ASSOCIATED WITH THE TRANSPORT OF DANGEROUS GOODS

This chapter contains a more general description of the policy on the transport of dangerous goods by road, explains how a risk assessment is made for the surrounding area and clarifies how much insight there is into the actual situation. The chapter provides answers to the following research questions:

- How much is known about the transport of dangerous goods and the related incidents and accidents which occur? What is the relationship between this and the current safety policy?
- What are the anticipated trends regarding the risk of accidents involving tank lorries and the consequences of such accidents? Are the risks expected to increase or decrease?

As part of the analysis intended to find answers to the above questions, this chapter also examines fuel tanks. The related questions are:

- How vulnerable is a lorry's fuel tank in the event of accidents?
- What are the possible consequences?
- What are the expectations regarding the risk of fuel tank leaks and the consequences thereof?
- Can any measures be taken to reduce the risk and consequences of a damaged fuel tank?

4.1 POLICY, RISKS AND PRACTICAL INSIGHT RELATED TO THE TRANSPORT OF DANGEROUS GOODS

4.1.1 Safety policy relating to the transport of dangerous goods

The policy relating to the transport of dangerous goods is made by the Ministry of Transport, Public Works and Water Management. This policy is aimed at making the transport of dangerous goods possible while attempting to guarantee a certain minimum level of safety at locations at which people live, work and engage in leisure activities. Within the framework of safety policy, a distinction is made between internal and external safety. Internal safety means, among other things, the safety of members of the emergency services and the safety of road users. External safety relates to the people who are in the surrounding area for the long term (those who live, work and engage in leisure activities nearby).

In their recommendations, the Council for Public Works and Water Management and the VROM Council[27] examine the differentiation between internal and external safety. The reason for doing so were the plans relating to the *Zuidas* (the A10 motorway near Amsterdam), and specifically the plan to cover in the road to limit the external safety risks of LPG transport for the surrounding area: *'The Zuidas example... shows that the standards for external safety are regarded purely in isolation. As a result, changes to the transfer or the method of transfer can limit the risk for the surrounding area. The downside of this type of 'transfer measure' is that internal safety (in this case the safety of the motorway, the domain of the network manager) is negatively influenced, potentially even leading to far more victims than would be the case externally. The one-sided focus on external safety does not, therefore, lead automatically to the best solution. The final objective (management of the entire risk) is lost sight of.'*

In order to guarantee a minimum level of safety, the government wants to create a situation whereby checks are carried out as to whether the set risk standards are fulfilled in the case of certain spatial developments or the transport of dangerous goods. In this context, a distinction is made between two kinds of risk[28].

The local risk (LR)
The local risk[29] is the risk that a fictitious person bound to one and the same spot without protective measures for one year, dies as a result of an accident associated with a certain activity (e.g., the transport of dangerous goods by road). The LR is shown on maps by drawing lines

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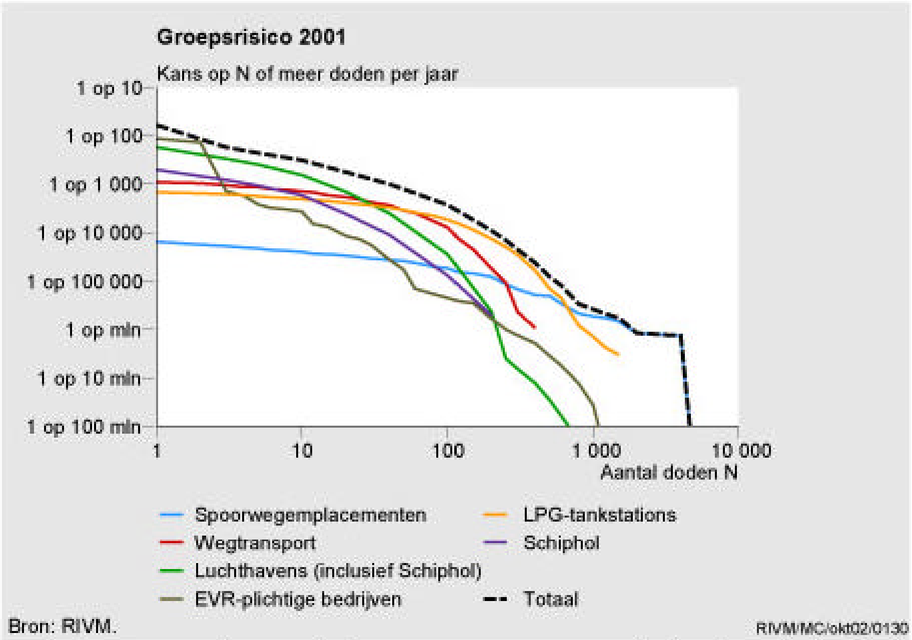
[27] Source: Council for Public Works and Water Management and the VROM Council, *Verantwoorde risico's, veilige ruimte* (Responsible Risks, Safe Space) (2003).

[28] Source: Ministry of Transport, Public Works and Water Management, *Nota Vervoer Gevaarlijke Stoffen* (Transport of Dangerous goods Memorandum) (2006) and Ministry of Transport, Public Works and Water Management, *Circulaire Risiconormering vervoer gevaarlijke stoffen* (Risk Standards for the Transport of Hazardous Goods Circular) (2004).

[29] This used to be referred to as the Individual Risk (IR).

between points with the same risk (the LR contours). The RNVGS (Risk Standards for the Transport of Dangerous goods) define an LR bottleneck as a (part of a) transport axis whereby the local risk of 10^{-6}/year falls outside the dimensions of the road, railway or waterway. This is shown as a 10-6 contour. This means that the chance of death by an accident involving this activity inside that contour is greater than once every 1,000,000 years if someone is present continuously and without protection at the location for a year. A specific bottleneck referred to in the ANKER project (see section 2.1.1) is the situation in which, additionally, a vulnerable designated use is located within the 10^{-6} contour.

The group risk (GR)
The GR for transport is the chance per year per kilometre of transport route that a group of ten or more people in the area surrounding the transport route are simultaneously killed in an accident on that transport route. The GR is generally shown in a graph in which N is the number of deaths on the horizontal axis and f the cumulative chance per year of an accident on the vertical axis whereby N or more deaths occur (graph 1 shows the group risk per sector of industry).



Graph 1: Overview of the risk of a disaster in the Netherlands per sector of industry, and for various numbers (10, 100, ...) of victims[30]

Legend:
Groepsrisico 2001: Group risk 2001;
Kans op N of meer doden per jaar: Risk of N or more deaths per year;
Aantal doden: Number of deaths;
Spoorwegemplacementen: Railway yards;
Wegstransport: Road transport,
Luchthavens (inclusief Schiphol): Airports (including Schiphol);
EVR-plichtige bedrijven: Companies with an EVR obligation;
LPG-tankstationsL LPG filling stations;
Totaal: Total

The GR focal point was indicated as being the situation (one kilometre of transport route) whereby the product of the risk of an accident with the related subsequent risks and the square of the number of victims in the event of that risk is greater than 0.01. This is the focal value of the group risk, as indicated in the RNVGS circular.

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[30] Source: *Groepsrisico: de kans op een ramp in Nederland per bedrijfstak* (Group Risk: The Chance of a Disaster in The Netherlands per Sector of Industry) (2001) in: *Milieu- en Natuurcompendium*. MNP, Bilthoven and CBS, Voorburg. 16 September 2002.

As stated in section 2.1.1, these PR standards and GR focal points have not yet been legally established. Such a move can be performed by the Minister of Transport, Public Works and Water Management based on the foundation provided by the ANKER[31] project.

4.1.2 Risk calculations and external safety bottlenecks

In the Transport of Dangerous goods Memorandum, the Minister of Transport, Public Works and Water Management announced that RBM II[32] is to be designated the standard calculation method for determining the external safety risks relating to the transport of dangerous goods. RBM II is to be used to calculate safety risks based on the nature and the extent of the traffic flow over the transport route, the chance of a traffic accident, subsequent risks of dangerous good emissions (various scenarios), the risk of injury, the extent of the area affected, and the number of people resident or present in the surrounding area. This substantiation of the current risks of failure and scenarios for road transport used in RBM II is laid down in CPR 18, part II[33].

RBM II is to be used to calculate the LR and GR, with the LR being determined by the nature of the source and the GR by (the number of people in) the surrounding area plus the nature of the source. RBM II is an advanced and complex calculation method which, at the same time, fulfils the need for a standardised calculation tool and for ease of use (low usage threshold) as regards the calculation, for example by initiators and policymakers (e.g. local and provincial authorities), of the risks for the surrounding area associated with the transport of dangerous goods. With this ease of use and standardisation in mind, the method includes a number of different points of departure and assumptions designed to restrict the amount of data that has to be entered. For example, the calculation leaves out certain factors which have practically no effect on the end result. The aim of the calculation method is to allow standardised comparisons of certain situations (for example as a result of changes in the traffic flows, spatial developments or specific measures).

The external safety policy ensures that people are not present for prolonged periods of time in a place where the risks are too high. Road users and members of the emergency services therefore fall outside the scope of the external safety policy and of risk standardisation as well. This is examined in greater detail in section 4.1.4.

Risk calculations which have been carried out in the context of the ANKER project with RBM II show that the (arithmetical) risk level at some locations exceeds the standard value applied. The following table shows that the number of so-called LR bottlenecks differs per mode of transport and that, above all, the transport of dangerous goods by rail generates a large number of bottlenecks. The transport of dangerous goods by road also produces a number of vulnerable locations. These are located primarily along the A15 motorway in the Rijnmond region and along the Amsterdam Zuidas route. On the basis of the following table, the number of vulnerable locations alongside roads appears to increase in the period up to 2010.

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[31] Source: *Bouwstenen voor een wettelijke verankering van het externe veiligheidsbeleid inzake het vervoer van gevaarlijke stoffen* (Building blocks for the statutory integration of external safety policy concerning the transport of dangerous goods). Ministry of Transport, Public Works and Water Management (2006).

[32] RBM stands for Risk Calculation Method (*Risico Berekenings Methodiek)*. It is based on CPR guidelines. For more information surf to: www.rbmii.nl.

[33] The Committee to Prevent Disasters Caused by Dangerous goods (CPR) no longer exists. It was replaced by the (independent) Dangerous goods Advisory Board in 2004. The effort to convert the CPR guidelines to the Dangerous goods Publication Series (PGS) began in 2005. These guidelines have come in the place of the frequently used CPR guidelines.

	Number of addresses within PR 10^{-6} contour (number of vulnerable addresses in brackets[34])		
	2010 gg	2010 Cp0	2010 hg
Road	37 (18)	42 (19)	55(26)
Rail	1278 (1129)[35]	11 (10)	68 (58)
Water	4 (1)	10 (4)	10 (4)

Clarification of abbreviations used in table: gg = no growth; cp0 = average growth; hg = high growth.

Table 3: Overview of LR bottlenecks relating to the transport of dangerous goods (source: ANKER project[36])

4.1.3 Proposed measures

The Transport of Dangerous goods Memorandum (2006) proposes measures to manage the conflicting interests of the transport of dangerous goods, spatial development, and safety and also to improve safety (incl. the Basic Network). The ANKER project provides a number of possible solutions for specific bottlenecks.

Routing: The Basic network

The Mobility Memorandum by the Ministry of Transport, Public Works and Water Management (2004) already stated that safety risks are being exacerbated by spatial developments along the infrastructure and by increasing levels of transport via that infrastructure. The government therefore aims to lay down and administratively guarantee the space required for the transport of dangerous goods and spatial development. With this in mind, the government created a Basic Network whose aim is to manage the potential conflict between spatial planning and the transport of dangerous goods. The Basic Network divides the main roads into three categories. One category is for roads for which no limitations are imposed on transport but on the surrounding area instead. Another category is the reverse (limited transport but free spatial development), and then there is a middle category with restrictions being applied to transport and spatial developments alike. Different safety zones are linked to all three categories.

The Basic Network is currently being developed in greater detail, which involves consultations with all the parties concerned. As yet, no specific prediction can be made as to when the Basic Network might be introduced.

Measures for solving bottlenecks

The ANKER project provides a foundation for embedding the external safety policy for the transport of dangerous goods in legislation and regulations. The report uses risk calculations made with RBM II as a basis for proposing a number of measures to eliminate (potential) bottlenecks observed within the framework of the same project. A start was made with a general list of around 160 measures (both general and oriented specifically to rail, road and inland navigation) which was drawn up in consultation with the parties with an interest in the transport of dangerous goods. A selection was made from this list of those measures which can be implemented before 2010 and which contribute to a reduction of the pre-defined bottlenecks (in accordance with the calculation carried out using RBM II). This selection does not include measures which are effective in the longer term and measures which may improve safety, but which do not affect the risk calculation

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[34] Objects are designated as vulnerable or partially vulnerable in the policy based on the idea that some social groups need more protection than others. Contributing factors include long-term residency (homes), vulnerable groups (children, the elderly and the sick), functional link with the risk-generating activity and the presence of adequate means of escape.

[35] This scenario is still based on the infrastructure that existed in 2002, so in the case of transport by rail no account is taken of, for example, the alternative routing of dangerous goods as a consequence of the existence of the Betuwe Line.

[36] Source: *Bouwstenen voor een wettelijke verankering van het externe veiligheidsbeleid inzake het vervoer van gevaarlijke stoffen*, (Building blocks for the statutory integration of external safety policy concerning the transport of dangerous goods). Ministry of Transport, Public Works and Water Management (2006).

(for example measures aimed at preventing victims at the accident location). On the basis of the calculations with RBM II, the following effective measures have been proposed for road transport:

- heat-resistant cladding materials (the introduction of this measure in RBM II gets rid of all LR bottlenecks, i.e. transgressions of the local risk standard);
- according to the calculation, another routing of LPG transport on the Zuidas route and the setting of windows for toxic substances in Tilburg and Utrecht would be effective measures as regards solving the remaining GR bottlenecks, i.e. transgressions of the group risk.

4.1.4 Insight into the actual situation

On the basis of the RNVGS and the handbook for the RBM II risk calculation method it can be concluded that the following factors are key for determining the (arithmetical) risk level along transport routes:

- the extent of the traffic flow, which determines the risk of accidents that affect the surrounding area
- traffic safety, which determines the risk of (large-scale) accidents
- the type of dangerous goods, which determines the effects on the surrounding area
- the number of people that live, work, engage in leisure activities, etc. along the route, which determines the possible number of fatalities.

These aspects can be used to describe which insights are known (and which are missing) with regard to the actual situation relating to the transport of dangerous goods.

This report does not examine the RBM II risk calculation method itself. Incidentally, the Dangerous goods Advisory Board recently issued recommendations[37] on QRA[38] modelling for the transport of dangerous goods. The Advisory Board concludes that there are still too many bottlenecks in the current practice of risk calculations in relation to the transport of dangerous goods. For example, the risk modelling is not always consistent because it is dependent on the software chosen and assumptions for specific situations not provided for in the model's parameters. The transparency of the risk models is also limited, since not all the original sources could be located. The RBM II software still contains a lot of glitches. The Advisory Board therefore wants RBM II to be adapted and it wants the government to indicate in which situations RBM II can be responsibly applied and in which situations it cannot. In the medium term, the models from the Coloured Books from the Dangerous goods Series on which RBM II is based need to be adapted in line with current scientific knowledge and developed in more detail in some areas. Lastly, the Advisory Board eventually intends to advise on the desirability of and possibilities for a different risk approach, alongside the current one.

Growth in transport flows expected, reliable data on transport performance limited

According to the Mobility Memorandum[39], 180 million tonnes of dangerous goods are transported in the Netherlands each year (excluding cabotage and third country transport). The majority of this concerns international transport via pipelines (57%). In addition, 34% is transported by inland shipping (in particular internationally), 7% by road and 2% by rail.

In 2003, the transport performance of domestic goods transport by road, expressed in 'load tonne kilometre' (1 tonne of goods moved over a distance of 1 kilometre) was 32.2 billion tonne kilometres[40]. The level of transport of dangerous goods by road was surveyed in the period 2000-2002 using sample counts (visual observations over a period of 24 hours) at 500 locations. On this basis, the transport performance of dangerous goods by road was estimated as being 873 million

[37] Dangerous goods Advisory Board (*Adviesraad gevaarlijke Stoffen*), *QRA-modellering voor vervoer van gevaarlijke stoffen* (QRA Models for the Transport of Dangerous goods). The Hague, 2006.
[38] QRA stands for Quantitative Risk Assessment.
[39] Source: Ministry of Transport, Public Works and Water Management, Nota Mobiliteit (2006)
[40] Source: CBS (Statistics Netherlands).

tonne kilometres[41]. This represents around 2.7% of the total transport performance by road. If an examination is carried out per location, this estimate is subject to a margin of error since the transport density at a certain location can change each day, meaning that an underestimation or overestimation of the local annual traffic flow is possible. In addition, only the vehicles are counted and not the weight of the loads.

In order to increase the reliability of the data on traffic flows, the Transport Research Centre (AVV) of the Ministry of Transport, Public Works and Water Management is currently carrying out video surveys at 400 locations with a view to determining transport performance as regards the transport of dangerous goods. This effort involves the transport movements on motorways, secondary roads and key local roads being counted over a long period of time on the basis of the orange plates. Vehicles transporting small quantities of dangerous goods and which therefore do not need to display an orange plate, are not included in the survey (these vehicles do not contribute to the external safety risks but are relevant to the accident reduction efforts). In order to continue improving the reliability of the measurements and supervision of the traffic flows in the future, the possibilities of reporting and monitoring systems, and tracking and tracing, are being studied. The Transport of Dangerous goods Memorandum refers to this as a system by which the position of vehicles on the Basic Network can be permanently monitored.

The Ministry of Transport, Public Works and Water Management[42] expects the transport of dangerous goods by road to increase. The prognosis for 2010 is that the transport of flammable substances (liquid and gas) will increase by 20% and the transport of toxic substances by 50%. LPG and ammoniac are exceptions since the transport of these substances is expected to remain unchanged.

Insufficient registration and analysis of accidents with dangerous goods on the roads

The international regulations for the transport of dangerous goods by road (ADR) include an obligation to report: if a serious accident or incident occurs during the transport of dangerous goods, the carrier should report this to the appropriate authority (in the Netherlands this is the Minister of Transport, Public Works and Water Management). This obligation to report applies to accidents and incidents which involved the (actual or potential) release of dangerous goods, personal injury or material or environmental damage, or for which the authorities were called in. The criteria which apply to the reporting of accidents and incidents (incl. the seriousness of the injuries, damage, quantity of substances released) are clearly described in the ADR.

A similar text is included in the Carriage of Dangerous Goods Act (*Wet vervoer gevaarlijke stoffen*) (Section 47): ‘those who perform an act as referred to in Section 2, paragraph 1, are obliged to report such immediately to the Minister if the act led to incidents which created a danger for public safety, or if such a danger was feared, or if accidents occur.’

In practice accidents are (or have to be) reported to a number of bodies:

- For example, incidents and accidents involving dangerous goods on the road are reported to the AVV of the Directorate General of Public Works and Water Management (*Rijkswaterstaat*) by the carriers themselves. In the event of incidents related to inland shipping and on the road, a registration form has to be sent to the AVV.
- The AVV also receives reports of all traffic accidents via the police (although registration is incomplete particularly in the event of accidents involving material damage or light injuries, partly because the police are not called to all these accidents and/or the accident is not reported to the AVV).
- If damage to a vehicle has occurred and, as a result, the safe transport of dangerous goods is no longer guaranteed, the owner has to report this to the authorising body, in this case the Road Transport Agency (RDW).

[41] Source: AVIV, *Risicoatlas wegtransport gevaarlijke stiffen* (Risk Atlas for the Transport of Dangerous goods). Commissioned by AVV of the Directorate General of Public Works and Water Management and in the name of the Ministry of Transport, Public Works and Water Management (2003)

[42] Source: Ministry of Transport, Public Works and Water Management, *Nota Vervoer Gevaarlijke Stoffen* (Transport of Dangerous goods Memorandum) (2006)

In addition, the Netherlands Road Traffic Control Centre (*Verkeerscentrale Nederland*) receives reports of lorry accidents on the main road network within the framework of its incident management tasks.

The evaluation of the Carriage of Dangerous Goods Act[43] and research into the transport and incident registration of dangerous goods[44] have revealed that the obligation to report in the Netherlands is not properly fulfilled (or interpreted) and neither is it enforced. It appears to be unclear to the carriers when they have to report an accident or incident and to whom. Representatives from a number of different government bodies are often at the scene of the accident at the same time, which leads the carrier to assume that no further reporting needs to be done. The dominant feeling is that reporting the accident or incident does not lead to any measures and people are worried about the legal consequences once they have officially reported an incident.

The AVV's registration of traffic accidents on the basis of information from the police does not contain any details from which the number of accidents with dangerous goods in the Netherlands can be derived. This registration does not include a record of the type of load that was being transported and neither, therefore, any information on whether a dangerous good was involved in the accident. Up until 2004, an indication was given as to the type of vehicle involved, for example 'tank lorry'. However, not all dangerous goods are transported by tank lorries and not all tank lorries transport dangerous goods (but also milk for example). In addition, not all accidents with tank lorries were recorded in this category. In some cases, 'truck with trailer' was entered under vehicle category, as was the case with the tank lorry fire at Ewijk. Since 2004, the term 'tank lorry' has no longer been used. These accident statistics cannot, therefore, provide an insight into the accidents involving vehicles which transport dangerous goods.

Since 1999, at least six fires involving tank lorries with dangerous goods have taken place in the Netherlands (see following table). In view of the incomplete registration of accidents by the Ministry of Transport, Public Works and Water Management, this estimate is based on a search for news items on the Internet and in databases containing details of (chemical) accidents.

When	Where	What	Consequences
22 January 1999	Hoogeveen	Tank lorry with 2,500 litres of petrol and 6,000 litres of diesel oil overturns and bursts into flames.	Surrounding area sealed off and evacuated. Tank lorry reduced to ashes, did not explode.
14 May 2001	Ewijk	Tank lorry with 27,000 litres of ethyl acetate involved in collision, lorry catches fire due to leak in fuel tank and flames spread to two other lorries.	Surrounding area sealed off and evacuated; people in traffic jam removed. Tank lorry and two other lorries reduced to ashes, trailer tank lorry did not explode.
14 July 2003	Eindhoven	Tank lorry with isobutane involved in collision; lorry catches fire due to leak in fuel tank.	Surrounding area sealed off and evacuated; fire quickly put out, and tank lorry cooled.
11 January 2004	Heemstede	Cab of tank lorry carrying fuel catches fire (cause unknown).	Feeder roads closed off and evacuation prepared (not carried out). Fire quickly put out.
6 September 2004	Wijngaarden	Fire in engine of empty tank lorry (unclean,	Feeder roads closed off. Fire quickly put

[43] Helsloot I., E.R. Muller, R. Pieterman and W.J.M. Voermans (ed.), *Vervoer gevaarlijke stoffen in perspectief: evaluatie van de Wet vervoer gevaarlijke stoffen 1996-2002.* Leiden, E.M. Meijers Institute (2003).
[44] Rijkswaterstaat Adviesdienst Verkeer en Vervoer, *Vervoer- en incidentregistratie gevaarlijke stoffen* (Transport and Registration of Dangerous goods) (2006)

		fire brigade feared possible accumulation of ethanol gas).	out.
29 August 2005	’t Harde	Tank lorry carrying petrol and diesel involved in collision with a lorry on the hard shoulder. Tank lorry trailer leaks and catches fire.	Feeder roads closed off. Tank lorry and other lorry reduced to ashes.

Table 4: Recent tank lorry fires in the Netherlands (based on reports on the Internet and accident databases)

As far as we know there have been three major explosions (BLEVEs) in Europe involving tank lorries in the past ten years. One took place in a tunnel in Italy (Palermo) on 18 March 1996 (5 fatalities and 15 casualties), one in Greece in 1999 (which claimed the lives of 2 fire officers) and one in Spain on 22 June 2002 (1 fatality and 14 casualties). In addition, a BLEVE occurred in Spain in 1978 after a collision involving a tank lorry with propylene near a campsite. This caused 216 fatalities and around 200 casualties. This accident is still regularly used as an example. In the same year a BLEVE took place in Wijchen in the Netherlands while a tank lorry was transferring LPG at a petrol station. There were no casualties.

Victims among road users and emergency services outside the scope of external safety

The focus of the policy on the transport of dangerous goods is on external safety. As regards determining the risk, the risk calculations based on the regulations relating to external safety only take account of the number of people who live, work and engage in leisure activities, etc. along the route.

Road users (for example people in the traffic jam that occurs after a tank lorry has overturned) are not covered by the scope of external safety and are therefore not included in the risk calculation. This is a policy-based choice within the framework of the external safety policy, based on the view that road users have more freedom of choice than, for example, someone in a house, and will not choose to stay in a high-risk location for a long time. The same applies to the transport of dangerous goods by rail. Potential victims among the train passengers are not covered by the scope of the risk calculation. Moreover, any victims who are members of the emergency services called to tackle tank lorry accidents (incl. fires) fall outside the scope of external safety and are therefore excluded from the risk calculation. The result is that when measures are extrapolated on the basis of external safety risks, it is not known what effect these measures have on the safety of road users and emergency services workers and whether the total risk increases or decreases (see also section 4.1.1)[45].

Reliability of data on orange plates and transport documents

The Transport, Public Works and Water Management Inspectorate (IVW) is responsible for supervising the transport of dangerous goods. In the period 2002-2005, the IVW carried out an average of 25,000 roadside checks each year, of which 1,600 (around 7%) focused on the transport of dangerous goods. On average a third of the inspections of vehicles carrying dangerous goods revealed violations. In the case of 3% of the vehicles checked the IVW discovered a violation relating to orange plates. As regards transport document checks, the IVW has, in the past four years, observed irregularities in 6-10% of the cases checked. According to the IVW, this concerns small administrative irregularities. The IVW is not able to indicate the percentage of cases in which wrong substance details (UN numbers or GEVI [Hazard Identification] codes) were displayed on the orange plates or transport documents.

[45] During the public inspection procedure, the Ministry of Transport, Public Works and Water Management indicated that the Dangerous goods Advisory Board was recently asked to issue recommendations on the way in which, in the context of disaster management and practical assistance, the effect assessment and, in the context of spatial development and environmental practice, the risk assessment can be more effectively coordinated.

According to the IVW, the assumption is that the substance referred to on the transport document corresponds to the load, unless other substance-related indications (type of vehicle, transport emergency card, packaging labels) give cause to think otherwise. This means that, in practice, a check as to what dangerous good is being transported, is only made in a limited number of[46] the inspections performed. Given the risks associated with the transport of dangerous goods and the importance of reliable substance details for members of the emergency services, the Safety Board is of the opinion that more insight is necessary into the reliability of the substance details on the orange plates and transport documents.

4.1.5 Findings

On the basis of recent risk calculations, the risks for people who live, work and engage in leisure activities along routes used for the transport of dangerous goods appear to be limited. According to these calculations, the standards are exceeded in only a limited number of locations. However, the Ministry of Transport, Public Works and Water Management expects the transport of dangerous goods to increase in the coming years. The number of spatial developments along transport axes is also on the rise. It can therefore be concluded that the safety risks are set to increase.

Within the framework of safety policy, a distinction is made between internal and external safety. The focus of the policy relating to the transport of dangerous goods is on external safety and it is only for this aspect of safety that a standardisation (to be laid down in law in the future) or zoning applies and a standardised calculation method is available. The calculations within the framework of external safety produce arithmetical risks for the surrounding area. These do not provide any insight into the risks for road users and members of the emergency services, because these fall outside the scope of the external safety policy and the risk calculations.

The Safety Board has also observed that limited monitoring of traffic flows and an insufficient registration and analysis of accidents involving dangerous goods in the past has led to poor insight into the actual risks and possible risk-determining factors. The Ministry of Transport, Public Works and Water Management is working to improve the monitoring of traffic flows by means of video surveys and is carrying out research into the possibilities of a reporting and monitoring system, and tracking and tracing. The Safety Board believes that, in addition, an improved registration and analysis of accidents involving dangerous goods is essential in order to acquire a better insight into the real risks and risk-determining factors and provide a better substantiation of policy and choices as regards measures. In addition, there is no insight into the extent to which substance characteristics on orange plates and transport documents correspond to the substance actually being transported. Even a small number of samples revealed discrepancies in this regard.

4.2 SPECIFIC RISK FACTOR: VULNERABLE FUEL TANKS

4.2.1 Size, construction and placement of fuel tanks

In the case of lorries used in a limited geographical area, the fuel tank capacity is restricted to around 500 litres in order to maximise the vehicle's carrying capacity. In the case of lorries used for long distances (internationally), the tank capacity is generally at least between seven and eight hundred litres. This segment is currently subject to a trend towards even larger tank capacities, increasing to almost 1,500 litres[47]. This makes it possible to realise savings by purchasing fuel in places where it is cheapest. The price differences can currently be as much as € 0.25 per litre of diesel oil meaning that, in the case of extra large fuel tanks, hundreds of euros can be saved at each refuelling.

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[46] Since April 2004 the IVW has carried out 38 surveys, of which five revealed discrepancies with the accompanying documents. In two cases this concerned a substance which was designated as being more hazardous than had been prescribed. In two cases, it transpired that a non ADR designated substance had been designated as such. In one case, the substance was not described specifically enough.

[47] If a fuel tank contains more than 1,500 litres of fuel, this itself qualifies as the transport of a dangerous good.

The fuel tanks of freight and tank lorries are, in practice, located between the front and rear axles, on the outside of the chassis bars. The fuel tanks are single-walled and made from thin steel plate (with a thickness of almost 2 mm) or aluminium plate (with a thickness of slightly more than 2 mm). Aluminium is becoming increasingly popular because it enables the weight of the tank to be reduced by tens of kilograms (which – despite the additional price of several hundred euros – is economically viable due to the related increase in effective carrying capacity).

Transverse partitions with holes in them are located on the inside of the tanks. On the one hand, these partitions are intended to stop the fuel from 'sloshing about' and, on the other hand, to prevent the tank wall from being crushed. The filling opening is fitted with a sprung flap which, when filling up, has to be pushed open using the fuel nozzle. This flap prevents any fuel spillage (tens of litres) when travelling around bends in the event of a missing filler cap.

Until recently, the tanks were not screened off at all. In the case of some makes of the last generation of lorries, the tanks are now shielded off by means of a side panel between the front wheel and the (foremost) rear wheel. However, the shield used is a plastic sheet fitted for aerodynamic and/or aesthetic reasons, rather than to protect the fuel tank. No information is available as to whether these plastic sheets have any protective value.

4.2.2 Number of lorry accidents that involved leaking fuel tanks

In the case of the tank lorry fires in Ewijk and Eindhoven the cause of the fire was a leaking fuel tank (containing fuel for moving the vehicle). A survey was therefore carried out into how often fuel tanks actually leak during accidents. Data on leaking fuel tanks and the resulting release of a large quantity of fuel is not included in the accident registrations described in section 4.1.4. For that reason, data was used from the Netherlands Road Traffic Control Centre (VCNL), which is part of the Ministry of Transport, Public Works and Water Management. In 2004, the VCNL registered 764 accidents involving lorries based purely on reports of accidents on the road network managed by Directorate General of Public Works and Water Management (the main road network). Data from the Truck Incident Management Foundation (*Stichting Incident Management Vrachtauto's,* Stimva) shows that, of these, around 250 can be referred to as serious because in those cases the Stimva experts were called to the scene to advise.

The reports which the Stimva experts compiled after having provided recovery advice show that, in around 10% of the accidents in question (around 25), a considerable quantity of diesel oil was released from the fuel tank (varying from a couple of hundred litres to 1,000 litres). Given that Stimva only operates on the main road network of the Directorate General of Public Works and Water Management, the number of cases whereby the fuel tank leaked is a minimum. According to the Technical Accidents Departments of a number of police forces, such accidents occur on the other road network 'a couple of times per year per police region'. Since there are 25 police regions, it can be estimated that 25-75 accidents occur on the other road networks whereby a considerable quantity of diesel oil is released from the fuel tank. Taking all this into account, the assumption would appear to be justified that the number of accidents with lorries that involve the release of a substantial quantity of diesel oil from the fuel tank(s) is probably between 50 and 100 per year.

4.2.3 Possible consequences of leaking fuel tanks

Leaking fuel tanks can cause fires. Diesel is less flammable than, for example, petrol. Normally, sparks are not enough to ignite diesel. However, if the diesel vaporises and/or comes into contact with hot parts of the engine/exhaust, it is more likely to ignite. Moreover, the temperature of the outside air can affect the risk of a fire. A pool fire consisting of a couple of hundred to 1,500 litres of diesel (the maximum fuel tank capacity) is a risk to the driver of the lorry and other road users, certainly if people become trapped in vehicles. If the accident involves a tank lorry (or another lorry) which is transporting dangerous goods, the fire can increase the risk of dangerous goods being released. Whether a burning fuel tank in combination with contributory burning elements, such as vehicle tyres, asphalt, or filling installation residues, are sufficient to cause a BLEVE in the case of a tank lorry with a pressure tank (see Appendix 5) is not known, but experts regard this to be possible. Fire due to a leaking fuel tank can also have major consequences in situations other than an accident involving dangerous goods. For example, a burning lorry with a flammable load (for example wood or butter) can be as powerful a risk as a pool fire caused by an accident involving a tank lorry with flammable liquids. Another scenario is that a burning pool of diesel spreads to other vehicles involved in the accident in which passengers might be trapped. Lastly, a leaking fuel tank can also have negative effects without causing a fire. The leaked diesel makes the road surface slippery and this can be dangerous for, among others, motorcyclists[48]. It also generates extra maintenance expenses, traffic problems and environmental damage. It takes quite a long time to clean the road after a spillage of several hundred litres of diesel oil.

4.2.4 Statutory requirements governing the construction and placement of fuel tanks

From a legal point of view, the fuel tanks of regular lorries are subject to only the following requirements[49]:

- the tank must be leak-proof in the sense that should the lorry overturn, no more than a certain quantity of fuel is released per unit of time
- the filling opening must be fitted with a safety flap
- if the tank (for example during an accident) shifts lengthways, it must not come into contact with any sharp components
- the content of the tank must be less than 1,500 litres (because otherwise this would be equivalent to the transport of dangerous goods within the meaning of the VLG.

The VLG imposes additional fire safety requirements on the construction of vehicles used in the transport of certain categories of dangerous goods. This involves, among other things, requirements applicable to the fuel tank:

- in the event of a leak, the fuel must flow across the surface without coming into contact with hot parts of the vehicle or the load
- petrol fuel tanks must have a fire stopper fitted in the filling opening or a stopper which can hermetically seal the opening.

In the past, an additional regulation applied which related to protection of the fuel tanks of vehicles subject to ADR approval in categories EX/II, EX/III, FL and OX. This regulation included a general part, namely that tanks had to be positioned in such a way that they were protected against collisions, without any additional performance requirements. The 1999 version of the ADR no longer contained this regulation. The regulation was interpreted differently in various countries. In the Netherlands a steel bracket around the fuel tanks was obligatory for vehicles used to transport flammable substances. In Belgium, a plate had to be fitted, in France a tube in the lowest section of the tank, while in Germany no additional requirements were imposed because it was assumed that this requirement would already be complied with by vehicles that fulfilled the requirements for regular lorries. The exclusion of the regulation from the ADR and therefore from Directive 94/55/EC as well meant that the national requirements for additional protection could no longer be enforced.

The ADR also included regulations which exempted the transport of up to 1,500 litres of fuel, to be used for the vehicle’s motor and equipment, from the regulations for the transport of dangerous goods. One condition was that the fuel tanks had to comply with UNECE order 34 or EC Directive 70/221/EEC. This obligation applied to all vehicles, including vehicles subject to ADR approval. Due to enforcement problems, obligatory compliance with UNECE order 34 or Directive 70/221/EEG was left out of the 2001 version of the ADR.

Since 2003, the subject of fuel tanks has not featured on the agendas of the international working groups involved in vehicle requirements.

4.2.5 Possibilities and support for improvements

In principle there are three ways in which the risk of leakage from the fuel tank in the event of an accident can be reduced. One is to change the position of the fuel tank on the vehicle, another is to change its construction and the third is to provide better shielding. In this context, the following general comments can be made:

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[48] In the English county of Devon a campaign is currently going on to combat diesel leakages. See http://www.devon.gov.uk/index/transport/roads/road_safety/biker_safety/spiller_killer.htm

[49] European Directive 70/156/EC concerning fuel tanks and protective measures at the rear.

- Positioning
Without making the lorry longer, the current location (on the outside of the chassis bars, between the front and rear wheel) is really the only place where there is room to fit an object of such dimensions. The space between the chassis bars is filled almost completely by the engine, the gearbox and the suspension. Similarly, there is insufficient space available in the cab since the space behind the seats is required for the two berths and baggage.

- Construction
The risk of leakage can be reduced by using a different material and/or by increasing the tank wall thickness. In the aircraft industry rubber bags are fitted inside fuel tanks (for example in helicopters) with a view, among other things, to preventing leakages in the event that the aircraft comes under fire. However, it cannot be assumed that such measures will be applied voluntarily. Thicker tank walls lead, of course, to a proportional increase in the weight and the material costs. The use of other materials (such as plastic/carbon composites) makes the cost price of a tank many times higher than is currently the case.

- Shielding
The chance that a tank starts leaking as a result of an accident can also be reduced by improving the tank's protection. Of course, such a shielding mechanism also increases the costs and weight. In addition, a certain amount of space is required for the shield construction (which probably means a proportional reduction in fuel tank capacity). Carriers are not expected to apply this option voluntarily.

4.2.6 Findings

Lorry fuel tanks appear to be quite vulnerable. Between fifty and a hundred accidents a year occur involving a lorry whose fuel tank is damaged to such an extent that a large quantity of diesel fuel is released. The consequences of leaking fuel tanks can be considerable, given that in the case of the tank lorry fires in Ewijk (2001) and Eindhoven (2003) the damaged fuel tank was the cause of the fire and the resulting risk of explosion. Given the trend towards increasing the capacity of fuel tanks and given the growing popularity of transporting dangerous goods by road, the Safety Board wonders whether the resulting increase in safety risk is acceptable. The Board therefore believes that measures should be considered to improve the collision safety of fuel tanks and/or to limit the capacity of fuel tanks of vehicles which transport dangerous goods.

4.3 CONCLUSIONS CHAPTER 4

This paragraph provides an answer to the research questions posed at the beginning of this chapter, in particular the questions relating to the risks of transporting dangerous goods.

How much is known about the transport of dangerous goods and the related incidents and accidents that occur?
On the basis of recent risk calculations, the risks for people who live, work and engage in leisure activities along the dangerous goods transport routes appear to be limited. According to these calculations, the standards are exceeded at only a few locations. However, the Ministry of Transport, Public Works and Water Management expects an increase in the transport of dangerous goods in the coming years. Spatial developments along these transport routes are also continuing. On the basis of these developments it can be concluded that the safety risks are set to increase as well.

The Board has established that the monitoring of traffic flows and an insufficient registration and analysis of accidents involving dangerous goods in the past has led to poor insight into the actual risks and possible risk-determining factors. The Ministry of Transport, Public Works and Water Management is working on improved monitoring of traffic flows by means of video surveys and is also researching the possibilities for a reporting and monitoring system and tracking and tracing. Nor is there any insight into the extent to which substance characteristics on orange plates and transport documents correspond with the substance actually being transported. Even a small number of samples revealed discrepancies in this regard.

What is the relationship between this and the safety policy?
Within the framework of the safety policy a distinction is made between internal and external safety. The focus of the policy relating to the transport of dangerous goods is on external safety and it is only for this aspect of safety that a standardisation (to be laid down in law in the future) or zoning applies and a standardised calculation method is available. The calculations within the framework of external safety produce arithmetical risks for the surrounding area. These do not provide any insight into the risks for road users and members of the emergency services, because these fall outside the scope of the external safety policy and the risk calculations.

What is the anticipated trend regarding the risk of accidents involving tank lorries and the consequences of such accidents? Are the risks expected to increase or decrease?
On the basis of the available details, the Safety Board cannot assess whether the safety risk as a consequence of the transport of dangerous goods by road is increasing. The number of accidents involving injury per vehicle kilometre appears to be declining, but this is not necessarily a reliable indicator for the number of accidents involving the transport of dangerous goods. In addition, the Ministry of Transport, Public Works and Water Management expects the transport of dangerous goods by road to increase in the coming years, and spatial developments along transport axes are also going to continue. Both will increase the risk.

How vulnerable is a lorry's fuel tank in the event of an accident?
It is estimated that between fifty and a hundred accidents a year occur involving a lorry whose fuel tank is damaged to such an extent in the process that a large quantity of diesel fuel is released (varying from a couple of hundred litres to 1,000 litres). No requirements are imposed on the design and shielding of lorry fuel tanks to prevent the leaking of these tanks, not even for lorries used in the transport of dangerous goods.

What are the possible consequences?
The consequences of a leaking fuel tank can be substantial. Large-scale fires can occur leading to roads having to be closed to traffic for several hours. In each of the three large-scale tank lorry fires referred to in this report, the leaking fuel tank was the cause of the fire.

What is the anticipated trend regarding the risk of leaking fuel tanks and the consequences thereof if a large quantity of fuel is released?
The volume of goods transport (including the transport of dangerous goods) is set to continue increasing in the coming years. There is also a trend towards increasing the capacity of fuel tanks. The risk of fuel tank leakages will increase as a result.

Can any measures be taken with regard to fuel tanks which may reduce the risk of leakages and the related consequences?
Measures which may reduce the risk of leaking fuel tanks are:

1. shielding the fuel tanks;
2. reinforcing the fuel tanks, for example with thicker walls and the use of higher-strength materials.

The consequences of leakages can be limited by, for example, reducing the capacity of the fuel tanks or by compartmentalising the tank, so as to reduce the risk of the entire tank capacity being released in one go.

5 CONCLUSIONS

This chapter presents a summary, in the form of a number of conclusions, of the thematic study into tank lorry fires that involve dangerous goods.

1. Actions by the fire department
In the case of large-scale tank lorry fires, the fire department appears to be insufficiently equipped to be able to make a careful assessment of the risks that underlie its decision whether to actively fight the fire or await its development from a distance and contain its (potential) effects. There are several options available that would help to improve the risk assessment process. However, a certain degree of uncertainty can never be ruled out.

Explanatory notes:

- The study conducted by the Safety Board has revealed that:
  - it sometimes proves problematic – and occasionally even impossible – to identify the dangerous good involved, because the transport documents are not always available to the fire department, because the extent of the fire or intensity of the smoke make it difficult to read the information on the orange plates, and/or because the fire department is unable to contact the driver;
  - it is difficult to carefully establish the condition of, and any damage to the walls of the fuel tank;
  - the fire department makes incorrect assumptions (because it lacks the relevant expertise) regarding the various types of fuel tanks, safety precautions and potential accident scenarios.
- in addition, it appears that even in the presence of substance specifications, staff at the Ministry of transport, Public Works and Water Management only have limited insight into the reliability of those specifications indicated the transport documents and on the orange plates.
- in many cases the fire department does not have (timely) access to sufficient quantities of water to be able to fight a large tank lorry fire effectively.

2. Chance of a tank lorry fire
The chance of a tank lorry fire for which the fire department must be called in is not negligible. Moreover, the consequences of such a fire for relief workers, road users and other people nearby can be substantial.

Explanatory notes:

- An investigation by the Safety Board has shown that six tank lorry fires have occurred in the Netherlands since 1999.
- In each of those cases, the area was sealed off and/or evacuated. These measures were taken because, in the fire department's view, there were real risks to the safety and health of road users and other people at or near the scene of the accident.
- In three of these six cases, the tank lorry burnt out completely.
- In the other three cases the fire was extinguished.

3. Specific risk factor: the vulnerability of the fuel tank
Combined with the overall trend to increase the capacity of fuel tanks in lorries, the vulnerability of those tanks has aggravated the safety risks in the transport of dangerous goods by road.

Explanatory notes:

- Investigations into the large tank lorry fires have shown that a fire that is caused by a leak in a fuel tank can have very serious consequences.
- Data provided by recovery experts reveals that the fuel tanks of lorries tend to be rather vulnerable in practice. There are around fifty to one hundred accidents every year involving lorries whose fuel tanks are damaged to such an extent that several hundreds of litres of diesel fuel are released.
- According to the experts, there is a (small) chance that a ruptured fuel tank, in a worst-case scenario, develops into a BLEVE.
- There are no special requirements (in terms of design or protection) which the fuel tanks of articulated lorries must meet to prevent leaks, not even for lorries used in the transport of dangerous goods.

- As a general trend, the capacity of the fuel tanks is increasing.

4. Risks involved in the transport of dangerous goods
Accident data on the road transport of hazardous goods is not systematically collected, analysed and disseminated. As a result, there is not enough insight into the actual risks (and the factors that determine those risks) involved in the transport of dangerous goods by road.

Explanatory notes:

- Pursuant to the Netherlands Carriage of Dangerous Goods Act (*Wet vervoer gevaarlijke stoffen*), carriers are obliged to report incidents and accidents involving dangerous goods to the Minister of Transport, Public Works and Water Management.
- However, compliance with and enforcement of this statutory obligation are poor.
- As a result, the Ministry lacks adequate insight into the number, nature and cause of accidents that involve dangerous goods.

5. Safety policy for the transport of dangerous goods
Within the safety policy for the transport of dangerous goods, external safety has top priority. This means that the safety of road users, emergency services workers and bystanders is not optimally guaranteed.

Explanatory notes:
Policy guidelines concerning the transport of dangerous goods give priority to external safety. As a result, external safety is the only segment of overall safety policy for which specific standards or zones and standardised methods are available (which will gain statutory force in the future). This may cause the effects on external safety to take priority in decision-making. However, if the risks incurred by road users, emergency services workers and bystanders are not considered (in time), and if no integrated assessment is made, this may lead to the implementation of suboptimal solutions and/or measures.

6 RECOMMENDATIONS

On the basis of the study results, the Safety Board has formulated a number of recommendations for the parties involved in fighting tank lorry fires and, in a more general sense, in promoting the safety of the transport of dangerous goods by road. We recommend:

1. that the Ministers of the Interior and of Transport, Public Works & Water Management set up an information system, in consultation with the fire department (via the NVBR and/or the *Veiligheidskoepel*), to ensure the fast provision of information to fire fighters about the load (such as the type and quantity of the substance involved) and the vehicle (such as the type of tank and presence of a pressure relief valve).
2. that the Minister of the Interior investigate the extent to which the knowledge available within the fire department (in addition to vehicle know-how) could be enhanced and/or put to use more effectively in order to help the fire department choose between defensive and offensive action in fighting tank lorry fires, and recommends that the Minister take measures accordingly.
3. that the Ministers of the Interior and of Transport, Public Works & Water Management investigate the extent to which the timely availability of sufficient quantities of extinguishing water can be guaranteed at bottlenecks along dangerous good transport routes (and stretches of motorway nearby residential areas), and recommends that they take measures accordingly.
4. that the Minister of Transport, Public Works and Water Management implement an effective supervision and enforcement policy to gain more insight into the reliability of the substance data on the orange plates and in transport documents, and take all the necessary measures to that effect.
5. that the Minister of Transport, Public Works & Water Management call for tighter regulations in an international context in order to prevent leaks in the fuel tanks of lorries – especially, to begin with, lorries used in the transport of dangerous goods. Such measures could include devices to screen off or reinforce the fuel tanks.
6. that the Minister of Transport, Public Works & Water Management and the carriers (through their umbrella associations) take measures to promote the systematic reporting, registration and analysis of accidents and near accidents (incidents) in the transport of dangerous goods, learn the lessons and share that knowledge in a national and international context.
7. that the Ministers of Housing, Spatial Planning & the Environment, Transport, Public Works and Water Management, the Interior and Social Affairs & Employment see to it that safety measures relating to the transport of dangerous goods are formulated with due regard not only for the effects on external safety, but also for the safety of road users, emergency services workers and bystanders.

The governmental bodies towards which a recommendation has been issued must take a stance regarding the follow-up of this recommendation within 6 months of publication of this report to the minister concerned. Non-governmental bodies or individuals towards which a recommendation has been issued must take a stance regarding the follow-up of this recommendation within a year of publication of this report to the minister concerned. A copy of this reaction must simultaneously be sent to the Chairman of the Dutch Safety Board and to the Minister of the Interior and Kingdom Affairs of the Netherlands.

ANNEX 1 DESCRIPTION OF ACCIDENTS

This appendix presents the information gathered by the Dutch Safety Board about relief operations in the case of two accidents that involved tank lorries transporting dangerous goods in which a fire broke out. Only information that is relevant to the assessment process by the fire department is presented.

1. EINDHOVEN: DESCRIPTION OF THE ACCIDENT AND RELIEF OPERATIONS

1.1. BRIEF OVERVIEW OF THE FACTS OF THE ACCIDENT

On 14 July 2003, at around 1:00 PM, a tank lorry was driving northwards on the A2 motorway. Near Eindhoven, the right front wheel of the lorry crossed the white margin on the right-hand side of the road, after which the right-hand front section of the lorry hit a temporary road works barrier. The lorry then skidded, overturned and ended up on its right-hand side. When the lorry tipped over, it was disconnected from the trailer (the tank). The lorry itself landed upside down on the central crash barrier, approximately 150 metres from the point where the temporary barrier began. The trailer with a tank loaded with isobutane (a flammable gas) slid across the right lane, also for about 150 metres. The map below indicates the approximate location of the accident, which was very close to an industrial estate.

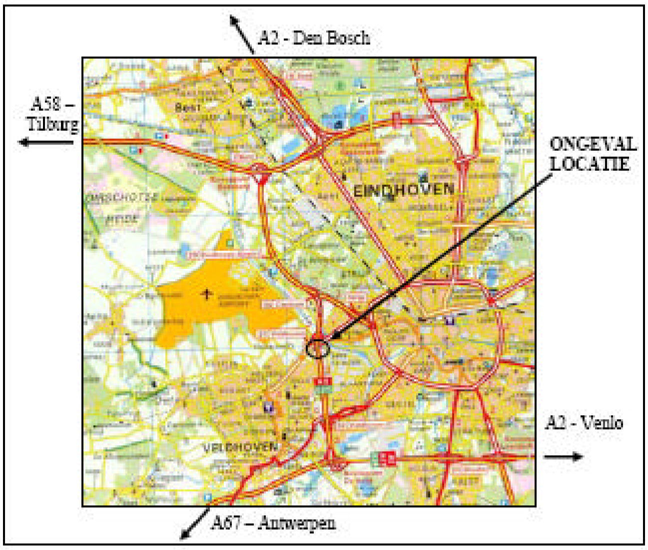

Illustration 4: Site of the accident on the A2 motorway near Eindhoven

In addition to the tank lorry, three passenger cars were involved in the accident, two of which were driving in the same direction as the lorry and the third in the opposite direction on the southbound lane. The lorry was severely damaged, and diesel was leaking out of the fuel tank. Outside the tank the diesel caught fire and the lorry burnt out completely. The undercarriage of the trailer (plus the fittings cabinet) and the tyres also caught fire. Below is a photograph of the burning lorry and the two other cars involved in the same lane.


Illustration 5: Burning trailer of tank lorry near Eindhoven

The driver of the tank lorry died in the accident. The lorry was seriously deformed in the crash, as a result of which the driver (who was the only person in the lorry) was trapped inside the cabin. The rescue workers were unable to get him out of the cabin in time, and he died as a result of the fire in the cabin. The three passenger cars involved in the accident were also seriously damaged, and their occupants were slightly injured.

1.2. ACCIDENT RELIEF OPERATIONS

The dangerous good involved
The tank lorry was loaded with a dangerous good: approx. 15,000 kg (around 23,000 litres) of LPG mixture (including isobutane), destined for industrial applications[50]. At room temperature, this is a flammable gas that is used as a fuel. The LPG mixture was transported as a liquid in a compression tank. LPG[51] mixtures are highly flammable and explosive, and are classified in the highest category of flammable gases. LPG vapours can cause dizziness.

General course of repressive measures
Fire fighting operations began as follows. The fire department received the first report at around 01:10 PM, arrived at the scene of the accident shortly after and immediately began extinguishing the fire in the tank lorry and passenger cars using a foam and dry chemical extinguisher, a vehicle with very large quantities of water on board (tank capacity 8,000 litres). Once the fire had been extinguished, the trailer was cooled off further to reduce the risk of an explosion. The fire department followed the procedure

Reducing the risk of an explosion in the immediate vicinity
Due to the risk of an explosion, the police closed off the A2 motorway and the Noord-Brabantlaan in both directions, and evacuated an area with a radius of 500 metres around the accident site. That area included homes as well as a number of businesses (shops/offices/restaurants). The cars in the traffic jam that had formed on the A2 on both sides of the accident site were also evacuated. In addition, the emergency services made sure that within a radius of 150 metres around the accident there was nobody who did not have to be there.

Around 8:00 PM cooling operations had reduced the risk of an explosion to such an extent that the radius of the evacuated zone was reduced to around 150 metres, which meant that most of the people concerned could return to their homes, offices and abandoned cars. Relief operations were completed around 11:00 PM.

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[50] In this specific case, the mixture consisted mostly (96%) of isobutane, a type of butane obtained from mineral oil. Isobutane has countless applications in the chemical industry, for example in the production of 4 star petrol.
[51] Liquefied Petroleum Gases (LPG) are mixtures of hydrocarbons (butane, propane and ethane).

Below is a summary of what the fire department found at the scene of the accident:

- a crashed tank lorry loaded with an LPG mixture
- a tank lorry trailer heated as a result of fire
- an immediate threat to the driver and the area around the scene (industrial estate).

The fire department took the following measures:

- they extinguished the fire immediately after arriving on the site
- after extinguishing the fire they cooled off the trailer
- they sealed off and evacuated the area.

2. EWIJK: DESCRIPTION OF THE ACCIDENT AND RELIEF OPERATIONS

2.1. BRIEF OVERVIEW OF THE FACTS OF THE ACCIDENT

The accident took place on 14 May 2001 at around 03:45 PM near the Ewijk motorway junction, on the western connecting road to the A50, and involved three vehicles. The first of these vehicles, a lorry, was driving down the A-50 from the north and was about to take the south-westerly connecting loop to the eastbound section of the A73 (see map below).

Illustration 6: General indication of the site of the accident on the A50-A73 motorway junction. The tank lorry was driving down the A50 from the north and was about to take the eastbound A73.

Traffic was intense at the time. Just before the relatively sharp turn to the left in this particular loop of the junction, the driver of the first lorry had to brake hard to avoid crashing into the vehicles slowing down in front of him. As a result, a lorry driving immediately behind the braking lorry also had to brake hard. Both lorries being unloaded, their brake paths were relatively short. The driver of a third lorry driving behind the second also had to slam the brakes. This third vehicle was a German tank lorry carrying around 27,000 litres of ethyl acetate. There was not enough distance between the second and the third lorries to avoid a rear-end collision. The driver of the third lorry made an attempt to avoid the second lorry by swerving to the left, but hit the vehicle all the same with the right-hand front part of the cabin. That collision caused the second lorry to be pushed against the first lorry (see picture below).

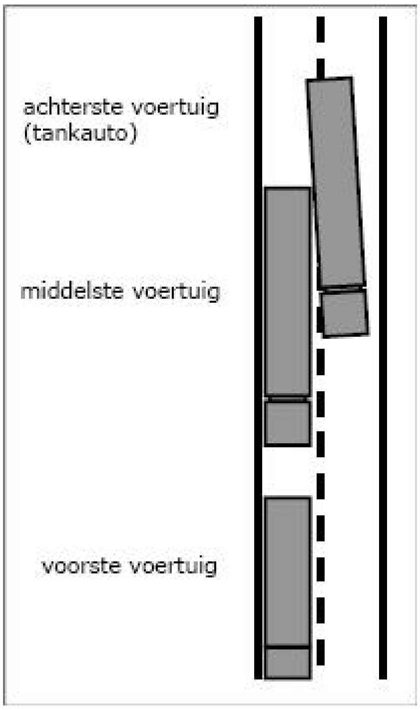

Illustration 7: Overview of the positions in which the vehicles ended (two lorries and a tank lorry)

[achterste voertuig (tankauto) = third vehicle (tank lorry)
middelste voertuig = second vehicle
voorste voertuig = first vehicle]

The fuel tank of the third lorry was ruptured in the collision with the second lorry, which caused a fire. At a certain moment the fire spread to the second lorry; the flames radiated so much heat that even the first lorry – at some distance from the other two – was damaged.

None of the three drivers was injured. They jumped out of their vehicles and ran away for fear of an explosion. The driver of the tank lorry left his transport documents in the cabin. The three drivers walked in a south-westerly direction under the viaduct of the A73 and awaited further developments at around 200 metres from the tank lorry. The spot where they stood was opposite from the point, relative to the scene of the accident, where the emergency services would gather. An area with a radius of 300 metres from the accident was sealed off. This meant that the driver was unable to reach the emergency services without crossing the forbidden zone.

2.2. ACCIDENT RELIEF OPERATIONS

The dangerous good involved
At the moment of the accident, the tank lorry contained a load of around 27,000 litres of ethyl acetate, which is an ester[52] of ethanol and acetic acid. Ethyl acetate is used for various applications, for example as a solvent for glues and as an artificial aroma. Being poisonous, corrosive and highly flammable, ethyl acetate qualifies as a dangerous good which, on account of its low flash point, belongs to the higher risk categories. Its acute toxicity is low, i.e. it is not sufficiently poisonous to cause a major risk of fatalities. However, its vapour may cause drowsiness and dizziness. Ethyl acetate boils at 77 °C and can form an explosive mixture of vapour and air.

General course of repressive measures
The fire department was alerted by a motorist who passed the scene of the accident and reported the UN number (1171) and the danger code of the substance concerned. There was no contact between the fire department and the driver, who was outside the sealed-off section on the other side of the accident scene. The fire department based its strategy on the risk of an explosion or a BLEVE. Initially, the fire fighters stayed at a considerable distance from the burning tank lorry (300

[52] An ester is a chemical compound created when an alcohol reacts with a carboxylic acid, releasing water.

metres north-east of it) and made no attempt to extinguish the fire.

After around twenty minutes, the Regional Dangerous goods Officer (ROGS) for the Nijmegen region was alerted. While driving to the site of the accident, the ROGS was informed that a BLEVE was unlikely due to the high[53] boiling point (135 °C) of the substance the fire department thought was involved. A more likely scenario was that the tank would burst, giving way to a pool fire[54]. However, given the duration and intensity of the irradiation[55] caused by the flames, as a result of which the second lorry had also caught fire, the risk of a BLEVE was not ruled out.

When the flames began to subside (after nearly two hours), the fire fighters came into action. Supported by two foam extinguishing vehicles, it took them around fifteen minutes (see the picture below) to extinguish the fire. Only then did they discover that the UN number stated on the tank lorry (UN 1173) was different from the number that had originally been reported. The tank lorry, which had been heated considerably as a result of the fire, was then cooled off with water for around four hours.

Illustration 8: Fire damage to the vehicles involved

Reducing the risk of an explosion in the immediate vicinity
Bystanders were pushed back to a distance of 300 metres from the scene of the accident. In view of the potential presence of toxic combustion gases, the fire department considered evacuating part of the municipality of Beuningen. Eventually that plan was abandoned; instead, siren trucks drove through the streets warning local residents to keep doors and windows shut.

Below is a brief summary of events.

This is what the fire department found at the scene of the accident:

- a tank lorry carrying a load of ethylene glycol monoethyl ether[56] with a boiling point of 135 °C
- considerable heat radiation (which had caused the lorry next to the burning vehicle to catch fire as well) and a tank lorry at risk of exploding
- no buildings in the area that might contain people.

The fire department took the following measures:

- they did not start extinguishing/cooling activities until the intensity of the fire had subsided spontaneously
- they sealed off an area with a radius of 300 metres from the site of the accident and evacuated all vehicles in the traffic jam.

[53] Boiling points in excess of 100°C qualify as relatively high. The boiling point of this particular substance was 135°C. However, after about two hours it was discovered that the substance number was incorrect, and that the actual substance involved had a boiling point of 77°C. This did not affect the fire department's decision. This is discussed in further detail in Chapter 3.
[54] See Glossary: a leaked quantity of liquid that has caught fire.
[55] See Glossary: heat rays emitted by the flames.
[56] This is the substance that had been reported; the substance that was actually involved was ethyl acetate.

ANNEX 2 THE PARTIES INVOLVED

1. POLICY, LAWS AND REGULATIONS

Directorate-General for Civil Aviation and Freight Transport of the Ministry of Transport, Public Works and Water Management
The Directorate-General for Civil Aviation and Freight Transport (DGTL) of the Ministry of Transport, Public Works and Water Management is responsible for the development of policy and regulations concerning the transport of dangerous goods.

Ministry of Housing, Spatial Planning and the Environment
The Ministry of Housing, Spatial Planning and the Environment (VROM) is responsible for coordinating external safety policy. External safety is about containing the risks for the local environment associated with the use, storage and transport of hazardous goods such as fireworks, LPG and ammunition by road, rail, water or through pipeline systems. The concept of external safety also covers the risks associated with the use of airports.

Ministry of the Interior and Kingdom Relations
The Minister of the Interior and Kingdom Relations (BZK) is responsible, among other things, for legislation and policy concerning relief operations for accidents in the transport of dangerous goods. Direct administrative and operational responsibility for disaster relief efforts rests with the municipalities concerned and their mayors, as well as with the operational services such as police and fire department.

Ministry of Social Affairs and Employment
As regards dangerous goods policy, the Ministry of Social Affairs and Employment (SZW) is responsible for internal safety policy for employees.

Dangerous goods Advisory Board
The Dangerous goods Advisory Board (*Adviesraad Gevaarlijke Stoffen*) has the task of advising the two Houses of the States-General about policy and legislation concerning technical and organisational measures to prevent accidents and disasters associated with the use, storage, production and transport of dangerous goods, and to limit the consequences of such accidents and disasters should they occur. In addition, the Advisory Council identifies and investigates developments in the field of safety that are important for current and future dangerous goods policy.

2. IMPLEMENTATION

Fire department
Under the Netherlands Fire Services Act (*Brandweerwet*), the Municipal Executive (mayor and city managers) is charged with the task of preventing, containing and fighting fires, limiting fire risks, preventing and limiting the consequences of accidents in case of fire, and all related issues, as well as reducing risks for people and animals in accidents not related to fire. Another responsibility of the fire department is to prepare coordination with other emergency services for joint relief operations.

There is a local and a regional fire department. The local fire department is a municipal service that operates within the municipal administrative frameworks and under the auspices of the mayor. The regional fire department operates within the administrative boundaries of a regional or intermunicipal partnership, subject to the administrative control of one coordinating mayor. Incidentally, this does not mean that the latter assumes executive responsibility for the whole area in the event of a serious accident in which several municipalities are involved. In such a case, administrative responsibility continues to rest with the mayor of each municipality involved.

Provinces
In connection with disaster relief operations, provincial authorities have the power to assign specific duties. For example, they can ask the mayor to implement specific changes in the relief plans. Provincial authorities have the statutory task to oversee dangerous good transport routes.

Municipalities

Municipalities have certain responsibilities in connection with fire services and disaster relief operations. In the event of disasters and serious accidents, the Netherlands Disasters and Major Accidents Act (*Wet rampen en zware ongevallen*) and the Netherlands Municipalities Act (*Gemeentewet*) assign supreme authority to the mayor. Like the provinces, municipalities have a statutory task to oversee dangerous good transport routes.

Manufactures of dangerous goods
Manufacturers of dangerous goods produce the substance and see to its proper storage at their own company sites. In the Netherlands the manufacturers are united in the Association of the Dutch Chemical Industry (*Vereniging Nederlandse Chemische Industrie*, VNCI), as well as in specific sector associations. For example, the Liquefied Gas Association (*Vereniging Vloeibaar Gas*, VVG) was founded in 1960 to promote the safe use of LPG (including propane, butane and mixtures thereof, as used in cars). The VVG represents the interests of virtually all parties involved in the production, storage, transport and sale of LPG.

Many business in the Dutch chemical industry have signed the Responsible Care programme, which means that they undertake to continuously improve their performance on safety, health and particularly environmental issues and to communicate the results achieved. In this connection, the European Chemical Industry Council (CEFIC), in 1990, drew up the ICE (International Chemical Environment) programme. The purpose of that programme is to prevent accidents involving dangerous goods where possible and, when such accidents do occur, to provide assistance when asked.

Carriers of dangerous goods
The carrier (who sometimes is also the manufacturer and/or shipper) is responsible for the shipment and transport of dangerous goods from the source to the destination. In the case of an accident, the carrier is involved as the owner of the tank lorry or as the driver's employer or client. Carriers have a statutory obligation to report incidents and accidents to the Inspectorate for Transport, Public Works and Water Management. Drivers involved in the transport of dangerous goods must meet additional training requirements, and must carry transportation documents that meet specific requirements as well.

Carriers have organised themselves in several sector associations: the Royal Dutch Transport Association (*Koninklijk Nederlands Vervoer*, KNV) and Transport & Logistics Netherlands (*Transport en Logistiek Nederland*, TLN), and the Own Transport Organisation (*Eigen Vervoers Organisatie*, EVO). These organisation are involved in efforts to update and implement regulations associated with the transport of dangerous goods. In 2005, TLN and KNV founded the Dutch Tank and Silo Association (DTSA), which promotes the interests of tank-based transport.

Tank lorry manufacturers
Another party involved in the transport of dangerous goods is the manufacturer of the tank lorry. Tank lorries are commissioned by the carriers, and built with due regard for the applicable regulations and customer requirements.

3. SUPERVISION AND ADMISSION

Inspectorate for Transport, Public Works and Water Management
The IVW supervises compliance with laws and regulations governing the transport of dangerous goods in the Netherlands. The IVW focuses on transport operations by road, rail, inland waterways, sea and air.

Inspectorate of Housing, Spatial Planning and the Environment
The Inspectorate of Housing, Spatial Planning and the Environment (also known by the Ministry's Dutch acronym, the VROM Inspectorate), oversees the safety, health and durability of the physical environment of people and animals.

Public Order and Safety Inspectorate
The Public Order and Safety Inspectorate (IOOV) supervises the manner in which municipal, provincial and national government bodies implement their tasks relating to fire services and disaster relief in practice.

Labour Inspectorate
The Labour Inspectorate supervises compliance with a large number of acts and decisions, many of which are aimed to protect the safety and health of employees. The Labour Inspectorate makes significant contributions in dealing with special risks in companies that may cause disasters with severe effects on the surrounding area. This concerns companies that are subject to the Hazards of Major Accidents Decree (*Besluit Risico's Zware Ongevallen*) or to a compulsory Supplementary Risk Assessment. In most cases, these are businesses, plants and processes that involve the processing of huge quantities of dangerous goods.

Road Transport Agency
The Road Transport Agency has been responsible, among other things, for vehicle certification since 1949. Originally a government body subject to the Minister of Transport, Public Works and Water Management, the Agency was privatised in 1996, when it became an independent administrative body – a public non-profit organisation that performs tasks for the Dutch government. As regards the transport of dangerous goods, the Road Transport Agency is the body that is responsible for testing high-risk vehicles, such as tank lorries carrying dangerous goods. In addition to its supervisory and monitoring tasks, the Road transport Agency regulates the admission of tank lorries to the Dutch and European markets on the basis of technical standards. In this connection, the Agency[57] checks the extent to which vehicles meet the requirements in the various stages of their production process (tank vehicle design, carcass/body, complete vehicle). Operational tank lorries undergo a periodical test every year (the *APK* test). In addition, a special department of the Road Transport Agency inspects the tanks for leaks once every three years, and performs a tank material strength test once every six years. The vehicle owners are obliged to report any damage or changes to their vehicles to the Agency.

Traffic Law Enforcement Office of the Public Prosecution Service
The Traffic Law Enforcement Office of the Public Prosecution Service (BVOM) formulates recommendations in the field of traffic and transport for the Public Prosecution Service, the judiciary, the police and road users. The BVOM draws upon its vast expertise in the settlement of cases. With respect to the transport of dangerous goods, the BVOM, being a centre of expertise on traffic and transport, has the dual task of developing policy and issuing advice. The overall aim is to formulate an unambiguous and effective investigation and prosecution policy. To that end, the BVOM partners with the enforcement units of the Public Prosecutor's Office, the National Police Services Agency (KLPD), Customs and the IVW.

As regards responsibility, the primacy rests with the Public Prosecution Service from a criminal law perspective and with the IVW from an administrative law perspective (supervision).

4. OTHER: KNOWLEDGE INSTITUTES, PROFESSIONAL ASSOCIATIONS

Netherlands Institute for Physical Safety (Nibra)
The Netherlands Institute for Physical Safety Nibra (formerly the Netherlands Institute for Fire Services and Disaster Control) is an independent administrative body that has the statutory task to provide training programmes for the fire department. In addition, Nibra performs research commissioned by third parties and provides advice.

Netherlands Association for Fire Departments and Disaster Relief
The Netherlands Association for Fire Departments and Disaster Relief (NVBR) is a professional association without legal powers, which aims to support fire departments in the Netherlands by updating their knowledge and disseminating new insights. The NVBR has several specific portfolios, including Fire Services, which itself is divided into several networks. Each network comprises a group of specialists (from fire services practice) who, at sector lever, focus on a specific policy area and operational field. The NVBR includes a total of eighteen of such networks. The Dangerous goods Accident Relief network is one of the networks in the Fire Service portfolio, and aims to structure knowledge and experience within the various fire departments concerning the response to accidents involving dangerous goods and to make that knowledge available at the central level.

[57] Or a different appropriately accredited testing agency.

National Information Centre for Accidents Involving Dangerous goods
The National Information Centre for Accidents Involving Dangerous goods (LIOGS), part of *DCMR Milieudienst Rijnmond* (originally established as the Rijnmond Central Environmental Management Department) offers expert advice and information about dangerous goods. The LIOGS' principal task is to provide a second opinion for the Regional Dangerous goods Officer and to offer "peer" advice to the expert of a regional fire department in the settlement of a specific incident. The Chemical Advice cluster can be contacted by telephone 24 hours a day. In principle, telephone contact can be established between the regional expert asking for advice and the chemical substances advisor within fifteen minutes after the request comes in. The chemical substances advisor has access to a wide range of reference works and automated files. The LIOGS is the Dutch section of the ICE (International Chemical Environment) programme, which aims to ensure the rapid provis ion of information about specific substances by an industry expert.

Policy Support Team for Environmental Incidents
The Policy Support Team for Environmental Incidents (in short BOT-mi) was founded by the Ministry of Housing, Spatial Planning and the Environment to improve advice in connection with environmental incidents and accident response. The team is available seven days a week, 24 hours a day, to provide assistance to the competent authorities and disaster relief teams and advise them about the measures to be taken in the event of accidents involving dangerous goods and environmental disasters. The BOT-mi has eleven members who represent a range of participating institutes and disciplines, such as the Royal Netherlands Meteorological Institute (KNMI), the National Poison Information Centre (NVIC), the External Safety Centre (CEV) and the Environmental Accidents Service (MOD) of the National Institute for Public Health and the Environment (RIVM).

ANNEXX 3 JUSTIFICATION OF THE INVESTIGATION

Legal framework

The Dutch Safety Board (and the Dutch Transport Safety Board before 1 February 2005) was instituted by an act of Parliament, and is charged with the task of investigating and establishing the actual or suspected causes of individual incidents or categories of incidents. The sole purpose of such investigations is to prevent similar incidents in the future and, if justified by the results of the investigation, to issue relevant recommendations.

Internal decision-making about the delineation of (partial) investigations

As discussed in Chapter 1 (Introduction), the present investigation was launched in connection with the accident in Ewijk. At the time, the then Dutch Transport Safety Board decided to commission an exploratory inquiry into that particular accident by the Dutch Institute for Fire Service and Disaster Relief. The result of that inquiry was published in mid 2003, and led to the proposal to restrict further investigation efforts to 'the reason the tank lorry caught fire' and 'the problems that occurred in connection with the relief operations'. This implies that the following aspects would not be investigated in further detail: the choice for the type of transport (road) and the route, the cause of the collision, the provision of information to the public, and the evacuation issue in connection with disaster relief efforts. The Dutch Transport Safety Board adopted the proposal at its meeting of 12 June 2003.

Not longer after that decision, on 14 July 2003, a similar accident took place on the A2 motorway near Eindhoven, when a tank lorry carrying a load of LPG crashed and caught fire. That accident was also subjected to an exploratory inquiry, which led to the proposal to conduct a combined investigation into the two accidents, with special attention for a) safety measures in connection with temporary road works, b) accessibility issues faced by the fire department in the event of accidents on motorways, c) the location, fastening and design of fuel tanks in lorries, d) the provision of information about tank lorry loads in the event of an accident, and e) risk assessment and decision-making processes in the response to tank lorry fires. The Dutch Transport Safety Board discussed and adopted the proposal at its meeting of 11 September 2003.

Due to a lack of resources and capacity, the investigation could not be started straight away and it was decided to postpone it until further notice. In addition, in mid 2004 a request came in to draw up a report that dealt exclusively with the aspect of the fuel tank. The Dutch Transport Safety Board nevertheless decided, by the end of September 2004, that a more comprehensive report was called for. It drew up a plan of action which stated that the investigation was to focus on the following three aspects:

a) collision safety of fuel tanks on lorries
b) transfer of information about the load of the tank lorry
c) risk assessment and decision-making in the response to tank lorry fires.

On 5 April 2005, this plan of action was discussed by the newly instituted successor of the Dutch Transport Safety Board: the *Onderzoeksraad voor Veiligheid* (Dutch Safety Board). The decision was made to narrow down the scope of the investigation as much as possible, also – and especially – as regards component c), to dangerous goods and, more specifically, the risk of an explosion or BLEVE.

After discussing the first draft report, the Safety Board decided, in February 2006, also to devote attention to the transport policy for dangerous goods, the practical implementation of that policy and of the supervision of such transports, and measures to ensure that sufficient knowledge is available on site in the shortest possible time.

Set-up of the investigation

The investigation consisted of the following parts:

- interviews with (chief) fire department officers involved in the two tank lorry fires
- interviews with fire department officers of other fire department regions
- interviews with officials at the Ministry of Housing, Spatial Planning & the Environment, the Interior; the Ministry of Transport, Public Works & Water Management; the Inspectorate of Transport,, Public Works & Water Management; the Road Transport Agency, knowledge institutes and consultancy firms
- interviews with the manufacturers of the LPG tank lorries and recovery staff

- verification of the interview reports
- document study
- report about the relief operations, the risks associated with the transport of dangerous goods and with fuel tanks, and the drafting of a final report
- verification of the final report by the parties involved.

As regards the relief operations, interviews with fire fighters and document studies have yielded insight into the factors that play a role in the fire department's decision whether to take immediate action (extinguish the fire or cool the vehicle) or to wait and see how the fire develops. The facts underlying these factors have been described, and both events have been analysed to determine the practical value of those factors. A report was drawn up and submitted to the Dangerous goods Officers of seven different fire department regions. The information thus obtained has been incorporated into the draft report.

The final report of the Safety Board
A draft report was written after completion of the investigation. In all, the Guidance Committee studied the investigation and the report four times and made comments that have been integrated into the report. In addition, an internal assessment was conducted of the logic and consistency of the report, and of the quality of its recommendations. The Safety Board discussed the draft report on 11 July 2006.

In July and August 2006, the draft report was submitted to the organisations involved. The following organisations sent a reaction:

1. Netherlands Association of Fire Departments and Disaster Relief (NVBR)
2. Fire departments of Noord and Oost-Gelderland and Zuidoost-Brabant
3. Ministry of Transport, Public Works and Water Management
4. Ministry of Housing, Spatial Planning and the Environment
5. Ministry of the Interior
6. Road Transport Agency (RDW)
7. the RIVM's External Safety Centre
8. TNO's Industrial and External Safety Team
9. External Safety Advisors (AVIV)
10. Transport and Logistics Netherlands (TLN)
11. Own Transport Organisation (EVO)
12. Royal Dutch Transport Association (KNV Goederenvervoer)
13. Association of the Dutch Chemical Industry (VNCI).

The Netherlands Institute for Physical Safety Nibra and several individual experts returned a number of draft copies with comments instead of a formal response. All the reactions have been processed into the draft report, which was submitted to the Safety Board on 3 October 2006 and approved for publication by that same Board on 31 October 2006. Where comments could not be incorporated into the report, this is stated in the relevant texts (except for comments that did not concern the contents of the report). In addition, a document has been drawn up with details about how the reactions were dealt with.

ANNEX 4 VARIOUS TYPES OF LOAD AND POTENTIAL CONSEQUENCES IN THE EVENT OF A TANK LORRY FIRE

This appendix presents a concise overview of the potential consequences of a fire in or near a vehicle with different types of load, including dangerous goods. The sources that were consulted include the European Agreement concerning the Carriage of Dangerous Goods by Road (ADR), the Operational Manual for Dangerous goods Accident Relief (NVBR, April 2005) and contacts with experts.

Dangerous goods
The ADR distinguishes between various classes of dangerous goods. For each class, the overview below indicates the possible consequences of a fire in or near a vehicle that is transporting substances in that class. Note that individual substances may have multiple properties (e.g., they can be both poisonous and flammable).

1 Explosive substances and objects
- Mass explosion, in which all explosive substances explode at the same time. The shock waves thus produced will cause material fragments to be hurled away with tremendous force.
- Not a mass explosion, but explosions of separate pieces of ammunition. The resulting shock waves will hurl away fragments, burning parts of the packaging and bits of ammunition that have not exploded (but may still explode once they have hit the ground).
- Violent combustion of explosive substances and ammunition. Separate bits of ammunition may explode, causing minor pressure waves and material fragments or burning parts of the packaging to be hurled away with limited force.
- Combustion of explosives and ammunition fragments, without causing any major risks. The explosives will not significantly intensify the fire. On a limited scale, bits of ammunition may explode, but the fragments will not cover a great distance.

2 Flammable gases
- Torch fire, gas cloud explosion, or pool fire: when flammable gases or liquefied flammable gases leak and are ignited.
- BLEVE: See Appendix 5

3 Flammable liquids
- Pool fire: When a pool of flammable liquid ignites, the result is a pool fire. The pool fire will radiate heat to its environment.
- BLEVE: See Appendix 5.
- Vessels and tanks hurled away: Separate from a BLEVE, vessels and tanks can burst as a result of heating and be hurled away (whole or in pieces). This occurs regularly especially with small vessels or drums.
- Torch: A leak followed by fire can result in a torch fire. The size of the torch depends on various factors, including the size of the hole, the properties of the liquid and the pressure.
- Cloud fire or explosion: An explosion is only possible in the case of delayed ignition in a confined space. During road transport, the chance of a cloud explosion is very small; instead, ignition of a free gas cloud will result in a cloud fire. The flame front of such a fire travels at a high speed and the people inside the cloud have little chance of survival. Some materials within the gas cloud may catch fire, and secondary fires may develop.

4.1 Flammable solids
- Fierce and rapidly developing fire (especially in the case of finely distributed material).
- Slowly developing fire (in the case of porous degasified flammable or very finely distributed materials).
- Dust explosion: When a critical concentration of dust has built up in the air. Even a dust explosion of modest size may cause a chain reaction of dust explosions in its environment, as a result of the dust being blown up by the shock wave.

4.2 Substances prone to spontaneous combustion
- These substances can catch fire when they come into contact with air, potentially releasing toxic substances.
- Fires in which these types of substances are involved cannot simply be extinguished with water:
  - in the case of metal fires, the water will react to form hydrogen gas;
  - soot combined with water will trigger the so-called water gas reaction (carbon monoxide and hydrogen gas);

- creation of toxic gases.

4.3 Substances that develop flammable gases after contact with water
- When they come into contact with water, these substances may lead to the creation of flammable gases which potentially can ignite straight away.
- The fire cannot be extinguished with water. In most cases the only option is to allow the fire to burn up under controlled circumstances.

5.1 Oxidizing substances
- These substances release oxygen, as a result of which they can cause or stimulate the combustion of other materials – or of objects containing such materials – even if they are not flammable themselves. Toxic gases may be released in the process.

5.2 Organic peroxides
- Thermal decomposition or explosion following exposure to fire or a source of heat. This results in a cloud of vapour that consists of the peroxide and the products of its decomposition, which, mixed with air or otherwise, may produce a secondary explosion. The temperature inside the vapour cloud may rise to a level where it triggers the spontaneous combustion of the cloud and its subsequent explosion (the latter is only possible, however, in confined spaces and does not apply to all substances).
- Fire danger: some organic peroxides are highly flammable.

When released, the following substances pose a threat to people in the area due to their inherent properties. No specific scenarios have been described for cases in which vehicles carrying these substances catch fire:
- 6.1 Toxic substances
- 6.2 Infectious substances
- 7 Radioactive substances
- 8 Corrosive substances
- 9 Various types of dangerous substances and objects

Other types of load

Fire can also have severe consequences in the case of vehicles carrying other types of load. This includes, among other things,
- flammable materials, such as wood, paper, and fatty substances. When a vehicle carrying such a load catches fire, the flammable materials offer a substantial additional fire potential. This may cause damage to vehicles in the immediate vicinity which may themselves be loaded with dangerous goods.
- materials which do not qualify as hazardous themselves may produce toxic vapour products when they are burnt.

ANNEX 5 BLEVE[58]

What is a BLEVE?
BLEVE is short for Boiling Liquid Expanding Vapour Explosion.

Definition of a BLEVE
A BLEVE is caused when a pressure vessel that contains a liquid/gas equilibrium of a (pure) chemical substance bursts. The distribution of liquid and vapour (i.e. the pressure in the vapour phase) is determined entirely by the boiling line of the substance and the temperature inside the vessel. When the pressure at a given tank temperature is above the atmospheric pressure, the liquid inside the tank will be overheated and will evaporate virtually instantaneously, either wholly or in part, in the event that the tank ruptures. The degree of overheating determines the extent to which the liquid evaporates.

In connection with the attempt to model the (external safety) risks associated with dangerous goods (also see the coloured books), the term BLEVE is used more specifically for cases in which the pressure tank of a compressed liquefied gas bursts. In the context of transport, in most cases the gas concerned is LPG. With LPG, the extent of "overheating" is such that virtually all the contents of the tank will evaporate instantaneously.

Note that a BLEVE cannot occur, therefore, when the flammable substance concerned has a relatively high boiling point (and is transported in an atmospheric tank). A BLEVE is also impossible in the case of flammable gases.

In the transport of liquefied gases, a BLEVE can have two causes:

1. Fire or flames that come into contact with the tank. This will heat up the contents of the tank and increase the pressure (according to the vapour/liquid equilibrium). At the same time, the rising temperature may reduce the strength of the tank in places. The combination of increased pressure and (locally) reduced strength will eventually cause the wall to rupture. No details about this process are known.
2. Mechanical impact (for example, from a collision) causing the tank wall to rupture. The pressure at which the liquid is released may be lower than in the case of a fire.

To distinguish between these causes, the first is sometimes referred to as a hot and the second as a cold BLEVE.

What are the consequences of a BLEVE?
With regard to a BLEVE, three mechanisms are distinguished that can cause damage and injury:

1. First of all, the shock wave, which causes damage in particular near the source (physical explosion).
2. In the case of fire and flammable substances, this is followed by a fireball. The fireball is the decisive cause of damage, and produces a combination of heat radiation and oxygen depletion, across a considerable distance (depending on the size), which, especially in tunnels, is fatal to human beings.
3. The third mechanism is the violent fragmentation of the pressure tank. The fragments can be hurled away across substantial distances.

Note that in the event of fire, no (chemical) gas cloud explosion will occur. However, theoretically such an explosion is possible when the BLEVE is caused by mechanical impact: in that case, flammable gases disperse into the atmosphere where they create a flammable and explosive mixture which can give way to a gas cloud fire and an explosion when ignited. Whether the cloud explodes depends on the degree of its confinement. In practice, the risk of an explosion is very small: in many cases the impact is likely to be accompanied by sparks or contact with hot surfaces which will ignite the gas immediately.

[58] This appendix was drawn up by the Dangerous goods Advisory Council.

ANNEX 6 PRESSURE RELIEF VALVES AND THEIR WARNING FUNCTION FOR THE FIRE DEPARTMENT

Pressure relief valve technique
Some pressure tanks are fitted with a valve that is able to relieve overpressure inside the tank, reducing the chance of a rupture and of an explosion of the tank lorry. A pressure relief valve, which is around 60 cm long[59], consists of a large spring (see figure 10) and is fitted inside the tank lorry. It should not project anywhere on the outside of the tank, because in that case it might break off when the tank is scratched or hit and cause a hole in the tank wall. When compressed due to rising internal pressure, the spring creates an opening through which gas can flow out, causing the internal pressure to fall. The spring will then return to its original position.

Illustration 9: Pressure relief valve

The valve is usually fitted in the top rear section of the tank lorry, which means it is only visible on that side. When the tank lorry has overturned, liquid may spurt out of the valve instead of gas.

The pressure relief valve was not designed to withstand fire, which means it cannot rule out an explosion or BLEVE. This can be explained as follows. Three different types of pressure should be distinguished: the (internal) pressure needed to compress the gas, the opening pressure of the relief valve, and the design pressure of the tank wall[60]. When the internal pressure in the tank rises to the level of the opening pressure (due to heating), the valve will open and gas will flow out. This will cause the internal pressure to fall, as a result of which the valve will close again automatically. When the heat source remains active, pressure will rise once again. When the valve remains open and continues to release gas, it may be the case that the pressure inside the tank rises faster than the rate at which the valve can release the gas. This means that the internal pressure will continue to rise and will exceed the opening pressure of the valve. In principle, a fire in the fuel tank of the vehicle could be enough to trigger this scenario, as diesel fires may cause other components of the vehicle to catch fire as well, such as the tyres, or even other vehicles nearby. Nevertheless, pressure relief valves will help to keep the internal pressure lower than the design pressure of the tank wall for a long time, even in the case of fire. An additional advantage is that this will give fire fighters more time to take action to prevent the tank wall from rupturing, although they will not know exactly how much more time they have and, as indicated above, the valve cannot guarantee that the tank will remain intact. The tank will burst when the internal pressure rises to a level one and a half or twice the design pressure of the tank. This is a rough indication, because conditions during a fire can be different from the standard situation that served to calculate the design pressure. Intense heating may cause the strength of the steel to decline in certain sections of the tank.

One disadvantage of the pressure relief valve is the fact that it cannot function properly unless it is in contact with the vapour phase, i.e. positioned above the surface of the liquid. In the event that the tank lorry has overturned or has been overfilled, liquid will leak or spurt out of the valve if the pressure inside the tank exceeds the design pressure of the valve. This can be dangerous in the case of dangerous goods, because the leaked fuel can catch fire and thus increase the intensity of the overall conflagration. In addition, the gas, vapour or liquid may cause injury (through freezing)

[59] The size is determined by a capacity calculation based on the ADR (6.7.3.8.1.1).
[60] The calculated pressure of an LPG tank depends on the gas to be transported. Given that carriers tend to prefer tanks that are suitable for a wide variety of substances, in 99% of cases the calculated pressure is 25 bar with an awning and 27 bar without an awning. The design pressure of the valve should be 0,9 to 1.0 times the design pressure of the tank. For most LPG tanks without an awning this is 24.3 to 27 bar.

when it comes into contact with the human body.

The warning function of the pressure relief valve
The release of gas through the valve produces a sharp hissing or wheezing sound, which accounts for the warning function of the valve in addition to its pressure relief function. When the valve is blowing off, this is a sign for the fire department that the internal pressure is rising and that the situation is or may soon become unsafe. Several fire fighters have indicated that they stay clear of a vehicle as soon as they hear the sound of a valve blowing off. However, this poses a problem. Although not compulsory, pressure relief valves are still a common feature on LPG tanks. If, in the case of an accident, fire fighters assume there is a valve on the tank while in fact there is not, they are potentially in danger. When they mistakenly believe the tank is fitted with a valve but cannot hear it blowing off, they may assume that the internal pressure has not yet reached a critical level. Moreover, even when the fire fighters do hear the sound, they cannot tell whether the valve is able to cope with the rising pressure level. Additionally, due to local heating (see section 3.6) the wall of the tank may rupture even before the valve has begun to blow off.

The fire department does not always know whether a tank lorry is fitted with a pressure relief valve. This can be explained by the fact that such valves are not compulsory under international regulations, but can be required under local laws.

In an international context, the ADR and Directive 94/55/EC refer to safety valves as an optional feature for the transport of LPG and some other substances. Nationally, the VLG provides supplementary regulations taken from CPR Directive 8-2 (the directive on LPG tank lorries drawn up by the then Committee for the Prevention of Disasters involving Dangerous goods). The regulation that made safety valves compulsory was withdrawn when Directive 94/55/EC came into force, because under that Directive the valves were not compulsory. This is why tanks in the Netherlands no longer have to be fitted with a safety valve.

The CPR 8-2 and the textually copied (and superseded) PGS 17 (from the Dangerous goods Publication Series) are both recommendations. They cannot be made compulsory unless they are included in other regulations. Municipal authorities are free to take CPR and PGS as points of departure for issuing Nuisance Act permits, and to impose specific conditions on the provisioning of filling stations by tank lorries fitted with pressure safety devices. Those measures would then constitute an obligation to fit a safety valve for tank lorries used for distribution purposes, depending on the municipality that issues the Nuisance Act permit. Note, however, that tank lorries used in international transport operations would be exempt.

Vehicles used for transporting liquids such as ethyl acetate are only occasionally provided with a pressure relief valve, depending on the specific properties of the liquid. The ADR contains a list that specifies for each substance the type of tank in which it must be transported. Under the ADR, an ‘air relief valve’ is sufficient in the transport of ethyl acetate. The ADR tank hierarchy also allows the use of a hermetically sealed tank or a safety valve (pressure relief valve).

Illustration 10: Pressure relief valve fitted to the rear of a tank lorry (top)

The fire department should check the presence of a valve on site, and go by information provided by the driver or obtained through its own observations. Pressure relief valves are not easily seen from a distance (see figure 11 above), especially when there are flames and smoke.