DUTCH
SAFETY BOARD

Fire in a CNG bus

Fire in a CNG bus

Wassenaar, 29 oktober 2012

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Dutch Safety Board

The aim in the Netherlands is to limit the risk of accidents and incidents as much as possible. If accidents or near accidents nevertheless occur, a thorough investigation into the causes, irrespective of who are to blame, may help to prevent similar problems from occurring in the future. It is important to ensure that the investigation is carried out independently from the parties involved. This is why the Dutch Safety Board itself selects the issues it wishes to investigate, mindful of citizens' position of independence with respect to authorities and businesses. In some cases the Dutch Safety Board is required by law to conduct an investigation.

	Dutch Safety Board		
Chairman:	T.H.J. Joustra E.R. Muller P.L. Meurs		
General Secretary:	M. Visser		
Visiting address:	Anna van Saksenlaan 50 2593 HT The Hague The Netherlands	Postal address:	PO Box 95404 2509 CK The Hague The Netherlands
Telephone:	+31 (0)70 333 7000	Fax:	+31 (0)70 333 7077
Website:	www.safetyboard.nl		

NB: This report is published in the Dutch and English languages. If there is a difference in interpretation between the Dutch and English versions, the Dutch text will prevail.

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Reason for the investigation

On 29 October 2012 a fire broke out in a natural gas (CNG)-powered regional bus in Wassenaar. After the driver had brought the bus to a halt and the passengers had evacuated, the fire spread from the engine compartment to the rest of the bus. The fire caused the natural gas cylinders on the roof of the bus to heat up, activating the safety valves to prevent the cylinders from exploding. Horizontal flames 15 to 20 metres in length shot up from the natural gas that had been released. The shooting flames continued for about four minutes in total. Since no people or buildings were located within reach of the shooting flames, the consequences of the fire were limited.

Although there were no casualties in the bus fire, the shooting flames could have had much worse consequences had the location been different – a narrow shopping street or a tunnel, for instance. What is striking in this incident is that precisely the safety mechanism which is built in to prevent an explosion, in turn, posed another hazard, namely the long shooting flames. Partly in view of the fact that the use of CNG has rapidly grown in recent years, the Dutch Safety Board felt that it was important to conduct an investigation.

This report is the result of the Dutch Safety Board's investigation. This *Consideration* describes the main lessons learned from the investigation and concludes with recommendations.

Lessons learned from the investigation

Risks to the surroundings posed by CNG-powered buses
The flames that shot up during the bus fire in Wassenaar pose a safety risk for its operating environment. If environmental risks are associated with road vehicles, these risks usually relate to the carriage of dangerous goods as *cargo*. Comprehensive laws and regulations apply to the *carriage* of dangerous goods, and set out regulations for the vehicle's equipment and the packaging of the cargo as well as the roads that may and may not be used. The principle underlying these provisions is that the road traffic risks to which people located in the vicinity of roads are exposed may not exceed a certain level. However, these regulations only apply to vehicles carrying dangerous goods as cargo. Engine fuel used to propel the vehicle is not subject to the above regulations. This in itself is logical because engine fuel in a sense forms part of the vehicle itself, which means that vehicle regulations should provide for adequate control of the risks associated. In certain situations, however, engine fuel could pose a risk for people and objects located in the vicinity. As the Wassenaar incident showed, this could, for instance, be the case if fire breaks out on a CNG-powered bus. The municipalities located in The Hague Region

[*regio Haaglanden*], where the CNG-powered buses operate, failed to recognise that in certain situations CNG-powered buses carry other or higher risks than the diesel-powered buses used in the past. Incidentally, these specific risks were not pointed out to the municipalities by the transport parties involved, who likewise failed to recognise these risks, as explained further on in this report. Consequently, the specific risks posed by CNG-powered buses were not assessed systematically. Given the potentially severe consequences, in the Dutch Safety Board's opinion a risk assessment should still be performed.

The decision to switch from diesel to CNG-powered buses in the above region was taken by The Hague Region. The public transport company (Veolia) was only involved in implementing the decision but had no role in the decision-making process itself (choice of fuel). The investigation established that the municipalities involved opted for CNG based on environmental objectives and failed to assess the possible consequences for safety during the process. In the Dutch Safety Board's opinion, the safety consequences should have been assessed on account of the risks described above. The Dutch Safety Board is furthermore of the opinion that it would be advisable to involve public transport companies in the choice of fuel.

Vehicle regulations
The bus involved in the fire in Wassenaar complied with all technical regulations, including its CNG system. The CNG system operated as envisaged in these regulations. This means that the current requirements applicable to CNG systems allow for the occurrence of shooting flames, as was the case in Wassenaar. The above requirements are drawn up at the international level. RDW, a public service associated with the Ministry of Infrastructure and the Environment, represents the Netherlands in this context. In terms of safety, international vehicle requirements relate mainly to road safety and occupant protection. The requirements only partially acknowledge that environmental risks may also occur. A measure has, for instance, been taken to prevent gas cylinders from exploding by means of a valve, which allows the cylinder contents to escape if the cylinder heats up. The regulations, however, fail to recognise that this creates other risks, such as shooting flames or an explosive gas cloud. In the Dutch Safety Board's opinion vehicle requirements must be tightened in this area.

Risk awareness and interpretation of duties by the parties involved
The Hague Region is the contracting party for public transport bus services in The Hague metropolitan area, which includes Wassenaar. The concession was awarded – in accordance with the legislation – on the basis of a public tendering procedure. The schedule of requirements for the tender contained several criteria, such as the frequency of bus services, punctuality and self-evidently the cost. No requirements on physical safety, however, were imposed by the Hague Region. Incidentally, this is not laid down by law. The Dutch Safety Board believes that a contracting party who engages another company to perform high-risk activities has a responsibility towards society to ensure that the contract is performed in the safest possible manner, even if no such legal requirement exists. The Dutch Safety Board fails to see why public passenger transport should form an exception in this respect. On the contrary, in this sector too contracting parties (in this case the public transport authorities) should jointly feel responsible for the safety of the operations performed under their contract. The Dutch Safety Board has

established that the Hague Region's limited interpretation of its duties is not an isolated case. In previous investigations into incidents involving public passenger transport (such as the metro fire and collision in Amsterdam and hydrofoil safety issues) the public transport authorities involved held the view that they had no role in limiting the safety risks. In these instances too, the argument put forward was that joint responsibility cannot be assigned to the public transport authorities under the current laws and regulations. For this reason in the Dutch Safety Board's view the relevant legislation should be amended such that the requirement is still imposed on the public authorities to ensure that they pay due attention to limit the risks. Incidentally, during the procedure in which the parties involved were given an opportunity to respond to the draft version of this report, The Hague Region stated that it now in fact endorses the assignment of responsibility referred to above.

Veolia, a public transport company, won the tender at that time and thus became the 'concessionaire'. The company did not perform its own risk analysis concerning switching to CNG, but limited itself to the purchase of approved CNG-powered buses. Had Veolia included additional safety measures, it could possibly have priced itself out of the market as the contracting party had not requested any such measures in its schedule of requirements. Apart from this issue in the tendering procedure, the Dutch Safety Board deems that a public transport company is primarily responsible for the safe operation of transport services. In this context the Dutch Safety Board finds it striking that companies operating public bus services are not required by law to ensure they have a safety management system (SMS) in place. This contrasts with other modes of public transport, where – based in part on European regulations – this either already is mandatory (rail transport) or is due to become mandatory in the near future (tram and metro). In the Dutch Safety Board's view this should also be mandatory for public transport bus services.

The bus operating in Wassenaar was built by MAN, a German manufacturer. MAN had purchased the CNG system for this particular type of bus from a supplier. Since this system complied with the regulations, MAN had taken no additional safety measures. The manufacturer pointed out that its customers do not ask for such measures. This means that there is no incentive in the bus market to exceed the stipulated regulations. Bus manufacturers apparently compete mainly on price, and to a lesser extent on safety, unlike the passenger car sector where safety is a key selling point. In view of the manufacturers' attitude, which the Dutch Safety Board similarly observed in a previous investigation, improvements can only be expected if customers (in this case the transport companies) request that improvements be made, or if vehicle requirements are tightened. In the Dutch Safety Board's opinion – and as stated earlier – the latter should be carried out.

Fire brigade deployment procedure

When the CNG-powered buses were launched in The Hague Region the fire brigades in this area were not notified by the organisations concerned. The fire brigades therefore only began to make preparations for fire prevention in CNG-powered buses after the buses had already been operating for some time. In addition, there was no joint or coordinated approach and the fire brigades did not hold the requisite expertise. This gave rise to different and partly incorrect deployment protocols among the various fire

brigades. The Dutch Safety Board deems it advisable to centralise the development of deployment protocols.

Learning from accidents
The Dutch Safety Board established that none of the parties involved systematically learns lessons from incidents and accidents. This occurs at different levels. In terms of vehicle regulations, the authorities concerned – RDW in the Netherlands – do not systematically collect information about relevant accidents to determine whether there is a need to tighten the technical requirements with which vehicles must comply. In respect of the implementing parties, neither the public transport authorities nor the public transport companies have put procedures in place to collect and analyse accident information for the purpose of learning lessons. The Dutch Safety Board deems it vital to learn lessons on a structural basis on both fronts.

Wider perspective

The safety problems identified are not unique to CNG-powered buses in The Hague Region. In the first place CNG-powered buses similar to the buses operating in The Hague Region are also used in other areas. The number of CNG-powered buses in the Netherlands currently totals over 600. CNG moreover is increasingly being used as engine fuel for other types of vehicles. In the Netherlands over 3,000 passenger cars and around 2,500 vans currently run on CNG. The CNG cylinders in these vehicles are also fitted with temperature-triggered pressure relief devices (PRDs) and in the event of heating up may vent the supply of natural gas. It should be noted that the capacity of CNG cylinders in passenger cars and vans is generally five to ten times lower than those of CNG-powered buses. However, CNG-powered trucks carrying a supply of CNG similar to that of CNG-powered buses are now available on the market. It is striking that CNG-powered trucks too are mainly deployed in urban areas (such as refuse trucks). The explanation lies in the specific advantages and disadvantages of CNG (low exhaust emissions and less engine noise or a relatively narrow operating range). Regrettably, however, it is precisely in the urban environment where the specific safety risks inherent in CNG are the most prevalent.

At the administrative level, the Dutch Safety Board largely sees the same pattern for other CNG-powered vehicles as described earlier for CNG-powered buses; municipal and the provincial authorities promotes the use of CNG as engine fuel yet fails to take account of the specific safety aspects.

The Dutch Safety Board is aware that alternative engine fuels, such as CNG and hydrogen, can have significant advantages. When introducing alternative fuels, however, a proper assessment should be made of the extent to which they carry specific safety risks, not only for the occupants of the vehicle, but also for its operating environment and other road users. The environmental risks may, for example, relate to large shooting flames in the event of a bus fire, which moreover are invisible in the case of hydrogen. It is key to prescribe as mandatory that these risks be controlled in adequate vehicle regulations. Furthermore both the manufacturers and the operators of these types of vehicles should be aware of the fact - now more than has been the case to date - that an innovation

carries inherent risks. These parties should not automatically rely on vehicle regulations but should, where necessary, take additional measures based on their own critical assessment. In addition, the authorities involved should critically assess in what situations or on what conditions new vehicle technology can be deployed responsibly in the light of the residual risks for the vehicle's operating environment.

Recommendations

The Safety Board has formulated the following recommendations:

1. **Identification and analysis of the environmental risks associated with current CNG-powered buses**

To the public transport authorities and public transport companies operating CNG-powered buses:

Identify the risks for the operating environment associated with the use, maintenance and parking of CNG-powered buses and take measures to reduce these risks.

2. **Formulate and tighten vehicle regulations**

To the Minister of Infrastructure and the Environment:

a. Ensure that the international vehicle regulations applicable to CNG systems (UN/ECE Regulation 110) are tightened to ensure that the risks for the environment are controlled in the event of vented gas.
b. Ensure that RDW systematically collects the relevant accident information and applies that knowledge when international vehicle regulations are established or amended.

3. **Safety obligations on the part of the public transport authorities and transport companies**

To the Minister of the Environment:

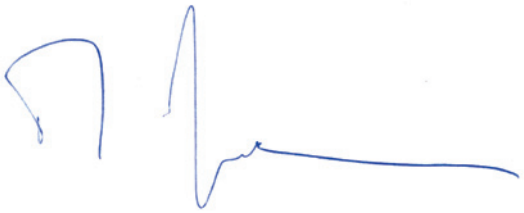
Incorporate in the Passenger Transport Act 2000 [Wet personenvervoer 2000] the following requirements:

- that bus companies systematically manage the risks associated with their operations by means of a safety management system;
- that the authorities contracting public transport bus services impose requirements on the transport company for managing safety risks.

4. Development of the fire brigade deployment procedure in the event of vehicle fires

To the Safety Council [Veiligheidsberaad]:

Ensure the central development of the deployment procedure for fighting fires in vehicles powered by non-conventional fuels (such as CNG and hydrogen).



T.H.J. Joustra
Chairman, Dutch Safety Board

M. Visser
General Secretary

GLOSSARY OF TERMS AND ABBREVIATIONS

ADR	The European Agreement concerning the International Carriage of Dangerous Goods by Road, commonly known as ADR [*Accord européen relatif au transport international de marchandises Dangereuses par Route*]
ALARP	As Low As Reasonably Practicable
Bar	Unit of pressure (1 bar ~ 1 atmospheric pressure = 1 kgf/cm2)
CBS	Statistics Netherlands [*Centraal Bureau voor de Statistiek*]
CCV-B Diploma	Diploma of professional competence for truck and bus drivers in the road transport sector [*Commissie Chauffeurs Vakbekwaamheid*]
CNG	Compressed Natural Gas
EU	European Union
HART	Guidelines for the Analysis of Risks inherent in the Transport of Dangerous Goods by Road [*Handleiding Risicoanalyse Transport*]
ILT	Human Environment and Transport Inspectorate [*Inspectie Leefomgeving en Transport*]
KIWA	An independent organisation mandated by the Minister to issue passenger transport operating licences to transport companies
LPG	Liquefied Petroleum Gas
MAN	Manufacturer of trucks, buses and other commercial vehicles
MDT	Mobile Data Terminal
PRD	Pressure Relief Device
PT	Public Transport
RI&E	Risk Inventory and Evaluation
RAC	Regional Alarm Centre
RDP	Regional Deployment Procedure
RDW	An autonomous public body charged with the admission of vehicles and for monitoring the technical condition of vehicles (formerly the Government Road Transport Agency [*Rijksdienst voor het Wegverkeer*])
RNVGS	Circular on Risk Standardisation for the Carriage of Dangerous Goods [*Circulaire Risiconormering vervoer gevaarlijke stoffen*]

SGH	The Hague Region, the conurbation around The Hague in the Province of South Holland in the Netherlands [Stadsgewest Haaglanden]
UN/ECE	Economic Commission for Europe (a regional commission of the United Nations)
Wvgs	Transport of Dangerous Goods by Road Act [*Wet vervoer gevaarlijke stoffen*]

1 BACKGROUND INFORMATION

1.1 The accident

On 29 October 2012 a fire broke out in the engine compartment of a CNG-powered public transport bus.[1] The bus, which was carrying one driver and five passengers, was operating in the Wassenaar urban area at that time. When the bus driver looked in his mirror and saw smoke developing, he continued driving to the next suitable location where he felt he could bring the bus to a halt. He had meanwhile alerted the transport company's traffic control centre, which in turn alerted the emergency services. After he had allowed the passengers to evacuate the bus, the driver walked around the back of the bus to the engine compartment with a fire extinguisher, but the fire had already reached such an advanced stage that he was unable to extinguish it. The fire then spread rapidly to the interior of the bus.

The fire had already fully developed when the fire brigade arrived (11 to 14 minutes after the fire had first been reported by the driver to the transport company's alarm centre). In accordance with the deployment instructions, the fire brigade decided to allow the fire to burn out in a controlled manner.

Figure 1: Bus on fire (left) and shooting flame. (Source: Regio15.nl)

1 CNG is the abbreviation for compressed natural gas.

In CNG-powered buses, gas is stored in roof-mounted high-pressure cylinders. When the cylinders heat up pressure builds up inside and the tensile strength of the cylinders weakens. To prevent the risk of explosion the cylinders are fitted with a mandatory temperature-triggered pressure relief device. If the temperature exceeds the threshold value of 110° Celsius, a valve opens venting the gas in the cylinder.

Several blow-off valves opened during the fire. The vented natural gas ignited, causing flames to shoot out. As a result of the high pressure in the cylinders and the type of blow-off valves, flames 15 to 20 metres in length shot out. The blow-off valves were located in a position which caused the flames to shoot out in a horizontal and sideward direction (see Figure 1).

Since no buildings were located directly alongside the road and there were no people in that particular area, the consequences of the shooting flames were limited to fire damage on the road surface, trees and shrubs. No personal injuries were sustained by the occupants, bystanders or emergency response personnel. However, the bus was completely destroyed.

The relevant facts of the Wassenaar incident are explained in greater detail in Appendix B.

1.2 Reason for the investigation

The Dutch Safety Board generally believes that companies and organisations should control the safety risks associated with their operations to the best possible extent (ALARP[2]). The fact that such long shooting flames were emitted in the Wassenaar bus fire raises the question of whether the risks were adequately controlled. The laws and regulations form an important risk control framework. An exploratory investigation showed that the natural gas fuel system complied with the applicable technical requirements and that the temperature-triggered pressure relief device functioned as intended during the fire. Shooting flames occurred nonetheless. This raises questions about how these rules were established and the degree to which they provide for adequate control of the risks associated with the use of CNG as a fuel.

Aside from the above, the risk in question justifies an investigation by the Dutch Safety Board. Both the extent of the possible consequences and the probability of occurrence are greater than the incident in Wassenaar initially seems to suggest. The shooting flames that were emitted could have inflicted more damage and possibly injuries had they occurred at another location. The bus involved in the fire came to a halt on the main carriageway of a wide road containing a service road. This meant that the distance to the surrounding buildings was relatively large. With buildings located directly alongside the road, at a bus station or in a tunnel – all of which are areas where these buses also operate services – the consequences of a similar incident could have been considerably severer.

2 Abbreviation for 'as low as reasonably practicable'.

On top of that, natural gas is increasingly being used as a fuel for bus transport in the Netherlands (see Appendix D). The number of public transport buses powered by CNG has risen from several dozen to more than 600 in the past seven years. As the number of CNG-powered vehicles rises, so too does the probability of similar accidents. An exploratory investigation (see Appendix C) shows that there is a 0.1% chance of a fully developed fire occurring per public transport bus per year. With over 600 CNG-powered public transport buses in service, this means that a fully developed fire in a CNG-powered bus can be expected once every 18 months in the Netherlands.

Even though this incident is the first to have occurred on Dutch territory, it is by no means unique in its kind. Eight fires in buses are on record in other EU member states and the USA (see Appendix E), three of which involved shooting flames.

In view of the above considerations, the Dutch Safety Board decided to investigate the incident in Wassenaar for the purpose of learning safety lessons.

1.3 Focus of the investigation

The investigation focuses on how the parties involved in public transport bus services (the contracting authorities, transport companies, bus manufacturers, regulators and supervisory authorities) address the identification, evaluation and control of safety risks when introducing CNG-powered public transport buses. This was transposed into the following three research questions:

1. *How do the parties involved in public transport bus services control the safety risks associated with the use of CNG as engine fuel?*
2. *Can impediments be identified in their (joint) performance of risk control?*
3. *What factors explain the occurrence and persistence of such impediments?*

The research questions were answered in respect of the incident in Wassenaar. The investigation subsequently examined to what extent the relevant findings have wider applicability.

The importance of a good risk control process took central stage in the investigation. The underlying rationale was that the same issues could also arise when launching 'new' fuels or other vehicle types. Furthermore the Dutch Safety Board decided not to examine whether the use of natural gas as engine fuel is sufficiently safe at all. In the Dutch Safety Board's view, the question of whether and on what conditions the advantages and disadvantages of new technological possibilities outweigh each other should be answered by the politicians and the relevant parties themselves.

2 THE ORGANISATION AND OPERATION OF PUBLIC TRANSPORT BUS SERVICES

2.1 Background

The organisation of public transport is set out in the Passenger Transport Act 2000 [*Wet personenvervoer 2000*]. The Act provides for the operation of public transport services by transport companies on the basis of concessions granted by the regional authorities. The Netherlands has been divided into concession areas for this purpose and a contracting authority designated for each concession area (denoted as the public transport authority). The contracting authority and the transport company make agreements in the concession on aspects such as the frequency, quality and costs of the transport services to be provided.

Currently there are 53 concession areas for public transport bus services, distributed across 18 contracting authorities (12 provinces and six urban regions) and 13 transport companies.

2.2 Organisation

2.2.1 Concession rules

The Passenger Transport Act 2000 stipulates requirements for the creation, terms and duration of concessions. Two aspects are important for this investigation:

Firstly, the Act stipulates that a concession will be granted by means of a public European tendering procedure. The general rules on tendering apply, as set out (at the time of awarding the concession) in the Public Procurement (Tendering Rules) Decree [*Besluit aanbestedingsregels voor overheidsopdrachten*].[3] The aim of the Decree is to open up public procurement in the domestic market to all companies located in the European Union, irrespective of their country of origin. This means inter alia that tender should be based on a contract document, which exhaustively describes the criteria on which tenders are assessed for the purpose of awarding the contract.

Secondly, the above Act provides that the concession should contain conditions for a number of topics. One such topic is safety. The Act requires the contracting authority to attach conditions to the concession to 'ensure a responsible level of safety for the benefit of both passengers using public transport and public transport employees'.

3 The Decree became inoperative effective 1 April 2013. The Tenders (EEC Regulations) Framework Act, on which the Decree was based, was superseded by the Public Procurement Act 2012 [*Aanbestedingswet 2012*]).

2.2.2 Vehicle safety rules

The Passenger Transport Act does not provide for the safety of vehicles used for public road transport. The rules laid down in the Road Traffic Act [*Wegenverkeerswet 1994*], however, apply to public transport vehicles and these rules provide that road vehicles must comply with the technical safety regulations in order be admitted on the public road in the Netherlands. These regulations are determined at the international level in order to create the largest possible market for vehicle manufacturers. The regulations focus on various vehicle aspects, such as crashworthiness (secondary safety), lighting, brakes and the fuel system. The technical regulations derive from a European framework directive which provides for the admission of road vehicles. Only in exceptional cases are EU member states allowed to demand additional requirements.

The technical regulations applicable to CNG systems are set out in UN/ECE Regulation 110, drawn up by the United Nations European Economic Commission (UNECE).[4] The regulations relate among other things to the crashworthiness of CNG cylinders and the performance of the CNG system in the event of fire. The Regulation stipulates that CNG cylinders must be fitted with a temperature-triggered pressure relief device. These are designed to allow compressed gas to escape in the event of fire before an explosion occurs.

2.2.3 Other rules

Under the Passenger Transport Act 2000 bus drivers must meet certain requirements. Apart from a driver's licence B (passenger car) and D (bus) and a medical certificate issued by a certified occupational health and safety physician, they must hold a CCV-B bus driver's diploma of professional competence for road passenger transport services.

The Act does not set out any other provisions for monitoring the safety of public transport services but it does stipulate a licensing requirement for transport companies. Conditions relating to the creditworthiness, reliability and professional competence of the transport company are attached to the licence.

2.3 The parties and their role in controlling risks

The parties listed below have a role in controlling safety risks associated with public transport bus services.[5]

2.3.1 Public transport authority

The Dutch provinces and urban regions act as the contracting authority. They determine the terms and conditions that the contracted transport company must meet. The relevant public transport authority for the fire in Wassenaar was The Hague Region [*Stadsgewest*

4 Fifty-six countries are represented in the UNECE, including Russia, the USA and Canada. The Commission, which forms part of the United Nations, is engaged in the economic development of its work territory. Formulating international vehicle regulations is only one of its activities.

5 The description relates to the bus services situation in The Hague Region. Some aspects are organised differently in other concessions. Concessions have been issued, for instance, in which the vehicles are not owned by the transport company but by the contracting authority.

Haaglanden]. The Hague Region determined in this concession that the transport services should be operated using CNG-powered buses.

2.3.2 Transport company

Transport companies operate public transport services under the conditions set out in the concession. They decide on the make, type and design of the buses, bus maintenance and parking, the education and training of drivers and the specifics of the transport process (timetable, traffic control, etc.). The transport company involved in the incident was Veolia Transport Nederland B.V., which forms part of TransDev, a global French group. Veolia outsourced the maintenance of its fleet to the importer (MAN Truck & Bus BV) and the affiliated dealer organisation.

2.3.3 Bus manufacturer

The manufacturer supplies buses which comply with the technical regulations and the additional requirements agreed by the manufacturer with the transport company. The bus involved in the fire in Wassenaar was manufactured by MAN Truck & Bus AG, a German manufacturer, and then delivered to Veolia by MAN Truck & Bus B.V. (the private importer in the Netherlands).

2.3.4 Ministry of Infrastructure and the Environment

Within the legal framework laid down in European regulations, the Ministry proposes national legislation (see Section 2.2), monitors compliance with the regulations and issues licences. In terms of the safety aspects, these duties are performed by the following three bodies:

- The Human Environment and Transport Inspectorate (ILT) is charged with monitoring the professional competence of drivers (including driving time and rest periods).
- The autonomous public body RDW (formerly the Government Road Transport Agency) is charged with licensing and monitoring the technical condition of buses (by means of a periodic vehicle inspection [*Algemene Periodieke Keuring, APK*]. RDW also represents the Netherlands in the UN/ECE working groups, which establish the technical requirements for road vehicles.
- KIWA N.V., a private corporation, has been mandated by the Minister to issue passenger transport operating licences to transport companies.6

2.3.5 Fire brigade

The fire brigade is responsible for fighting fires and providing emergency services in the event of a bus fire.

6 Operating licences were previously issued by the former Transport, Public Works and Water Management Inspectorate until 1 June 2010.

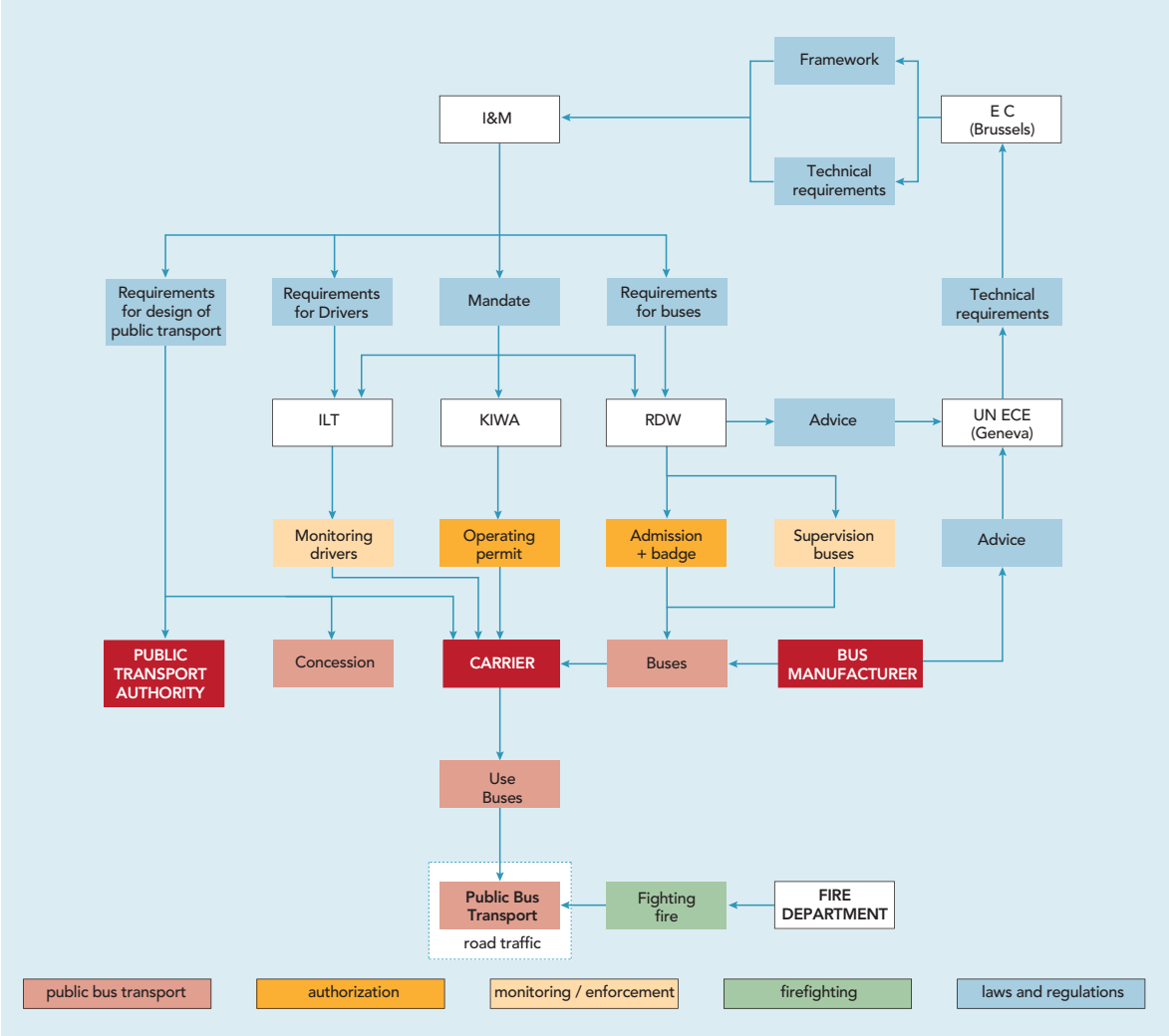


Figure 2: Diagram showing the parties involved and their respective roles.

2.4 CNG as engine fuel

CNG is the abbreviation for compressed natural gas. It is produced by compressing natural gas to a pressure of around 200 bar using a compressor. CNG is mainly used as an alternative fuel for petrol and diesel in motor vehicles. CNG offers the following advantages over conventional fuels:

- Currently, when CNG is used as engine fuel the exhaust fumes emitted usually contain fewer particulates, nitrogen oxides ($NO_{x)}$ and carbon dioxide (CO_2) than diesel or petrol. This difference is subject to change as a result of the development of new petrol and diesel engines. Apart from the potential emissions advantages, the use of CNG causes less engine noise.
- If natural gas alone is used as a basis for CNG, it will still be an 'unsustainable' fossil fuel. However, natural gas can be mixed or replaced entirely by biogas (also known as 'green gas'). Biogas is produced as a result of the fermentation or heating up of crop residue, animal dung, waste from waste water purification plants, organic waste, etc. After reprocessing, biogas – like natural gas – consists primarily of methane (CH_4) and

offers the same emissions advantages when used as engine fuel. Biogas is distributed (by admixing) through the regular natural gas network.
- Aside from the above, for users at least, CNG is cheaper than petrol or diesel. This is mainly because environmental tax on energy on natural gas and biogas is considerably lower than the duty on diesel and petrol.

Compared with similar vehicles running on petrol or diesel, the disadvantage of current CNG-powered vehicles is that they require a larger volume of fuel for the same operating range. The capacity of the fuel cylinders on a CNG-powered public transport bus is more than 1,700 litres (for an operating range of 500 km), whereas diesel versions of these vehicles suffice with a tank capacity of several hundred litres. For this reason the fuel cylinders in low-floor CNG-powered buses are mounted on the roof. To reduce weight, CNG cylinders are made of synthetic material rather than steel. A high-capacity cylinder filling system is also required to fill the cylinders in a reasonable time frame.

In the Netherlands over 5,200 vehicles currently run on CNG, mainly passenger cars, light commercial vehicles (vans) and public transport buses. This is but a small portion of the total national vehicle fleet comprising around nine million vehicles. Based on EU directives[7] a national target was defined to increase the share of biofuels (a mere 2% in 2010) to 10% in 2020. Alongside biodiesel, biogas is expected to make a substantial contribution to the target figure.

A total of over 5,100 public transport buses operate in the Netherlands. At the end of 2012 some 12% (over 600 buses) ran on CNG, distributed across eight concession areas and seven transport operators.

In recent years a number of public transport authorities have explicitly stipulated in their call for tenders for public transport bus services that CNG be used as fuel. This also applies to the concession awarded to Veolia in 2009 for bus services in The Hague Region, which included the bus involved in the fire in Wassenaar. The same applies to the concessions for the city bus service operating in The Hague, which was awarded to HTM in 2009.

The condition stipulating that CNG be used as fuel for buses stems from a political decision taken by the relevant municipalities based on their aim to achieve environmental objectives. During the decision-making process consideration was neither given to the safety risks, nor to the consequences of matters such as parking, fuelling stations, etc.

7 The European Commission promotes the use of alternative engine fuels such as CNG in the interests of the European climate objectives and energy safety.

3 ANALYSIS

The investigation established that a defect in the engine cooling system caused the bus fire in Wassenaar (see Appendix B). The fire can therefore not be attributed to the CNG system in the bus. It furthermore became clear that this system complied with the regulations and during the fire functioned as intended by these regulations. Nonetheless long shooting flames were emitted during the fire. The investigation found that the explanation lies primarily in the gaps in the technical regulations, the complacency of the parties involved and that insufficient attention was paid to the risks posed by CNG as engine fuel to the operating environment of the vehicle. These contributing factors are explained in more detail in Section 3.1. Section 3.2 describes the measures taken by the parties involved as a result of the fire in Wassenaar. The last section of this chapter (3.3) examines the extent to which these issues apply to other types of vehicles.

3.1 Contributing factors

3.1.1 Technical regulations for CNG systems

CNG systems in road vehicles are subject to the international regulations set out in UN/ECE Regulation 110. The fire safety requirements focus mainly on reducing cylinder explosion risk. It should be borne in mind that a bus fire can develop at such a rapid pace that the fire brigade does not always have an opportunity to prevent the fire from spreading into a fully developed fire. To prevent an explosion the fuel cylinders are fitted with a mandatory temperature-triggered pressure relief device, which vents the cylinder contents, should a critical temperature be exceeded.

The regulations do not set out any further requirements for the direction or length of a shooting flame if the pressure relief device is activated. Since the normal pressure in the CNG system is around 200 bar, in the event of overheating, in principle, the regulations allow gas to be discharged in a hazardous direction at very high speed. Aside from the above, the Regulation, for instance, does not require the system to allow any gas released to burn out in a controlled manner as is common in industrial production facilities such as and refineries and chemical plants (referred to as 'flaring off').

If parties comply with the regulations only, two risks are not controlled. First, the risk of shooting flames as evidenced by the fire in Wassenaar. Depending on their direction, shooting flames can pose a serious threat to neighbouring gas cylinders, the bus or the environment.[8] Second, the risk exists of an explosive gas cloud forming if the pressure

8 The lateral cylinders mounted on the bus type involved in the Wassenaar fire were fitted with a blow-off valve on either side: the venting direction on the left-hand side is horizontal and sideways, while the valves on the right-hand side point downward (in the direction of the bus). There are other CNG systems where all or a number of the blow-off valves in some cases point upward. In other cases the blow-off valves on some cylinders point towards one or several neighbouring cylinders in the same system.

relief device is activated in an enclosed or partially enclosed space, such as a tunnel, a cover or parking facility. To control these risks, manufacturers would have to take additional measures when designing the CNG system or the system components. However, UN/ECE Regulation 110 does not incorporate a provision setting out an objective for that purpose either. In contrast, the Dutch Safety Board has noted that the European Regulation concerning hydrogen-powered motor vehicles does indeed set out regulations for the direction of blow-off valves[9] as does the US equivalent of UN/ECE Regulation 110.[10]

A number of similar incidents have occurred in recent years involving CNG-powered buses (see Appendix F). These incidents could have prompted the relevant parties to identify these gaps and amend Regulation 110 accordingly. But the Regulation was not amended. These facts raise the question of whether the gaps in the technical regulations can be explained by the manner in which the regulations are established and maintained.

Deliberations on Regulation 110 take place in a technical sub-committee of the UN/ECE body charged with vehicle regulations.[11] The relevant industries and member states are represented on the committee, which convenes in Geneva. The Netherlands is represented by RDW. The interviews the Dutch Safety Board conducted with RDW and the Ministry of Infrastructure and the Environment showed that information relating to incidents, such as the fire in Wassenaar, is not systematically included in the periodic consultations on the regulations. Whether incidents give cause to reconsider the current regulations depends on the input provided by the participants during the sub-committee meetings.[12] This explains why previous incidents have not led to amendment of the regulations: as far as we know they were not discussed in Geneva.

RDW put forward the Wassenaar bus fire for discussion during the following consultation on the regulations. The matter is still being examined and it is not yet clear to what extent or in what respect the Regulation will be amended. However the Dutch Safety Board points out that no measures have been taken to ensure that RDW systematically obtains incident information relevant to the Geneva consultation. No reporting system is in place for informing RDW of potentially relevant incidents. Furthermore, police accident investigations focus on the investigation and prosecution of criminal offences, which means that these investigations are not entirely suitable for learning safety lessons from a vehicle perspective. A comprehensive police investigation moreover is usually disregarded if there are no fatalities and/or no one sustains serious injuries in the accident (as was the case in the Wassenaar bus fire). Finally, no regular consultations are held about potential technical improvements to vehicles between RDW, on the one hand, and the police and fire brigade on the other.

9 See EU Regulation No. 406/2010 of the European Commission of 26 April 2010 concerning the type approval of hydrogen-powered motor vehicles.
10 See NFPA 52, Vehicular Gaseous Fuel Systems Code.
11 This is the Working party on General Safety Provisions (GRSG). Under the auspices of the UN/ECE, vehicle rules are established by the World Forum for Harmonization of Vehicle Regulations based on the 'Agreement concerning the establishment of global technical regulations for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles' (Treaty Series 2007, 216).
12 Incidentally, this also applies to knowledge of technical developments in industry or science. Such knowledge is only discussed if communicated by the participants.

Sub-conclusions

- The Regulation concerning road vehicles using CNG fuel (UN/ECE Regulation 110) primarily aims to prevent the explosion of CNG cylinders, and to that end has laid down that temperature-triggered pressure relief devices are mandatory. The Regulation, however, does not provide regulations relating to the direction and/or length of the shooting flames that may result from the activation of the temperature-triggered pressure relief device.
- In establishing and administering the international vehicle regulations there is no guarantee that the relevant information obtained from day-to-day practice – from accidents, for instance – is systematically taken into account during the deliberations.
- In the Netherlands there is no systematic exchange of relevant accident information in day-to-day practice between the parties involved in the incident (public transport authorities, transport companies, fire brigade and the police) and the parties who influence the regulatory framework (Ministry of Infrastructure and the Environment and RDW).

3.1.2 Fulfilment of responsibility by the parties

The Dutch Safety Board established that MAN, the bus manufacturer, complied with the technical regulations that apply to the CNG system on this bus. Additional safety measures, including those aimed at controlling the risks outlined above for burning off any gas released, however, were not considered by MAN. This similarly applies to the transport company; it too failed to consider whether additional measures were required, either in its own operations or in the requirements it had specified for the bus manufacturer as the vehicle supplier. The contracting authority likewise failed to ascertain whether and in what manner the transport company had undertaken every effort as was reasonably possible to identify and control the risks.

The Dutch Safety Board considered whether additional technical control measures are conceivable that control the risks related to to the activation of the pressure relief device. The Dutch Safety Board's underlying intent is to illustrate that more could have been done than provided for by the parties. The following two categories of measures for controlling

CNG-related risks can broadly be distinguished: a) measures to prevent a fire in the engine compartment from fully developing, and b) measures to reduce the risk to the environment posed by the release of gas (in the form of shooting flames or an explosion). To prevent the fire from spreading, the relevant parties could, for instance, have opted for buses containing small holes for extinguishing a fire[13] (in the engine compartment from the outside) or an automatic fire extinguisher in the engine compartment. The risk

13 The public transport buses operated by HTM-Buzz used for the city bus service in The Hague are also type MAN Lion's City, CNG-powered buses. The engine covers in these buses do contain a hole for extinguishing fires.

of shooting flames could be reduced by designing the pressure relief system such that smaller shooting flames (shorter) would be emitted and/or would shoot out in safer direction. The risk of creating an explosive mixture when venting in an enclosed space could, for instance, be reduced by designing the pressure relief system such that the gas released will always flare off in a controlled manner.

The previous section states that these types of measures are not mandatory under the current regulations. Nevertheless, the parties involved could have opted to take additional measures all the same. The Dutch Safety Board sees three explanations for them waiving the opportunity to do so.

Interpretation of obligations
First of all, the contracting authority (The Hague Region) and the transport company's (Veolia) interpretation of their duties play a role. The contracting authority did not deem monitoring safe transport operations as its responsibility but rather that of the transport company.[14] Hence, the contracting authority failed to direct the transport operator in this area. The contracting authority also failed to assess the risks (RI&E) for the bus services operating in its concession areas. The contracting authority pointed out that the vehicles deployed by the transport operator are required to comply with the regulations discussed earlier in this report. The contracting authority assumed that these regulations sufficiently guaranteed safety. The contracting authority therefore did not require the transport operator to consider taking additional measures (such as holes for extinguishing fires or an automatic fire extinguisher). In the Dutch Safety Board's view the contracting authority in its role as the contracting party is in fact responsible for ensuring that the transport operator pays sufficient attention to controlling risks. This applies all the more if the contracting authority does not confine itself to the strategic issues concerning public transport alone but is also closely involved in tactical decision-making (as reflected in the Hague Region's management philosophy) .[15]

While the transport company did see it as its duty to ensure safety, it deemed that safety was sufficiently guaranteed if the vehicles complied with the technical regulations. The transport operator did not systematically assess the risks posed by its operations and for this reason failed to consider any additional measures. Similarly, when introducing CNG-powered buses, the transport company saw no reason to provide its drivers with instructions on the risks specific to the CNG system.[16] As a result, the driver involved in the Wassenaar accident had no prior knowledge of the fact the fire could cause shooting flames of this type.

As stated in Chapter 1, the Dutch Safety Board believes that safety should be a shared responsibility of the parties involved (the transport operator and the contracting authority). They should preferably fulfil this shared responsibility by systematically identifying the risks and taking appropriate control measures accordingly. A legal

14 The contracting authority does, however, monitor public safety.
15 Policy document entitled *Meer en beter openbaar vervoer,* Haaglanden Urban Region, 2003.
16 Veolia has meanwhile stated that it is working on implementing an integral RI&E in its bus transport safety management system, with a specific focus on CNG-related risks. In the intervening period Veolia has furthermore provided its drivers further instruction on the specific risks posed by CNG in the event of fire.

requirement could prove a major incentive for pursuing such a safety policy. It should be noted that the legislature has not provided for any such requirements, unlike in public transport by train where this is regulated by Act of Parliament: the Railways Act [*Spoorwegwet*] states that railway undertakings are required to provide for a safety management system which ensures that the risks are controlled as far as is reasonably practicable.[17] A similar requirement is due to enter into force for public transport by tram and metro under the new Local Railways Act [*Wet lokaal spoor*].

Effect of the tendering rules
Apart from the assumption that compliance with the vehicle regulations ensures an adequate level of safety, the rules that apply to public procurement also serve to explain the manner in which the transport company addresses safety.

As explained in Chapter 2, the concession is awarded on the basis of a public tendering procedure. In view of ensuring that the process is fair, the rules require the contracting authority to predefine the selection criteria it will use to assess the tenders submitted. This implies that transport operators can only distinguish themselves from their competitors by exceeding the minimum safety requirements defined by law, if the contracting authority includes this as a selection criterion in its call for tenders. The Hague Region not only failed to include this criterion when putting this concession out to tender, but also did not consider doing so. The contract documents merely stated that the buses that were to be deployed were required to comply with the statutory regulations.

While the Passenger Transport Act 2000 [Wet personenvervoer 2000] stipulates that regulations should be attached to the concession 'to ensure a responsible level of safety for both passengers and employees'[18], 'safety' in this context only refers to public safety. When drafting the Act, the Lower House of the Dutch Parliament insisted that such a regulation should equally apply to physical safety but it ultimately acquiesced in the Minister's opinion that the parties should be given room to make agreements among themselves within the broadest possible framework.[19]

Market forces
As explained above, the bus manufacturer used a CNG system that complied with the regulations, but failed to perform any further assessment of the potential risks and the appropriate control measures. This attitude can be partially explained by the fact that the market for public transport buses competes strongly on price. This forms a negative incentive for manufacturers in distinguishing themselves in the area of safety; ultimately there is no requirement from the market to do so. As a result the safety levels of public transport buses are almost entirely determined by the quality of the requirements imposed by the government, unless an individual client seeks additional measures. The Dutch Safety Board previously identified this market force in the commercial vehicle sector when conducting investigations into tank lorry fires and truck accidents on

17 In this context the Railways Act refers to 'railway undertakings' and 'safety management systems'.
18 Passenger Transport Act 2000, Section 32(2)(h).
19 Lower House Proceedings, session year 1999-2000, 4579.

motorways.[20] It was found there that more could be done to control the safety risks associated with fuel tanks and underrun protection, but that manufacturers waive these opportunities because there is no such requirement from the market. By contrast, in the passenger car market manufacturers do take further safety measures over and above those stipulated by laws and regulations. Safety evidently is a selling point in this market.

Sub-conclusions

- When introducing CNG buses the parties involved failed to perform a risk inventory and evaluation of the CNG-related safety risks. Consequently, no conscious consideration was given to the potential technical and organisational control measures. The contracting authority deemed that it had no role, while the transport company felt it could suffice with the deployment of approved buses.
- The tendering rules preclude that public transport companies that submit tenders from distinguishing themselves by ensuring good risk control measures, unless the contracting authority incorporates this criterion in the contract documents.
- In respect of safety measures, the bus manufacturer confined itself to adhering to the international vehicle regulations. Safety is not a selling point for buses.

2.4.3 Preparations by the fire brigade

When launching CNG-powered vehicles, it is vital for the fire brigade to know how CNG systems react in the event of a fire in order to be able to deploy the appropriate resources in the event of a fire. In particular, the fire brigade should be conversant with the circumstances under which the supply of natural gas can be vented as well as the direction, size and duration of any shooting flames emitted, plus the explosion risk.

The firemen involved in the Wassenaar bus fire were generally familiar with how a CNG system reacts in the event of fire. They knew that the system could vent natural gas at a certain temperature and that this could cause shooting flames. What they did not know, however, was in what stage of the fire gas would be vented, in what direction that would occur, how long the shooting flames would be and for what length of time they would continue.

When fighting the fire, the fire brigade acted in accordance with a Regional Deployment Procedure. The instruction basically entailed that the fire brigade had to cool down the CNG system, if possible. When the fire brigade arrived on the scene, however, the fire had already reached an advanced stage. For this reason the fire brigade allowed the fire

20 See the reports entitled *Tank lorry fires involving dangerous goods* and *Truck Accidents on Motorways*, Dutch Safety Board (2006 and 2012 respectively).

to burn out.[21] The Dutch Safety Board points out that the Haaglanden Fire Brigade had only incorporated detailed information on CNG-powered buses in the deployment procedure when these buses had already been operating for quite some time. The fire brigade stated that it had not been actively involved in the Hague Region's decision to make the use of CNG mandatory in the concession.[22]

The deployment procedure was established on the initiative of two local fire brigades (Delft and Rijswijk).[23] Similar initiatives were also developed by other fire brigades. A variety of deployment procedures are now circulating in the Netherlands, a number of elements of which differ. A coordinated approach, standard procedures and quality assurance at national level does not (yet) exist.

Sub-conclusions

- When drafting the concession, the Haaglanden Fire Brigade was neither notified about nor involved in the launch of CNG-powered buses. As a result, the fire brigade only began to prepare for the issues relating to CNG when the buses had already been put into service.
- At the time of the fire in Wassenaar the fire brigade only had general knowledge of the potential behaviour of a CNG system in the event of fire. If the fire brigade had strictly adhered to the deployment procedure for CNG-powered buses which was in force during the fire in Wassenaar, this could have created a risk of explosion.
- Knowledge of the risks associated with non-conventional engine fuels is not systematically shared among the fire brigades in the Netherlands.

3.1.4 Environmental risks associated with the use of CNG as fuel

In addition to the problems referred to in the previous sections, the Dutch Safety Board wishes to discuss the laws and regulations for controlling the environmental risks associated with engine fuels and the rules that should ensure safety in buildings where CNG-powered vehicles are parked.

Laws and regulations

The flames that shot up during the bus fire in Wassenaar posed a threat to the operating environment of the vehicle. This is also known as 'external risk' or 'third-party risk. The same applies to the risk described earlier of the formation of an explosive gas cloud in the event a CNG-powered bus heats up in a more or less enclosed space.

21 After the Wassenaar fire, the Haaglanden Fire Brigade concluded that a CNG system should not be cooled down during a fire as this can disrupt the temperature-triggered pressure relief device and thus cause an explosion. The Regional Deployment Procedure was amended accordingly.

22 The topic was discussed in the municipal council meetings held by the municipalities concerned at that time (2006/2008).

23 These fire brigades have now become departments of the Haaglanden Regional Fire Brigade.

Comprehensive laws and regulations apply to the external risks inherent in road traffic, insofar the carriage of dangerous goods as cargo is concerned. Under the Carriage of Dangerous Goods Act [*Wet vervoer gevaarlijke stoffen (Wvgs)*], the international rules set out in the ADR apply to this particular type of transport, in addition to several national rules.[24] The ADR classifies dangerous goods based on their hazardous characteristics and sets out specific conditions of carriage and restrictions for the various hazard classes.

The 'Circular on Risk Standardisation for the Carriage of Dangerous Goods' [*Circulaire Risiconormering vervoer gevaarlijke stoffen (Rnvgs)*] sets out government policy[25] for reducing/controlling the environmental risks posed by the carriage of dangerous goods. The document states what external risk factors the relevant public authorities should weigh up when taking decisions on traffic, on the one hand, and buildings/development, on the other. The regulations lay down risk exposure limits for people located in the vicinity of a road. The terms 'location-related risk' (the likelihood of an unprotected person dying per year) and 'group risk' (the likelihood of a group of ten or more persons becoming casualties at once, per year, per kilometre) are used to quantify risk. The *Guidelines for the Analysis of Risks inherent in the Carriage of Dangerous Goods* (HART) set out how these two risks should be assessed. The above Circular provides target and limit values for both risk types. Several different categories apply with respect to the vulnerability of the environment; the most stringent requirements apply to the category in which buildings are classified, such as houses, schools, hospitals, office buildings and shopping centres.

The regulations described above apply to the carriage of natural gas and other fuels (petrol, diesel and LPG) as cargo. However, the regulations do not apply to substances carried as *engine fuel* for the vehicle itself. A maximum volume of 1,500 litres applies to liquid fuels (such as diesel and petrol), but this is not the case for gaseous fuels (such as CNG). The only regulations that apply to engine fuel are the vehicle regulations mentioned earlier, also in respect of controlling the third party risks. The vehicle regulations for CNG, however, contain gaps when it comes to this aspect, as evidenced by the Wassenaar incident.

Even though the Dutch Safety Board itself has not investigated the matter any further, it deems the assumption justified that CNG-powered buses (like other commercial vehicles powered by natural gas) can pose considerable risks in the event of a fire in a tunnel. After all, as stated earlier, if these vehicles heat up a large volume of gaseous fuel could be released. Specific legislation applies to road tunnels (Tunnel Act [*Tunnelwet*]).[26] According to these regulations, the safety of long tunnels should be assessed on the basis of a quantitative risk analysis (known as the QRA method). This method is used to calculate the probability and risks of a large number of potentially hazardous events. The assessment method laid down, however, does not factor in the specific risks associated with CNG nor those of other non-conventional engine fuels (such as hydrogen). The

24 ADR is the abbreviation for the European Agreement concerning the International Carriage of Goods by Road [*Accord européen relatif au transport international de marchandises Dangereuses par Route*].
25 The Minister of Infrastructure and the Environment is responsible for the safe carriage of dangerous goods and is additionally charged with the interdepartmental coordination of external safety policy.
26 Additional Rules for the Safety of Road Tunnels Act [*Wet aanvullende regels veiligheid tunnels*].

Advisory Council on Hazardous Substances and the Tunnel Safety Committee [*Adviesraad Gevaarlijke stoffen, Commissie Tunnelveiligheid*] brought this issue to the attention of the Minister of Infrastructure and the Environment in early 2012. It is currently being examined further at the Minister's request.

Sub-conclusions

- The regulations for reducing/controlling the third party risks associated with the carriage of dangerous goods do not apply to the fuel carried in a vehicle. However, engine fuel, can, indeed pose such risks.
- It is unclear to what extent the risks specific to CNG and other non-conventional engine fuels have been factored into the method laid down by law for assessing road tunnel safety. This issue is currently being further examined at the request of the Minister of Infrastructure and the Environment.

Parking CNG-powered buses

Even though the risks of parking CNG buses is not related directly to the Wassenaar incident, the Dutch Safety Board still wishes to adress this aspect briefly. Several striking developments have occurred in the decision-making process on parking CNG buses, which in the Dutch Safety Board's view reflect underlying issues similar to those in the Wassenaar incident. The relevant municipality's actions (Zoetermeer) illustrate that when introducing CNG-powered buses, it initially had no notion of the safety risks involved in parking these buses.

Nationwide safety standards[27] with which parking facilities and garages for CNG-powered buses should comply, are lacking. The laws and regulations do not seem to be geared towards vehicles that run on 'new' fuel types. When introducing CNG-powered buses (in 2008-2009) the Haaglanden Fire Brigade advised the municipality of Zoetermeer on the licence to be issued for the garage the transport company (Veolia) wanted to use for parking the buses. The garage concerned had been used before by another transporter operator (Connexxion) for parking public transport buses, but these buses were diesel-powered. The fire brigade's advice basically entailed that while the CNG-powered buses were allowed to be parked in the garage, the garage would need to be modified accordingly. After the requested modifications (including installing gas detection sensors and automated ventilation shutters in the roof structure) had been carried out, the municipality of Zoetermeer allowed the transport company to park the buses in the garage.

At around the same time, The Hague, the municipality's neighbour, decided that the transport company, HTM, was only permitted to park its CNG-powered buses in the

27 The information contained in Publication Series 26 on Dangerous Goods [*Publicatiereeks Gevaarlijke Stoffen* (PGS 26)] applies to buildings for parking and repairing CNG-powered vehicles and safety.

open air.[28] This decision was based in part on a report published by Expertcentre Regulations in Building (Expertisecentrum Regelgeving Bouw, ERB). The ERB report likewise prompted the municipality of Zoetermeer to no longer allow CNG-powered buses to be parked in a covered parking garage.

Interestingly in the Arnhem-Nijmegen region, where CNG-powered buses have been in services since the commencement of the current concession (late 2012), the buses still are allowed to be parked inside.

Sub-conclusions

- The two municipalities in The Hague Region where the parking facilities for CNG-powered buses are located – The Hague and Zoetermeer – substantially revised their requirements for these locations following the launch of CNG-powered buses.
- There is no consensus among the local authorities on the requirements with which parking areas for CNG-powered buses should comply.

3.2 Measures taken as a result of the fire in Wassenaar

A number of the parties involved stated that they had taken action as a result of the Wassenaar bus fire.

The *public transport company* (Veolia) conducted an investigation into the cause of the bus fire in association with the *bus manufacturer* (MAN). The investigation found a defective component in the engine cooling system (see Appendix B). Based on the findings the manufacturer inspected and, where necessary, repaired all of its trucks and buses containing that particular component. Veolia provided its bus drivers further instructions on the CNG system's possible reaction in the event of fire. The transport company is currently developing a Risk Inventory and Evaluation for CNG-related safety risks. In addition, it is considering installing automatic fire extinguishers in the engine compartment of CNG-powered buses.

RDW formed an opinion on the Wassenaar bus fire based on video images shown on the Internet as well as news coverage. Based on the above RDW has put forward the incident for further discussion in the European Working Group that administers UN/ECE Regulation 110. It is not yet clear whether this will lead to amendment of the Regulation.

28 Expertcentre Regulations in Building (2009). *Advies inzake HTM busremise*. Recommendation at the request of the Municipality of The Hague.

The *Haaglanden Fire Brigade* revised the deployment procedure for fighting a fire on a CNG-powered bus. The instruction stating that the CNG system should be cooled down, if possible, has now been deleted.

3.3 Wider context

CNG as engine fuel is not only increasingly being used in public transport buses but also in passenger cars and commercial vehicles. According to RDW statistics (see Appendix D), in addition to the over 600 public transport buses, around 3,100 passenger cars and some 2,400 commercial vehicles (mainly vans) now run on CNG. Since the CNG cylinders on all of these vehicles are fitted with pressure relief valves, the safety issue identified (the release of natural gas when the cylinders heat up) can also occur in other types of CNG-powered vehicles, although the CNG cylinder volume on public transport buses is significantly higher than that of passenger cars and vans.

In the meantime, however, CNG-powered trucks (refuse trucks, for instance) are currently being put into operation with a similar cylinder capacity as that of public transport buses.

4 CONCLUSIONS

4.1 Relevant facts

The Wassenaar bus fire was caused by a defect in the cooling system (located in the engine compartment and not part of the CNG system). After the driver had brought the bus to a halt and the occupants had evacuated the bus, the fire spread to the interior of the bus and then raged into a fully developed fire.

The fire brigade arrived on the scene 11 to 14 minutes after the bus driver had reported the fire to the transport company's traffic control centre. Since the fire was already at an advanced stage at that time, the fire brigade allowed the fire to burn out in a controlled manner. Around one to four minutes after the fire brigade had arrived, the rising temperature of the roof-mounted CNG system, activated the temperature-triggered pressure relief device on various gas cylinders. The released gas ignited, causing flames 15 to 20 metres in length to shoot out in a horizontal and sideward direction. The shooting flames continued for over four minutes. The CNG system complied with the international vehicle regulations and functioned as intended by these regulations.

4.2 Safety issues

The investigation brought the following safety issues to light.

- The international vehicle regulations for CNG systems on road vehicles do not rule out the occurrence of hazardous shooting flames in the event of fire and that an explosive gas cloud can arise in the event CNG cylinders heat up in an enclosed space. There is no assurance in the international consultation, in which these regulations are established and maintained, that the relevant knowledge derived from day-to-day practice, such as incident information, will systematically be taken into account when drafting and updating the rules. Likewise at national level there is no adequate structure in place for accessing information derived from accidents that could prove relevant to the development/amendment of vehicle regulations. Consequently, it is uncertain whether such information reaches RDW, the body involved in establishing the international regulations on behalf of the Netherlands.
- A number of opportunities for controlling CNG-related risks were not utilised for these buses. Increased efforts could have been undertaken to prevent an engine fire from developing into a large-scale fire, posing a threat to the CNG system. Increased efforts could even have been undertaken to control the risks arising when venting natural gas (occurrence of shooting flames or the formation of an explosive gas cloud). No conscious consideration was given by the parties directly involved (the bus manufacturer, the transport company and the contracting authority) to applying safety measures.

- The bus driver involved in the Wassenaar incident – like his colleagues – had not received proper instructions about the potential reaction of the CNG system in the event of fire. As a result, he was unaware of the size and direction of possible shooting flames.
- The firefighters who had been deployed for the incident in Wassenaar were not fully familiar with the reaction of the CNG system in the event of fire. Their deployment procedure for fighting a fire on a CNG-powered bus moreover contained the potentially hazardous instruction to cool down the CNG system, if possible. The Haaglanden Fire Brigade was not involved in the granting of the concession. As a result, they only began to prepare for the launch of CNG-powered buses after the buses had already been put into service.
- The assessment of the third party risks posed by road traffic only takes account of the carriage of dangerous goods as 'cargo'. The potential risks posed by engine fuel, including those of CNG, are not taken into account.
- The tunnel safety assessments carried out to date have omitted to factor in that CNG-powered vehicles carrying a relatively large volume of gaseous fuel on board, which could be released when heating up, are meanwhile being driven on the road. This issue is currently being further examined at the request of the Minister of Infrastructure and the Environment.
- In respect of the requirements for buildings in which CNG-powered buses are parked, the policy pursued by the municipalities concerned (Zoetermeer and The Hague) was based on a risk assessment carried out by the local fire brigade. In 2011/2012 (in other words some three years after the CNG-powered buses were put into service) that policy was revised based on further research. CNG-powered buses operating in The Hague Region are now required to be parked outside. In the region Arnhem-Nijmegen where CNG-powered buses have been operating all public bus services since the end of 2012, these buses are parked inside.

4.3 Underlying causes

In the Dutch Safety Board's opinion the above safety issues have arisen primarily as a result of the following:

Insufficient incentives for ensuring safety management by the parties involved in public transport bus services
Until the fire in Wassenaar, the parties involved assumed that compliance with the technical vehicle regulations guaranteed a sufficient level of safety for the operation of bus services. However, if the safety risks arising in the event of a fire in a CNG-powered vehicle are to be controlled, increased efforts are required to be undertaken other than merely adhering to the vehicle regulations. The way public transport bus services are currently organised offers the parties no incentive in spurring them to ensure they properly fulfil their individual responsibility for safety.

- The *contracting authorities* failed to set out requirements for safety. They are not subject to any legal requirement to do so either.
- In respect of safety, the *transport companies* confine themselves to what they are asked to do under the regulations, on the one hand, and by the party who has

contracted their services (the contracting authority), on the other. A further factor that comes into play is that they would otherwise price themselves out of market when tendering for the concession. They are not subject to any legal requirement to employ a safety management system.
- *Bus manufacturers* confine themselves to compliance with the statutory regulations because safety is not a selling point in the bus market.

Knowledge is not systematically developed by fire brigades
The fire service in the Netherlands does not have a standard deployment procedure for fires involving CNG-powered vehicles. Fire brigades create their own instructions when faced with this technology; there is no such thing as the systematic development of knowledge. Moreover, the fire brigade is not structurally involved in the launch of new vehicle technology.

Third party risks inherent in non-conventional fuels go unrecognised
The Netherlands too is seeing ever more CNG-powered vehicles on its roads. The relevant authorities seem to be unaware of the specific safety risks these types of vehicles pose to their operating environment. Consequently, the authorities are not working on systematically controlling these types of risks. Since legal provisions on the carriage of dangerous goods (the Carriage of Dangerous Goods Act) apply only to the carriage of dangerous goods as cargo, the only regulations applicable to the external risks posed by engine fuel are the vehicle regulations. Those, however, contain gaps, as explained above. The laws and regulations governing tunnel safety do not factor in that vehicles carrying a relatively large volume of gaseous engine fuel (e.g. CNG and hydrogen) are now being driven on the road. Finally, there is no clear structure for assessing the risks arising, if such vehicles are located in a building or under a roof/covered space.

4.4 Final conclusion

Having considered all factors, the Board has reached the following final conclusion:

When making its call for tenders, for environmental reasons The Hague Region decided for environmental reasons to no longer operate public bus services with diesel-powered buses but with CNG-powered buses instead. The decision gave rise to new safety risks, not only when the buses are driven but also in respect of maintenance, parking and refuelling. These consequences, however, were not taken into account in the decision-making process. When implementing the decision the parties relied entirely on the regulations, without giving any consideration to what extent additional measures were required to ensure the responsible deployment of CNG-powered buses. By adhering solely to the vehicle regulations, at least as far as current CNG-powered buses are concerned, the risks for the operating environment, however, have not been adequately controlled.

The safety issues identified are not unique to the CNG-powered buses operating in The Hague Region. The release of natural gas when CNG cylinders heat up can, in principle, occur in *all* CNG-powered vehicles currently in use. The worst potential consequences are posed by vehicles carrying relatively large CNG cylinders (such as buses and trucks). Similar problems can occur when using other alternative engine fuels (such as hydrogen). Generally speaking, the parties and authorities concerned should not blindly rely on vehicle regulations when opting for these types of innovations, but should thourougly assess on what conditions or in what situations new technology can be deployed in a responsible manner.

5 RECOMMENDATIONS

The Safety Board has formulated the following recommendations:

1. Identification and analysis of the environmental risks associated with current CNG-powered buses

To the public transport authorities and public transport companies operating CNG-powered buses:

Identify the risks for the operating environment associated with the use, maintenance and parking of CNG-powered buses and take measures to reduce these risks.

2. Formulate and tighten vehicle regulations

To the Minister of Infrastructure and the Environment:

a. Ensure that the international vehicle regulations applicable to CNG systems (UN/ECE Regulation 110) are tightened to ensure that the risks for the environment are controlled in the event of vented gas.
b. Ensure that RDW systematically collects the relevant accident information and applies that knowledge when international vehicle regulations are established or amended.

3. Safety obligations on the part of the public transport authorities and transport companies

To the Minister of the Environment:

Incorporate in the Passenger Transport Act 2000 [Wet personenvervoer 2000] the following requirements:

- that bus companies systematically manage the risks associated with their operations by means of a safety management system;
- that the authorities contracting public transport bus services impose requirements on the transport company for managing safety risks.

4. Development of the fire brigade deployment procedure in the event of vehicle fires

To the Safety Council [Veiligheidsberaad]:

Ensure the central development of the deployment procedure for fighting fires in vehicles powered by non-conventional fuels (such as CNG and hydrogen).

Administrative bodies to which a recommendation is addressed should state their position in respect of compliance with this recommendation to the relevant minister within six months of the date of publication of this report. Non-administrative bodies or persons to whom a recommendation has been addressed should state their position in respect of compliance with this recommendation to the relevant minister within one year of the date of publication of this report. A copy of the response should at the same time be sent to the Chairman of the Dutch Safety Board and the Minister of Safety and Justice.

APPENDIX A

INVESTIGATION DETAILS

Investigative approach

The incident reconstruction was conducted on the basis of various sources, including:

- DEKRA report (12175682) on the investigation into the cause of the fire.
- Reports on fire brigade deployment
- An interview with the bus driver

In an effort to obtain background information, interviews were held with employees of the following organisations: The Hague Region, Veolia, RDW, the Ministry of Infrastructure and the Environment and the Kennisplatvorm Verkeer en Vervoer. Written questions were also submitted to the bus manufacturer (MAN).

As a part of the Safety Board's investigation, a sub-investigation was conducted by the Expertcentre Regulations in Building (Expertisecentrum Regelgeving Bouw, ERB) in order to address these research questions. This investigation focused on regulations for the deployment of CNG-powered buses. De Oude Mol BV consultancy also supplemented the draft text of the final report with relevant comments at the request of the Dutch Safety Board.

Appendix G provides an overview of the various sources.

Review

In accordance with the Dutch Safety Board Act, a draft version of the report was submitted to the various organisations and individuals involved, along with a request to check the document for errors, omissions and inaccuracies and to make notes where appropriate. The report was submitted to: the Hague Region, Veolia, MAN Truck en Bus B.V., the Ministry of Infrastructure and the Environment, the Human Environment and Transport Inspectorate, RDW and the Kennisplatvorm Verkeer en Vervoer.

All the above parties responded. The responses can be subdivided into the following two categories:

The Dutch Safety Board has incorporated corrections of factual inaccuracies, additional details as well as editorial comments (where relevant). These responses have not been separately included.

The Dutch Safety Board has replied to the responses that were not included in the report. These responses are set out in a table that can be found on the Dutch Safety Board's website (www.onderzoeksraad.nl). In addition to the responses, the table also features the following information: the section relevant to the response, the party providing the response and the Safety Board's reply. The responses have been listed by party.

Project team

Professor P.L. Meurs was responsible for the portfolio on behalf of the Dutch Safety Board. The investigation was conducted by the project team under the supervision of investigation manager H. van Duijn. The project team consisted of the following members:

H.J.A. Zieverink	Project leader
W. Boutkan	Investigator
R.J.H. Damstra	Investigator
M.J. Schuurman	Investigator
A. Sloetjes	Investigator
N. Smit	Investigation adviser
A.B.M. van Overbeek	Investigator

APPENDIX B

INCIDENT, FIRE-FIGHTING MEASURES AND CNG SYSTEM

The fire occurred on a CNG-powered bus (no. 6745) operated by Veolia, which was being used at the time for public transportation in the Haaglanden region (line 43 to The Hague). The bus CNG-powered model was a 'MAN Lion's City'.

Figure 1: CNG-powered MAN Lion's City bus (with CNG system on the roof)

Just before eleven o'clock – on his normal route through Wassenaar (having departed from De Kieviet stop on the Stoeplaan) – the driver smelled something burning as the bus passed the Groen van Prinstererlaan. The driver consulted the dashboard display, but saw no warning signals: The engine temperate was normal and the on-board computer system did not show any special warning signals. The five passengers seated in the bus at the time did not report (to the driver) signs of fire, smoke or any other irregularities. However, the driver saw grey smoke (haze) rising from the left rear corner of the bus in his left rear view mirror as he turned onto the Wittenburgerweg. The driver decided to stop the bus at the nearest suitable location. He eventually stopped at the next bus stop, which was located approximately 600 meters down the road (the Beukenhorstlaan stop on the Wittenburgerweg) (see figure 2).

Having stopped the bus, the driver then exited via the rear door and walked to the back of the bus. Having arrived at the back of the bus, he saw smoke plumes emanating from the engine door (located in the rear of the bus). He then instructed the passengers to leave the bus and move to a safe place. Once the passengers had evacuated the bus, the driver used the radiotelephone to contact the Veolia control centre and reported the fire.

The time was approximately 10:50. The Veolia control centre then contacted the Regional Alarm Centre (at around 10:53).

After having reported the fire, the driver took a fire extinguisher from the bus and walked to the rear. The smoke was now becoming more intense, and had a darker colour. While assessing the situation, the driver heard the sound of an 'explosion' coming from the engine compartment, and noticed liquid seeping onto the tarmac from under the right section of the engine compartment.[29] With a view to his own safety, he then decided against his original plan to open the engine door in order to extinguish the fire.[30] The driver then walked to the front of the bus, removed his personal belongings from the bus and took up a position approx. fifty metres in front of the bus. Here, he was not affected by the smoke as the wind was coming from the front of the bus.

Figure 2: Route used by CNG-powered bus (blue line) in Wassenaar. Position 1: driver notices a burning smell. Position 2: grey smoke visible in rear view mirror. Position 3: driver stops bus at Beukenhorstlaan stop (Wittenburgerweg).

In response to the notification sent out to the Regional Alarm Centre, a police surveillance unit was sent out to the accident site. As the vehicle approached the accident site, the responding officers saw large plumes of smoke. Upon arrival (at 10:53:48) the responding officers contacted the Regional Alarm Centre and reported smoke emanating from the engine compartment. Immediately afterwards, (at 10:53:52) they put out a request for the fire brigade and further police assistance.

29 Subsequent investigations showed that a plastic fluid reservoir mounted in the right section of the engine bay had melted as a result of the fire. This reservoir was filled with 20 litres of engine oil.

30 It is relevant to point out that the engine doors used in this bus type are not equipped with holes for extinguishing a fire.

The Regional Alarm Centre then (at 10:54:18) instructed the fire brigade to deploy units to the accident site. In response, units from two fire stations (Wassenaar and Leidschendam-Voorburg) were called out. The Leidschendam-Voorburg fire engine departed from the station at 10:56:26, while the Wassenaar engine departed almost simultaneously at 10:56:43. According to the information on the emergency notification receiver, the emergency consisted of a burning bus on the Teylingerhorstlaan; however, the Mobile Data Terminal (MDT) in the fire trucks incorrectly indicated that the fire was taking place on the Beukenhorstlaan. The crew in the fire engine from Wassenaar concluded that the fire was almost certainly taking place on the 'Wittenburgerweg near the Beukenhorstlaan'. The Regional Alarm Centre also sent out notification that the bus was powered by natural gas. This information was also visible on the MDT. The fire trucks arrived on site between 11:01:44 and 11:04:46.[31] The commander of the Leidschendam–Voorburg fire engine (first to arrive on the scene) took charge of the situation. After having discussed the situation, the two commanders decided to keep a safe distance and create a water screen to protect the surrounding area. As the fire brigade got to work, the police sealed off the Wittenburgerweg to all traffic. One of the fire engines created a water screen.[32] This activity was halted after several minutes, as the intensity of the flames subsided.

As regards the development of the fire, we can draw the following conclusions:

- The responding officers reported that the bus had caught fire at 10:53:48.
- Some eight minutes later, (11:01:44) the police reported a major fire developing inside the bus, with flames reaching higher than the roof.
- Approximately three minutes later, (11:04:46) the police informed the Regional Alarm Centre that gas cylinders had 'exploded'. From this moment onwards, horizontal flames started to shoot out from the left side of the CNG system on the bus roof. These flames varied in length, with a maximum length of between 15 to 20 metres.
- The shooting flames continued for approximately four minutes.
- The bus burnt out entirely. At 11:41:00, the fire brigade declared the fire officially under control.

For a chronological overview of the events and the development of the fire, see figure 3. Figure 4 features various photographs illustrating the development of the fire.

31 The precise time of arrival is unknown, as the crew members of both fire engines failed to record their time of arrival (by activating the 'arrival key' on the MDT, for example).

32 The crew of the other fire engine was not able to provide any assistance in creating the water screen. Due to a mechanical failure in the supply pump, fire hoses had to be rerouted to the nearest fire hydrant.

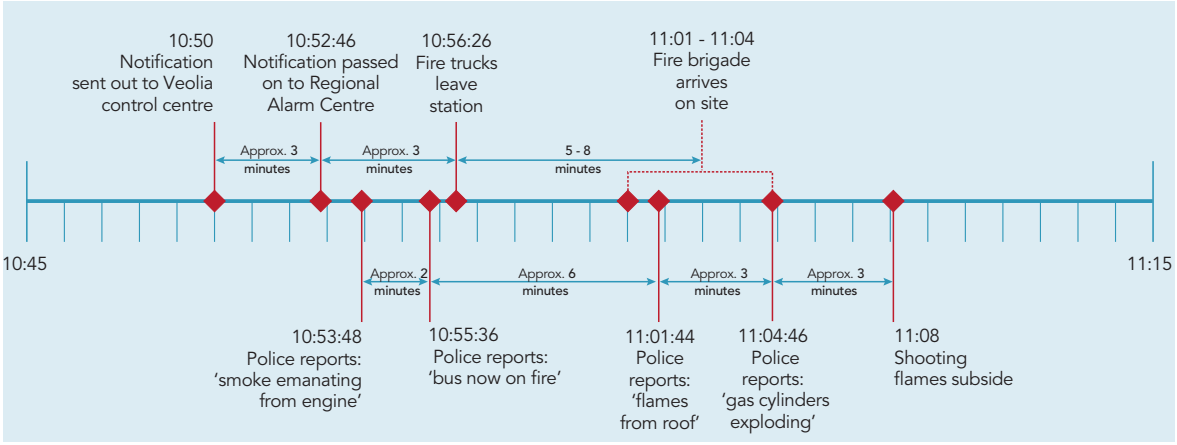


Figure 3: Timeline: fire and emergency response.

The CNG system

All CNG-powered MAN 'Lion's City' buses feature a roof-mounted CNG system. This system, which is purchased from an external supplier (Raufoss) rather than manufactured in-house by MAN, basically consists of an aluminium frame with eight adjacent and lateral gas cylinders (see figure 5). The cylinders are used to store natural gas at a pressure of 200 bar. The tanks have a combined capacity of approximately 1,700 litres and can store (under atmospheric pressure) around 350 cubic metres of natural gas in total at a pressure of 200 bar.

The gas cylinders used in this type of bus are made out of plastic with a carbon fibre coating. The walls of these cylinders (Type 4) start to weaken once temperatures rise above a certain point. Temperature increases can also cause pressure in the tanks to rise, as the natural gas starts to expand. For this reason, each individual gas cylinder must be fitted (legal requirement) with a temperature-sensitive blow-off valve on both sides (also known as a Pressure Relief Device or PRD) in order to ensure that gas can escape from the cylinder in the event of a temperature increase, before an explosion can occur. These pressure relief devices are activated upon reaching a temperature of 110°Celsius (+/- 10°Celsius), thus allowing the gas to escape from the gas cylinder. The pressure relief device on the left side of the gas cylinders is fitted horizontally (see figure 6, left). The pressure relief device on the right-hand side of the cylinders comprises part of a unit that also includes a magnetic and a manually-operated valve, and a supply/drainage pipe. The blow-off valves on these units (see figure 6, right) are positioned at a 45-degree angle, pointing downwards towards the bus roof.

Figure 4: Several photographs of the developing fire and burnt-out bus. (Source: Upper three photos: Christiaan Dekkers, Youtube.com. Source for bottom photograph: Rene Hendriks, Regio15.nl)

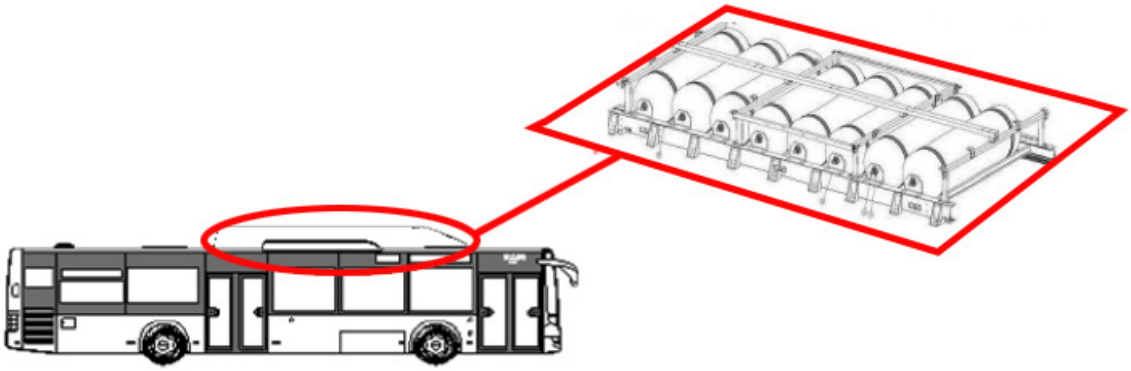


Figure 5: Position of the CNG tanks on the roof of the MAN Lion's City bus

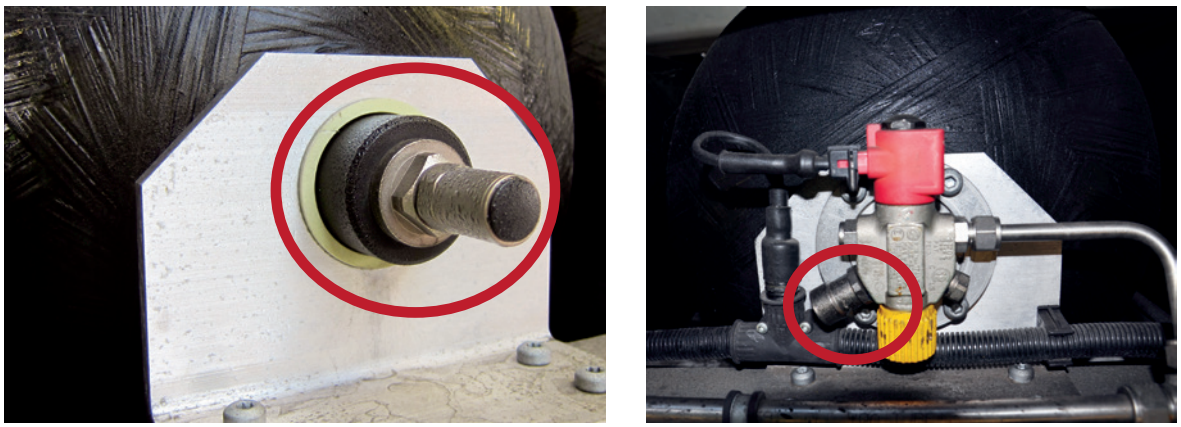


Figure 6: The left photo shows (circled in red) the temperature-sensitive pressure relief device on the left side of the gas cylinders (positioned to release pressure in a horizontal direction). The right photo shows the combined unit on the right side of the cylinders with (circled in red) the pressure relief device positioned in a 45-degree downward angle.

Cause of the fire

Veolia commissioned investigators from Dekra to investigate the cause of the fire in association with staff members from the bus manufacturer (MAN). This investigation also briefly focused on the roof-mounted CNG system. The conclusions of this investigation can be summed up as follows:

- The fire was almost certainly caused by oil leaking from the hydraulic drive system of the cooling fan in the engine compartment. The oil released from the drive system was under pressure, causing an oil mist that subsequently ignited as a result of hot engine components.
- The engine compartment houses a plastic tank containing engine oil (capacity of approximately 20 litres) and a smaller plastic tank containing hydraulic oil. These reservoirs melted as a result of the fire. The oil subsequently released from both reservoirs fuelled the fire, which then spread to the passenger section via the engine compartment.

- Once the fire had spread to the bus interior, the gas cylinders on the roof heated up further as result of the radiated heat. The bus windows also shattered due to the heat. As a result, the fire also started to spread via the outside of the bus.

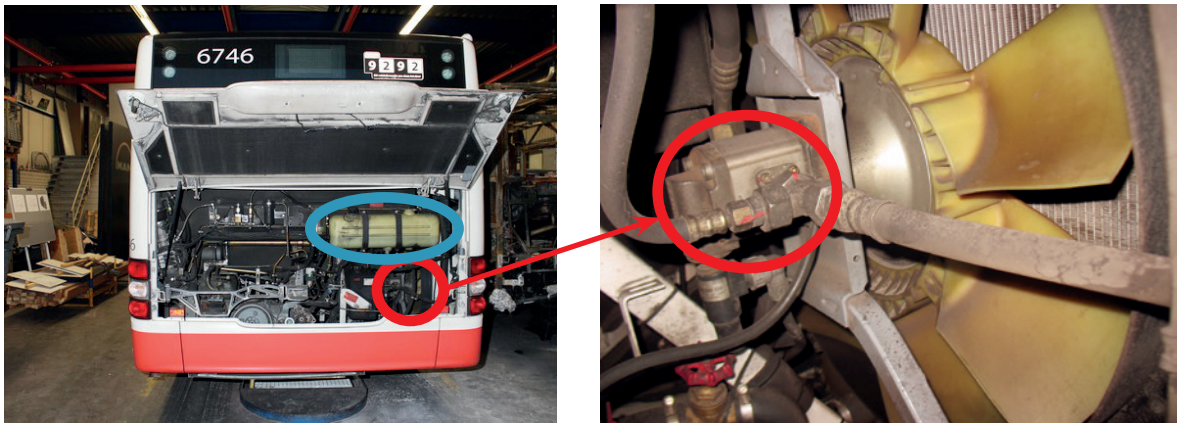


Figure 7: CNG-powered MAN bus with open engine door. The position of the cooling fan's hydraulic drive system is circled in red, the plastic oil reservoir positioned above the drive system is circled in blue.

As a part of the investigation to determine the cause of the fire, photos were also made of the CNG system. As these photos show, none of the natural gas cylinders exploded, while the aluminium frame affixed to both sides of the bus (designed to hold the fuel cylinders) melted as a result of the fire (see figures 8a and 8b).

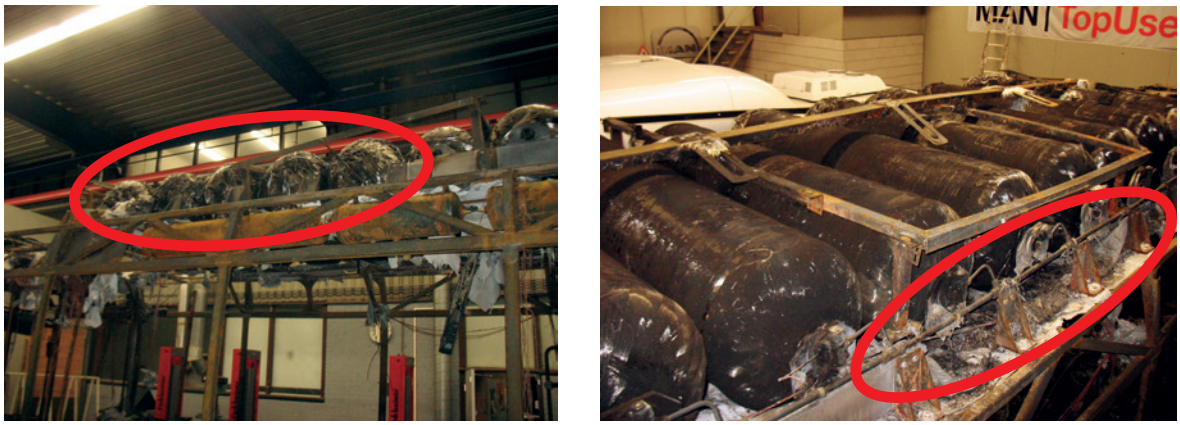


Figure 8: These two photos show the fire damage to the metal frame. The sections where the aluminium frame has melted are circled in red.

Two temperature-sensitive blow-off valves were detached for further inspection as a part of the investigation. This concerns the left valves on the fifth and eighth fuel cylinders, respectively (counted from the front of the bus). Both valves proved to have been activated. The other valves were not investigated in further detail. Based on the fact that none of the natural gas cylinders exploded, we can conclude that the blow-off valves functioned adequately.

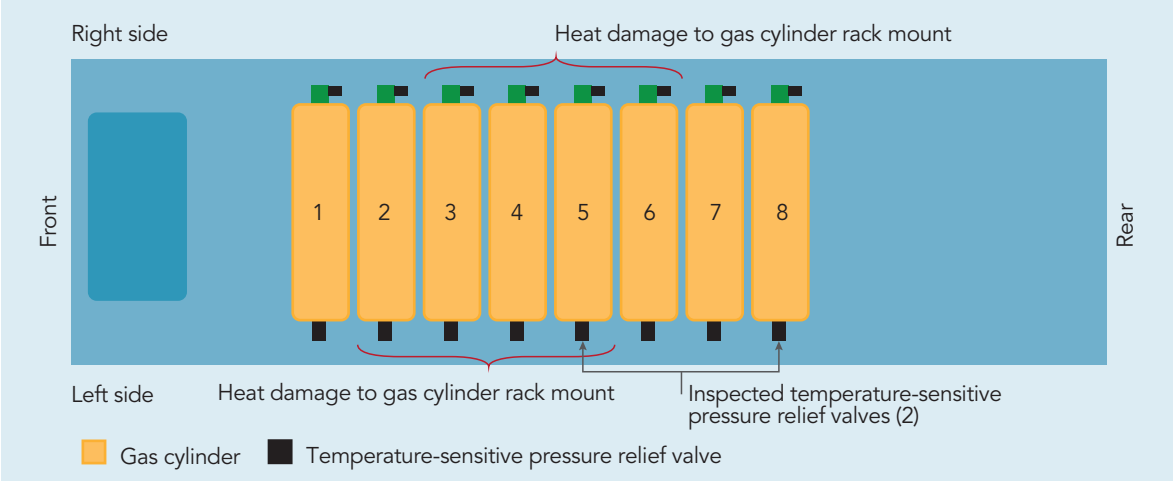


Figure 9: Overview of heat damage to the roof mount construction.

NUMBER OF BUS FIRES

The CBS (Statistics Netherlands) does not have any specific information on the number of bus fires in the Netherlands.

However, there is available information on the number of bus fires to take place in Norway and Sweden over the 1996-2004 period (see the graphs below). During this period, a total of approximately 8,500 buses were active on the Norwegian road network, with the figure for Sweden at around 14,500 buses (source: Fire safety in buses, SP, 2006). Based on this data, the likelihood of a public transport bus catching fire in Norway and Sweden was approximately 0.6% to 0.7% per year, based on the registered figures of 0.9% to 1.1% per year (taking into account the expected degree of under-registration).

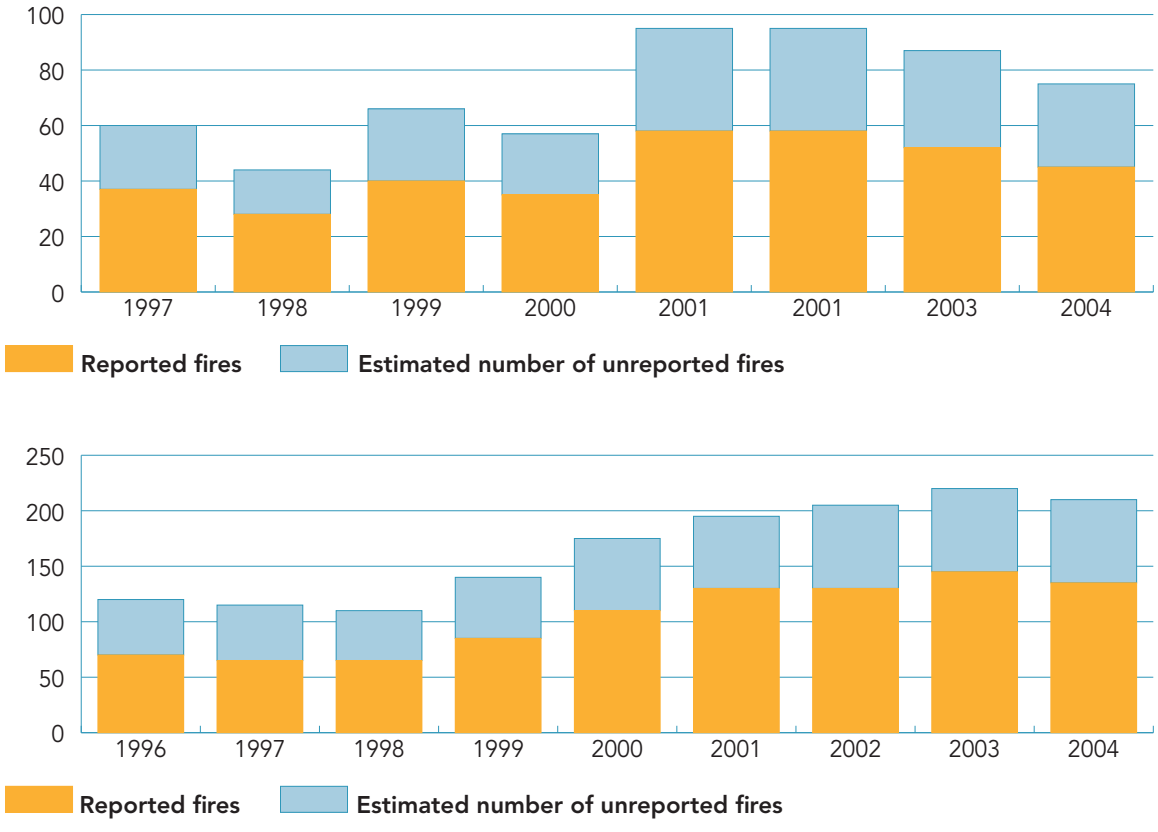


Figure 1: Number of bus fires in Norway (left) and Sweden (right) during the 1996-2004 period (source: Fire safety in buses, SP, 2006)

In order to gain insight into the situation in the Netherlands, the Dutch Safety Board requested that all (13) transport companies active in the Dutch public transport sector specify how many buses were deployed during the 2008-2012 period and provide statistics on the relevant number of bus fires. The resulting data is summarised in brief below.

- The total number of operational public transport buses in the Netherlands was over 5,100 in 2012, a figure that remained relatively constant during the 2008-2012 period.
- The information on the number of fires during the 2008-2012 period covers a large part of the overall fleet. This part, made up of both local and regional buses, consisted of a total of 4473 buses during the relevant period (more than 87% of the overall fleet) with the average number of fires totalling 16.8 per year.
- We can thus conclude that approximately 0.4% of all public transport buses operating in the Netherlands catch fire on an annual basis. When applied to the overall fleet, this results in an average of more than 18 bus fires per year. Based on a rough estimate, it would seem that approximately 1/3 of all fires (a total of around six fires per year) develop into a serious fire.

NUMBER OF CNG-POWERED BUSES

The Netherlands

The number of CNG-powered buses has grown significantly over the past few years. In the Netherlands, this development started relatively late. This may be attributable to the previous use of LPG. The nineteen eighties and nineties saw efforts to experiment with the use of LPG as a fuel source for the public transport sector. These experiments did not yield satisfying results. This is partly due to the use of modified diesel engines which cause problems when used with LPG over a longer period of time. The Netherlands also has a longstanding tradition of LPG-fuelled passenger cars, thus limiting interest in natural gas and the likelihood that the use of this fuel type would become economically viable. As a result, investment in the facilities needed to accommodate the use of natural gas were minimal.[33]

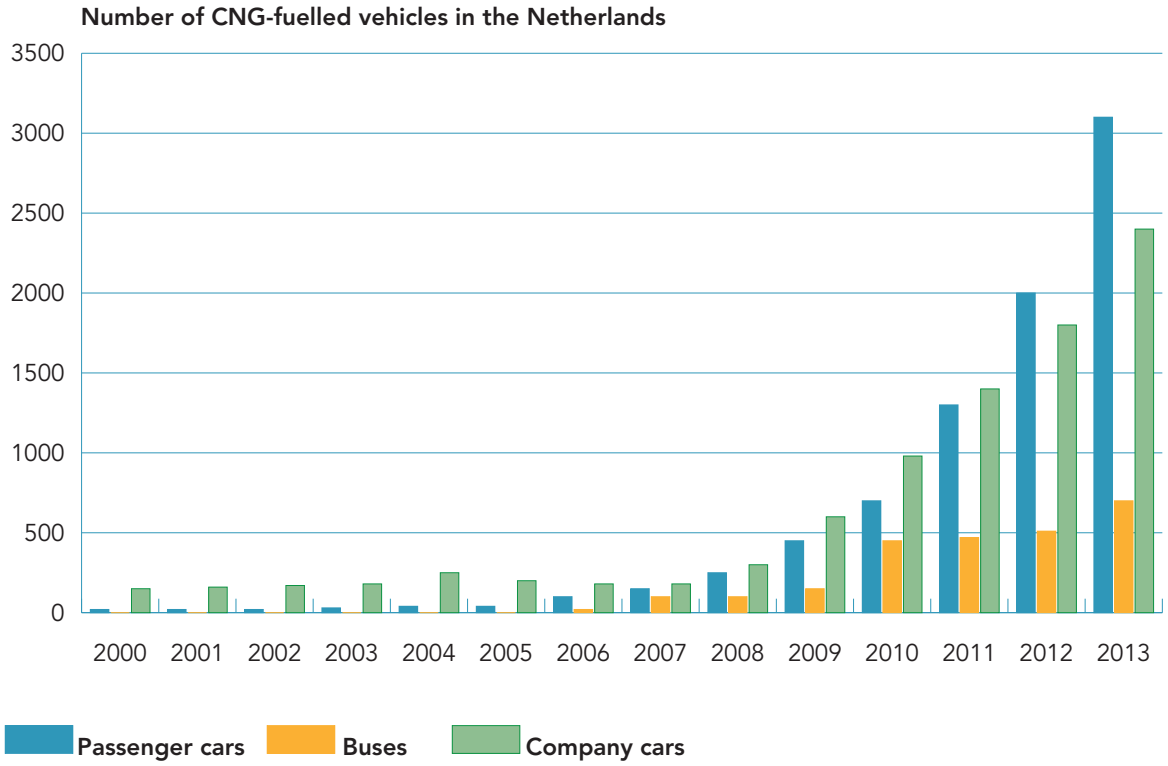


Figure 1: Number of CNG-fuelled vehicles in the Netherlands (Source: RDW)

33 Source: "*Lucht voor schone bussen*", Kennisplatvorm Verkeer en Vervoer , November 2009.

As the above graph shows, the use of CNG as an engine fuel (with the exception of several pilot projects) did not become widespread in the Netherlands until around 2005. As the statistics also show, the number of CNG-powered passenger cars totalled around 3,100 in early 2013, with the number of CNG-powered company cars (mainly consisting of vans) at approximately 2,400 and the number of CNG-powered buses at over 600.

It should be pointed out that the vast majority of CNG-powered buses (over 550) were manufactured by the same company (MAN) as the bus involved in the incident in Wassenaar. Furthermore, the current number of CNG-powered buses (over 600) is divided over a total of eight concessions, involving seven authorities contracting public transport bus services and seven transport companies.

General data on foreign CNG use

The use of CNG-powered engines is significantly more popular in various countries including Italy, Brazil, Argentina and the United States. Both large CNG-powered road vehicles (buses, trucks) and passenger cars are normal in these countries, where CNG fuelling stations are also a common phenomenon. The use of natural gas in these countries served as an example for Europe. Special CNG bus engines without any of the negative effects associated with the use of LPG in modified diesel engines have also been developed.[34]

34 Source: "*Lucht voor schone bussen*", Kennisplatvorm Verkeer en Vervoer, November 2009.

Europe

The graph below provides an overview of the number of CNG-powered vehicles in Europe.

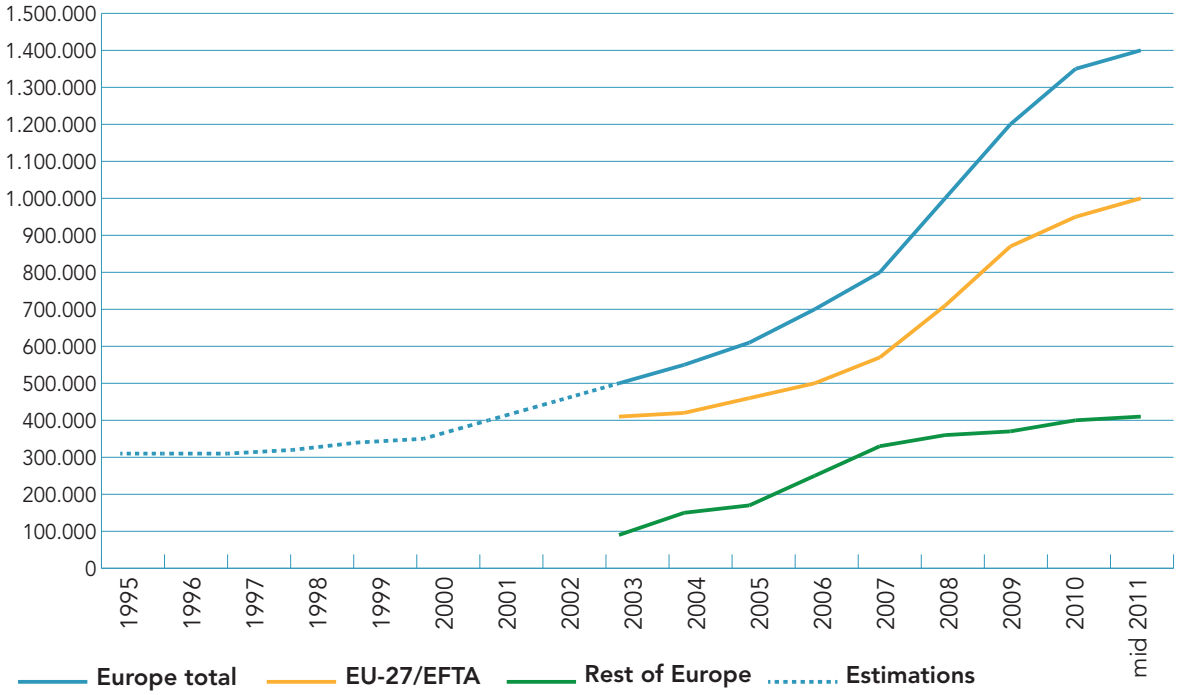


Figure 2: Number of CNG-powered vehicles in Europe (Source: An overview of global NGV developments, Manuel Lage, NGV Global, January 2012)

As regards the use of CNG as a bus fuel in Europe, we can draw the following conclusions:[35]

- The total number of CNG-powered buses in Europe is around 156,800.
- The vast majority of these buses are located in Eastern European countries (such as Russia, Ukraine, Georgia, Armenia and Turkey)
- The number of CNG-powered buses in Italy, France, Germany, Spain, Sweden, Greece, Portugal and the Netherlands (mainly in the urban regions) totals at least 9,000.

35 Source: An overview of global NGV developments, Manuel Lage, NGV Global, January 2012.

APPENDIX E

FIRES IN CNG-POWERED BUSES

To the best of the Safety Board's knowledge, no fires occurred on CNG-powered buses in the Netherlands prior to the incident in Wassenaar. However, a second fire did take place over the course of the investigation. This incident is described in brief below. An effort was also made to take stock of recorded bus fires in CNG-powered buses abroad, by means of Internet research.

Fire in CNG-powered bus in Vlaardingen on 12 April 2013

On 12 April 2013, a CNG-powered bus operated by Veolia caught fire. The bus, of the same type that burnt out in Wassenaar (MAN Lion's City CNG), was travelling on the A20 motorway from Maasland to Vlaardingen with approximately 15 passengers on board. As the driver accelerated after having entered the motorway, a loud bang could be heard emanating from the engine compartment. The engine subsequently shut off. The driver stopped the bus on the emergency lane and reported the incident to the Veolia traffic control centre.

The bus passengers then noticed smoke emanating from the engine air inlet, which is located in the left rear section of the roof construction. The driver then escorted the passengers (approximately 15 in total) outside, fully disengaged the bus' electrical system and closed the CNG system's main stopcock. The driver then notified the Veolia traffic control centre, which alerted the emergency services. In view of the fire's location (in the upper section of the bus' rear left corner) and the passing traffic, the driver did not attempt to extinguish the fire.

The police were the first emergency service to arrive at the scene. The driver managed to convince the police that the motorway (A20) should be closed off in both directions in view of the danger that flames would shoot from the bus. The fire brigade, which arrived at the scene with units from several brigades, put out the flames before they could develop into a serious fire. As a result, the fire was restricted to the engine air inlet system and the rear section of the bus interior.

Figure 1: This photograph shows the CNG-powered bus on the A20, with the fire brigade working to extinguish the fire. (Source: Omroepwest.nl)

Figure 2: Fire damage to the engine air intake (after removal of safety grille)

Figure 3: Fire damage to the bus interior.

The fire was probably caused by a backfire, an incident involving an explosion in the engine air inlet. According to Veolia, this phenomenon has occurred in several of its other buses of the same type. On the day of the incident, the bus in question had experienced engine problems that restricted its maximum speed to 20 km/hour. After repairs had been carried out at a stop near Zanddijk, the bus resumed normal service. Later that day, the bus experienced new engine problems and was temporarily decommissioned and transferred to the garage on the Telexstraat in The Hague. Once the bus had been inspected, repaired and tested, the vehicle was returned to normal service at around four thirty in the afternoon. The fire occurred at around seven pm.

According to the technical investigation conducted by staff members of the transport company and the bus manufacturer, the fire occurred in the engine inlet system and was probably caused by a broken cylinder in the inlet valve. The investigation also showed that the relevant inlet valve had experienced abnormal – albeit less serious – wear on various other buses of the same type.

As regards this fire and the relevant similarities/differences with the incident in Wassenaar, we can draw the following conclusions:

- Both fires started in the engine compartment. Their immediate causes can be traced back to a technical failure. However, the nature of these failures did vary: in one case (Wassenaar) the failure concerned an oil leak in the cooling system, whereas the other (A20) involved a defective inlet valve.
- The incident in Wassenaar involved 'open fire' in the engine compartment that subsequently spread to the bus interior. The incident on the A20 started as an internal fire, that subsequently spread to the air filter (in the roof construction) via the engine air inlet system. The fire on the A20 also eventually spread to the bus interior.

Fires on CNG-powered buses in other countries

Internet research yielded information on eight fire incidents involving CNG-powered buses. The photos below show three fires during which the blow-off valves were activated.

Figure 4: CNG-powered bus fire in Jesi, Italy.
(Source: Youreporter.it)

Figure 5: Fire in CNG-powered bus operated by Italian public transport company ATAC.
(Source: YouTube.com)

Figure 6: Fire in CNG-powered bus in the US
(Source: Fundamentals and practise of CNG safety, Hien Ly, 2010)

CNG-powered buses also burnt out in Montbéliard, Nancy and Bordeaux, France. In response to the first two incidents, an investigation was conducted by the French Bureau d'Enquêtes sur les Accidents de Transport Terrestre. The fires in Montbéliard and Bordeaux involved the explosion of a gas cylinder.

On 3 September 2010, a fire occurred in a bus garage in Rome. A total of 24 CNG-powered buses operated by ATAC burnt out during the incident. In May of 2003, two CNG-powered buses parked in a bus garage in Saarbrucken (Germany) burnt out. A natural gas cylinder exploded during this fire. It appeared that the incident was investigated by TÜV-Saarland.

Figure 7: CNG-powered buses on fire in Saarbrucken
(Source: Fundamentals and practise of CNG safety, Hien Ly, 2010)

APPENDIX F

SOURCES

Aanbestedingswet 2012. Wet van 1 november 2012, houdende nieuwe regels omtrent aanbestedingen, werken, leveringen en diensten

Adviesraad Gevaarlijke stoffen, Commissie Tunnelveiligheid [Advisory Council on Hazardous Substances, Commission on Tunnel Safety] (2012, 16 januari). *Risico's gebruik CNG en waterstof in tunnels en parkeergarages* (Brief aan het kabinet, p/a Ministry of Infrastructure and the Environment, drs. M.H. Schultz van Haegen-Maes Geesteranus), Gouda.

Arbeidstijdenbesluit vervoer [Working Hours Decree for the Transport Sector], Besluit van 14 februari 1998, houdende nadere regels inzake de arbeids- en rusttijden in of op voertuigen, aan boord van vaartuigen en voor loodsen.

Basisnet vervoer van gevaarlijke stoffen (Wetsvoorstel). Ministry of Infrastructure and the Environment.

Besluit aanbestedingsregels voor overheidsopdrachten (BAO). Besluit van 16 juli 2005, houdende regels betreffende de procedures voor het gunnen van overheidsopdrachten voor werken, leveringen en diensten, Ministry of Economic Affairs.

Bouwbesluit 2012, Besluit van 29 augustus 2011 houdende vaststelling van voorschriften met betrekking tot het bouwen, gebruiken en slopen van bouwwerken (Bouwbesluit 2012). Staatsbladpublicatie nr. 416, 2011.

Brandt, J. & Försth, M. (2011). Testing active fire protection systems for engine compartments in *buses and coaches - a pilot study*, SP Technical Research Institute of Sweden, Fire Technology SP Report 2011:22

Brandweer Amsterdam-Amstelland (2009). *Werkinstructie, Alternatieve aandrijving, 1/012/2009*

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DUTCH
SAFETY BOARD

Visiting Address
Anna van Saksenlaan 50
2593 HT The Hague
T +31(0)70 333 70 00
F +31(0)70 333 70 77

Postal Address
PO Box 95404
2509 CK The Hague

www.safetyboard.nl