DUTCH
SAFETY BOARD

Risk management for the transport of dangerous goods by rail

Train collision Tilburg

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6 March 2015

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Dutch Safety Board

When accidents or disasters happen, the Dutch Safety Board investigates how it was possible for them to occur, with the aim of learning lessons for the future and, ultimately, improving safety in the Netherlands. The Safety Board is independent and is free to decide which incidents to investigate. In particular, it focuses on situations in which people's personal safety is dependent on third parties, such as the government or companies. In certain cases the Board is under an obligation to carry out an investigation. Its investigations do not address issues of blame or liability.

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SUMMARY AND CONSIDERATION

On 6 March 2015, a passenger train ran into the back of a stationary freight train, in Tilburg. As a result of the collision, a leak occurred in the rearmost wagon of the freight train, a tank wagon filled with fifty tonnes of flammable gas (butadiene). There were no serious injuries, and the scale of the leak remained limited. The Dutch Safety Board has investigated which safety lessons can be drawn from the accident in respect of the fact that a dangerous substance escaped. This report describes the findings and recommendations.

Summary

The freight train was travelling from the Chemelot industrial estate (in South Limburg) via the Brabantroute to the Kijfhoek marshalling yard (near Zwijndrecht). During the run, an intermediate stop was made in Tilburg, and the train was guided onto a side track. The collision occurred when the freight train was standing on the side track, and was the consequence of a chain of events.

The final link in the chain consisted of a red signal passage by the passenger train. That subject is part of the investigation initiated by the Human Environment and Transport Inspectorate (ILT). That investigation also included consideration of the compliance with recommendations from the Dutch Safety Board issued in previous reports on similar problems.

The purpose of this investigation is to draw new safety lessons from the accident in Tilburg, in respect of the fact that a dangerous substance leaked from a tank wagon as a result. In that connection, the investigation revealed the following problems:

Additional risks due to rescheduling of the freight train
In the chain of events that led to the accident, the intermediate stop undertaken by the freight train played a role. As a result, the freight train ended up on a section of track which, unlike the through tracks, did not enjoy additional protection against red signal passages (by means of the automatic train protection system ATB - Improved Version). As a consequence, the red signal passage by the passenger train resulted in a collision with the freight train. Another contributing factor to the occurrence of the red signal passage was that in the request for the intermediate stop, the incorrect length of the freight train was specified. As a consequence, the freight train was placed on a section of side track that was too short, causing the train to occupy a switch, so that the signal for the passenger train remained at red.

Unused available measures

The investigation further revealed that measures were available for limiting the risk of the escape of dangerous goods following a rear end collision, but that those were not utilised, because they are not legally required. Namely:

- The passenger train collided not only with the under frame of the tank wagon but against the tank itself. This was because the passenger train was of an old type (1964) with no buffers and hence poor collision compatibility. Several years ago, admission requirements for passenger trains were tightened up on this point, but the requirements did not apply to 'old' trains.
- If the tank wagon had been fitted with a buffer overriding protection device, it is possible that the passenger train would not have overridden the buffers and hit the tank. However, this kind of system is only required for tank wagons transporting (very) toxic substances.
- The risk of leakage of a dangerous substance following a rear end collision can be further limited by ensuring that the rear wagon of a train carries no dangerous goods. However, this too is not legally required.

Over the past few years, proposals have been made to tighten up international requirements for the last two items, but there was insufficient support.

Responsibility of chemical companies for the chain

The chemical company on whose behalf the tank wagon was being transported had reached no agreements with the railway undertaking for avoiding risk-increasing operational decisions during the implementation of the train run in question. It turned out that it is not common practice for chemical companies to reach such agreements with railway undertakings. As contracting party for transport, this option is open to them. In the opinion of the Board, it is their social responsibility to apply all necessary influence.

Consideration

Every year, 200 to 250 million tonnes of dangerous goods are transported in the Netherlands. The majority is carried by pipelines and on inland shipping. Approximately two percent (4 to 5 million tonnes) travel by rail; this amounts to approximately 400 tank wagons per working day. Rail transport unavoidably passes through densely populated areas, thereby representing safety risks for the environment. For that reason, extensive international regulations apply, which for example relate to the crash safety of tank wagons. Over the past few years, in establishing the Basic Network Act, additional measures have also been taken in the Netherlands. Examples include the installation of the automatic train protection system ATB - Improved Version at signals on the railway routes via which dangerous goods are transported, and a covenant on the hot-BLEVE-free composition of trains carrying dangerous goods.

The investigation into the train collision in Tilburg makes it clear that in operating practice, for logistic and commercial reasons, operational decisions are taken that reduce the effect of the safety measures taken. As a consequence, in this accident, risks occurred which had been recognised in advance, and for which measures were indeed taken.

Introducing an intermediate stop on a side track reduced the additional protection against red signal passages thanks to automatic train protection system ATB - Improved Version on the through tracks, and the use of an old type of passenger train with poor collision compatibility reduced the effect of the crash buffers on the tank wagon run into. One important lesson from this investigation, for the Board, is that for the safety of the transport of dangerous goods by rail, it is essential that no operational decisions be taken that deduct from existing safety provisions. Otherwise, to a certain extent, known and managed risks are reintroduced.

The chemical companies on whose behalf dangerous goods are transported by rail have an important role in risk management during transport. The Board has raised the importance of chain responsibility and good business practice in the chemical sector in previous investigations. The argument is that the responsibility of a chemical company does not end when the dangerous goods leave the company site and are transported or stored on their behalf by another company. The chemical companies and their umbrella organisations previously underwrote the vision of the Board, and for some years (via the action plan Safety First) have been working to improve the situation. The course of events in the accident in Tilburg makes it clear that additional attention is needed for the transport of dangerous goods by rail.

The above described risks occurred at operational level. However, this does not mean that safety is only important on the 'shop floor'. In the railway sector, too, safety starts at the top. It is crucial that the senior management recognises and consistently underlines the importance of safety. Safety will only acquire the priority it deserves at operational level if the employees in question are fully supported on safety issues by their management.

Recommendations

Operational control of transport of dangerous goods by rail

1. *The railway companies responsible for the control of the run-into freight train (ProRail and DB Schenker):*
   Organise the operational control of freight trains with dangerous goods in such a way that no operational decisions are taken that lead to an increase in known and managed safety risks.

Responsibility of chemical companies for the chain

2a. *The chemical companies involved as shippers of dangerous goods in the run-into freight train (SABIC, DSM and OCI):*[1]
Fulfil responsibility for the chain by demanding from railway undertakings that in the operational control of freight trains carrying dangerous goods, no risk-increasing decisions are taken. Include this in transport agreements and monitor compliance.

2b. *The sector organisations coordinating the action programme Safety First:*[2]
Consider the transport of dangerous goods as part of the responsibility for the chain in the action programme Safety First. Ensure that all chemical companies acting as shippers in the transport of dangerous goods by rail fulfil recommendation 2a.

Technical measures for the transport of dangerous goods by rail

3a. *The State Secretary for Infrastructure and the Environment:*
Ensure the tightening up of international regulations for the transport of dangerous goods by rail (RID) in such a way that the following is adopted:
- no dangerous goods may be contained in the final wagon of a train;
- tank wagons for the transport of non-toxic dangerous goods should also be equipped with buffer overriding protection devices.

3b. *The State Secretary for Infrastructure and the Environment:*
In advance of the proposed change to the RID in 3a, reach agreement with shippers from the chemical industry and goods carriers to introduce these measures in the Netherlands as quickly as possible. This could take place along the line of the already existing agreement on the 'hot-BLEVE-free' composition of freight trains.

Collision compatibility of passenger trains in relation to the transport of dangerous goods by rail

4. *The railway undertaking of the passenger train involved in the accident (NS Reizigers):*
For all relevant types of passenger trains, assess the collision compatibility in respect of freight stock. Do not use train types with poor collision compatibility on routes designated for the transport of dangerous goods.[3]

Recommendations 1, 2 and 4 - in accordance with the Dutch Safety Board Order[4] - will also be addressed to the Human Environment and Transport Inspectorate (ILT). ILT will monitor compliance with these recommendations by the organisations in question, and

1 The following were approached: SABIC Petrochemicals B.V., AnQore B.V. (Previously DSM Acrylonitrile B.V.) and OCI Nitrogen B.V.
2 *VNO-NCW, Association for the Netherlands Chemical Industry (VNCI), Association for the Netherlands Petroleum Industry (VNPI), Association of Traders in Chemical Product (VHCP) and the Association of Independent Tank Storage Companies (VOTOB).*
3 This recommendation ties in with recommendation 6 in the report previously published by the Dutch Safety Board into the Train collision at Amsterdam Westerpark (available via www.safetyboard.nl).
4 By Order of 26 November 2015 (Bulletin of Acts and Decrees 2015, 470), the Dutch Safety Board Order (in connection with further implementation of EU Directive 2004/49/EC) was duly revised.

duly report to the Board. For the other recommendations (3a and 3b), in accordance with the same Order, the Board will be informed directly on compliance by the State Secretary for Infrastructure and the Environment. In both cases, a maximum reaction period of six months following publication of the report applies.

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

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1 INTRODUCTION

1 INTRODUCTION

On 6 March 2015, a passenger train ran into the back of a freight train carrying dangerous goods, in Tilburg. A number of passengers on the passenger train suffered minor injuries. A leak was caused in a tank wagon loaded with more than 50 tonnes of flammable gas (butadiene). The leak remained limited, and no fire occurred. A number of police officers became briefly unwell having inhaled the escaped gas.

Figure 1: Situation following the collision between the tank wagon and the passenger train. (Photo: Dutch Safety Board)

1.1 Investigation

The aim of the investigation by the Dutch Safety Board is to draw safety lessons from this accident in respect of the fact that it led to the leak of a hazardous substance.

This report concentrates on the following questions:

1. Why did the freight train with dangerous goods become involved in the collision?
2. How was a leak caused in a tank wagon following the collision?

In investigating the occurrence of the collision, the Board has opted to focus specifically on the fact that a freight train carrying dangerous goods was involved. The underlying thought is that the Board has already carried out investigations on several occasions into the general aspects of (preventing) train collisions.[5] Those general aspects and monitoring of the recommendations issued in the past by the Board were dealt with in the investigations undertaken by the Human Environment and Transport Inspectorate (ILT) into the accident in Tilburg.[6] The railway companies involved in the train collision in Tilburg (ProRail, NS Reizigers and DB Schenker) have also investigated this accident. The findings of these investigations are summarised in appendix C.

On the basis of the initial investigation shortly after the accident, the Board decided to not consider the handling of the consequences of the accident in this investigation. Partly given the fact that the emergency services involved have already investigated the handling of the consequences, the Board considers that investigation of the questions already referred to will generate the greatest added value.

In this investigation, the Safety Board considered the transport of dangerous goods by rail as a given. The underlying thought is that extensive discussions have been held on these safety aspects over the past few years, between all parties involved.[7] The agreements reached in that connection were reflected in the Basic Network Act, introduced on 1 April 2015.

1.2 Parties involved

The freight train involved in the accident was traveling under the responsibility of DB Schenker.[8] That company supplied the driver and the locomotive and - as railway undertaking - was responsible for the request and implementation of the train run. The wagons of the freight train belonged to various owners. The assembly and preparation for departure of the freight train were carried out by the Marshalling service in Chemelot (part of DB Schenker).

The freight train comprised 27 tank wagons, six of which were filled with dangerous goods. The tank wagons containing dangerous goods were transported on behalf of the following three shippers:[9] DSM, OCI and SABIC.[10] These are chemical companies based at Chemelot. The rearmost wagon, which suffered the leak, was owned by GATX, on a

5 The most recent report from the Safety Board on this subject is the investigation into the train collision on 21 April 2012 at Amsterdam-Westerpark. The reports of the Safety Board are available via www.safetyboard.nl.
6 Report RV15-0138 from the ILT. See also the summary in appendix C2.
7 The transport by rail of dangerous goods is also subject to extensive regulations (see 3.3 and appendix D).
8 DB Schenker Rail Nederland N.V. (In this report abbreviated to DB Schenker), as a railway undertaking is responsible for a large share of goods transport by rail in the Netherlands, and as such is also active in Belgium and Germany. The company is part of the European-operating DB Schenker Rail, head offices of which are based in Germany.
9 The RID uses the terms filler (the party filling the tank wagon) and consignor (party issuing the order for transport). In this report, this distinction is not made, but instead the term 'shipper' is used for readability.
10 These are: DSM Acrylonitrile B.V., OCI Nitrogen B.V. and SABIC Petrochemicals B.V. (In this report DSM, OCI and SABIC, respectively). DSM Acrylonitrile B.V. was renamed into AnQore B.V., on 1-12-2015.

long-term charter to SABIC. For this train run, this company was shipper for the transport of the rearmost tank wagon, and was owner of the cargo of butadiene.

The passenger train involved in the accident was travelling under the responsibility of NS Reizigers. On the basis of a concession awarded by the Dutch government, this company is responsible for public passenger transport on the basic section [11] of the national railway network. The company is owner of the relevant multiple units and employer of the train personnel.

Traffic control was provided by ProRail. On the basis of a concession awarded by the Dutch government, this company operates as manager of the national railway network. In that capacity, ProRail is responsible for the construction and maintenance of the railway infrastructure, the distribution and allocation of railway capacity to railway undertakings (such as NS Reizigers and DB Schenker) and traffic control. The latter activity, traffic control by ProRail, involves preparation of the timetable (including the handling of rescheduling requests by railway undertakings) and the setting of the route by operating switches and signals.

11 The national railway network comprises a basic section (on which NS Reizigers is responsible for transport) and regional lines (on which other passenger carriers such as Arriva, Veolia, etc. are active).

2 THE ACCIDENT

2 THE ACCIDENT

The occurrence and consequences of the accident are described in detail in appendix B. This chapter summarises the key aspects.

2.1 The collision

On 6 March 2015, at around 16:45 hours, a passenger train ran into the back of a freight train, in Tilburg. The passenger train consisted of two multiple units of the type Mat'64, and was travelling between Eindhoven and Tilburg-University, as a stopping train. The freight train consisted of a locomotive and 35 wagons, and was travelling from the Chemelot industrial estate in Geleen to the Kijfhoek marshalling yard near Zwijndrecht. Both were regular train runs, included in the basic timetable (the annual plan [12]) of ProRail.

The collision took place on track 912-B at the Tilburg-Goods yard, located between the railway stations Tilburg and Tilburg-University (see figure 2). On the intervening route, the trains involved would normally travel on different tracks: the freight train via the through tracks (in a westerly direction via 921 and in an easterly direction via 922) and the passenger train via the adjacent track 911-B/C (outward and return).

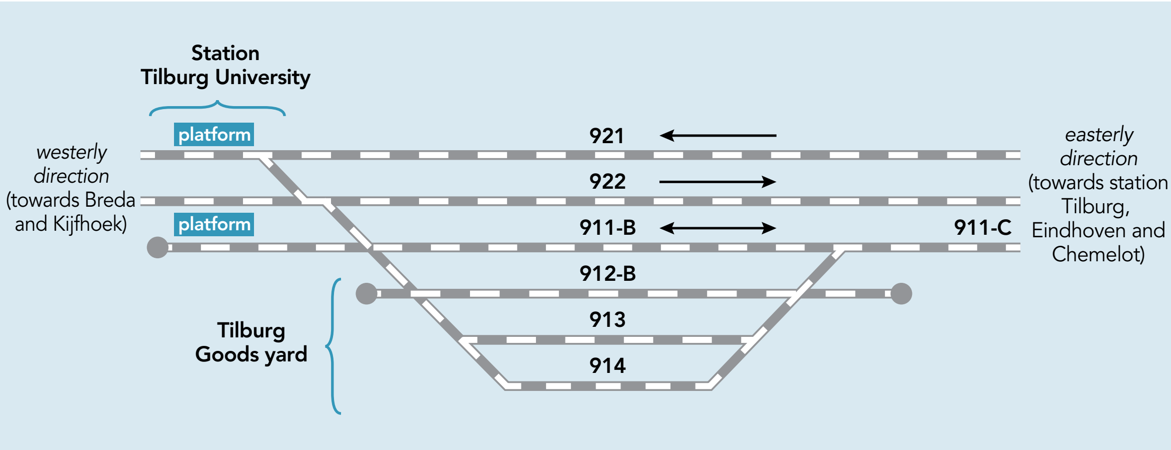

Figure 2: Diagrammatic representation of the track layout at the location of the accident. The top two tracks are the through tracks; below are an adjacent track and three side tracks of the Tilburg-Goods yard.

On the day in question, the run by the freight train differed from the run contained in the basic timetable. The alterations to the train run included the later departure and the inclusion of an intermediate stop (during the train run from Chemelot to Kijfhoek) in

12 For train traffic on the main railway network, a basic timetable (annual plan) is drawn up each year. The timetable includes the departure and destination, the route and the time-line, for all regular train runs. The annual plan, drawn up by ProRail is based on the transport requirements for passenger and freight railway undertakings.

Tilburg. The shift in departure time was made in order to create more time to compare and prepare the train for departure. The intermediate stop was introduced in order to allow the driver to be changed with the driver from another freight train, en route. The purpose of this change was to prevent the driver exceeding his maximum journey time for that day. The request for the required changes to the train run was submitted by DB Schenker to the ProRail traffic control, via a so-called rescheduling request.[13] The employees in question accepted the requested alterations and processed them in the operational timetable (daily plan).[14]

To allow the driver change to take place, both freight trains were guided to the side tracks at the Tilburg-Goods yard (see figure 3). The first to arrive, from a westerly direction, was the freight train that departed from Kijfhoek, which was guided onto track 913. Approximately fifteen minutes later, the freight train that departed from Chemelot arrived from an easterly direction, and was guided onto track 912-B. During its arrival, the freight train passed a switch (W87B) that is also part of the route of the passenger train. The freight train passed the switch several minutes before the passenger train was due to pass the same switch, according to the plan. After the freight train had been placed on the side track, it turned out that the train was several tens of metres too long for the side track in question. As a result, the back end of the train was too close to switch W87A/85, so that in the protection system, that switch retained its 'occupied' status. This meant that the switch for the passenger train (W87B) could not be switched to the correct setting[15] and the accompanying signal (96) remained at red, as the passenger train approached.

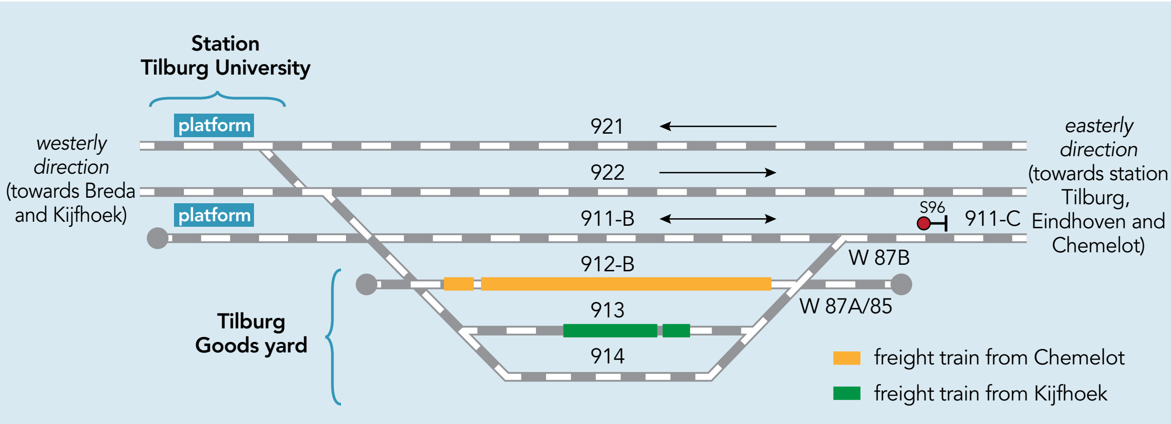

Figure 3: Because of the specially scheduled driver change, both freight trains were guided onto side tracks at the Tilburg-Goods yard. Because the train from Chemelot was too long for the side track, signal 96 remained at red.

13 Rescheduling requests are issued 'online' via the Traffic Control Information System (ISVL) intended for that purpose, see also explanatory notes in 4.2.3.

14 For the actual control of the train traffic, ProRail draws up an updated timetable (the daily plan) each day. This is more detailed than the annual plan and also contains alterations due to temporarily unavailable tracks and change requests from the railway undertakings. In the operational timetable, used by the traffic control, it may be necessary to still make changes to the daily plan, for example because of delayed trains or rescheduling requests from the railway undertakings.

15 The two switches in question (W87A/85 and W87B) are linked together, which means that the switch cannot be released as long as one of the two has the status *occupied*.

However, the driver of the passenger train did not preceive the signal at red, and as a consequence he failed to brake as he approached the signal. Because the signal is not equipped with an automatic train protection system ATB - Improved Version,[16] no automatic braking was initiated.[17] The eventual consequence was that the passenger train was guided onto the side track on which the freight train was still stationary (see figure 4) via the switch which was still in the diverging position. The driver of the passenger train did start to brake at the last moment, but this had little effect. Because of the limited remaining distance, the speed of the passenger train at the start of the collision was still almost identical to the original approach speed, namely approximately 45 km/hour.[18]

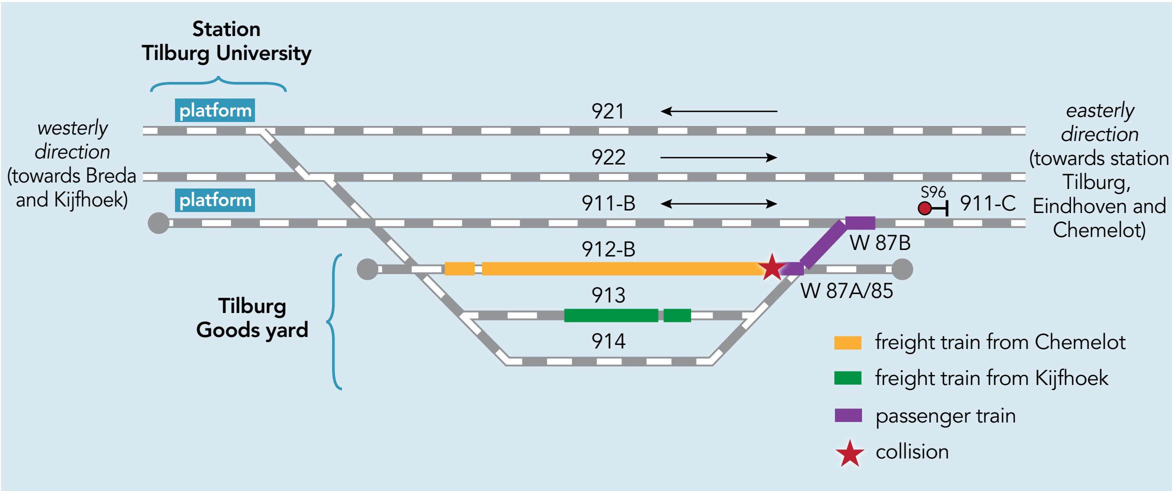

Figure 4: The passenger train passed the signal at red and then ran into the back of the freight train which stood on track 912-B.

16 Because the signal was not equipped with the additional ATB - Improved Version system, only the basic system ATB-EG (Automatic Train Protection System - first generation) was in use. In situations of this kind (approaching a red signal at 40 km/hour area), this basic system ATB-EG notes that the speed is not rising to '40 km/hour plus a specified tolerance'. For locomotives, the tolerance is not more than 3 km/hour and for multiple units not more than 5 km/hour.

17 If the signal had been equipped with ATB - Improved Version, during the last 120 metres prior to the signal, the system would have checked whether the driver was activating the braking system on time; if not, the braking system would have activated an automatic braking intervention, and the train would have been halted on time.

18 The way in which speed is determined is explained in appendix B3.

Figure 5: The three trains shortly after the accident. (Photo: ANP / Andy Smulders)

The collision of the passenger train into the back of the last wagon of the freight train can be divided into three distinct phases:

- The first contact occurred between the automatic coupler on the front of the passenger train and the coupling hook on the back of the under frame of the rearmost wagon (a tank wagon) of the freight train.
- After the automatic coupler on the passenger train had been pushed backwards, the front of the passenger train collided with the buffers of the tank wagon. As a result of height differences, only the top section of the buffers was hit. As a consequence, the front of the passenger train rose up and over the buffers.
- The passenger train then continued to slip forwards, and the front of the passenger train collided with the rear wall of the tank (see figure 6).

Figure 6: The front of the passenger train rose up and over the crash buffers on the tank wagon, and ended up against the tank. (Photo: Dutch Safety Board)

Due to the collision, the rear tank wagon was pushed forwards by approximately four metres. This forward pushing movement shifted the freight train forwards, and eventually the locomotive, which was located some six hundred metres further on, was also pushed forward by several metres.

During the collision, the kinetic energy of the passenger train was converted into other forms of energy: approximately 45% was converted into deformation of the passenger train and the tank wagon, approximately 35% was absorbed by the compression and subsequent extension[19] of the buffers on the freight train, while the remainder (more than 20%) was converted into friction between the braked wheels[20] of the passenger train and the locomotive on the rails.[21]

19 As the buffers are compressed and re-extended, energy is converted into friction.
20 The analysis of the ARR files revealed that on the passenger train and on the locomotive of the freight train, the braking system was active and that the wagons of the freight train were not 'braked'.
21 See the collision analysis in appendix B4.

2.2 The consequences of the accident

As a result of the abrupt reduction in speed experienced by the passenger train as a result of the collision, four passengers and the guard suffered minor injuries.

The collision caused damage to both trains (see figure 7). The front of the passenger train and the coupling components between the multiple units suffered damage. On the freight train, only the back end of the rearmost tank wagon suffered damage. This mainly involved the impression and minor deformation of the crash buffers,[22] bending of the tow coupling and a dent in the rear wall of the tank.

Figure 7: The damage to the rear of the tank wagon (left) and the front of the passenger train (right). (Photos: left = Dutch Safety Board, right = fire brigade)

The damage to the back of the tank was accompanied by a leak (see par. 2.3). The fire brigade restricted the scale of the leak, and no fire occurred. A number of police officers who were in the vicinity of the leaking tank wagon shortly after the collision became unwell[23] by inhaling the escaping gas.[24]

2.3 The leak from the tank wagon

The technical inspection of the tank wagon (see appendix B2) showed that the leak occurred along the seal of the manhole cover.[25] The purpose of such manhole covers is

22 The tank wagon was equipped with crash buffers. The purpose of these buffers is to absorb energy in the event of a collision, by deforming. See also explanatory notes in appendix E1.
23 The police officers in question were taken to a hospital, but were released on that same day.
24 The gas in question was butadiene. This is a flammable gas, which can have an asphyxiating effect due to oxygen displacement.
25 In this report, the term 'manhole cover' is used for the panel used to seal the manhole opening; other terms such as inspection cover are also used.

to allow entry to the tank during periodic inspection of the inside.[26] On tank wagons of this kind, the manhole cover consists of a thick round steel panel which is screwed against a ring-shaped steel flange, with bolt fastenings, and which is welded slightly below the centre in the end wall (see figure 8). The actual seal is achieved with a plastic sealing ring (gasket), which is clamped between the cover and the steel ring (see figure 9).

Figure 8: The manhole cover as fitted (left) and removed (right). (Photos: Dutch Safety Board)

On tank wagons of this kind there is only one manhole cover, located in one of the convex end walls.[27] During the collision the end wall in question was located at the rear (in respect of the direction of travel). Because the front of the passenger train collided with the rear wall, the rear wall suffered a deformation with a diameter of approx. 1.5 metres and a depth of approx. 35 cm, see left-hand photograph in figure 8.

26 On tank wagons of this kind, periodic internal inspection of the tank must be carried out at least every eight years. See also RID 6.8.2.4.2.
27 Tank wagons generally have a cylindrical tank with convex ends. Both ends are known as end walls.

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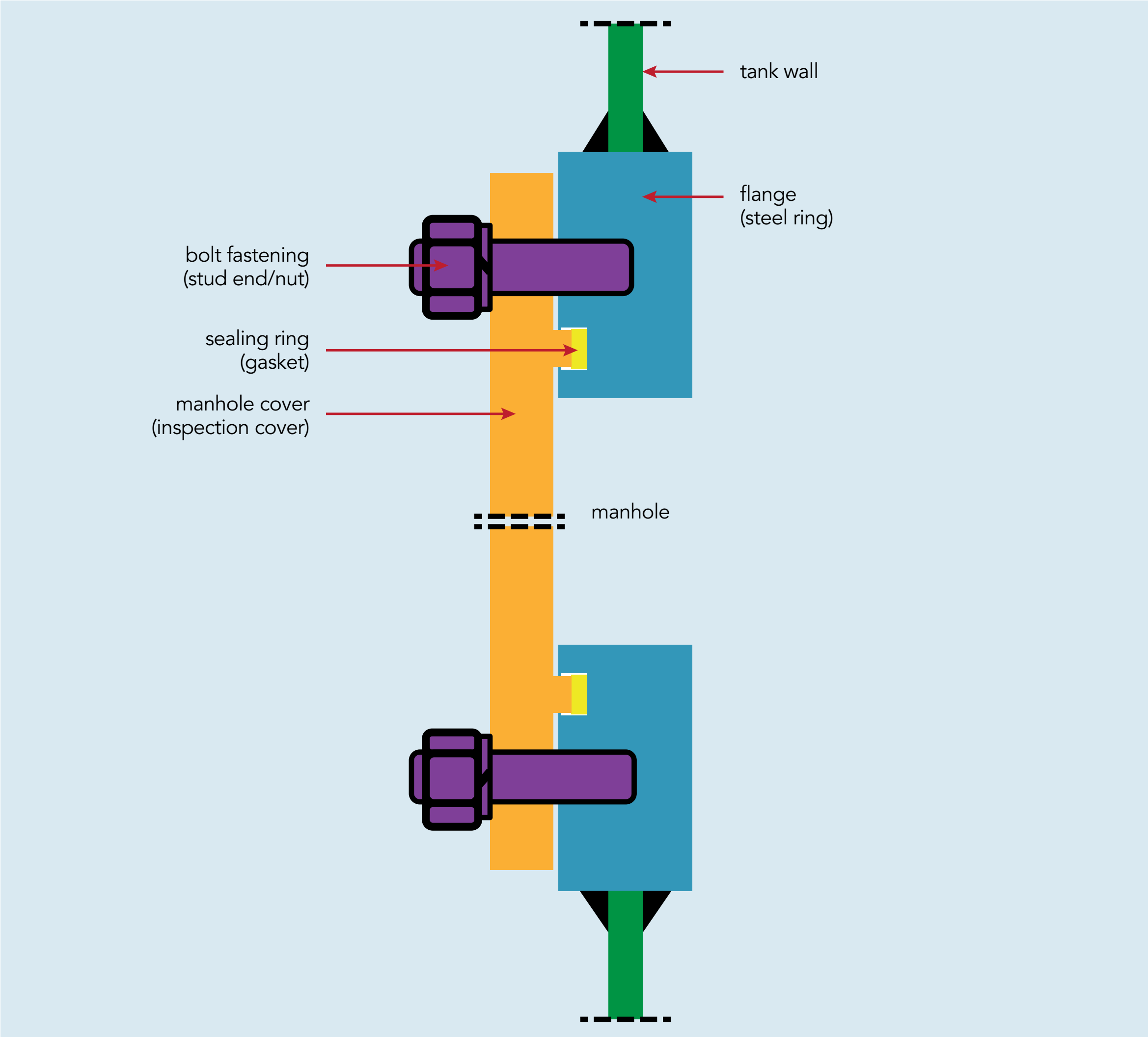

Figure 9: Cross-section of the manhole cover, diagrammatic representation.

The cover, the flange and the sealing ring complied with the regulations. The tightening torque[28] of the bolt fastenings, following the collision, proved to be less than the torque to which they should be tightened when the cover is applied (see appendix B2). That the bolt fastenings were insufficiently tight following the accident is probably explained by the fact that during the collision, considerable external forces were applied to the manhole cover. The underlying thought is that the sealing ring was probably somewhat crushed by the collision forces applied to the cover, and as a consequence it lost some of its elasticity.

The leak was relatively small (drip level). Before towing away the tank wagon, the content was pumped into another tank wagon, using a mobile pump. It took approximately two days to remove the stock in question and to re-release the accident location for train traffic.

28 The tightening torque of a bolt fastening is the measurement of intensity (force) with which the bolts are tightened.

Figure 10: The damaged tank wagon was pumped empty with mobile pumps. (Photo: Dutch Safety Board)

2.4 Sub conclusions

During the accident in Tilburg, a passenger train ran into a stationary freight train at a speed of approximately 45 km/hour. The collision occurred because the driver of the passenger train failed to stop the train for a signal at red. Because the signal was not equipped with an automatic train protection system ATB - Improved Version, no automatic brake intervention occurred.

The run-into freight train included several tank wagons containing dangerous goods. Due to the collision, a minor leak occurred in one of the tank wagons. This tank wagon was filled with more than 50 tonnes of butadiene, and was located at the end of the freight train. Because this was a head/tail collision, the tank wagon was hit directly.

During the collision, the front of the passenger train rose up and over the buffers of the rear tank wagon, and ended up against the tank itself. As a result, the rear wall of the tank was deformed. At that point in the rear wall was the manhole cover, intended for periodic inspection of the inside of the tank.

The leak only occurred along the seal of the manhole cover. There was no tearing in the tank shell. The scale of the leak remained limited.

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3 TRANSPORT OF DANGEROUS GOODS BY RAIL

3 TRANSPORT OF DANGEROUS GOODS BY RAIL

3.1 General

The bulk transport of (liquid and gaseous) dangerous goods generally takes place from and to the production and storage locations of the chemical companies. In the Netherlands, these are mainly located on ten industrial estates spread around the country.[29] A large share of international transport takes place via the seaports of Rotterdam, Amsterdam and Antwerp.

In the Netherlands, dangerous goods are primarily transported via pipelines (approx. 52%) and inland shipping (approx. 40%). The remainder travels by road (approx. 6%) and rail (approx. 2%).[30] Although the share of rail transport is small, it still relates to considerable volumes: the total transport of dangerous goods by rail amounts to approximately four to five million tonnes per year. This equates to approximately 10% of all goods transport by rail, and on average transporting these goods involves 400 tank wagons per working day.

The transport of dangerous goods by rail is carried out in tank wagons[31] and tank containers (see figure 11). With a tank wagon, the tank forms a complete unit with a under frame; tank containers are removable and are transported (by rail) on container carrier wagons. To improve readability, this report refers to tank wagons at all times, even if actually referring to tank containers.

On freight trains with tank wagons, a proportion of those wagons are generally designated 'empty, uncleaned'. This does not mean that the wagons do not contain any hazardous material. After pumping a tank wagon empty, a certain volume (up to several hundred litres) of the cargo often remains behind. The tank wagon is then designated as 'empty, uncleaned'. Only once these residual amounts have also been removed and the tank has been rinsed (for example using nitrogen) is a tank wagon designated 'empty, cleaned'. Tank wagons that are 'empty, uncleaned' must comply with the same safety regulations during transport as filled wagons, because in the event of an accident, even a residual cargo can represent a hazard. In certain situations, an empty, uncleaned tank wagon can in fact represent additional risks. For example, if a tank wagon is exposed to a fire, tank wagons with a small volume of liquid cargo heat up considerably more rapidly than tank wagons fully or mostly filled with a liquid cargo.

29 The most important centres for the chemical industry are located at Pernis, Europoort, Botlek, Dordrecht, Moerdijk, Geleen, Vlissingen, Terneuzen, Delfzijl and Emmen.
30 These percentages are based on estimates from Statistics Netherlands (period 2010-2013).
31 The Dutch RID uses the term 'reservoir wagon'.

Figure 11: Examples of a tank wagon (top) and of three tank containers on a container carrier wagon (below). (Photos: SABIC)

3.2 Rail transport from/to Chemelot via the Brabantroute

The freight train involved in the accident in Tilburg, had started from the Chemelot industrial estate near Geleen, which is home to major chemical companies including DSM, SABIC and OCI. At Chemelot, each year, approximately 28,000 tank wagons with dangerous goods are handled. These are divided into approximately eight (departing and arriving) trains per working day. This means that the freight trains to/from Chemelot on average include 14 tank wagons filled with dangerous goods. These trains also include empty, uncleaned tank wagons and other wagons (with or without dangerous goods).

Of those trains travelling from and to Chemelot carrying dangerous goods, approximately half travel via the Brabantroute, the railway line that links South Limburg via Eindhoven, Tilburg and Breda to the Rotterdam port area.[32] The other half of the trains are international and travel via Venlo or sporadically via Maastricht or Heerlen. See also figure 12.

32 One of the major railway projects in the Netherlands and part of the High-frequency Rail Programme (PHS) involves the construction of a south-western curve at Meteren that could make a direct link possible between the Betuweroute (towards Kijfhoek) and the railway track from Utrecht to 's Hertogenbosch. Once this curve is finished, the volume of goods transport through Tilburg will be reduced.

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The collision in Tilburg took place between the stations Tilburg and Tilburg-University, a section of track that is part of the Brabantroute. The table in figure 13 shows how many tank wagon equivalents (KWE)[33] per substance category have been carried over this section of the Brabantroute over the past few years.

Figure 12: Transport of dangerous goods by rail in the southern half of the Netherlands. (Picture: Dutch Safety Board)

Number of KWE dangerous goods on the Brabantroute (through Tilburg)

year	flammable gases	toxic gases	very toxic gases	very flammable liquids	toxic liquids	very toxic liquids	total
	A	B2	B3	C3	D3	D4	
2012	6,260	787	0	4,988	2,009	467	14,511
2013	5,927	619	0	4,674	1,823	285	13,328
2014	4,953	1,068	0	3,519	2,223	361	12,124

Figure 13: The number of tank wagon equivalents (KWE) in the various hazard categories transported over the past few years along the Brabantroute between the stations Tilburg and Tilburg-University. (Source: ProRail)

33 During the transport of dangerous goods by rail, the size of the transport flows is expressed in the unit tank wagon equivalent (KWE). In this unit, 1 KWE represents 1 tank wagon (irrespective of the type of substance) or 2 tank containers for a flammable substance or 3 tank containers for a toxic substance. An average tank wagon carries between 50 and 60 tonnes of the substance in question.

3.3 Legislation and regulations

The transport of dangerous goods by rail is subject to the Transport of Dangerous Goods Act (Wvgs), including the *Transport of Dangerous Goods Order* (Bvgs), the *Ministerial Regulation on the Transport of Dangerous Goods by Rail* (VSG) and the *Ministerial Regulation on the Basic Network*.

Figure 14: Overview table of the relevant legislation and regulations.

In respect of the management of the external safety risks,[34] for the transport of dangerous goods by rail, broadly speaking the following two regimes can be distinguished: the RID and the Basic Railway Network. The essence of these two regimes is summarised below, and described in more detail in appendices D and E.

3.3.1 RID

According to the *Transport of Dangerous Goods Order* (Bvgs) and the Ministerial Regulation VSG, the transport of dangerous goods by rail - in addition to a number of national rules - is subject to the international rules as contained in the RID.[35] The RID classifies dangerous goods on the basis of their hazard characteristics, and for the various classes imposes specific transport conditions and restrictions in respect of packaging, labelling and transport documents.

The RID also lists requirements for tank wagons. In respect of crashworthiness, these requirements relate above all to the presence of crash buffers, anti climbing devices and protective shields. These protection systems are explained in further detail in appendix E. Crash buffers[36] are intended to absorb energy in the case of a collision, thereby helping prevent deformation/damage to the tank. An anti climbing device or protective shield[37] is intended to limit the risk that in the event of a collision, the tank will suffer a direct hit,

34 External safety should be taken to mean the safety for the environment.
35 RID stands for *Règlement concernant le transport international ferroviaire des marchandises dangereuses*. Appendix D contains a summary of the relevant legislation and regulations.
36 See also explanatory notes in appendix E1.
37 An anti climbing device is a mechanism, the purpose of which is to prevent one vehicle climbing over another (also known as buffer overriding), in the event of a collision. A protective shield is a vertical panel, which is placed before the end wall of a tank, to prevent the tank wall being penetrated by a sharp object in the event of an accident. See also the explanatory notes in appendix E2.

and as a result start to leak. Whether a tank wagon has to be equipped with these systems will depend on the category of dangerous goods being transported, and the year of construction of the tank wagon (see figure 41 in appendix D).

The RID also imposes requirements on the training of personnel involved in the transport of dangerous goods by rail. The essence of those requirements is that the personnel of the railway managers in question and the railway undertakings transporting goods must be trained in the regulations governing the transport of dangerous goods that relate to their tasks and responsibilities. Railway undertakings responsible for the transportation of goods must always employ one or more safety advisers whose task is to ensure that the transport of dangerous goods by rail is undertaken in accordance with the regulations, and in optimum conditions, and for ensuring awareness of the risks involved in the transport operation.

3.3.2 Basic Railway Network

In the last part of the previous century, the transport of dangerous goods by rail increased in volume while at the same time, the extent of building along railway routes also increased. Around fifteen years ago, it was recognised that if policy was not changed, these two developments would mean that the threshold or target values for external safety along considerable sections of the railway system would be exceeded. In 2005, the central government (the then Ministries of Public Housing & Employment, Public Health, Spatial Planning & the Environment, Economic Affairs and the Interior & Kingdom Relations) recognised the importance of managing the field of tension in the long term, between the transport interests of the (chemical) industry on the one hand, and the interests of spatial planning and external safety on the other. The aim of that policy was to create a balance between the various interests, and subsequently provide clarity on when which forms of dangerous goods transport may be carried out, and the consequences of those transport operations for citizens, industry, the emergency services and contingency planning.

A multi-year preparation programme resulted in the Basic Network Act, which was introduced on 1 April 2015 (as part of chapter III of the Transport of Dangerous Goods Act).[38]

The Basic Network Act was drawn up in the following three phases:

a. *Risk inventory*
   The first step was to draw up an inventory of the locations where the standards for external safety would be exceeded. The calculations revealed that if policy remained unchanged, by 2020, along approximately 220 km of railway track, the societal risk[39] would be greater than the applicable orientation value (along 41 km of track indeed by more than a factor of 10).

38 The Basic Network Act (Bulletin of Acts and Decrees 307, 2013) includes a component on Rail as well as Road and Water. This was subject to the Circular Risk Standard for the transport of dangerous goods (Netherlands Government Gazette 14678, 20-07-2012). In advance of the introduction of the Basic Network Act, this Circular broadly described the same.

39 'Societal risk' is: "the cumulative risk per year and per kilometre of track that ten or more persons will die as a direct consequence of an unusual occurrence on the basic network, involving dangerous goods" (Source: Wvgs, chapter III, paragraph 1, article 11).

b. *Measures*

The parties involved (central government, provinces, municipalities, chemical industry, the railway undertakings and ProRail as manager of the railway infrastructure) then consulted for a number of years on the measures to improve external safety. Broadly speaking this resulted in the following measures:

- On railway routes along which dangerous goods are transported, at approximately 350 signals, an additional safety system (automatic train protection system ATB - Improved Version) was installed, so that the risk of a red signal passage at these signals was reduced. The selection of the signals was made on the basis of a risk assessment.
- A network of thermal measuring points (HotBox detectors) was installed, via which wheel set defects that result in temperature increase can be detected, with a view to preventing derailments. ProRail also equipped its network of wheel load measuring points (the QuoVadis stations) with an online detection system for wheel set defects, that can be detected on the basis of a deviating track load.
- The vast majority of shippers/railway undertakings signed an agreement according to which they committed to composing trains with dangerous goods 'hot-BLEVE-free'.[40, 41]
- A number of the shippers (including SABIC) decided, for the transport of flammable substances by rail, to only use tank wagons equipped with crash buffers (even if this is not a legal requirement, because they were built before 2007).
- In Dordrecht and Zwijndrecht, additional measures on the railway infrastructure have been taken, to further reduce the risk of collision and derailments. These include the alteration/removal of switches and the installation of guidances between the rails.[42]
- At a limited number of places, buildings close to the track were purchased by the government for demolition, or so they could be allocated a less vulnerable purpose.

c. *Limiting of transport/building*

Finally, for all relevant railway connections, risk limits were adopted, expressed in the distance to the railway, within which a specific location-based risk may not be exceeded. In the adoption of this standard, which took place in 2010, a consensus was reached between all participating parties. The adopted risk ceilings were mathematically linked to an annual number of tank wagon equivalents in the various hazard categories on those routes. The agreed risk ceilings, laid down in (appendix II of) the Ministerial Regulation on the Basic Network, restrict the transport of dangerous goods over the

40 BLEVE stands for *Boiling Liquid Expanding Vapor Explosion*. A 'hot-BLEVE' is a large-scale explosion that can occur if a gas wagon is exposed to a pool fire. Due to the rising temperature, the pressure in the tank increases, and the strength of the tank shell falls, which can result in the tank shell failing, followed by the instantaneous release of the content, forming an explosive cloud.

41 The covenant demands that freight trains with dangerous goods are composed in such a way that at no point is a tank wagon containing flammable liquid (e.g. petroleum) linked to a tank wagon containing a flammable gas (e.g. LPG). The aim of this measure is to limit the risk of a 'hot-BLEVE'.

42 Despite the other measures, in those two cities, along certain sections of track, the calculated societal risk remains greater than the applicable orientation value. For that reason, the Ministry of Infrastructure and the Environment agreed on additional measures with both municipalities at the end of 2014. The measures specifically relate to the alteration and/or remediation of the switches on the relevant sections of the Brabantroute.

various railway lines, and also determine the safety zones which municipalities and provinces must take into account in zoning plans, building permits, etc.[43]

3.4 Railway accidents with dangerous goods

Appendix G provides an overview of the number of railway accidents with dangerous goods that have occurred over the past few years in the Member States of the European Union. This overview also indicates in which proportion of those accidents dangerous goods escaped. The overview reveals that in the period 2011/2012, in the EU countries, in each year between 28 and 36 relevant railway accidents occurred, and that in approximately one third of those accidents, dangerous goods actually escaped.

Train collisions resulting in damage to tank wagons

The accident in Tilburg involved a tank wagon with a hazardous substance, which was seriously damaged by a collision. Such accidents have occurred on five occasions over the past few years in the Netherlands, including the accident in Tilburg (see the table in figure 15). Of those five collisions, two took place on the main railway network and the other three at a marshalling yard. In one case (which occurred in 2011 at the Kijfhoek marshalling yard) there was a considerable leak of a hazardous substance (ethanol) and a large fire, but there were no victims. In the recent collision in Tilburg, the consequences were restricted to a small leak of butadiene, while in all the other cases, no dangerous goods escaped.

43 This is further elaborated in the Order on External Safety of Transport Routes.

	Collision	Consequences
2015 Tilburg	A passenger train ran into the back of a stationary freight train at a speed of approx. 45 km/hour (as a consequence of a red signal passage).	Due to the collision, the rear wagon of the freight train (a tank wagon with approx. 50 tonnes of butadiene) suffered a minor leak.
2014 Onnen (rangeerterrein)	A shunting locomotive collided at low speed against the flank of a shunting unit.	The locomotive collided with a tank wagon loaded with natural gas condensate. The tank was dented but did not leak. The cab of the locomotive was also damaged. There were no injuries.
2011 Kijfhoek (rangeerterrein)	Two sets of tank wagons collided with one another during shunting, at a speed of approx. 30 km/hour.	Due to the collision, one tank wagon loaded with ethanol sprang a leak, as a consequence of which a major/fierce fire occurred.
2009 Barendrecht	Two freight trains collided head on at a speed of approximately (70 + 40 =) 110 km/hour (as a result of a red signal passage) due to the driver falling ill.	As a result of the collision (during which one driver was killed and the other seriously injured), two tank wagons derailed and were damaged, but there was no leak.
2005 Pernis (rangeerterrein)	During the shunting process, a locomotive collided with a tank wagon (containing butadiene) at low speed.	The tank wagon was damaged, but there was no leak.

Figure 15: Train collisions with damage to tank wagons (2005-2015) in the Netherlands.

Train collisions also occurred in other European countries, leading to damage to tank wagons containing dangerous goods. The table below (see figure 16) shows the six most serious accidents of this type over the past few years. In two of these collisions a considerable volume of hazardous substance escaped, and a fire occurred. Five of the six collisions (as was the case of the accident in Tilburg) involved a head/tail collision and the damage to the tank wagon affected the rear wagon of the run-into freight train.

	Collision	Consequences
2012 Godinne (Belgium)	Collision of a freight train running into the back of another freight train (the last wagon of which was a tank wagon containing dangerous goods).	The collision caused serious damage, but no dangerous goods escaped.
2012 Tintigny (Belgium)	Collision of a freight train running into the back of another freight train containing dangerous goods (methyl acrylate) in a tunnel.	The collision caused a minor leak but no fire.
2011 Bleicherode (Germany)	A freight train ran into the back of a moving freight train. The rear wagon of the front freight train was a tank wagon containing gas oil.	Due to the collision, the tank wagon containing gas oil suffered a leak. This was followed by a fire.
2010 Glons (Belgium)	A locomotive ran into the back of a freight train transporting flammable gas (LPG).	The collision did not result in a leak.
2010 Bialystok (Poland)	A freight train collided with the side of another freight train. The freight train, which was hit in the flank, was transporting a large volume of dangerous goods (including LPG and diesel oil).	The collision led to leaks in dozens of tank wagons. This was followed by an explosion and a huge fire.
2009 Berlin (Germany)	A passenger train ran into the back of a slowly moving freight train. The freight train consisted of 14 tank wagons with propylene, butane and propane.	In the collision, 12 of the 24 passengers on the passenger train were injured. The rear tank wagon (which was filled with propylene) was damaged, but there was no leak.

Figure 16: Train collisions with damage to tank wagons in other European countries.

Potential consequences

Generally speaking, when a tank wagon suffers a leak the consequences for the environment can be very serious. An example of an accident with serious consequences involved the derailment of a freight train in the Italian Viareggio in 2009.[44] In this accident, a tank wagon filled with LPG[45] suffered a leak, resulting in a violent explosion and serious fire in the urban area. In this accident, more than thirty people were killed, and dozens of people were injured. LPG belongs to the same hazard category as butadiene, which escaped in Tilburg. Other types of dangerous goods can also lead to very serious consequences in the event of an uncontrolled escape. In 2013, for example, a freight train travelling from the Netherlands carrying acrylonitrile and (empty, uncleaned) butadiene derailed at Wetteren, in Belgium.[46] During this derailment, several tank

44 "Relazione di indagine sull'incidente ferroviario del 29 giugno 2009 nella stazione di Viareggio" Ministero delle Infrastrutture e dei Trasporti. (Rome, 23 March 2012, supplemented on 30 May 2013).

45 The freight train consisted of 14 tank wagons containing LPG, several of which derailed. That 'only' one tank wagon suffered a leak means that no leak occurred in several tank wagons, while they had tipped over and were damaged, and were exposed to the fire. However, this also means that the content of only one tank wagon was responsible for the large-scale explosion and the fire.

46 Safety investigation report 'Derailment of a freight train Wetteren 4 May 2013', Investigating body for Accidents and Incidents on the Rails.

wagons suffered a leak, resulting in a major fire accompanied by several explosions. Following the accident, acrylonitrile and the decomposition products (including hydrocyanic acid) that were created during fire fighting, spread into the adjacent urban area via the sewer system. It is probable that one person died as a result.[47]

3.5 Sub conclusions

Of all bulk transport of dangerous goods, approximately two percent is transported by rail, which equates to on average approximately 400 tank wagons per working day. Of the trains travelling from/to Chemelot carrying dangerous goods, approximately half (or on average four trains per working day) travel via the Brabantroute.

During the transport of dangerous goods by rail, in respect of the management of external safety risks (as part of the Transport of Dangerous Goods Act), two regimes apply:

- the RID, that contains instructions for the crashworthiness of tank wagons;
- the Basic Network Act and Ministerial Regulation, which lay down via which railway routes which volume of dangerous goods may be transported, and which safety zones must be taken into account along which routes, in respect of building.

The accident statistics reveal that over the past few years, in the Netherlands, one train collision has occurred whereby a considerable volume of a hazardous substance escaped from a tank wagon, and that as a consequence there were no victims. Accidents that have occurred in other European countries have shown that the consequences can be very serious, in the event of a major leak.

47 The cause of death was never announced - as far as we were able to determine.

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4.1 Problem outline

As described in chapter 2, the accident was caused by a chain of events, the last of which consisted of a red signal passage by the passenger train in question. That subject is part of the investigation initiated by the Human Environment and Transport Inspectorate (ILT). In that investigation, the ILT also considered compliance with the recommendations issued by the Safety Board in previous reports on this problem. The findings of the ILT investigation are summarised in appendix C. The purpose of this investigation by the Safety Board is to draw lessons from the accident in Tilburg in respect of the fact that a hazardous substance leaked out of a tank wagon following the collision.

The consequences of the accident in Tilburg remained limited. The analysis of the occurrence of the collision (see appendix B4), however, revealed that the collision forces on the tank wagon (and hence the risk of a serious leak) would have been greater if more wagons of the freight train had been loaded, or if the wagons had been braked, at the time of the collision.[48] In the judgement of the Board, despite its limited consequences, maximum use must be made of these aspects of the accident in Tilburg, in drawing safety lessons.

Chapter 3 describes how extensive management measures are specified or have been taken with a view to managing the external safety risks. In creating the Basic Railway Network, for example, measures were taken to reduce the risk that freight trains with dangerous goods would be involved in a collision. The RID also imposes requirements on tank wagons to further reduce the risk of a leak occurring in the event of a collision.

The Board has investigated how - given these measures and regulations - a leak nonetheless occurred in Tilburg, as a result of a train collision. The findings are described in this chapter. Paragraph 4.2 first deals with the question how *the red signal passage by the passenger train could result in a collision with a freight train carrying dangerous goods*. Paragraph 4.3 then describes *how the collision of the passenger train with the rear of the freight train could result in a leak in a tank wagon*. Subsequently, paragraph 4.4 discusses the *underlying factors* in further detail.

48 The size of the collision forces, in addition to the mass and speed of the passenger train, was also dependent on the force needed to push the rear tank wagon forwards. Determining factors for that force include the level of loading of the wagons, and whether or not the wagons were braked.

4.2 Involvement of a train carrying dangerous goods

The reconstruction of the accident (as described in appendix B1) reveals that the following aspects above all played a role in the fact that the freight train carrying dangerous goods became involved in the collision:

- the planning for this specific run by the freight train was rescheduled;
- in the rescheduling request, an incorrect value for the train length was notified.

These two subjects are elaborated below.

4.2.1 Rescheduling of the freight train

The planning for the train run by the freight train, which was involved in the accident in Tilburg, was rescheduled during the final hours. This rescheduling meant for example that the freight train was placed on a side track in Tilburg, for the purposes of an intermediate stop. This rescheduling took place at the request of the railway undertaking (DB Schenker). To create more time for composing and preparing the freight train for departure, the Chemelot Marshalling service[49] postponed the departure time on several occasions, resulting in a total shift of approximately three hours. During the course of this time, the number of wagons was also increased, thereby increasing the total length of the train. Once the train had eventually departed, the transport coordinator of the railway undertaking realised that the driver would exceed his maximum running time for the day in question, if he were to complete the entire run (first from Chemelot to Kijfhoek and then back to Chemelot). In consultation with the traffic control of ProRail, he therefore arranged for the freight train to make an intermediate stop at the Tilburg-Goods yard. He also arranged that the other freight train, which had to travel from Kijfhoek to Chemelot, would be driven to Tilburg by another driver, and that that train would also make an intermediate stop at the Tilburg-Goods yard. When the second train arrived, the driver of the train brought his train to a standstill at the moment that his locomotive was positioned alongside that of the other train. The two drivers then changed locomotive, and the 'new' driver drove his train as far as possible onto the side track in question.

To reach the side track, the trains had to pass several switches in diverging position, at which point they ended up on a section of track for which the access switch was not fitted with an automatic train protection system ATB - Improved Version. Both actions engendered greater safety risks, whereby in this case the effect of the absence of the automatic train protection system ATB - Improved Version actually arose. If a signal is not equipped with automatic train protection system ATB - Improved Version, only the basic system (ATB-EG) applies; in situations like this (approaching a red signal in the 40 km/hour zone) this basic system offers no effective protection against red signal passages. The fact of passing switches is also accompanied by additional safety risks. During this action, certainly if the switch is in diverging position, there is a greater risk of derailment. For that reason, the passing of switches is heavily represented in the risk calculations on

49 The Chemelot Marshalling service is part of DB Schenker. The company is responsible for rail transport on the Chemelot industrial estate, including the composition and preparation for departure of outgoing freight trains.

the basis of which the risk ceilings and transport limits of the Basic Railway Network are drawn up.[50] Reference can also be made in this context to the Drechtsteden project in which a series of switches have been altered/removed at Dordrecht and Zwijndrecht, with a view to further reducing the external risks, which at these locations are still above the target values.

The additional risks were not taken into consideration, either in the rescheduling request by the transport coordinator at DB Schenker, or by the staff of ProRail who approved and implemented the rescheduling. Both the choice to make an intermediate stop, and the choice of location were made on the basis of logistic and commercial arguments.

It is relatively common for a freight train run to be rescheduled. The alterations may relate to the timeline, the route or the introduction of an intermediate stop. Broadly speaking, the following two issues may provide grounds for rescheduling a train run:

- *Disruption of passenger trains*: Freight trains are slower (both in terms of maximum speed and in respect of acceleration and braking) than passenger trains. As a result, a freight train can have a disruptive effect on passenger trains travelling on the same route. For that reason it is sometimes desirable to have a freight train make an intermediate stop.[51]
- *Logistic process*: Due to problems in an earlier link in the logistic chain of a freight train (e.g. loading/unloading, composition/shunting or a previous train run), it may be either necessary or desirable to adjust the departure time. The logistic process can also be a reason to introduce an intermediate stop. As was the case in Tilburg, for example, this may mean changing drivers, or it may involve the addition/removal of wagons, or switching locomotives.

Both companies (DB Schenker and ProRail) have made it known that in the day-to-day practice of requesting, approving and implementing train run rescheduling, 'freight trains with dangerous goods' are not treated differently from 'freight trains without dangerous goods'. Rescheduling the planning for a freight train with dangerous goods, however, can have consequences not only for the safety of the train traffic itself, but also for the track-side environment (external safety). It emerged from this investigation that these parties (even following the collision in Tilburg) have not introduced extra instructions for rescheduling these train runs. Paragraph 4.4 discusses this aspect in more detail.

4.2.2 Notification of incorrect train length

The freight train run into in the accident in Tilburg was longer than the side track of the Tilburg-Goods yard onto which the train had been guided for the intermediate stop. As a consequence, the rearmost wagon of the freight train remained so close to the access switch that the switch retained its 'occupied' status in the safety system. The switch in

50 The calculation method is explained in the Transport Risk Analysis Handbook (HART). According to this method, a section of track which contains a switch is awarded a higher accident frequency than is the case with no switches. The additional factors effectively mean that the presence of switches increases the accident risk (depending on the permitted section speed) by a factor of 2.2 to 3.4. See also paragraph 9.4.1 of the HART handbook, for situations with switches and increased risks.

51 For the time being, to uphold the (conflict-free) timetable, as far as possible, a freight train is kept moving, because it then causes less delay and fewer red signal approaches.

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question is linked to the switch that had to be passed by the passenger train. As a consequence, the switch for the passenger train could not yet be switched to the correct status, as the train approached, and the access signal remained at red.

The total length of the freight train was 624 metres and the side track in question was suitable for a maximum train length of 585 metres. The fact that the train traffic controller in question nonetheless opted for this side track was due to the fact that the railway undertaking had notified a value of 567 metres for the train length when requesting the intermediate stop.

- The original intention was for the freight train to depart Chemelot with a composition that amounted to a length of 567 metres. To alter the departure time, the railway undertaking submitted a rescheduling request to ProRail via the online system intended for that purpose (ISVL).[52] In that request, a length of 567 metres was notified for the train (which at that stage was still correct).
- However, the freight train did not depart in its original composition. The Chemelot Shunting service altered the composition in several different stages. These changes related to the decision to divide the wagons to be transported on that day among two trains, as opposed to the originally intended three. The train that eventually departed had a total length of 624 metres. In connection with the overrun of the composition process, following the first rescheduling request, the railway undertaking submitted a further three rescheduling requests. In those requests, the departure time was updated, but not the notified train length.
- After the freight train eventually departed, approximately three hours later than originally planned, the railway undertaking once again submitted a rescheduling request. This request related to the intermediate stop at Tilburg-Goods yard. Even in this final request, the notification of the train length was not adjusted, so that the incorrect value (567 metres) remained.

On the part of the railway undertaking, it was assumed that in handling the rescheduling requests, the staff of ProRail would base their train length calculations on the so-called wagon list. This list is submitted to another ProRail online system (OVGS) by the railway undertaking, prior to the departure of the train, and contains detailed information about the composition of the train and the goods it is carrying.[53] On the basis of this expectation, the staff at the railway undertaking assumed that notification of the train length in a rescheduling request (via ISVL) was of secondary importance. However, in handling rescheduling requests, the staff at ProRail base their calculation of train length on the value notified by the railway undertaking in the rescheduling request (in the ISVL system), and do not compare the notified value with the information in the wagon list.

52 ISVL stands or Traffic Control Information System. Via this system, ProRail communicates with the railway undertakings on the processing of train traffic, and railway undertakings can apply for/cancel train runs, or request rescheduling during the final days before implementation.

53 Railway undertakings operating trains with dangerous goods are required to issue information to ProRail about the composition of the train and the goods it is carrying (via the so-called wagon list) at the latest five minutes before departure of the train (detailed information). This information is entered/stored in the OVGS (Online Transport of Dangerous Goods) system. The OVGS is primarily intended to provide information to the emergency services about the composition/nature of the goods on trains carrying dangerous goods, in the event of an accident.

On the basis of their own investigations, DB Schenker and ProRail have both decided to link the two systems (ISVL and OVGS) (see also C1-2), as far as this is possible.

4.3 Occurrence of a leak in the tank wagon

The reconstruction of the accident (see appendix B1) and the technical investigation of the tank wagon (see appendix B2) reveal that the main contributing factors to the occurrence of the leak in the tank wagon were:

- that the run-into freight train was composed in such a way that a filled tank wagon was located at the rear end of the train;
- the front section of the passenger train climbed onto the preceding train, during the collision;
- there was a manhole cover in the rear wall of the run-into tank wagon.

These three subjects are discussed in further detail below.

4.3.1 Composition of the freight train

In the collision in Tilburg, the rearmost wagon was the only part of the freight train to suffer damage. In this case, the rear wagon was a tank wagon loaded with approximately 50 tonnes of flammable gas (butadiene). However, the freight train also consisted of a series of other wagons, which did not contain dangerous goods. If one of those wagons had been placed at the rear of the train when the train was composed, no hazardous substance would have escaped, and the risk would have been considerably reduced.

In the event of a rear end collision with a freight train carrying dangerous goods, the risk of product escaping is greatest with the rear wagon. The reason for this is that in the event of such a collision, generally speaking greater collision forces are applied to the rear wagon than to other wagons. Furthermore, as was the case in Tilburg, the risk is greatest that the tank on the rear wagon will be hit directly by the other train. Rear end collisions form a relevant share (approx. 30%) of all collisions involving freight trains.[54] Over the past few years (in other European countries), on a number of occasions a rear end collision has led to damage to/leaks from a filled tank wagon located at the end of a freight train (see figure 16 in paragraph 3.4).

With regard to the position of a tank wagon containing dangerous goods in a freight train, the only[55] applicable agreement is a covenant in which (the majority of) shippers/ railway undertakings transporting dangerous goods have promised to compose trains of

54 This is revealed by an investigation by the RIVM, the results of which were reported on in 2014 in: *Towards a new risk-calculation method for the transport of dangerous goods by rail; Technical report on failure frequencies of Dutch freight wagons based on incident data* (RIVM report 620550010/2014).

55 The RID also requires that wagons containing specified explosive substances may not be coupled to a wagon containing a flammable or oxidising substance.

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this kind 'hot-BLEVE-free'.[56, 57] This covenant, that applies to Dutch railway transport, demands that a freight train carrying dangerous goods must be composed in such a way that at no point is a tank wagon containing flammable liquids (e.g. petroleum) coupled to a tank wagon containing a flammable gas (e.g. LPG or butadiene). This covenant is now generally complied with.[58] The regulation is not intended to prevent the occurrence of leaks in tank wagons, but to limit the consequences if a tank wagon containing a liquid fuel suffers a leak.

The risk of the escape of a hazardous substance as a consequence of a rear end collision can be limited by ensuring that no hazardous substance is carried in the rearmost wagon of a freight train. In practical terms, this can be achieved by attaching a wagon that is 'empty and clean' or a wagon that is loaded[59] with other goods than dangerous goods to the back of the train. If this is not possible, an additional (buffer) wagon could be added.

4.3.2 Climbing of the passenger train onto the tank wagon

The leak occurred because the passenger train ended up against the tank itself. In the first instance, the passenger train collided with the under frame (tow coupling/buffers) of the tank wagon, but subsequently the front section of the passenger train rose upwards, mounting the tank wagon, and colliding with the tank itself. See also the explanatory notes in appendix B4-1.

The fact that the passenger train was able to 'climb' onto the tank wagon was due to the poor collision compatibility between the colliding fronts. The passenger train was of the type Mat'64, a train series designed more than fifty years ago (around 1964). Unlike with modern trains, the fronts of these trains are not fitted with crash absorbers[60] nor with an obstacle deflector[61] (see also the explanatory notes in appendix F2). As a consequence, in the event of a collision, the section which is located beneath the floor of the cab provides no noteworthy resistance. In the accident in Tilburg, this fact meant that the front of the passenger train rose upwards (climbed) during the collision, and eventually ended up against the tank of the rearmost wagon of the freight train.

In the currently applicable admission requirements for passenger trains, requirements are laid down in respect of collision compatibility. These requirements relate not only to

56 BLEVE stands for *Boiling Liquid Expanding Vapor Explosion*. A 'hot-BLEVE' is a large-scale explosion that can occur if a gas wagon is exposed to the pool fire. The rising temperature leads to an increase in pressure in the tank, which can reduce the strength of the tank shell itself, so eventually the tank shell fails and the content (instantaneously) escapes, and forms an explosive cloud.

57 Over the past few years (see appendix E4), a series of proposals have been made for including further requirements on the composition of trains with dangerous goods in the RID, but (to date) this has not resulted in any changes.

58 More than 98% of the relevant undertakings have signed the agreement (which does not apply to trains travelling on the Betuweroute). In 2013, more than 97% of the relevant trains were composed hot-BLEVE-free. Source: Appendix 5 to the Letter to Lower House of the Dutch Parliament TK 26956 no. 195 (Lower House, Session year 2013-2014), Ministry of Infrastructure and the Environment.

59 On the basis of a risk analysis, it is possible to consider whether empty but uncleaned tank wagons are also suitable as rearmost wagon.

60 Crash absorbers are deformation elements, the purpose of which is to absorb energy in the event of a collision, thereby preventing vehicle components deforming, that are important for the safety of the passengers or cargo. Crash absorbers are fitted on passenger trains at the same point (in terms of height and width) where buffers are located on freight stock.

61 An obstacle deflector is a construction on the front of a train located just above the rails, the purpose of which is to deflect objects located on the track, thereby preventing the train from derailing.

compatibility in the event of collisions between passenger trains and other passenger trains, but also collisions with freight wagons/tank wagons. To meet those requirements, passenger trains are equipped with crash absorbers at the front, at the points where the (crash) buffers are located on freight stock (see also explanatory notes in appendix F3). In the event of a collision with a freight wagon, the (crash) buffers on the colliding trains will come into contact with one another. These requirements were introduced in 2011, and apply only to passenger trains admitted after that date.

According to the original planning (the annual plan), trains of the DDZ type were due to be deployed on the route between Eindhoven and Tilburg-University. In the framework of a reallocation of the various train types, NS Reizigers decided at a later stage to have the train service in question carried out by Mat'64 trains. In arriving at that decision, consideration was only given to logistic issues, such as the number of standing and seating places, the maximum speed and the acceleration and braking capacity. The fact that Mat'64 trains have poorer collision compatibility with tank wagons than DDZ trains, that are equipped with buffers, was not considered in the decision-making process.

In response to questioning, NS Reizigers has announced that the remaining (approximately forty) multiple units of the type Mat'64 are due to be decommissioned in 2016. A rough inventory of the train fleet of NS Reizigers (see appendix F4) reveals however that a large proportion of the other NS trains also demonstrate only poor to fair collision compatibility with respect to tank wagons. To date, NS Reizigers has not considered collision compatibility in the decision-making process on the deployment of its stock on lines over which dangerous goods are transported. In response to the accident in Tilburg, the company has now announced that it will be carrying out a new risk assessment.

Tank wagons used for the transport of flammable gases must be fitted with crash buffers at the front and rear. This requirement applies to tank wagons admitted since 2007. The tank wagon run into in Tilburg dated from 2004, but was nonetheless fitted with crash buffers.[62] The purpose of these buffers is to prevent damage to the tank (due to deformation of the under frame or the climbing of the collision partner), by absorbing the collision energy. In the collision in Tilburg, the crash buffers were unable to fulfil this task because the passenger train (due to its unfortunate shape) did not collide 'fully' against the buffers, but instead only hit the upper section. If the passenger train had been of a modern design (with crash absorbers), the overriding of the crash buffers (and hence the occurrence of the tank leak) would probably not have occurred. The same would possibly also apply if the tank wagon had been equipped with a buffer overriding protection device. However, the obligation to fit such a device only applies to tank wagons transporting toxic substances such as chlorine. In 2010, within the RID, it was proposed to extend this obligation to tank wagons for other groups of dangerous goods, however there was insufficient support for this move within the Member States (see appendix E3).

62 For tank wagons built after 2007, crash buffers are compulsory. The shipper in this case (SABIC) exclusively makes use of tank wagons equipped with crash buffers (including those built before 2007).

4.3.3 Manhole cover on tank wagon

In the case of this collision, to some extent, the manhole cover in the tank shell represented a 'weak link'; if there had been no manhole cover at this precise location in the end wall, it is unlikely that a leak would have occurred as a result of this collision. This raises the question to what extent a different position or construction of the manhole cover could result in improved safety.

In respect of this aspect, the Board has made the following considerations:

- A manhole cover is necessary on a tank wagon for the periodic inspection and for carrying out (repair) work on the inside of the tank. It is of course essential that both the position and construction of the manhole cover be selected in such a way that the risk of a leak following an accident is kept as small as possible. Neither the position nor the construction of the manhole cover are covered by any legal requirements. There is a European standard (DIN-EN12561-6) on this subject, which recommends the same position and construction for the manhole cover as on this tank wagon. According to the companies consulted, the position and design have been the common standard for decades, and have proven ideal, in practice.
- The fact that the seal of the manhole cover started to leak following this accident is related to the fact that the tank shell was run into directly in the zone in which the manhole cover was located. Because this was a rear end collision, the rear end wall of the tank wagon was damaged. The first idea that comes to mind is to fit the manhole cover in one of the two end walls, but to ensure that during transport the end wall in question always remains at the front (in relation to the direction of travel). However, in practice, this condition cannot be met, because many loading and unloading locations (where generally speaking the direction of travel is changed) do not have a facility for turning the tank wagons around.
- Consideration could be given to the idea of positioning the manhole cover in the side, top or bottom of the tank, instead of the end wall. However, it must be remembered in that connection that a large proportion of accidents are in fact flank collisions or derailments (in which the wagons sometimes turn over) whereby any of those sides of the tank also run the risk of suffering a direct hit.
- In respect of the construction of the manhole cover, it should be noted that even in this collision, which involved considerable collision forces applied directly to the manhole cover, the leak was restricted to the level of a drip. According to the technical investigation of the tank wagon (see appendix B2), it can be concluded that with this form of damage, the risk of a more serious leak remains small. The investigation also revealed no other accidents that led to a large-scale leak as a consequence of the failure of the manhole cover.

Based on these considerations, it can be concluded that no clear possibilities emerge for improvements in respect of the manhole cover.

4.4 Underlying factors

Paragraphs 4.2 and 4.3 describe the factors that influenced the involvement of dangerous goods in the accident in Tilburg, and the resultant leak from the tank wagon. The findings effectively mean that in three respects, decisions were taken at operational level, which increased the level of risk:

- The RID specifies the obligation that tank wagons built after a given year must be equipped with crash buffers. The aim of this measure is to improve the crash resistance of tank wagons, to prevent leaks following a collision. The run-into tank wagon was also fitted with crash buffers but these had no effect because the passenger train was of an old train type with poor collision compatibility. For operational reasons, NS Reizigers had decided to deploy this type of train on the route in question.
- In the establishment of the Basic Network Act, a series of measures were taken to promote the safety of the transport of dangerous goods by rail on the Brabantroute. In this connection, for example the automatic train protection system ATB - Improved Version was fitted on the signals relevant for the through tracks. This also applied to the signals on the through tracks in Tilburg, but this effect was negated by the fact that the freight train was guided onto a side track, that was not covered by an automatic train protection system ABT - Improved Version.
- In the framework of the Basic Railway Network, on certain sections of the Brabantroute, switches were installed or removed, to further reduce the risk of derailment and collisions. On the other hand, instigating a driver change at the Tilburg-Goods yard meant that the two freight trains in question were required to pass several diverging switches.

These decisions are further analysed below.

4.4.1 Operational decisions resulting in increased risk

In respect of the run by the freight train with dangerous goods, the following changes were made in the operational phase:

- The process of composing and preparing the freight train for departure took longer than intended as a result of which the train was not ready at the original departure time. For that reason, the railway undertaking shifted the departure time on several occasions. Eventually the train left approximately three hours later.
- During the run, in consultation with the ProRail train traffic control, the railway undertaking instigated an intermediate stop at the Tilburg-Goods yard, to make a driver change. The fact that this change was needed related directly to the shift in departure time.

As a result of these changes, two freight trains (both of which were transporting tank wagons with dangerous goods) were required to pass several diverging switches, and subsequently ended up on tracks that were not covered by the automatic train protection system ATB - Improved Version. As a consequence there was a greater risk of derailment or collision.

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For the slow trains on the route in question (Eindhoven/Tilburg-University), according to the annual plan, passenger trains of the type DDZ were to be deployed. The railway undertaking (NS Reizigers) decided at a later stage to deploy the train type Mat'64 for the train runs in question. Trains of the type Mat'64, however, unlike the DDZ trains, have no buffers and as a consequence have poorer collision compatibility in respect of freight stock (including tank wagons). As a consequence of this fact, the risk was greater that in the event of a collision with a tank wagon, a leak would occur.

The investigation makes it clear that when it came to rescheduling the run by the freight train, and deploying another type of passenger train, in taking the operational decisions, account was only taken of logistic and commercial arguments (optimised deployment of stock and personnel). The Board would note in this connection that the decisions in themselves are not in contravention of the regulations, but did engender safety risks: this applies both to shifting the departure time of the freight train, instigating a driver change at the Tilburg-Goods yard, and the deployment of Mat'64 trains on the Brabantroute. Furthermore, the employees in question had received no other instructions according to which they should not have taken these decisions.

The decisions in question were indeed not exceptional. It is relatively common for freight trains to instigate an intermediate stop during the implementation of a run, and it is certainly not unusual that a different train type is deployed than originally planned for passenger train runs.

4.4.2 Backgrounds to operational decisions

The above observation effectively means that the companies in question failed to consider the question which parameters apply in implementing the train service, in order to ensure optimum management of the safety risks (including ensuring the minimum possible negative effect of safety measures taken).

This conclusion relates both to the railway undertakings in question (DB Schenker and NS Reizigers) and the railway manager (ProRail), as well as to the shippers of tank wagons containing dangerous goods (SABIC, DSM and OCI).

- DB Schenker and ProRail were responsible for ensuring the safe running of the freight train with dangerous goods. The legal basis for this responsibility consists of both the Railways Act and the Transport of Dangerous Goods Act.[63]
- (On the basis of the Railways Act) NS Reizigers is responsible for the safe deployment of its passenger trains. This includes managing the safety risks represented by those trains for other railway users.
- SABIC, DSM and OCI - as explained below - in their capacity as shipper/contract awarding party - at least in the judgement of the Board, had the social responsibility for the safety of the transport by rail of dangerous goods being carried out on their behalf.

63 Chapters 1.3 and 1.8.3 of the RID describe the conditions applicable to the personnel of companies involved in the transport of dangerous goods by rail.

The Board has identified the following explanations as to why the companies in question took the above described operational decisions that led to an increased risk.

The railway companies
The railway companies (ProRail, DB Schenker and NS Reizigers) assumed that the safety risks were sufficiently managed, on condition they complied with the regulations in implementing the train transports. As a consequence, in the implementation of those train transports, decisions were taken that negatively affected the safety measures taken. In this connection it must be remembered that the operational control of train traffic is effectively a logistic process, in which the dangerous goods merely represent 'the cargo to be transported'. In that sense, during the rail transport operations, those goods have a clearly different position/status than within a chemical company, where (either as a raw material or as a means of production, either in the form of semi-manufacture or finished product) they do represent an essential factor within the primary business process.

On top of this, for some considerable time, no railway accidents have occurred in the Netherlands involving dangerous goods, which resulted in human victims. This may have influenced the decisions, given the fact that the danger that safety risks will receive insufficient attention increases as the length of time during which no serious accidents have occurred also grows. In academic literature, this phenomenon is referred to as the 'social attenuation of risk'.[64] Because in the operational control of train traffic no distinction is made between freight trains with and those without dangerous goods, the Safety Board considers the assumption justified that this phenomenon applied in this case.

The chemical companies/shippers
The chemical company SABIC, on whose instructions the run-into tank wagon was being transported, had reached no agreements with the railway undertaking (DB Schenker) on risk management during the implementation of the train run in question. It became clear from the investigation that it is not common practice for shippers to reach such agreements with the railway undertakings. Nonetheless, the Board believes that when it comes to dangerous goods, (chemical) companies also have a social responsibility for the way in which other companies working on their behalf handle those goods (e.g. in transporting or storing them). Although those other companies themselves bear primary responsibility, certainly when it comes to dangerous goods, the contract-awarding parties also have a social responsibility to make and keep 'the chain' safe. In this connection, the term 'chain' refers to the fact that the transport of dangerous goods by rail generally involves the bulk transport of these goods between two BRZO companies.[65]

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64 This phenomenon is for example described in *The Social Amplification of Risk*, N. Pidegon - R.E. Kaspergon - P. Slovic, Cambridge University Press, 2003 (ISBN 0 521 817285) and *The Impact of Social Amplification and Attenuation of Risk and the Public Reaction to Mad Cow Disease in Canada*, R.E. Lewis and M.G. Tyshenko, Risk Analysis, May 2009.

65 BRZO stands for the Order governing the Risk of Serious Accidents. This Order represents the Dutch implementation of the European Seveso Directive, the aim of which is to prevent serious accidents involving large volumes of dangerous goods, and restricting the consequences of such accidents. The BRZO order consists of the legislation and regulations in respect of both industrial safety and external safety and contingency planning. Whether or not a company is subject to the BRZO regime depends on the answer to the question whether the volume of dangerous goods present and/or permitted exceeds a specified threshold value. The Netherlands has more than 400 BRZO locations.

The fact that chemical companies/shippers are jointly responsible for safety during the transport of their dangerous goods of course also applies for the transport of those same substances via road and water. For those modes of transport, the tankers and vessels in question are generally exclusively used for the transport of dangerous goods, and the transport company is specialised in the transport of dangerous goods. When it comes to the transport of dangerous goods by rail, specific wagons (tank wagons and tank containers) are used, but during actual transport, they are often part of a mixed freight train that is operated by a railway undertaking that although authorised to transport these substances is not a specialist in that activity. Against that background, it is particularly important that chemical companies involved in the transport of dangerous goods by rail apply their influence in monitoring the safety of the transport operations.

In this connection, the Board sees similarities with the findings of its earlier investigations into the fire at Chemie-Pack in Moerdijk (2011) and the safety of the Odfjell terminals in Rotterdam (2002-2012).[66] In the report on the fire at Chemie-Pack, the Safety Board concluded that suppliers and customers of dangerous goods must impose requirements on the level of safety provided by undertakings they do business with. In response, the relevant sector organisations[67] drew up the action programme Safety First, which is focused on improving the safety culture of companies that work with large volumes of hazardous substances.[68] One of the four pillars of that programme is 'taking responsibility for the chain'.[69] In the report on the safety of the Odfjell terminals, the Board concluded that the chemical sector needs to specify precisely what chain cooperation means and how the companies can better fulfil their responsibility for the chain. In response to the Odfjell report, the sector organisations in question further expanded the action programme Safety First, in particular in respect of the transfer (loading/unloading) and (external) storage of dangerous goods. The course of events in the accident in Tilburg makes it clear that the practical elaboration/fulfilment of the responsibility for the chain within the chemical sector also needs to be expanded in respect of having its dangerous goods transported. [70]

66 This refers to project numbers M2011CH0105-06 and 20120731. The reports, published respectively in February 2013 and June 2013, are available to the public and can be accessed via the website (www.safetyboard.nl).
67 This initiative was taken by VNO-NCW, VNCI, VNPI, VOTOP and VHCP. Other sector organisations subsequently joined in, including VOMI, NVDO, Profion and VVVF.
68 See www.veiligheid-voorop.nl.
69 The other three pillars of the actions programme are: 'management involvement', 'improved safety management systems' and 'participation in safety networks'.
70 In respect of responsibility for the chain, the action programme Safety First has to date focused primarily on suppliers, clients and customers, respectively.

5 CONCLUSIONS

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5.1 The accident

In the accident in Tilburg, a passenger train ran into the back of a stationary freight train, while travelling at a speed of approximately 45 km/hour. The collision was the consequence of series of events, the last of which consisted of a red signal passage by the passenger train. The signal in question was at red because the freight train had been guided onto a side track that was too short for the length of the train, as a consequence of which the switch remained occupied. Because the signal in question was not equipped with the automatic train protection system ATB - Improved Version, no automatic brake intervention occurred.

The run-into freight train included several tank wagons with dangerous goods. As a result of the collision, a leak occurred in one of the tank wagons. The tank wagon in question was filled with more than 50 tonnes of butadiene, and was located at the rear end of the freight train. In the collision, the front of the passenger train climbed up over the buffers of this tank wagon, and ended up against the tank itself. This caused the rear wall of the tank to be deformed. At that particular location in the rear wall of the tank was the manhole cover, intended for the periodic inspection of the inside of the tank. Only a minor leak occurred along the seal of the manhole cover. There was no tearing of the tank shell, and the leak was limited to a drip.

5.2 Safety problems

On the basis of its investigation, the Board has identified the following safety issues:

a. **Involvement of a freight train carrying dangerous goods in the collision**
In respect of the involvement of dangerous goods in the train collision in Tilburg, it is important to note that the freight train was guided from the through track onto a side track. This was the result of an intermediate stop made to allow a driver change (at the request of the railway undertaking). For the purposes of that stop, the train was guided onto a (too short) side track, as a consequence of the incorrect notification of the train length in the online notification system (ISVL). As a consequence, the rear wagon kept a switch occupied, which in turn led to the signal intended for the passenger train remaining at red. The driver of the passenger train failed to stop for the signal at red. Because the signal was not protected with the automatic train protection system ATB - Improved Version, there was no automatic braking intervention.

It is relatively common for freight trains to make intermediate stops. Rescheduling of this kind can however engender additional safety risks. As was the case with the accident in Tilburg, those risks relate to the fact that the train ends up on a track which is not covered by the automatic train protection system ATB - Improved Version, and to the passing of (diverging) switches. Both in the case of the request for an intermediate stop by the railway undertaking, and in the acceptance and implementation of that request by ProRail, these additional risks were not taken into account. The same applies to the rescheduling of freight trains carrying dangerous goods, whereby in addition to risks to train traffic, there are also external risks.

b. Leak in tank wagon

In the collision in Tilburg, the rearmost wagon of the run-into freight train was a tank wagon filled with a hazardous substance. This led to risks for (external) safety, because the accident was a rear end collision, in which the tank wagon suffered a direct hit, and the tank itself was damaged. The applicable regulations allow the rearmost wagon of a freight train to contain dangerous goods.

In the collision in Tilburg, the passenger train collided not only with the under frame of the tank wagon but also with the tank itself. This was because an old type of passenger train (Mat'64) was used, that offers poor collision compatibility in respect of freight stock (including tank wagons). Several years ago the admission requirements for passenger trains were tightened up, so that since that time, new passenger trains offer better collision compatibility. However, the stricter requirements do not apply to already-admitted trains.

Another contributing factor to the occurrence of a leak in the tank wagon was the fact that the rear tank wagon was not fitted with a buffer overriding protection device. The statutory obligation to fit such a device only applies to tank wagons carrying certain categories of dangerous goods, which was not the situation in the case of the tank wagon involved in the collision in Tilburg.

In respect of the location and the construction of the manhole cover on tank wagons, the investigation revealed no clear possibilities for improvement.

5.3 Underlying factors

The issues referred to above that contributed to the involvement of the tank wagon in the collision and the resultant leak were the consequence of decisions taken by the companies involved in the implementation of their train runs. Those decisions were not as such contrary to the regulations, but the consequence of those decisions was that the safety risks were less well-managed than they could have been.

- By guiding two freight trains containing filled/uncleaned tank wagons onto side tracks, the effect of the automatic train protection systems ATB - Improved Version that were fitted on the signal on the through tracks of the Brabantroute was negated.

Furthermore, the trains had to pass several sets of diverging switches, which itself represented an increased risk of derailment and collision.

- By deploying passenger trains with poor collision compatibility on this specific route, the crash buffers on the run-into tank wagon proved ineffective, resulting in a leak.

These operational decisions were based on logistic and commercial arguments. Despite the fact that the trains in question were carrying dangerous goods, no consideration was given to the fact that these decisions could have the effect of increasing the risk level. In the judgement of the Board, this suggests insufficient risk awareness in respect of the transport of dangerous goods by rail, at the railway company in question. The Board considers it likely that this situation is partially due to the fact that within the rail transport sector, dangerous goods are 'just' freight, and the fact that for some considerable time, no accidents have occurred in the Netherlands, in the transport of dangerous goods by rail, which have led to human victims.

The chemical company (SABIC) on whose behalf the run-into tank wagon was being transported had not reached any agreements with the railway undertaking aimed at as far as possible avoiding decisions at operational level that could lead to an increased risk. It emerges that it is indeed not common practice for chemical companies (in their role of shipper) to reach such agreements with the railway undertakings. In their capacity as contract-awarding party for the transport operation, these companies are in fact in a position to reach such agreements, and the Board views it as their social responsibility to apply that influence.

5.4 Final conclusion

The investigation makes it clear that in addition to a red signal passage by the passenger train, the train collision in Tilburg was also brought about by decisions concerning the operational control of the freight train, which led to an increased risk level.

It has also become clear that the safety of the transport of dangerous goods by rail could be improved through additional measures in respect of the composition of freight trains with dangerous goods, the design of tank wagons and the deployment of passenger trains with poor collision compatibility on routes via which dangerous goods are transported, respectively.

Given the potential seriousness of railway accidents involving dangerous goods, both issues need to be tackled urgently. The responsibility for these actions lies with the railway undertakings involved, the railway manager (ProRail), and the chemical companies that order the transport of dangerous goods.

6 RECOMMENDATIONS

On the basis of the outcome of its investigation, the Safety Board has issued the following recommendations.

Operational control of transport of dangerous goods by rail

1. *The railway companies responsible for the control of the run-into freight train (ProRail and DB Schenker):*
   Organise the operational control of freight trains with dangerous goods in such a way that no operational decisions are taken that lead to an increase in known and managed safety risks.

Responsibility of chemical companies for the chain

2a. *The chemical companies involved as shippers of dangerous goods in the run-into freight train (SABIC, DSM and OCI):*[71]
Fulfil responsibility for the chain by demanding from railway undertakings that in the operational control of freight trains carrying dangerous goods, no risk-increasing decisions are taken. Include this in transport agreements and monitor compliance.

2b. *The sector organisations coordinating the action programme Safety First:*[72]
Consider the transport of dangerous goods as part of the responsibility for the chain in the action programme Safety First. Ensure that all chemical companies acting as shippers in the transport of dangerous goods by rail fulfil recommendation 2a.

Technical measures for the transport of dangerous goods by rail

3a. *The State Secretary for Infrastructure and the Environment:*
Ensure the tightening up of international regulations for the transport of dangerous goods by rail (RID) in such a way that the following is adopted:
- no dangerous goods may be contained in the final wagon of a train;
- tank wagons for the transport of non-toxic dangerous goods should also be equipped with buffer overriding protection devices.

3b. *The State Secretary for Infrastructure and the Environment:*
In advance of the proposed change to the RID in 3a, reach agreement with shippers from the chemical industry and goods carriers to introduce these measures in the

71 The following were approached: SABIC Petrochemicals B.V., AnQore B.V. (previously DSM Acrylonitrile B.V.) and OCI Nitrogen B.V.
72 *VNO-NCW, Association for the Netherlands Chemical Industry (VNCI), Association for the Netherlands Petroleum Industry (VNPI), Association of Traders in Chemical Product (VHCP) and the Association of Independent Tank Storage Companies (VOTOB).*

Netherlands as quickly as possible. This could take place along the line of the already existing agreement on the 'hot-BLEVE-free' composition of freight trains.

Collision compatibility of passenger trains in relation to the transport of dangerous goods by rail

4. *The railway undertaking of the passenger train involved in the accident (NS Reizigers):* For all relevant types of passenger trains, assess the collision compatibility in respect of freight stock. Do not use train types with poor collision compatibility on routes designated for the transport of dangerous goods.[73]

Recommendations 1, 2 and 4 - in accordance with the Dutch Safety Board Order[74] - will also be addressed to the Human Environment and Transport Inspectorate (ILT). ILT will monitor compliance with these recommendations by the organisations in question, and duly report to the Board. For the other recommendations (3a and 3b), in accordance with the same Order, the Board will be informed directly on compliance by the State Secretary for Infrastructure and the Environment. In both cases, a maximum reaction period of six months following publication of the report applies.

73 This recommendation ties in with recommendation 6 in the report previously published by the Dutch Safety Board into the Train collision at Amsterdam Westerpark (available via www.safetyboard.nl).
74 By Order of 26 November 2015 (Bulletin of Acts and Decrees 2015, 470), the Dutch Safety Board Order (in connection with further implementation of EU Directive 2004/49/EC) was duly revised.

APPENDIX

APPENDIX A

JUSTIFICATION OF INVESTIGATION

A.1 Investigation approach

For the purposes of the investigation, information was collected about the occurrence and consequences of the accident, and the underlying problems. This information was obtained by carrying out an investigation at the site shortly following the accident, analysing documentation and by questioning the parties involved both in writing and verbally. The Dutch Safety Board also carried out a technical investigation on the leaking tank wagon, and the records from the Automatic Run Registration (ARR) system on the trains involved. Use was also made of studies undertaken by the affected railway companies and the Human Environment and Transport Inspectorate (ILT) into this accident.

As explained in chapter 1.1, the Safety Board focused its investigation above all on the fact that the accident led to a leak in a tank wagon containing a hazardous substance. The investigation was not specifically focused on the general aspects of red signal passages or the way in which the consequences of the accident were dealt with.

A.2 Reactions to the draft report

In accordance with the Safety Board Act, a draft version of this report was submitted to the parties involved with the request to check the report for factual errors and ambiguities. The draft version of this report was submitted to DB Schenker, NS Reizigers, ProRail and SABIC.

All parties responded to the draft version of the report. The comments received were processed as follows:

- Corrections to factual errors, additions at detail level and editorial comments were adopted by the Board (where relevant). The appropriate text sections in the final report were revised. These comments have not been separately listed.
- Wherever the Dutch Safety Board did not adopt the comments, an explanation is provided of why the Board decided not to do so. These comments and the explanatory notes are contained in a table available on the website of the Dutch Safety Board (www.safetyboard.nl).

A.3 Guidance committee

For this investigation, the Dutch Safety Board appointed a guidance committee. This committee was made up of external members, and chaired by a member of the Dutch Safety Board. The external members, who were represented on the guidance committee in a personel capacity, were selected for their expertise relevant to the investigation. The guidance committee met on three occasions during the investigation, to exchange ideas with the project team on the structure and results of the investigation. The committee fulfilled an advisory role within the investigation; final responsibility for the report and the recommendations lie with the Dutch Safety Board.

The guidance committee for this investigation was composed as follows:

M.B.A. van Asselt	board member of the Dutch Safety Board (chair of the guidance committee).
D.A. van Riel	chairman of the Netherlands Association of Private Freight Wagons (NVPG), director of Trimodal.
P.W.A. Gerritzen-Rode	former member of the Advisory Council on Dangerous Goods.
A.S. Scholten	Mayor of Venlo, former mayor of Zwijndrecht.
E.J. Wijdeveld	director of the consultancy firm AGM Consultant and former policy advisor on Environment and Safety at Deltalinqs.

A.4 Project team

The investigation was undertaken by the following project team, under the responsibility of investigation manager G.W. Medendorp:

A. Sloetjes	project manager
P.M. van der Eerden	investigator
D.C. Ipenburg	consultant Administrative Affairs/Consultancy/ Communication
E. Willeboordse	consultant Investigation & Development

In the investigation, further use was made of the expertise of the following experts: C.N. Smit (Arcadis Nederland), R. Knuvers (Lucros Railway Engineering), and W.A.M. van der Marel, W. Plantagie and P.K. Wiersma (DEKRA Rail).

APPENDIX B

TECHNICAL FINDINGS

This appendix is a summary of the findings of the technical investigation. The first part (B1) relates to the occurrence and consequences of the collision. The second section (B2) describes the technical investigation on the tank wagon that suffered a leak as a result of the accident. The third section (B3) relates to the analysis of the ARR files and the fourth section (B4) deals with the analysis of the actual collision (speed changes and energy conversion).

B.1 Occurrence and consequences of the collision

B1.1 Trains

a. Passenger train
The passenger train consisted of two multiple units of the type Mat'64[75] and was operated by NS Reizigers. The total length of the train was 104 metres and the mass (empty) 174 tonnes. There were more than forty persons on board the train.

Figure 17: This photograph shows a passenger train of the same type (Mat'64) as that involved in the collision in Tilburg. (Photo: Roel Hemkes)

75 These were multiple units with the numbers 957 (front) and 476 (rear).

b. Freight train

The freight train consisted of a locomotive and 35 wagons and was operated by DB Schenker. Of the 35 wagons, seven were loaded. Of those seven, in six cases the cargo consisted of a 'hazardous substance'. All six were tank wagons: four were filled with acrylonitrile, one with ammonia and one (located at the rear end of the train) with butadiene. Figure 18 shows the section of the list of wagons of the freight train in which the wagon types and loading status are specified. Including the locomotive (of the type 6400, with number 6510), the total length of the freight train was 624 metres and its total mass 1313 tonnes.

Serial no.	wagon		cargo			
	reference	type	Status	mass (tonnes)	HIN	UN-no.
1	3354 7931 002-1	Zacens	Empty		60	2312
2	3380 7931 252-0	Zacens	Empty		60	2312
3	3384 7932 313-5	Zacens	Empty		60	2312
4	3354 7931 028-6	Zacens	Empty		60	2312
5	3354 7931 060-9	Zacens	Empty		60	2312
6	3380 7931 247-0	Zacens	Empty		60	2312
7	3384 7932 305-1	Zacens	Empty		60	2312
8	3354 7931 022-9	Zacens	Empty		60	2312
9	3380 7931 248-8	Zacens	Empty		60	2312
10	3354 7931 056-7	Zacens	Empty		60	2312
11	3384 7932 306-9	Zacens	Empty		60	2312
12	3354 7931 005-4	Zacens	Empty		60	2312
13	3380 7931 249-6	Zacens	Empty		60	2312
14	3354 7931 021-1	Zacens	Empty		60	2312
15	3354 7931 025-2	Zacens	Empty		60	2312
16	3354 7931 031-0	Zacens	Empty		60	2312
17	3180 2770 691-6	Habbins	Empty			
18	3180 2777 025-0	Habbills	Empty			
19	3380 2742 552-3	Habbiins	Empty			
20	3380 2742 429-4	Habbiins	Empty			
21	3780 7841 402-6	Zacns	Empty		336	1230
22	3380 7840 076-3	Zacns	Empty		336	1230
23	3380 7840 063-1	Zacns	Empty		336	1230
24	3380 7840 075-5	Zacns	Empty		336	1230
25	3780 7819 753-0	Zags	Full	53.9	268	1005
26	3368 3546 417-1	Rilns	Empty			
27	3780 3546 062-5	Rilns	Empty			
28	3780 7846 107-6	Zacs	Full	63.7	336	1093
29	3384 7846 619-0	Zacs	Full	64.0	336	1093
30	3380 7933 887-1	Zacens	Full	64.6		

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Serial no.	wagon		cargo			
	reference	type	Status	mass (tonnes)	HIN	UN-no.
31	3780 7846 109-2	Zacs	Full	54.8	336	1093
32	3384 7846 608-3	Zacs	Full	54.8	336	1093
33	3368 3546 441-1	Rilns	Empty			
34	3187 4771 022-2	Shimms	Empty			
35	3380 7809 737-9	Zagns	Full	52,5	239	1010

Figure 18: Composition and loading status of the run-into freight train.

The rearmost wagon was a tank wagon suitable for the transport of (liquefied) gas. The wagon in question was a tank wagon of the type Zagns, built in 2004; the vehicle is the property of GATX and has been hired on a long-term charter by SABIC. The tank wagon was loaded with 52.5 tonnes of 1,3 - butadiene (HIN 239, UN-no. 1010).

Figure 19: The run-into tank wagon. (Photo: Dutch Safety Board)

B1.2 Train runs

The freight train (with train number 61802) was travelling from Lutterade-DSM (Geleen-Lutterade) to the Kijfhoek marshalling yard (near Zwijndrecht). A train run of this kind, and the return run from Kijfhoek to Sittard, takes place twice every working day. On the day in question, the train run differed from the original timetable (annual plan) in two respects:

- The composition of the freight train was not ready at the originally planned departure time (11:40 hours). For that reason, in the operational timetable, the *timeline* for the freight train was shifted by approximately three hours (to 14:41 hours).
- Following departure of the freight train, the duty process coordinator at the railway undertaking (DB Schenker) realised that the driver would ‘overrun his shift hours’ if - as had been planned - he were to drive the train to Kijfhoek, and then also drive the return train back to Chemelot. For that reason, he arranged for the return train from Kijfhoek to be driven towards this train by another driver, so that en route a driver change could be carried out. In consultation with the local traffic controller and the ProRail train traffic controllers, the decision was taken to have the driver change carried out at the Tilburg-Goods yard (located between the stations Tilburg and

Tilburg-University). The route of the freight train was duly adjusted: the change meant that between the stations Tilburg and Tilburg-University, the freight train would not remain on the through track (921) but would be guided onto one of the side tracks (912-B) at Tilburg-Goods yard (see figure 20). The freight train arrived on that track at 16:34 hours. The other freight train (travelling to Sittard, which had departed early from Kijfhoek) had arrived in Tilburg approximately a quarter of an hour earlier (around 16:17 hours) travelling from the opposite direction, and had been placed on track 913 (see figure 21).

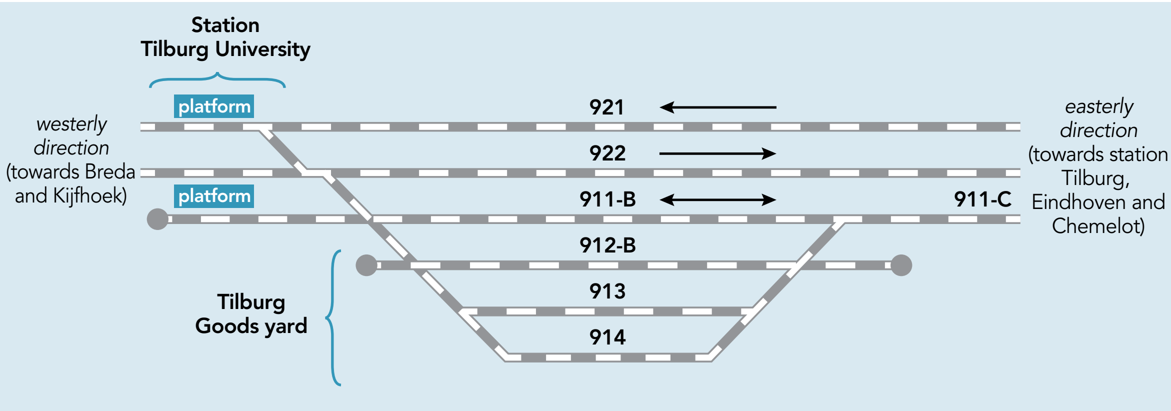

Figure 20: This drawing is a diagrammatic representation of the track layout between the stations Tilburg and Tilburg-University. According to the original timetable, the freight train would have travelled through Tilburg via track 921. In connection with the planned intermediate stop, the train was temporarily placed on track 912-B (via track 911-C).

The passenger train (with train number 5258) was travelling as a slow train from Eindhoven to Tilburg-University. This train run takes place twice an hour on working days. During this train run, the train made a regular intermediate stop at station Tilburg. From that intermediate stop (on track 902A, alongside platform 2), the train departed at 16:37 hours; the signal in question (114) showed yellow.[76] Subsequently, via a series of switches, the train transferred to track 911-C, and continued on towards station Tilburg-University on that track (see figures 20 and 21). Shortly before reaching that station, the train passed signal 96. As the train approached/passed the signal, the signal was at red. The fact that contrary to the normal situation the signal did not switch from the stop setting as the train approached was because the connected switch (87B) could not be switched to the straight-on position. This was due to the position of the freight train, which was on track 912-B. Because the freight train was too long for that track (912-B), the train was still occupying the switch (87A/85) as a consequence of which switch 87B (which is coupled to 87A/85) could not be released on time for the approaching passenger train, so that the accompanying signal (96) remained at red, as the passenger train approached.

The driver of the passenger train did not (consciously) register the signal at red, as a consequence of which as he approached the signal, he did not initiate a braking action.

76 It was structural practice for passenger trains to 'depart at yellow'. This was because the next signal (signal 96 on track 911-C) was only released from its stop setting when the train in question had passed a trigger point located relatively close to that signal.

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Because the signal was not equipped with the automatic train protection system ATB - Improved Version,[77] there was no automatic braking intervention. The eventual consequence was that the passenger train, via switch 87B that had not yet been switched to the correct position, and switch 87A/85, was guided onto side track 912-B (see figure 21). As previously explained, that track was occupied by the freight train. The driver of the passenger train activated his brake at the last moment, but because of the limited distance this was not sufficient to avoid a collision with the freight train.

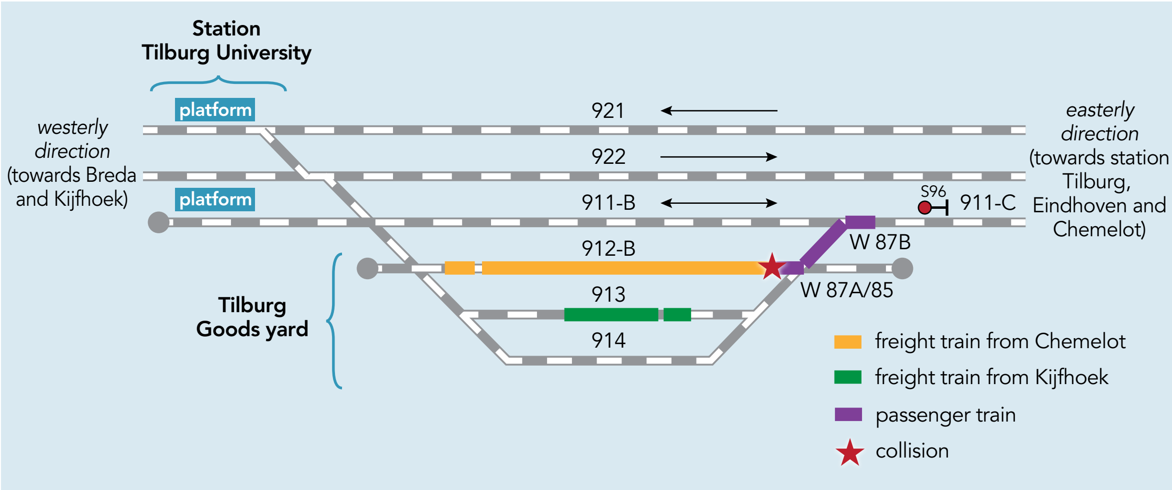

Figure 21: This drawing is a diagrammatic representation of the position of both freight trains and the passenger train at the moment of the collision.

B1.3 The collision

The freight train was stationary on track 912-B; the locomotive was braked but the wagons coupled behind the locomotive were not. The passenger train also drove onto track 912-B, via switches 87B and 87A/85. On making its approach, the passenger train was travelling at a speed of approximately 45 km/hour, and had not slowed down significantly prior to the collision (see B3 below).

An analysis of the damage to the vehicles shows that the collision consisted of three sub-collisions (see figure 22).

- The first contact took place between the automatic coupler on the front of the passenger train and the tow coupling at the back of the rearmost tank wagon of the freight train.
- As a result of the contact, the automatic coupler of the passenger train was compressed, at which point the front of the cab of the passenger train collided with the buffers of the tank wagon.
- Because only the top section of the buffers was struck, the front section of the passenger train 'climbed up' and over the buffers. The front of the passenger train then collided with the rear wall of the tank.

77 Signal 96 has now been equipped with an automatic train protection system ATB - Improved Version.

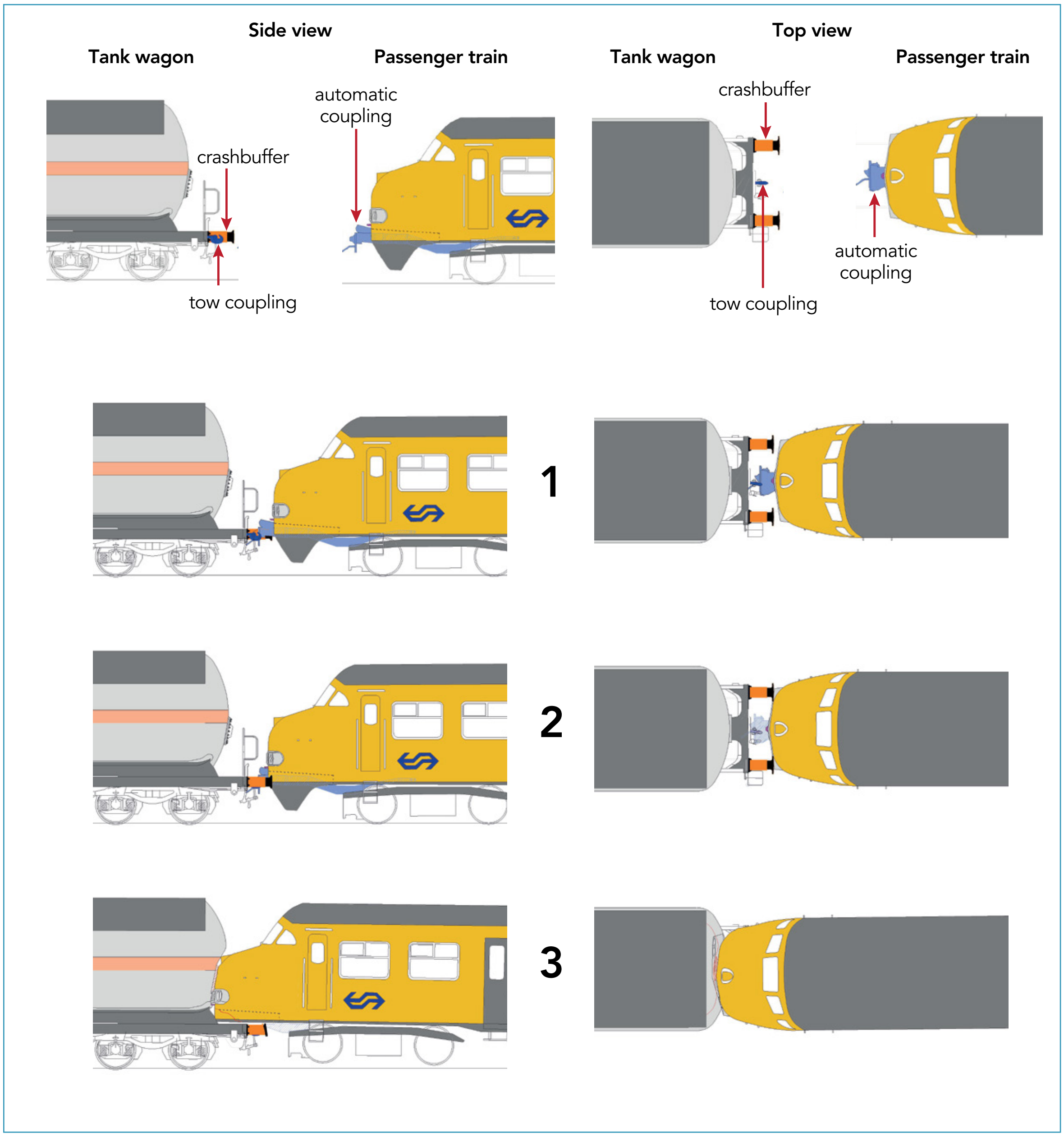

Figure 22: Broadly speaking, the collision consisted of three phases, whereby the front of the passenger train first collided with the tow coupling (1), then the buffers (2) and finally the tank of the rearmost tank wagon (3).

Figure 23: These photographs show that the nose of the passenger train had climbed up and over the buffers of the tank wagon, before colliding with the rear wall of the tank. (Photos: police)

Based on the analysis of the ARR files, the final positions and the observed damage, the following conclusions were drawn about the course of the collision (see also the explanatory notes to those analyses in B3 and B4):

- As a result of the collision, the rearmost tank wagon was pushed forward over a distance of several metres (probably approximately four metres). The forward pushing motion was transmitted forward along the length of the freight train; eventually, the locomotive, which was positioned approximately six hundred metres further away, was also pushed forwards several metres.
- The collision period in which the damage occurred probably lasted approximately between one half and one second. It then probably took approximately eight seconds until the front section of the freight train came to a standstill.

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- At the start of the collision, the kinetic energy of the passenger train was approximately 13½ MJ. The vast majority of that energy (approximately 10½ MJ) was converted into deformations of the rear tank wagon and the passenger train itself, and the compression and extension of the buffers/couplings between the freight wagons. The remainder of the original kinetic energy (approx. 3 MJ) was converted during the course of this movement into friction (because the braking system on the passenger train and the locomotive was active).

B1.4 The consequences of the collision

a. Victims
Due to the collision, the passenger train braked suddenly, and as a result five people on board suffered minor injuries. These were four (of the approximately forty) passengers and the guard. They received treatment at the site of the accident, and were able to leave the accident site without further care/assistance. In addition, two police officers became unwell, as they come close to the leaking tank wagon, shortly following the collision. They initially suffered a feeling of pressure on the chest, and concentration problems; as they walked towards the ambulance, they also experienced dizziness and nausea. Upon examination at hospital, the diagnosis was a probable shortage of oxygen during a short period of time. Both officers were able to leave hospital on that same day. The next day they were still experiencing mild headaches and fatigue.

b. Damage to the rolling stock and railway infrastructure
On the passenger train, most damage occurred at the front end of the front multiple unit, and the coupling between the two multiple units. The damage at the front end (see the left-hand photograph in figure 24) mainly affected the automatic coupler, the draw bar and its attachment. The damage to the midsection of the train (see right-hand photograph in figure 24) above all affected the coupling parts that joined the two multiple units together

Figure 24: These photographs show the damage to the passenger train. The left-hand photograph shows the front end of the front multiple unit, the right-hand photograph shows the connection between the two multiple units. (Photos: left = fire brigade, right = police)

According to information from NS Reizigers, and given the decision to decommission this type of rolling stock, the damage to the two multiple units will not be repaired.

On the run-into freight train, only the rearmost tank wagon suffered damage.[78] The damage only occurred on the side hit by the passenger train[79] and (as shown in figure 25) consisted primarily of respectively: minor deformation of both crash buffers, bending of the tow coupling and a considerable dent in the end wall of the tank. Appendix B2 provides further information about the damage to the tank. According to the statement from the owner (GATX), the immediate damage (repair costs) amounted to approximately 52,000 euro.

According to ProRail, repairing the damage to the railway infrastructure probably cost less than 100,000 euro.

78 The wagons and the locomotive were visually inspected for damage, before being removed from the accident location. At a later stage, the rear fifteen wagons were further inspected. With the exception of the rearmost wagon, no relevant damage was observed during either inspection.

79 No damage was observed on the other side of the tank wagon (located at the 'front' during the collision). The same applied to the crash buffers located on that side.

Figure 25: These photographs show the damage caused by the collision to (the back of) the rearmost tank wagon. (Photos: police)

B.2 Technical investigation of the tank wagon

The Safety Board carried out a technical investigation of the tank wagon that was involved in the accident in Tilburg. The investigation was focused on identifying the nature/scale and the cause of the leak in the tank, which arose following the collision. Below, the investigation activities are described (in B2-1) followed by a summary of the results (in B2.2).

B2.1 Investigations carried out

The tank wagon is of the type Zagns, bearing registration number 33 80 7809 737-9, for which GATX is registered as ECM (Entity in charge of maintenance). In the framework of this investigation, among others the following documents were consulted in the GATX tank files: certificate of initial inspection dated 07-09-2004, certificate of periodic inspection dated 16-04-2012, drawings (GATX file 7299).

Figure 26: The information panel on the run-into tank wagon. (Photo: Dutch Safety Board)

The investigation of the tank wagon consisted of five sub investigations, as described below. The first section (the visual inspection and 3D laser scan) was carried out on 11-03-2015 in Vlissingen; the remaining sub investigations were carried out on 06-05-2015 in Geleen. To record the findings, the (18) bolt connections on the manhole cover were numbered 1 to 18, in accordance with the right-hand photograph in figure 27.

Figure 27: The left-hand photograph was taken during the inspection carried out on 06-05-2015 in Geleen. The right-hand photograph shows the numbering of the bolt connections on the manhole cover (1 to 18) for the purposes of reporting. (Photos: Dutch Safety Board)

During the first part of the inspection in Vlissingen, and the subsequent inspections in Geleen, the tank was rinsed with nitrogen, in order to reduce the concentration of butadiene, so that the tank wagon could be safely opened. As a result of the overpressure generated during rinsing, which may have risen to approximately 4 Bar, the deformation (dent) caused in the rear wall by the collision was partially 'forced back out'. As a result, the depth of the deformation, which was originally approx. 0.35 m was approximately halved.

1. Visual inspection and laser scan
The tank wagon was visually inspected. Attention was above all focused on the general maintenance status and the damage the collision caused to the under frame and the tank. A photographic record was made of the most important elements, and a 3D laser scan was made of the entire tank wagon.

2. Tank leak test
After the internal pressure in the tank had been raised to an overpressure of 0.2 Bar using air, soapy water was used to determine the location(s) of any leak. It emerged that there was only a minor leak along the seal of the inspection cover (see B2-2). The leak test was repeated once the attachment nuts on the manhole cover had been retightened to the specified tightening torque (see 4).

3. Tightening torque bolt connections manhole cover
Following the initial leak test (see 2), the tank was depressurised, and the tightening torque of the attachment nuts on the manhole cover was checked using a torque wrench. A note was first taken of which nuts could/could not be turned with a tightening torque of 150 Nm. The same test was repeated at a tightening torque of 226 Nm and subsequently at a tightening torque of 350 Nm.

A record was also made of the angle by which the nuts could be turned at a tightening torque of 350 Nm, in relation to their original position. Both prior to and following the check of the tightening torque, the distance between the rear of the manhole cover and the flange (ring) was measured.

4. Manhole cover seal
The manhole cover was then removed. The attachment nuts were slackened using a pneumatic wrench. The gasket was then inspected, the roughness of the joint faces measured and the dimensions checked.

5. Wall thickness and crack detection
On the rear end wall, the tank shell was checked for crack indications at two locations, using a magnetic investigation. These locations were below the manhole cover (see the photograph in figure 29); the locations were mechanical (surface) damage and a zone with crackled paint (see below B2-2), respectively. At both locations, prior to the magnetic investigation, the paint layer was first removed with a file, and the tank shell was sanded bare, by hand. In the area surrounding the manhole cover, the thickness of the tank shell was also measured using an electronic thickness gauge.

B2.2 Findings

1. Visual observations

The photographs in figure 28 show the damage caused to the 'rear wall' of the tank wagon (which was hit by the passenger train during the collision). The damage mainly involved deformation of the two crash buffers and the tow coupling, and a considerable dent in the end wall of the tank. Below the manhole cover there was also mechanical surface damage (see left-hand photograph figure 29) and a zone with crackled paint (see right-hand photograph figure 29). No damage was visible at the 'front' of the tank wagon; the crash buffers on this side were also not deformed (see figure 30).

Figure 28: These photographs show the damage to the tank wagon. (Photos: Dutch Safety Board.)

Figure 29: The left-hand photograph shows the mechanical damage observed below the manhole cover on the rear wall of the tank. The damage is the imprint of the draw eye on the front of the passenger train. The right-hand photograph shows local crackling of the paint layer on the tank. (Photos: Dutch Safety Board)

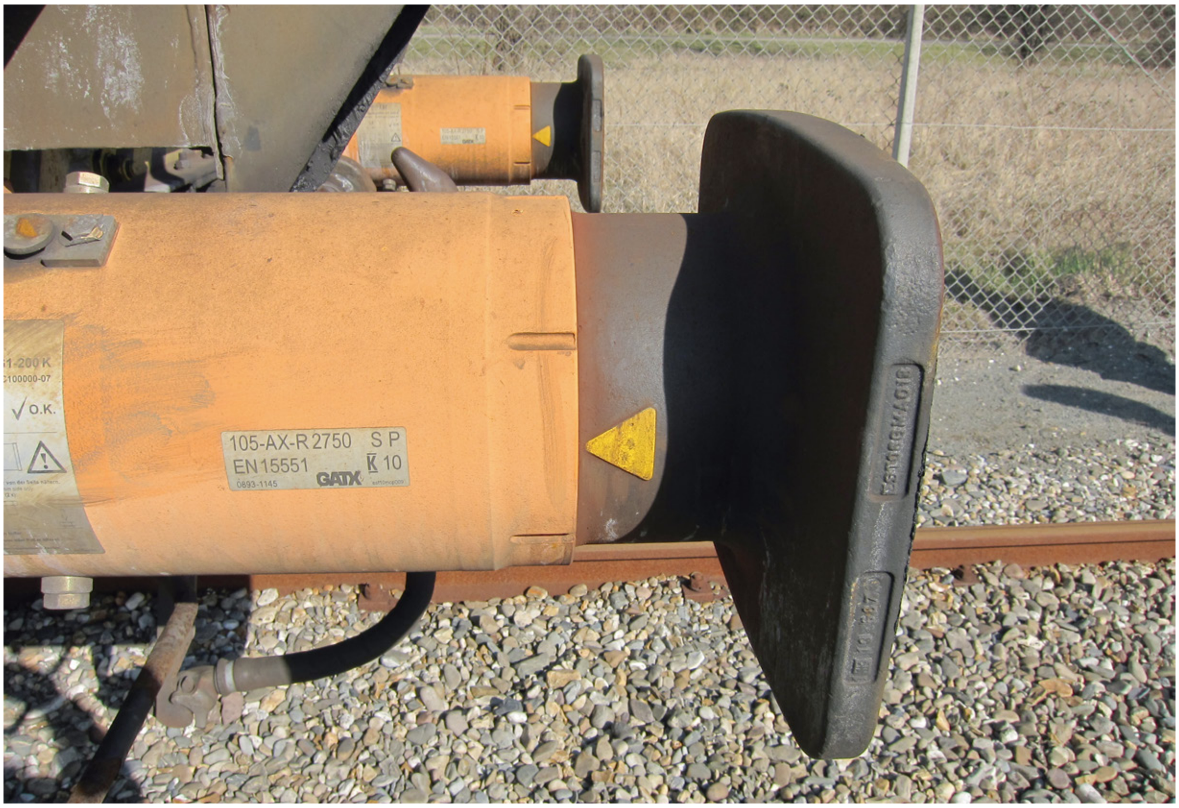

Figure 30: The crash buffers on the side of the tank wagon not run into showed no permanent deformation. (Photo: Dutch Safety Board)

2. Leak tests

During both the first and second leak test, the only leak observed was along the seal of the manhole cover.

- During the first leak test, the leak occurred in the following three zones: between nut 3 and the centre of nuts 5 and 6, between nuts 8 and 9, between nut 13 and the centre of nuts 14 and 15.
- In the second leak test (following the tightening of the nuts to 350 Nm), the leak had been reduced and was only observed between nuts 4 and 5.

3. Measured values for inspection tightening torque

nut	tightening torque test			separation cover/flange (mm)	
	loose/tight	los/vast bij 226 Nm	verdraaiing (grd) bij 350 Nm	begin	na aandraaien met 350 Nm
1	tight	tight	30	1.70	
2	tight	tight	40	1.40	1.00
3	tight	turnable	60	1.45	
4	tight	tight	15	1.65	
5	tight	turnable	40	1.70	
6	turnable	see 150 Nm	45	1.95	
7	tight	tight	20	2.20	
8	tight	tight	30	2.30	1.90
9	tight	turnable	30	2.10	
10	tight	turnable	80 (incl. stud bolt)	1.85	
11	turnable	see 150 Nm	30	1.85	
12	turnable	see 150 Nm	50	1.55	
13	turnable	see 150 Nm	70	1.50	1.05
14	tight	tight	15	1.50	
15	turnable	see 150 Nm	45	1.60	
16	tight	tight	10	1.90	
17	tight	tight	tight	1.95	
18	tight	tight	10	1.90	

Figure 31: Figure 31: This table provides an overview of the findings during the assessment of the attachment and/or sealing of the manhole cover.

4. Gasket and joint faces

The fitted gasket (see figure 32) was green in colour and bore the markings: 3820 VP401 KTW WrC. The thickness ranged from 2.45 to 2.82 mm. The width was between 13.35 and 13.85 mm. The gasket, which was of the prescribed type, showed no deviations which could explain the occurrence of the leak.

Figure 32: These photographs show the gasket. On the left-hand photograph the (green) gasket is still in the intended flange groove. On the right-hand photograph we see the markings. (Photos: Dutch Safety Board)

The manhole cover was 23.9 mm thick. The collar of the cover was between 13.55 and 13.70 mm wide, and between 5.4 and 5.5 mm high. The roughness of the joint face was measured at between Ra 1.3 and 1.8 µm.

The attachment ring (flange) welded in the end wall of the tank was 40.4 mm wide and 40.9 to 41.4 mm thick. The flange groove was 14.6 mm wide, and between 5.25 and 5.45 mm deep. The roughness of the joint face was measured at between 1.0 and 2.5 µm.

The cover, the gasket and the flange demonstrated tracks of a leak in two places, in the form of a rust-coloured mark (see photographs figure 33). A rust-coloured leak track was also visible on the inside of the tank. Given the location and route of the tracks, they were probably caused by moisture entering the tank from outside, prior to the inspection.

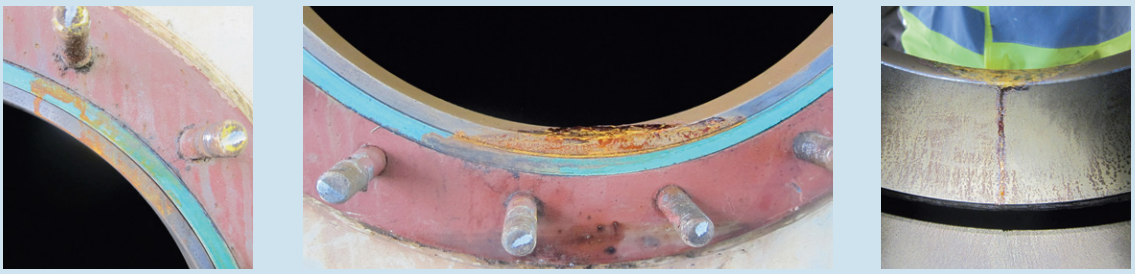

Figure 33: These photographs show the rust-coloured leak tracks, which became visible following removal of the manhole cover. The left-hand photograph and middle photograph show the outside of the flange (including gasket) while the right-hand photograph shows the inside (Photos: Dutch Safety Board)

5. Wall thickness and crack investigation
Close to the manhole cover, the wall thickness of the end wall (including the paint layer) amounted to 10.3 mm.

During the magnetic crack investigation at the location of the mechanical damage, and at the position of the crackling of the paint layer, no cracks were detected.

Figure 34: These photographs show the magnetic crack investigation, which was carried out at two locations on the rear wall of the tank. (Photos: Dutch Safety Board)

B2.3 Evaluation
Effectively, these findings mean that the only leak occurred along the seal of the manhole cover and that the parts relevant for the seal (cover, flange and gasket) demonstrated no deviations that could explain the leak. This means that the immediate cause of the leak was the fact that the bolt connection on the manhole cover delivered insufficient pressing force. This ties in with the observation that the tightening torque of the nuts in question turned out to be considerably less than the torque to which they should have been tightened, when originally fitted. In the judgement of the Safety Board, the insufficient tightening of the bolt fastenings can be attributed to the collision. The reason for this is that during the collision, considerable compression forces were applied to the manhole cover, which makes it plausible that the gasket was somewhat crushed, thereby partially losing its elasticity. Furthermore, there are no indications of the presence of a leak prior to the collision.

B.3 Analysis of ARR files

For a precise indication of the collision speed, the files of the Automatic Run Registration (ARR) from both trains were analysed. The most important findings are listed below.

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B3.1 Passenger train

The ARR files from both multiple units (957 and 476) of the passenger train were analysed, with the following outcomes:

1. The files from the two ARR systems were synchronised according to matching registrations. The ARR system in the rear multiple unit turned out to have gained 24 hours, 9 minutes and 3 seconds. On the ARR system in the rear multiple unit, the registration halted approximately 10 seconds before the moment at which the collision probably occurred. The reason for this could not be determined, not even after an assessment of the stored error codes.
2. The registration details from the ARR system in the front multiple unit showed that in all likelihood, the speed at the start of the collision was 44½ plus/min 2½ km/hour, and that the emergency brake was applied approximately 1 second before the collision. In this connection, the following assumptions were made:
   a. The ARR system continued to store registrations for approximately 2 seconds following the moment of collision. However, the values in question are allocated an error code (*), which means that they were not verified by the system before they were stored. The probable explanation is that a short circuit occurred during the collision in the automatic coupling on the front of the passenger train. The final two seconds of registration probably originated from 'after the collision', is also shown by the fact that those registrations suggest a deceleration of approximately 1.4 m/s^2; because the emergency brake had only been activated approximately 1 second earlier, a deceleration of this kind can effectively only be explained as 'slowing down as a result of the collision'.
   b. In this analysis, a correction of between 1.00 and 1.02 was applied, for system deviations (including wheel diameter). For the overall inaccuracy of the ARR system, a variation of +/- 5% was assumed.

B3.2 Freight train

To gain an insight into the movements of the run-into freight train (immediately prior to, during and after the collision), the files from the ARR system of this train were also analysed. The findings are summarised below.

1. The ARR system in question supplies two files: one contains registrations of 'every 1 m of distance travelled'; the other registrations show 'every 10 m of distance travelled'.
2. These registrations show the following:
   a. Prior to the collision, the train remained stationary for a period of approximately 3 minutes.
   b. As a result of the collision, the locomotive was pushed forward over a distance of at least approximately 3 metres, and possibly approximately 5 metres.
   c. The direct brake on the locomotive was applied approximately 3 minutes prior to the collision (when the train came to a standstill). The indirect brake (with ventilation of the train line) was operated approximately at the same moment that the locomotive once again started to move (as a consequence of the collision); in the two seconds that followed, the pressure in the train line fell from 4.9 to 4.3 Bar.

B.4 Analysis of the collision

B4.1 Analysis of the observed damage

By comparing the 3D scans of the undamaged fronts (see the top picture in figure 35), it became clear that the first contact occurred between the automatic coupler of the passenger train and the tow coupling of the tank wagon, followed by the front of the passenger train making contact with (the top section of) the buffers. By comparing the 3D scans of the damaged fronts (see the bottom photograph in figure 35), it also emerged that in the second part of the collision, the front of the passenger train rose by approximately two decimetres, and subsequently collided against the rear wall of the tank.

Figure 35: These pictures show the side views of the 3D scans of the passenger train and the tank wagon, in respect of one another. The top picture shows the undamaged fronts and the bottom picture the damaged fronts. (Photos: Dutch Safety Board - KLPD)

This reconstruction of the course of the collision is confirmed by the corresponding damage to both fronts (see figure 36). The damage in question includes the impression of the buffers of the tank wagon on the front of the passenger train and the impression of the front of the passenger train on the buffers, and the impression of the manhole cover on the front of the passenger train.

Figure 36: These photographs show the damage caused by the collision on the front of the passenger train (left) and the back of the tank wagon (right). On the front of the passenger train we see the impressions of the buffers and the manhole cover of the tank wagon; on the top section of the buffers of the tank wagon, we see an impression of the passenger train. (Photos: left = fire brigade, right = Dutch Safety Board)

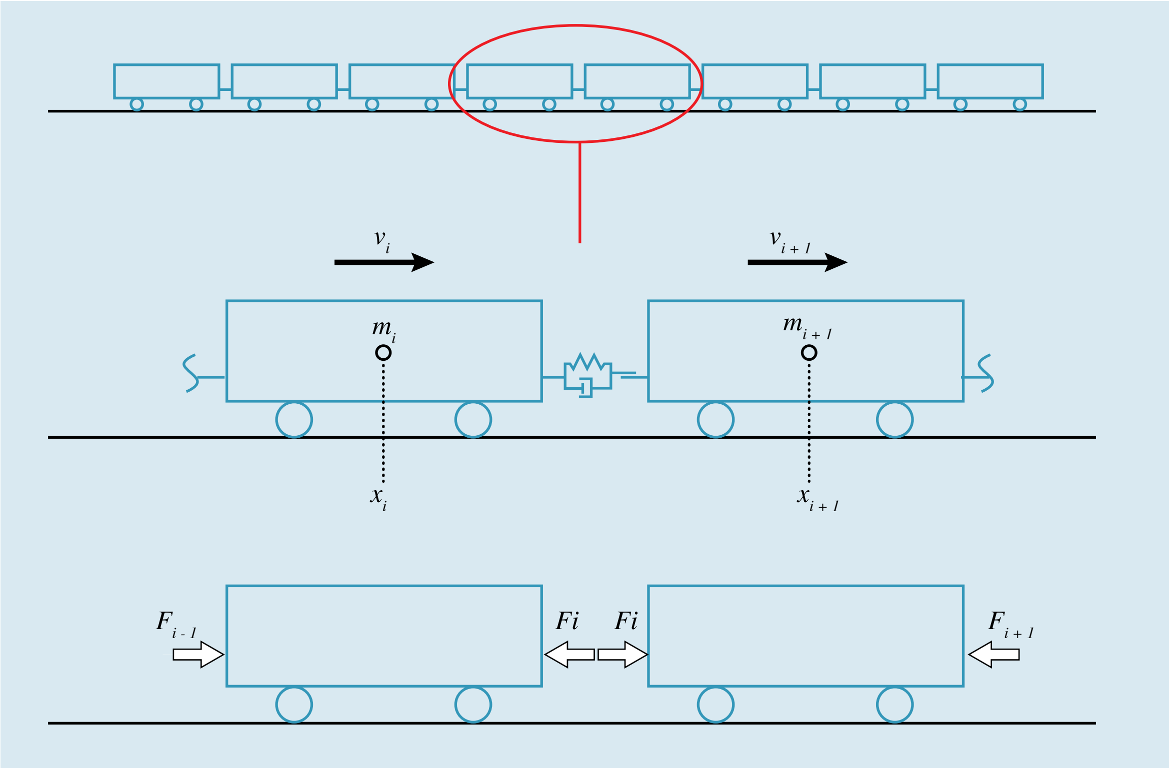
B4.2 Analysis of the movement and energy distribution

To gain an insight into the actual movement of the trains during the collision and the resultant forces, the collision was simulated using the BODYSIM calculation model supplied by Dekra Rail. The current values for the mass and initial speeds of the carriages/wagons and the locomotive in question were used as input. The deformation curves of the coupling elements between the carriages/wagons in the model were matched as accurately as possible with the actual curves of the couplings/buffers. Using the calculation model, the movements of the passenger train and freight train during the collision were reconstructed. These reconstructed movements were then used to determine how the kinetic energy originally delivered by the passenger train was converted by the collision into other forms of energy.

The calculation model (see a), the essential starting points (see b) and the most important findings (see c) are summarised below.

a. Calculation model

The calculation model used, as reproduced in diagram form in figure 37, consists of a series of coupling masses. The couplings between the masses take the form of elements of force, the force of which (over time) depends on the relative position (Δx) and relative speed (Δv); the elements of force consist of a spring linked in parallel (with the spring constant C) and an attenuator (with the attenuation constant K). The influence of the braking forces is accounted for by indicating for each mass whether or not a braking force was applied. The calculation model was implemented in the BODYSIM computer software (written in MATLAB version 2007b).



$$F_i = f\,(t, \Delta x_i, \Delta v_i), \text{ with } \Delta x_i = x_i - x_{i+1} \text{ and } \Delta v_i = v_i - v_{i+1}.$$

$$F_i = C * \Delta x_i + K * \Delta v_i$$

Figure 37: This figure is a diagrammatic representation of the calculation model.

b. Starting points

Figure 38 shows a diagrammatic representation of the (40) model elements, and the numbering of the coupling elements (KE).

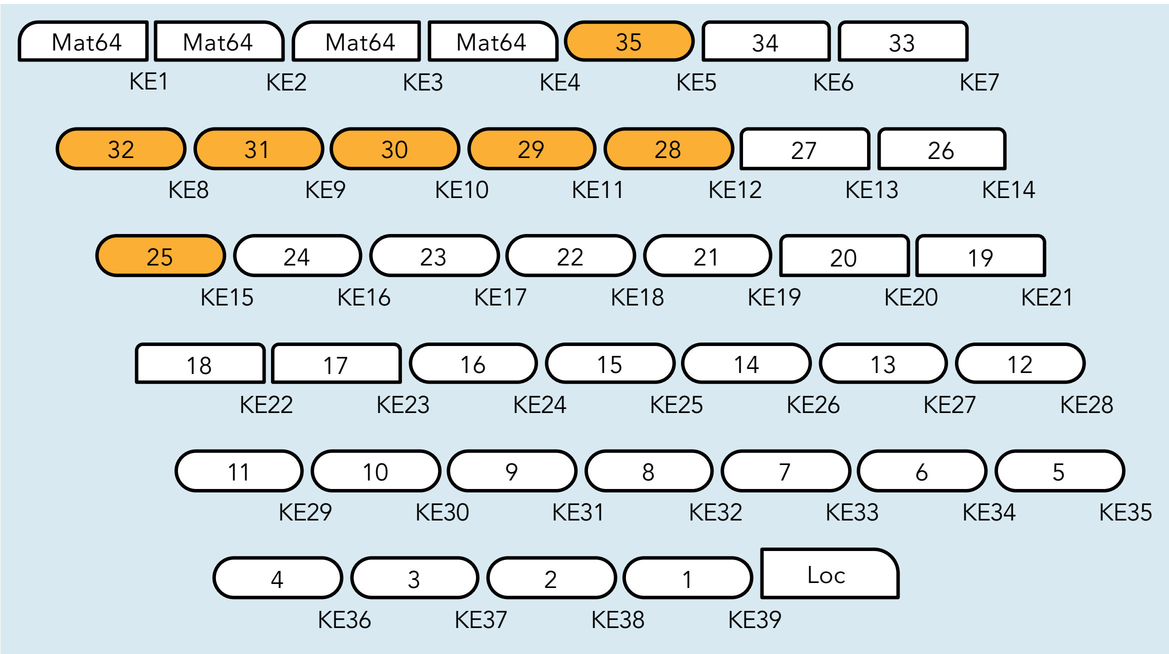


Figure 38: Diagrammatic overview of the calculation model in which the carriages/wagons are indicated, together with the numbering of the coupling elements (KE). The coloured wagons are loaded, the others are empty

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The following starting points were taken, for the various elements/couplings:

- The passenger train consists of four carriages with a mass of 43 tonnes per carriage. For the masses of the individual wagons, the values from the wagon list (as indicated in figure 18) were taken. A mass of 82 tonnes was assumed for the locomotive.
- Figure 39 shows the deformation curves employed for the various coupling elements. The course of the force/path diagrams is derived from the documentation concerning the (crash) buffers and couplings in question, and from deformations which were caused to the passenger train and tank wagon by the collision (as described in appendix B1). In respect of the deformation behaviour of the tank, a force/path development was assumed, such that the permanent deformation of the tank amounted to 0.35 m (in accordance with the measured value).
- On the basis of the analysis of the ARR files (as described in appendix B3), the following was assumed:
  - at the start of the collision, the passenger train was travelling at a speed of 44.5 km/hour, and the freight train was stationary;
  - the wheels of the passenger train and the locomotive were braked, while the wheels on the wagons were not.
- For the friction coefficient of the braked wheels, starting with a sliding speed of 0.1 m/s, a value of 0.2 was applied, and at lower sliding speeds, a linear relationship between sliding speed and friction coefficient (from 0 at 0 m/s to 0.2 at 0.1 m/s).

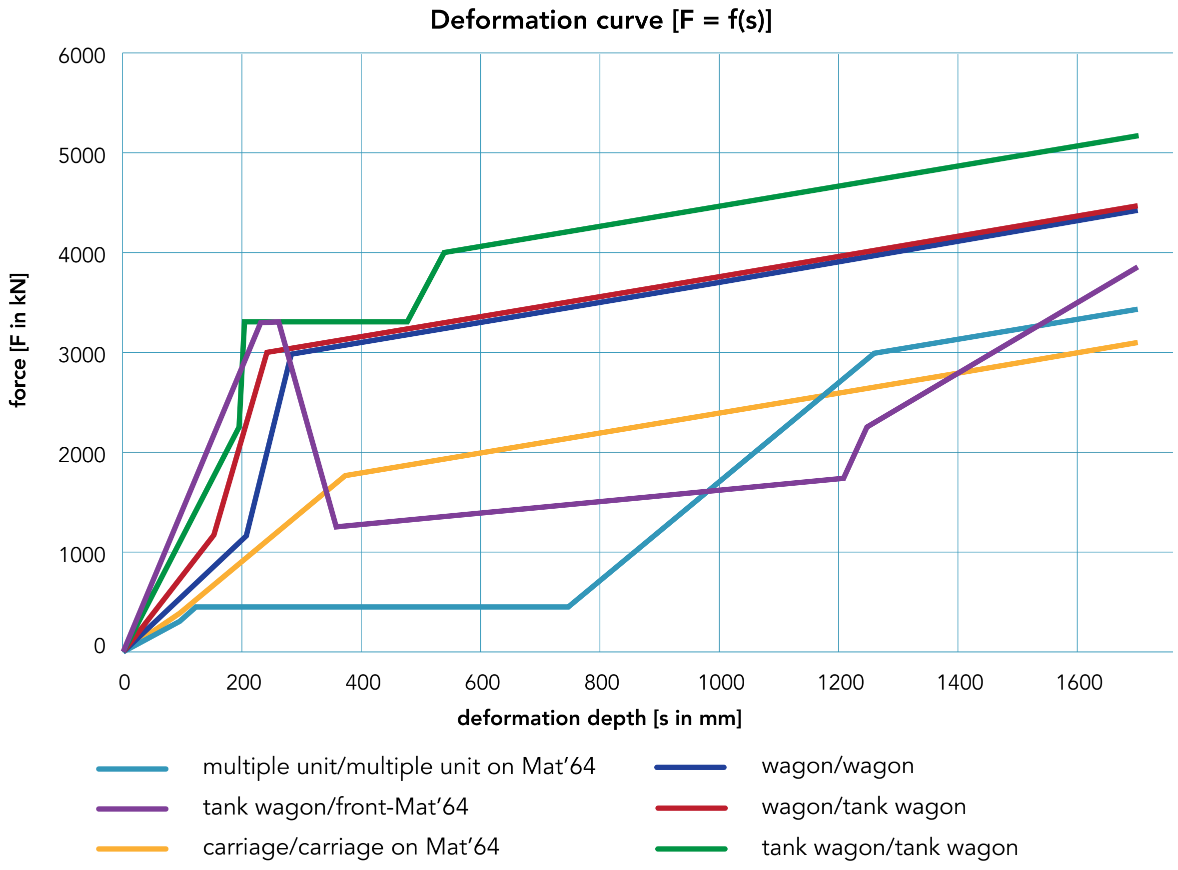
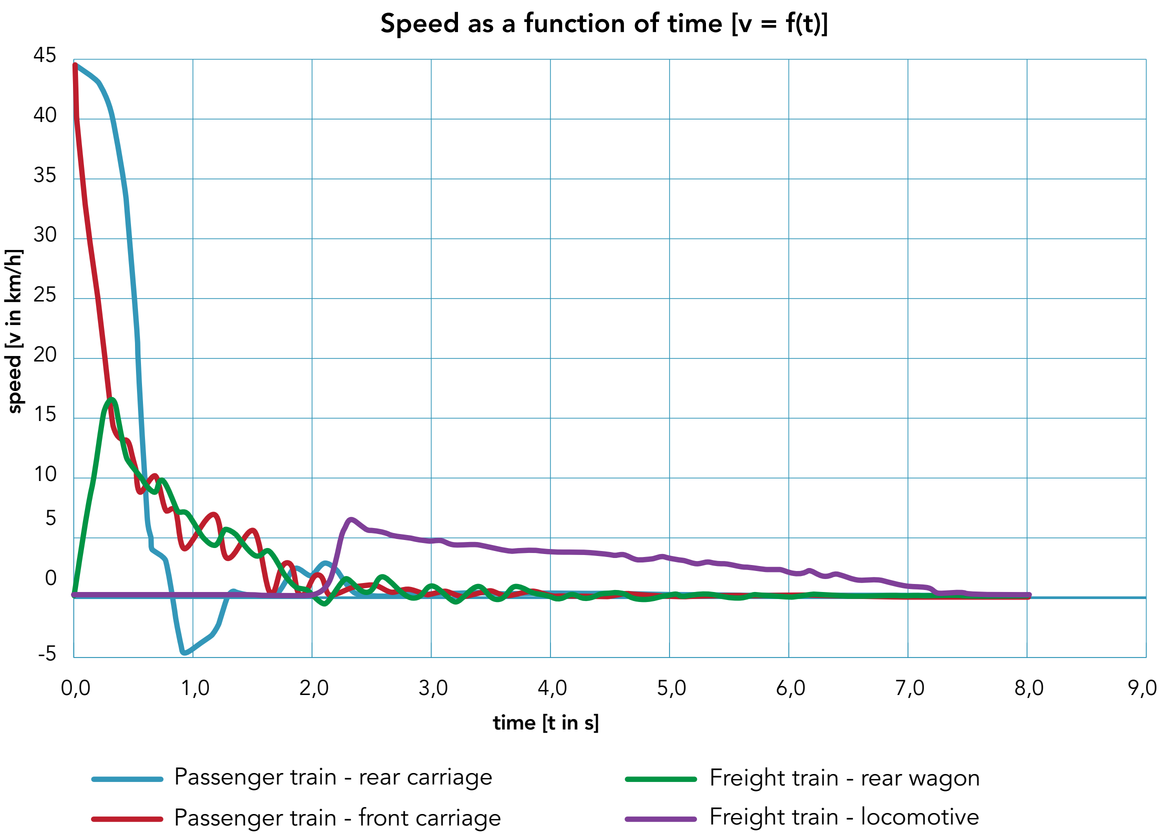


Figure 39: This graph shows the deformation curves (force/path diagrams) employed in the simulation of the calculation of the movements for the various coupling elements.

c. Results

The reconstructed collision (see the graphs in figure 40) broadly speaking amounts to the following:

- The part of the collision period during which permanent deformation (damage) was done to the passenger train and tank wagon lasted approximately 0.4 seconds. In that period, the front of the passenger train was slowed down to approximately 15 km/hour, while the rear tank wagon was accelerated to approximately the same speed.
- It then lasts approximately 4 seconds before the passenger train and the rear tank wagon come to a standstill. The rear tank wagon is pushed forwards by the collision over a distance of approximately 4 metres.
- The displacement of the rear tank wagon is then transmitted through the freight train. Approximately 2 seconds after the start of the collision, the locomotive also starts to move. Approximately 5 seconds later, the locomotive once again comes to a standstill; in the intervening period, that vehicle is moved forwards by more than 4 metres.



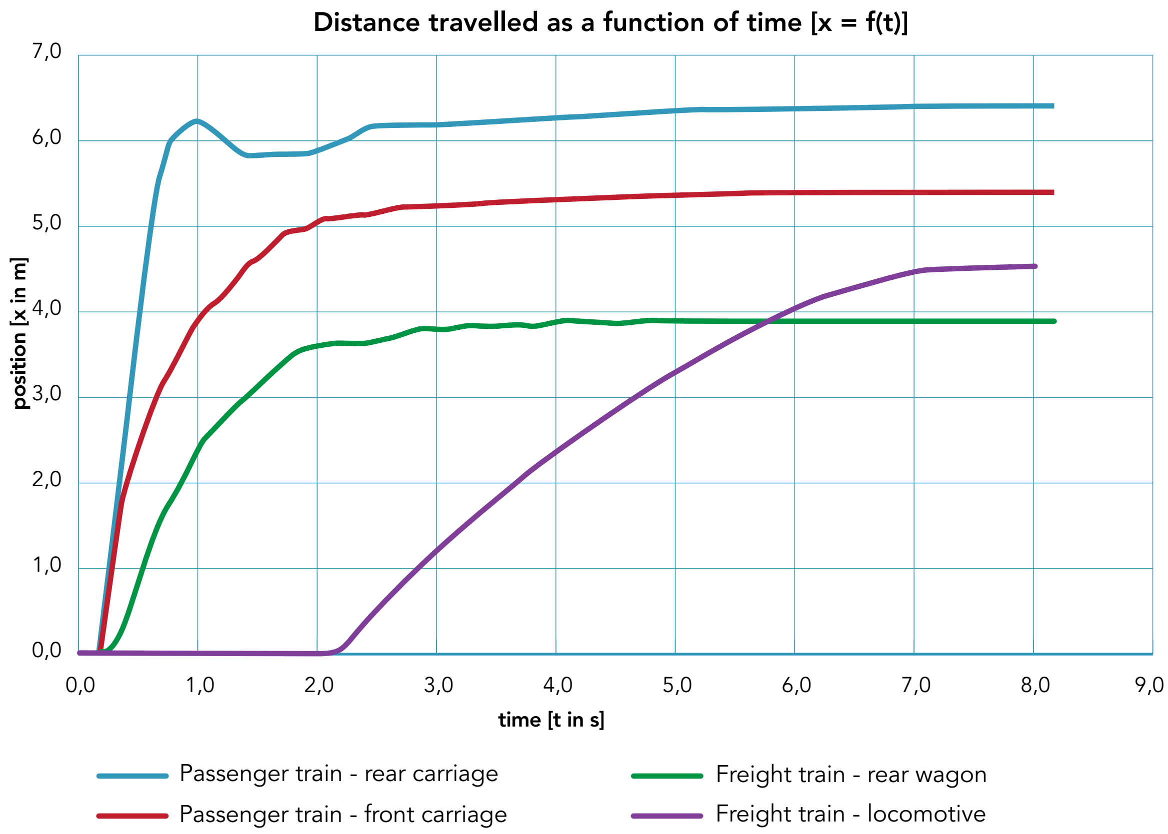


Figure 40: These graphs show the reconstructed movement of the two trains during the collision.

According to the reconstructed movements, the kinetic energy present in the passenger train at the start of the collision was converted as follows into other forms of energy (see figure 41):

- At the start of the collision, the kinetic energy of the passenger train amounted to approximately 13.3 MJ.
- Of that total, during the collision, approximately 5.9 MJ (almost 45%) was converted into permanent deformation (damage) of the passenger train and the rear tank wagon. Approximately half (3 MJ) of this amount related to damage to the front of the passenger train and the rear of the tank wagon; the remainder (also approximately half) related to damage to the connections/couplings between the carriages of the passenger train.
- Approximately 4.6 MJ (almost 35%) of the kinetic energy was absorbed by the extension and contraction of the buffers of the freight train, thanks to the absorption of energy by the inward and outward movement of the (crash) buffers.
- The remainder of the kinetic energy (2.8 MJ or more than 21%) was converted into friction between the braked wheels (of the passenger train and the locomotive) and the rails.

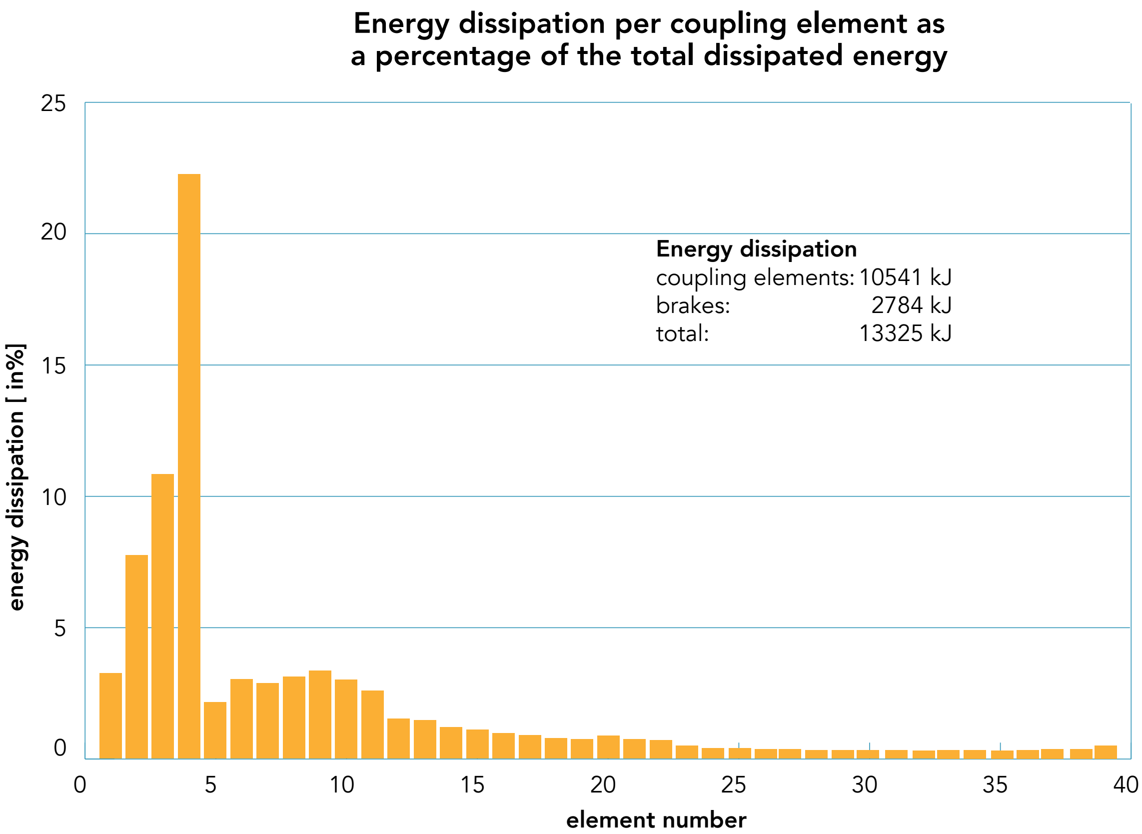


Figure 41: This graph relates to the energy conversion in the reconstructed collision. The graph shows which percentage of the original kinetic energy of the passenger train is absorbed during the collision by the various coupling elements (for numbering see figure 37).

APPENDIX C

OTHER INVESTIGATIONS INTO THE TRAIN COLLISION IN TILBURG

The railway companies involved and the Human Environment and Transport Inspectorate (ILT) carried out investigations into the train collision in Tilburg. The findings of these investigations are summarised below.

C.1 Investigation by the railway companies involved

C.1.1 Investigation undertaken

The railway companies directly involved in the accident, namely ProRail, NS Reizigers and DB Schenker, carried out a joint investigation.

This investigation focused on the following aspects:

- the occurrence of the red signal passage;
- the functioning of the train protection system (including the presence of the automatic train protection system ATB - Improved Version);
- the planning/implementation of the timetable (including the route/train pathways);
- the passenger train involved (including the operation of the brakes and the ARR);
- the length of the freight train (in relation to the length of the track and the driver change);
- the composition of the freight train;
- the collision compatibility between the passenger train and the tank wagon;
- the alarm notice and evacuation of the passengers; the removal of the tank wagons and the passing of other trains shortly after the accident;
- handling of the accident by government services.

The railway companies summarised their investigation findings in a report[80] in which they identified the following four issues as the 'most relevant (underlying) causes':

a. Red signal passage following 'departure at yellow'

The passenger train involved in the accident departed from Tilburg station at standard with a signal at yellow, after which the next signal (96) was almost always at green. Previous investigations including those by the Dutch Safety Board have revealed that 'departure at yellow' of this kind is undesirable because it can generate the wrong expectation pattern among drivers. At locations where this applies, the importance of yellow is thus degraded.

80 The findings are summarised in report 14817, entitled Final report into the causes and direct consequences of the train collision on 6 March 2015 in the municipality of Tilburg (dated 05-10-2015).

Despite previous recommendations from the Dutch Safety Board and the Human Environment and Transport Inspectorate (ILT), the policy at ProRail was not geared to altering situations such as that in Tilburg (with a structural 'departure at yellow').

b. The safety system did not intervene following a red signal passage
When approaching signal 96, which was at red, the passenger train was not automatically braked, because the signal was only equipped with the automatic train protection system ATB - First Generation, and not also with the automatic train protection system ATB - Improved Version. ProRail has introduced the automatic train protection system ATB - Improved Version in phases, on the basis of a risk assessment, in which the primary focus was on signals with crossing routes, with a risk of frontal and flank collisions. Because the signal in question (96) was not earmarked as representing a risk in this assessment, it was not equipped with the automatic train protection system ATB system - Improved Version.

Over the past few years, ProRail has launched a series of initiatives aimed at sending an automatic alarm to the train traffic controller in the event of a red signal passage. The 'Collision Hazard Warning' system was eventually introduced. However, this system does not generate an alarm in the event of a threatened head-tail collision.

c. The freight train was too long for the allocated track
The freight train was originally composed with a length of 567 metres. Subsequently, the composition and hence the length were changed as a result of a series of changes to the logistic planning of the railway undertaking; eventually, the length of the train (excluding locomotive) was 612 metres. In the ISVL order request (timetable change) by the railway undertaking, the original length (567 m) was incorrectly notified, rather than the actual length (612 m). On the basis of the ISVL order request, ProRail planned the requested intermediate stop on a track (912b) with a length of 585 metres. As a consequence, the freight train ended up on a track that was 'too short'.

The railway undertaking commented in this connection that the train length was correctly indicated in the wagon list which was entered in the OVGS system. ProRail pointed out that rescheduling is carried out on the basis of the ISVL order request (without the correctness of that request being verified according to the data submitted by the railway undertaking via the OVGS system).

d. Handling procedures in the event of disasters are not fully in line
In dealing with the accident, the head of the Incident Location Command (COPI) was instructed to remove the undamaged wagons from the two freight trains (61802 and 61080) from the yard. The carrying out of this instruction suffered several hours delay because the train traffic controller (Trdl) - in accordance with the regulations for normal situations - assumed that the route in question could not be released because the two trains were on tracks that had previously been taken out of service (BD) by the Workplace Protection Leader (LWB). The regulations do not cover a situation whereby in the event of a disaster, the duty officer Rail (OvD-Rail) (on behalf of the Head of COPI or the mayor) must be able to order the train traffic controller to undertake certain actions that would normally be forbidden. This could for example lead to a situation in the event of a fire on a leaking tank wagon, that the fire could spread to other wagons containing dangerous goods.

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C.1.2 Measures planned and/or taken

When questioned, the companies involved indicated that on the basis of the accident in Tilburg, they have taken/planned the following measures.

1. Preventing departure at signal at yellow:
   a. ProRail will draw up an inventory of locations where 'departure at yellow' occurs structurally.
   b. ProRail will Analysis the possibilities for improving ARI trigger points.
   c. ProRail and railway undertakings will Analysis ALARP measures.
   d. ProRail and railway undertakings will lay down measures for the remaining category.

2. Intervention by railway system following red signal passage:
   ProRail, NS Reizigers and DB Schenker will further implement the SPAD improvement plan.

3. Reliable registration of train length - track length in ISVL and OVGS:
   a. DB Schenker will tighten up its procedures so that no further train changes are made in the last hour prior to departure.
   b. DB Schenker will immediately correct the ISVL notification in the event of exceeding the planned train length (including locomotive).
   c. DB Schenker will ensure automatic correction to the current train length in the production system (RCS) and in OVGS.
   d. ProRail will investigate/correct the reliability of track and train length in the systems in question.
   e. ProRail and DB Schenker will if possible create an interface between OVGS and ISVL, so that train and track details need only be entered in a single system.

4. Handling procedure in the event of disasters:
   a. NS Reizigers and DB Schenker will ensure that any altered/expired train documents are removed or are recorded as such.
   b. ProRail will update the Train traffic controller's Work Instructions, and will inform railway undertakings and relevant stakeholders.
   c. ProRail will evaluate the handling of the accident at Tilburg, with the Safety Region

5. Collision compatibility of passenger stock:
   NS Reizigers and ProRail will be analysing the collision compatibility of various types of passenger train, without obstacle deflectors, in combination with the transport of dangerous goods and timetabling.

6. Automatic train protection system ATB - Improved Version on routes with dangerous goods:
   ProRail will investigate the extent to which safety gains can be achieved by installing the automatic train protection system ATB - Improved Version at signals along routes via which dangerous goods are transported.

7. Automatic/real-time readout of ARR and DRR:
   a. ProRail and DB Schenker will develop a system for the automatic/real-time reading out and storage of ARR and DRR data.
   b. NS Reizigers will decide, on the basis of the outcome of 7a whether and how monitoring of ARR functioning can be guaranteed.

8. Willingness of drivers to report dangerous situations:
   NS Reizigers will implement the project 'Improving the willingness of drivers to report unsafe situations'.

C.2 Investigation by the human environment and transport inspectorate (ilt)

C.2.1 Investigation questions

The investigation undertaken by the Human Environment and Transport Inspectorate (ILT) into the train collision in Tilburg focused on the following investigation questions:

1. What caused the collision between the passenger train and the freight train?
2. What caused the red signal passage by the passenger train?
3. To what extent did NS Reizigers and ProRail sufficiently comply with the recommendations issued by the Dutch Safety Board in response to previous collisions?
4. Did ProRail comply with its commitments on the automatic train protection system ATB - Improved Version on the Brabantroute?

C.2.2 Findings

The ILT summarised its findings in a report (RV15-0138) dated 01-09-2015. The reported findings are as follows:

1. The immediate cause of the collision was a red signal passage by the passenger train.

2. In addition to the fact that the driver of the passenger train was distracted, the two major contributing factors to the red signal passage were as follows. The first factor was the fact that the departure of the passenger train in question from station Tilburg structurally took place with the signal at yellow. This structural 'departure at yellow' probably contributed to the establishment of the wrong pattern of expectation in the mind of the passenger train driver. The other factor was the incorrect notification of the length of the run-into freight train by the railway undertaking, in requesting the intermediate stop. As a consequence, the train was guided onto a side track that was too short, which in turn meant that the signal for the passenger train remained at red.

3. Over the past few years, NS Reizigers and ProRail have taken a series of measures to prevent red signal passages by trains. A number of those measures have already been implemented. The improvements relate specifically to:
   - the drawing up of conflict-free plans, and improving the safety culture of planners, train traffic controllers and traffic controllers;

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- the introduction of software tools such as DONNA node (for identifying planning conflicts) and the Collision Danger Warning (to issue a warning to the train traffic controller in the event of a red signal passage);
- the development of the ORBIT system (to warn the driver when approaching a signal at red);
- installing flank zone protection at a number of locations (so that approaching signals switch to red whenever a train makes a red light passage)

In this connection, the ILT also refers to the installation of the automatic train protection system ATB - Improved Version at more signals, and the preparation/elaboration of the ERTMS implementation plan. On the other hand, the ILT points out that a number of these developments (including the introduction of ORBIT) are being carried out slowly.

4. The Ministry of Infrastructure and the Environment and ProRail together drew up a list of the signals due to be fitted in phases with the automatic train protection system ATB - Improved Version. They also drew up a step-by-step plan for installing the automatic train protection system ATB - Improved Version on the signals on the routes designated for the transport of dangerous goods (including the Brabantroute). For those routes, this includes all signals on the through tracks (which are generally used for trains carrying dangerous goods) and the signals on tracks that grant direct access to the through tracks.

   In accordance with the agreements reached and the action plan, ProRail equipped all operated signals on the main track and the signals granting direct access to that track on the Brabantroute with the automatic train protection system ATB - Improved Version.

5. NS Reizigers and DB Schenker paid very limited attention to the possible safety risks in changing the timetable. For NS Reizigers, the changes involved the deployment of the stock type (Mat'64 instead of DDZ) and at DB Schenker, the changes to the train runs by the freight trains involved (in particular arranging the driver change at Tilburg-Goods yard). ILT has called upon NS Reizigers and DB Schenker to focus more attention on these aspects.

C.2.3 Violations/shortcomings

In its report, the ILT identifies the following violations and shortcomings:[81]

- By passing signal 96 at red, the driver of the passenger train violated article 65 of the Railways Act.

81 ILT identifies a violation if it is observed that there are situations or actions that are contrary to legislation. A shortcoming is considered as being present if it is observed that a requirement/expectation laid down in company regulations or an underlying document is not met. ILT considers this distinction relevant, because violations can be made subject to sanctions (such as imposing a penalty, using administrative enforcement or imposing an administrative fine) while no enforcement is possible in respect of shortcomings.

- By allowing the freight train to depart without the correct data on the train length being available in the ISVL system intended for that purpose, DB Schenker violated article 4 section 2 subsection 1 b of the Railway Transport Order.
- The safety management systems at ProRail and NS Reizigers demonstrated a shortcoming in the sense that the systematic departure of passenger trains at yellow, at signal 114 in Tilburg over a long period of time was not recognised and tackled.

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LEGISLATION AND REGULATIONS

Items of legislation and regulations specifically relevant to this accident are: the Railways Act, the Transport of Dangerous Goods Act and the Circular on Risk Standards for the transport of dangerous goods and the Basic Network Act.

D.1 Railways Act

The Railways Act comprises a large number of implementing instructions and orders, relating to such issues as railway companies, railway traffic, railway vehicles, railway infrastructure, personnel, capacity and supervision. European directives are implemented by means of the Railways Act and the special orders and regulations. The European directives impose requirements on railway traffic, rolling stock and the railway infrastructure, and impose a distinction on the one hand between the management of the infrastructure and on the other the operation of train services. The European Railway Safety Directive (2004/49/EC) imposes requirements on safety. The Dutch Railways Act and the accompanying Ministerial regulations also refer to a series of international treaties and agreements. These include the RIV (*Reglemento Internazionale dei Veicoli),* the COTIF (*Convention pour le Transport International Ferroviaire*) and the GCU (*General Contract of Use For Wagons*) that is an integral part of the COTIF.

The following provisions are relevant:

- *Transport companies:*
  The transport companies must have a safety certificate. To obtain that certificate, these companies must demonstrate that they manage the safety risks relating to their operation by means of suitable measures. The transport companies must also demonstrate that they operate a safety management system that complies with statutory rules. The transport companies may only run railway vehicles that comply with the statutory requirements, and in running those vehicles, they must comply with the relevant regulations (in respect of such issues as speed, signalling, etc.).

- *Railway vehicles:*
  Railway vehicles must be provided with an EC inspection declaration or approval certificate (issued on the basis of the COTIF Treaty) and an operating certificate. Railway vehicles must also comply (and continue to comply) with certain technical specifications laid down in respect of safety, compatibility with the infrastructure and interoperability, etc. These requirements are laid down in the Technical Specifications on Interoperability (TSI).

- *Infrastructure:*
  The duty of care for construction, management and maintenance has been entrusted to the Minister of Infrastructure and the Environment. For the layout, equipment and technical characteristics, a certain level of basic quality is specified. The Minister of Infrastructure and the Environment must award a concession for infrastructure management. That management includes responsibility for the quality, reliability and availability, as well as the capacity distribution and traffic control. The management concession contains performance standards that demand that the safety risks of the use and management of the railway network are analysed and sufficiently managed. The management concession also specifies that the manager must have a safety management system (SMS) that complies with certain requirements.

Crash safety of passenger trains
The Railways Act specifies that new trains must comply with the requirements in Appendix III of European Directive 2001/16/EC. The specific elaboration of those requirements is laid down in the following documents: the Ministerial Regulation on the commissioning of railway vehicles (RIS), Technical Specifications on Interoperability (TSIs) and European standards (EN standards). In respect of the crash safety of passenger trains, the relevant documents are in particular the TSI 'Locomotives and passenger trains' and the EN standards 12663-1 (structural requirements of railway vehicle bodies) and 15227+A1 (crashworthiness requirements for railway vehicle bodies). With regard to crash safety, the essence of the current requirements is summarised in four crash scenarios, which new passenger trains must demonstrably be capable of withstanding (see appendix F3). In the specified crash tests, the passenger compartments and the cab may not experience more than a specified degree of deformation. Furthermore, for a number of the crash tests, limits are imposed on the average deceleration experienced by the train, and the degree to which the front of the train demonstrates the tendency to 'climb'.

D.2 Transport of dangerous goods act

According to the *Transport of Dangerous Goods Order* (Bvgs), the transport of dangerous goods by rail is subject to the international rules of the RID (*Règlement concernant le transport international ferroviaire des marchandises dangereuses*), together with a series of national rules. The RID classifies dangerous goods on the basis of their hazard characteristics, and for the various classes imposes specific transport conditions and restrictions in respect of packaging, labelling and transport documents. The RID contains rules and regulations in respect of the training of the persons involved, and the requirements with which the tank wagons must comply.

The requirements on tank wagons depend on the category of hazardous substance that may be carried, and the age of the tank wagon (whereby it should it be noted that the RID is revised/tightened up every two years). In respect of the crash safety of a tank wagon, the requirements relate in particular to the presence of crash buffers, anti climbing devices and protective shields/strengthened end walls. The purpose of crash buffers is to absorb energy in the event of a collision, thereby preventing deformation/damage to the tank. The purpose of an anti climbing device or protective shield/

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strengthened end wall[82] is to limit the risk that the tank will suffer a direct hit during a collision and as a consequence suffer a leak. Whether a tank wagon is required to be fitted with this system depends on the category of hazardous substance transported, and the year of construction of the tank wagon (see figure 42 and appendix E).

<table>
<tr><th colspan="2" rowspan="2">tank wagon for the transport of:</th><th colspan="2">compulsory crash protection</th></tr>
<tr><th>crash buffers</th><th>anti climbing devices or protective shields or strengthened end walls</th></tr>
<tr><td colspan="2">flammable liquid – all years of construction</td><td>–</td><td>–</td></tr>
<tr><td rowspan="2">flammable gas</td><td>year of construction before 2007</td><td>–</td><td>–</td></tr>
<tr><td>year of construction from 2007</td><td>X</td><td>–</td></tr>
<tr><td rowspan="2">toxic/corrosive liquid</td><td>year of construction before 2007</td><td>–</td><td>–</td></tr>
<tr><td>year of construction from 2007</td><td>X</td><td>–</td></tr>
<tr><td rowspan="3">very toxic or pyrophoric liquid</td><td>year of construction before 2005</td><td>X (light version)</td><td rowspan="2">–</td></tr>
<tr><td>years of construction 2005 and 2006</td><td rowspan="2">X</td></tr>
<tr><td>year of construction from 2007</td><td>X</td></tr>
<tr><td rowspan="3">toxic gas</td><td>year of construction before 2005</td><td>X (light version)</td><td rowspan="2">–</td></tr>
<tr><td>year of construction 2005 and 2006</td><td rowspan="2">X</td></tr>
<tr><td>year of construction from 2007</td><td>X</td></tr>
</table>

Figure 42: Overview of types of crash protection compulsory for the various types of tank wagons.

The RID also imposes requirements on the training of personnel involved in the transport of dangerous goods by rail. Chapter 1.8.3 of the RID specifies for example that transport companies involved in this work must have one or more safety advisers, and that their task is the ensure that the transport of dangerous goods by rail can be carried out in accordance with the regulations and under optimum conditions, as well as ensuring awareness of the risks relating to the transport operations.

82 An anti climbing device is a mechanism the purpose of which is to prevent one vehicle climbing (also known as buffer overriding) over another vehicle in the event of a collision. A protective shield is a vertical panel that is placed in front of the end wall of a tank to prevent this end wall being penetrated by a sharp object in the event of an accident.

In respect of manhole covers, regulations have been formulated in a European standard (DIN - EN 12561-6) governing the location, dimensions and design of the manhole cover. This standard is not an (statutory) obligation, but is generally complied with. In this connection there is effectively only one statutory requirement, which specifies that on tank wagons for toxic liquids and gases, the manhole cover must be located above the level of the liquid.

D.3 Circular on risk standards for the transport of dangerous goods or the basic network act

Government policy for restricting/managing environmental risks from the transport of dangerous goods was laid down until 1 April 2015 in the *Circular on Risk Standards for the transport of dangerous goods* (Rnvgs). Since that date, the Basic Network Act has been introduced, to govern theses aspects. In this Circular/Act, an indication is given of the considerations that the various levels of government must make in respect of external safety, when reaching decisions on the transport of dangerous goods and authorising building along transport axes. These regulations impose restrictions on the risks to which people in the environment of a road/waterway/railway may be exposed. In that process, in quantifying the risks, use is made of the terms 'location-specific risk' and 'societal risk'. Both relate to the risk that people will be killed as an immediate consequence of an accident involving dangerous goods. As concerns location-specific risks, these relate to the risk per year that an unprotected person will be killed in the open air. Societal risk refers to the cumulative risk per year per kilometre of road/waterway/railway that ten or more people will be killed. How these two risks are to be determined is described in the Transport Risk Analysis Handbook (HART). Target and threshold values for both risks are contained in the Rnvgs Circular and the Basic Network Act. In respect of the vulnerability of the environment, several categories are distinguished; the strictest requirements apply for the category in which buildings are included such as houses, schools, hospitals/ nursing homes, care homes for the elderly, office buildings and shopping centres.

For each railway line, a determination is made of which dangerous goods in which quantities are allowed to be transported. See the Ministerial Regulation on the Basic Network in the Netherlands Government Gazette dated 28 March 2014. The specified numbers relate to the expected level of transport in 2020. In respect of the nature of the substances, use is made of the categorisation in figure 43. For the limiting of the volume of dangerous goods per railway line use is made of the term tank wagon equivalent (KWE), whereby 1 KWE stands for one tank wagon (irrespective of the type of substance) or for two tank containers for a flammable substance or three tank containers for a toxic substance.

categorisation		(example) substances
type of substance	code	
flammable gas	A	LPG, propylene, butadiene
toxic gas	B2	ammonia
very toxic gas	B3	chlorine
very flammable liquid	C3	petroleum, natural gas condensate
toxic liquid	D3	acrylonitrile
very toxic liquid	D4	hydrogen fluoride, bromine

Figure 43: Categories for the transport of dangerous goods by rail.

CRASH PROTECTION ON TANK WAGONS

In this appendix (in E1 and E2), the three crash protection types referred to in the RID regulations are discussed. A historical overview is also provided of the development of the relevant regulations (in E3).

E.1 Crash buffers

Crash buffers (RID designation TE22) are a special type of buffer, the primary characteristic of which is that they are resistant to greater impact forces and can absorb more energy than standard buffers. The aim of these characteristics, in the event of a collision, is to prevent the under frame of the wagon/tank wagon becoming deformed. The underlying thought is that as a result the risk of tank leaks and of climbing/buffer overriding are reduced. In respect of energy absorption, a series of different systems have been developed whereby broadly speaking a distinction can be made between external and internal absorption elements. External elements generally take the form of a 'tube' which, when subjected to a specified degree of compression force start to tear/curl up, thereby absorbing energy (see photograph figure 44). In the case of internal elements, the energy absorption is achieved via a component (e.g. in the form of a so-called crumple tube) which is located (inside) the buffer.

In respect of the absorption capacity, there are two categories, namely 250 kJ and 400 kJ per crash buffer. The regulations in the RID specify that the energy absorption through permanent deformation of the crash buffers is only permitted to occur at a level of force (greater than 1,500 kN) which does not occur under normal circumstances (including shunting).

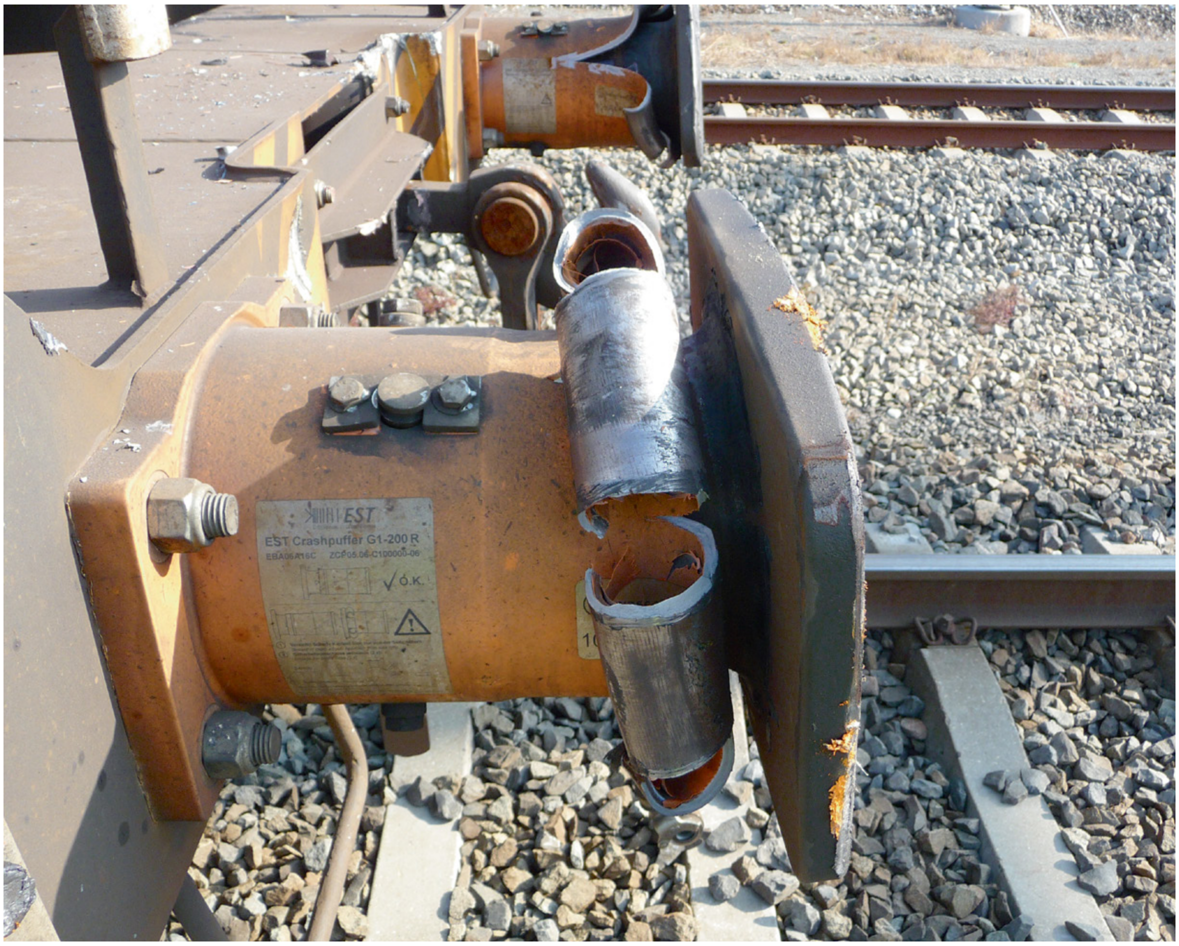

Figure 44: This photograph shows crash buffers with external absorption elements (the orange tubes) which as a result of a collision have torn and curled up, thereby absorbing energy. (Photo: Dutch Safety Board)

E.2 Buffer overriding protection

The purpose of buffer overriding protection devices (RID designation TE25) is to prevent one wagon mounting (climbing) another wagon in the event of a collision or derailment, so that parts (e.g. the buffers) of the one wagon do not come into contact with the tank on the other wagon (buffer overriding) and cause a leak. Broadly speaking, the following two system types can be distinguished: anti climbing devices (see E2-1) and protective shields/strengthened end walls (see E2-2).

E.2.1 Anti climbing devices

A number of different systems have now been developed. The common feature is that in essence they consist of a catch structure mounted above/below the buffers (see figure 45). The purpose of these catch structures is to halt buffer overriding as it starts.

The RID specifies that the catch structure must be resistant to vertical forces (upwards and downwards) of 150 kN. The structures must also be produced in such a way that they represent no hindrance to the normal use of the wagons (including tight bends), and that the risk of penetrating the base of the tank is not increased, as a result of an impact.

Figure 45: This photograph shows an anti climbing device. (Photo: SABIC)

E.2.2 Protective shields/strengthened end walls

Protective shields/strengthened end walls are structures intended to prevent leaks in a tank as a consequence of a sharp part of the colliding vehicle (or its cargo) penetrating the wall of the tank. Structures of this kind effectively consist of a solid steel panel that is placed vertically in front of or against the end wall of the tank (see figure 46). The construction requirements in the RID relate to the width, height and thickness of the shield, and to its attachment.

Figure 46: These photographs show two examples of protective shields. (Photos: SABIC)

E.3 Development of regulations

Requirements on the construction of tank wagons

The RID regulations for tank wagons were originally above all focused on the resistance of the tank to the dangerous goods to be transported (such as pressure resistance in the case of gases and corrosion resistance for acids). Until around the start of this century, the RID regulations contained no specific requirements in respect of the crashworthiness of tank wagons.

In 1996 and 1997, a series of serious railway accidents occurred in Germany, involving freight trains carrying dangerous goods, as a result of which large quantities of dangerous goods escaped.[83] In response to those accidents, in 1998 a national working group was established in Germany (Arbeitsgruppe Tank- und Fahrzeugtechnik). This working group issued proposals to improve the crashworthiness of tank wagons, including the introduction of the already mentioned crash buffers, anti climbing devices and protective shields and strengthened end walls. The working group placed their proposals on crash buffers on the RID agenda, in 2000.[84] In 2002, this German working group was expanded to form an international RID working group (Tank and Vehicle Working Group). The RID then made crash buffers compulsory for certain categories of tank wagon (see also figure 42 in appendix D2):

- From 2005 onwards, crash buffers were made compulsory on tank wagons (from year of construction 2007) carrying flammable and toxic gases, and (from year of construction 2005) for tank wagons carrying very toxic or very pyrophoric liquids.
- From 2007 onwards, anti climbing devices or protective shields/strengthened end walls were made compulsory for tank wagons (from year of construction 2007) carrying toxic gases and very toxic or pyrophoric liquids.

Over the following years, within the RID, a series of further proposals were made to extend the obligations outlined above:

- In 2010, on the initiative of the United Kingdom, consideration was given to extending the obligation to fit anti climbing devices or protective shields/strengthened end walls.[85] The background to this proposal was a serious derailment in Stewarton in Scotland, which led to a large-scale leak when the tank on a tank wagon was torn open by the tow coupling of another tank wagon. The response from the other Member States was broadly negative: no necessity was seen for extending the obligation to include other groups of substances.
- In 2012, on the initiative of the Netherlands, the proposal was submitted to extend the crash buffer obligation to 'all gases and liquids'. The immediate background was an accident in 2011 at the Kijfhoek marshalling yard.[86] A tank wagon containing

83 These included a derailment in Elsterwerda (during which more than 950,000 litres of petroleum escaped), a frontal collision in Hannover (during which 350,000 litres of diesel escaped) and a derailment in Schönebeck (whereby more than 300,000 litres of vinyl chloride escaped).

84 *Passive Sicherheitsmassnahme: Crashpuffer an Eisenbahnkesselwagen* {Inf. 4 ; 37e RID-Fachausschuss, Nürnberg, June 2000}.

85 Inf. 1 of 11th RID Meeting WG {RID Meeting in Berne} (May 2010).

86 Ref. OTIF/RID/CE/GTP/2012/8 {RID Meeting in Riga} (Nov. 2012).

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ethanol (which was not equipped with crash buffers) was involved in a collision with other tank wagons resulting in a leak and a major fire. In 2013, the Netherlands submitted a further elaborated proposal (including cost/benefit analysis).[87] Discussion of this proposal has not yet been concluded, but it appears that for the time being for the majority of Member States 'the costs' form an obstacle, and rapid introduction of this extended requirement is not probable.

Requirements on the composition of trains carrying dangerous goods

In respect of the composition of freight trains carrying dangerous goods, the only requirement contained in the RID relates to the position of wagons carrying certain types of explosives.[88] Over the past few years, three proposals have been submitted to impose further rules on the composition of freight trains carrying dangerous goods:

- In 2006, Finland proposed requiring that wagons containing toxic gas should not be coupled to a wagon with specific risk characteristics, and should not be fitted as the first or last wagon on a train.[89]
- In 2010, the Netherlands placed the theme 'hot-BLEVE-free' trains on the agenda.[90] In that connection, the proposal was made to maintain a minimum separation of at least 18 metres between wagons containing flammable gases on the one hand and wagons containing flammable liquids on the other.
- In 2012, Belgium proposed maintaining a similar separation between wagons containing dangerous goods and wagons with a cargo that could penetrate a tank/tank wagon in the event of (shifting during) an accident.[91]

These proposals have not (yet) led to a change to the RID.

87 OTIF/RID/CE/GTP/2013/13 {RID Meeting in Copenhagen} (Nov. 2013).
88 Paragraph 7.5.3 of the RID requires - briefly - that wagons containing certain explosive substances may not be coupled to a wagon containing a flammable or oxidising substance.
89 OTIF/RID/CE/2006-A {RID Meeting in Helsinki} (Oct. 2006).
90 OTIF/RID/CE/GT/2010/1 {RID Meeting in Berne} (May 2010).
91 OTIF/RID/CE/GTP/2012/2 {RID Meeting in Riga} (Nov. 2012).

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COLLISION COMPATIBILITY OF PASSENGER TRAINS

This appendix provides an explanation to the term collision compatibility (F1). This is followed (in F2) by an explanation of the collision compatibility of the type of passenger train (Mat'64) involved in the collision in Tilburg. This is in turn followed (in F3) by an explanation of the collision compatibility of modern passenger trains. Finally, (in F4) an overview is provided of the collision compatibility of the train types currently in use by NS Reizigers.

F.1 Collision compatibility

The term collision compatibility describes the extent to which two vehicles are made compatible with one another such that the consequences of a collision for the passengers and cargo are as limited as possible. Poor collision compatibility in the event of a collision with a car or a passenger train, for example, results in greater deformation of the passenger compartment, than is necessary given the intensity of the collision. In the event of a collision with a tank wagon, poor collision compatibility results in unnecessary damage to the tank.

The extent to which two vehicles of a specified collision type are 'compatible' is above all determined by the shape, dimensions and rigidity of the mutual vehicle zones that come into contact in the event of the collision. These characteristics determine to a considerable extent what deformations occur to the passenger compartment or the tank of the tank wagon. In the event of a major discrepancy in rigidity, for example, the less rigid vehicle will above all be deformed.

The collision compatibility can be seriously negatively influenced if in the upper section of the contact surface one vehicle is considerably less rigid (hard) than the other. This situation can mean that during the collision, one vehicle climbs or mounts the other vehicle. This phenomenon is known as 'climbing'. In extreme cases, it can even result in 'overriding', whereby one vehicle fully/partially climbs up and over the other.

F.2 Mat'64 trains

The passenger train involved in the accident in Tilburg was of the type Mat'64. The fronts of trains of that type, designed and purchased more than fifty years ago (around 1964), are not equipped with crash absorbers or an obstacle deflector[92] as is the case with modern trains. As a consequence, on trains of this type, the part of the vehicle below the cab floor offers no particular resistance in the event of a collision. As further explained in paragraph 4.4, this characteristic meant that in the accident in Tilburg, the front of the passenger train rose (climbed) during the collision and as a result ended up against the tank on the rearmost wagon of the freight train.

Figure 47: This photograph shows the damage to the front of the passenger train (Mat'64) involved in the accident in Tilburg. When the photograph was taken, the automatic coupler, which was seriously deformed, had already been removed. (Photo: police)

The absence of a solid construction in the bottom zone of the front also makes this type of train susceptible to derailment as a consequence of a collision with a 'low object on the track'. In the past, a number of collisions at level crossings have occurred between trains of this type and passenger cars, which actually led to derailments. In response to one such derailment, the Transport, Public Works and Water Management Inspectorate (IVW) advised NS Reizigers in 2008 to retrofit the Mat'64 trains with an obstacle deflector.[93] At the time, NS Reizigers did not follow this recommendation, because it looked as if the last few models of this train type would be definitively decommissioned shortly afterwards. However, approximately forty trains of this type (including the unit involved in the accident in Tilburg) were kept in service longer than was expected at that time. In response to questioning, NS Reizigers indicated its intention to definitively remove the remaining (approximately 40 units) from service, in 2016.

92 An obstacle deflector is a construction fitted just above the rails, the purpose of which is to deflect objects located on the track, thereby preventing the train from derailing.
93 This was a level crossing collision that took place in Coevorden on 5 December 2007.

F.3 Modern passenger trains

Since the period in which the Mat'64 multiple units were purchased, both the requirements and admission procedures for new trains have been fundamentally altered.[94] Until approximately 1998, admission was delegated entirely to the then (still undivided) NS, and the technical admission requirements consisted of internal NS regulations. In that period, it was standard practice for national railway companies (like the NS) to design their own trains. Until approximately the nineteen seventies, the vision on crash safety effectively meant that the carriages had to be built as solidly as possible, in order to prevent serious deformation in the event of a collision.

In the period 1998-2004, the process took place that resulted in the splitting up of the NS into railway infrastructure managers, railway undertakings, contractors and engineering firms, respectively. In parallel to this process, the original Railways Act (dating from 1875) was replaced by a new version (in 2003). During that same period, under the auspices of the European Commission, new design criteria and technical solutions were developed for improving the crash safety of passenger trains. These new insights also led to European admission requirements, laid down in the Technical Specifications on Interoperability (TSIs) and European standards (EN standards).[95]

The essence of the current requirements is that new passenger trains must be capable of withstanding four crash scenarios. Two of these include a collision at a speed of 36 km/hour, respectively against a passenger train of the same type and against a freight wagon (weighing 80 tonnes) with buffers. Limits have been imposed on the deformation and deceleration allowed to occur, and the tendency to override.

To meet these crash safety requirements, new passenger trains are, for example, equipped with crash buffers (see figure 48). Because these crash buffers are fitted in the same place as the (crash) buffers fitted on freight wagons, the assumption would appear justified[96] that the collision compatibility of modern passenger trains in respect of tank wagons is considerably better than is the case with the Mat'64 trains.

94 In the rapport published by the Dutch Safety Board on the train collision that took place at Amsterdam-Westerpark on 21 April 2012, the development of these regulations is described in (more) detail (in appendix 4).

95 Above all the TSI 'Locomotives and passenger trains' and EN standards 12663-1 (Structural requirements of railway vehicle bodies) and 15227+A1 (crashworthiness requirements for railway vehicle bodies) are relevant for the crash safety of passenger trains. These were introduced in 2011, 2010 and 2008, respectively.

96 As far as we are aware, no specific crash tests have yet been carried out, nor have any actual collisions occurred in practice between a tank wagon and a modern passenger train.

Figure 48: Both photographs show a modern passenger train equipped at the fronts with crash absorbers. On the train on the left-hand photo the crash absorbers are visible (on both sides of the automatic coupler). The right-hand photograph is a train of the type SLT operated by NS Reizigers: if the bottom section of the front panel is removed, the two crash absorbers and the obstacle deflector become visible. (Photos: left = Roel Hemkes, right = Dutch Safety Board)

F.4 Overview of trains NS reizigers

The table below provides an overview of the passenger trains operated by NS Reizigers, in 2015, divided into trains with good/reasonable and poor/bad collision compatibility in respect of freight material. This is an overall assessment on the basis of the shape/construction of the train fronts, whereby the presence of (crash) buffers is assumed as providing good/reasonable collision compatibility, while the absence of these provisions results in poor/bad collision compatibility.[97]

This global inventory of the total NS Reizigers train fleet reveals that approximately 1/3 of trains have a reasonable to good collision compatibility in respect of freight stock (including tank wagons). Of the approximately 2/3 of the trains with poor to bad compatibility, a large proportion is expected to still remain in service for a considerable period of time (15 to 30 years).

97 When questioned, NS Reizigers said it had no insight into the degree to which the different train types have a tendency to override, in the event of a collision with a tank wagon.

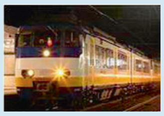
poor/bad collision compatibility			reasonable/good collision compatibility		
train type + number + end year	photograph (front)	comments	train type + number	photograph (front)	comments
DM90 n = 22 through to 2018		Obstacle deflector, but no buffers or crash absorbers.	SLT n = 131		Modern design, with crash absorbers (not visible).
Mat'64 n = 39 through to 2015		No buffers or crash absorbers and and no obstacle deflector.	DDAR/ E1700 n = 18		Front fitted with buffers and obstacle deflector.
SGM n = 90 through to 2024		No buffers or crash absorbers and no obstacle deflector.	DDZ n = 50		Front fitted with buffers and obstacle deflector.
ICM n = 137 through to 2029		Obstacle deflector, but no buffers or crash absorbers.	E1700/IC n = 23		Front fitted with buffers. The considerable mass results in limited buffer overriding tendency.
VIRM n = 176 through to 2045		Obstacle deflector, but no buffers or crash absorbers.			
total number = 464, fleet share = 68%			total number = 222, fleet share = 32%		

Figure 49: Overview of collision compatibility of the NS Reizigers train fleet. (Photos: NS Reizigers)

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APPENDIX G

RAILWAY ACCIDENTS WITH DANGEROUS GOODS

The table below (see figure 50) shows how often railway accidents have occurred over the past few years in the Netherlands and other European countries involving freight trains carrying dangerous goods. The table lists both collisions and derailments, and other accident types; the table also shows the proportion of accidents resulting in the escape of dangerous goods.

Country	2011		2012	
	total number of accidents	number with leak	total number of accidents	number with leak
Belgium	0	0	2	0
Bulgaria	0	0	0	0
Denmark	2	0	1	0
Germany	3	2	8	4
Finland	0	0	1	0
France	2	2	3	2
Italy	0	0	10	1
Latvia	2	1	2	1
Lithuania	3	1	4	1
Luxembourg	0	0	0	0
Netherlands	3	1	2	0
Austria	0	0	0	0
Poland	6	1	1	1
Portugal	0	0	0	0
Rumania	1	0	0	0
Slovenia	0	0	0	0
Spain	4	0	2	0
Czech Republic	0	0	0	0
United Kingdom	1	0	0	0
Channel Tunnel	1	1	0	0
TOTAL	28	9	36	10

Figure 50: Overview of railway accidents with dangerous goods in 2011-2012. Source: 'Railway safety performance in the European Union - 2014' (European Railway Agency).

The data in this table were provided by the European Railway Agency (ERA) and represent the formal EU statistics based on the obligation from the Railway Safety Directive (2014/88/EU) to report specific railway accidents involving dangerous goods. The criteria for reporting appear in article 1.8.5 of the RID. The reporting obligation broadly applies to accidents whereby at least a certain quantity of a dangerous substance escaped (or there was a risk of such an escape) and/or personal injury or damage to rolling stock or the environment occurred, relating directly to the transported dangerous goods.

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