INSTANTANEOUS LIQUID RELEASE FROM RAILTANKER:

THE INFLUENCE OF NOISE SHIELDS ON POOL SHAPE AND POOL SURFACE

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Abstract

Introduction

In the Netherlands, the Betuweline, a dedicated freight railway, will among other things, be used for transportation of all kind of hazardous materials from the Port of Rotterdam to the German Hinterland and vice versa. The line is about 150 kilometers long. Alongside the line, over more than 100 kilometers noise shields have been constructed. The question is how and to what extent this noise shield will affect the pool shape and surface of an instantaneous release of a flammable liquid, such as LPG.

Theory and method

In case of an instantaneous releases of a rail tanker ($50m^3$) both risk analysts and emergency responders reckon with a circle like pool shape of about $600m^2$ This shape and surface is based upon a full scale test without a noise shield or any other barrier nearby the rail tanker.

To asses the influence of the noise shield, a full scale test was conducted on an already constructed part of the Betuweline. A $50m^3$ rail tanker was filled with a red-colored liquid. The liquid was instantaneous released. Three camera's and three observers recorded the consequences.

Results

A very peculiar pool shape results due to the noise shield. A zone between the rails and the noise shield (2 meters wide and 90 meters long) is within 2 to 3 minutes filled with 15 centimeters liquid. The total pool surface was about $750m^2$. Both shape and surface deviate substantially from the traditional figures. These insights are both relevant to emergency responders for disaster abatement purposes and to risk analysts for effect modeling purposes. The ministry of Transport is examining the possibilities to deal with these results.

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Discussion

The results are based upon one single instantaneous release test. In addition, it is interesting to find out what the pool shape and surface would be in case of a continuous release from the rail tanker near a noise shield.

Introduction

In the Netherlands, the Betuweline, a dedicated freight railway, will among other things, be used for transportation of all kind of hazardous materials from the Port of Rotterdam to the German Hinterland and vice versa. The line is about 150 kilometers long. The railway is aligned closely to multiple cities and villages. Because of that, noise shields were designed to protect the inhabitants for too high noise levels of passing trains. Alongside the line, over more than 100 kilometers noise shields have been constructed. Legal criteria are absent in the Netherlands for designing noise shields along railways. Still, two main aspects are taken into account in designing such noise shields including the noise reduction and the way the noise shield fits in the environment. However, the effect of noise shields on hazardous material releases is not a part of the deliberations so far. One of the possible accident scenarios on the Betuweline is the instantaneous release of a rail tanker, for example filled with a flammable liquid (Werkgroep Betuweroute Regionale Brandweren, 1994). The question is how and to what extent this noise shield will affect the pool shape and surface of an instantaneous release of a flammable liquid, such as LPG.

Theory

In case of an instantaneous releases of a rail tanker ($50m^3$) both risk analysts and emergency responders reckon with a circle-like pool shape of about $600m^2$ (CPR, 2000). This shape and surface is based upon a full scale test without a noise shield or any other barrier nearby the rail tanker. The fluid could flow in all directions without being hindered by any barrier at all. The liquid flows through the permeable ballast of the railway and forms a circle-like pool. The depth of this pool is relatively small, about several centimeters. Large amounts of the liquid descend into the earth. In case of a fire, the pool surface in combination with its depth determines the heat release rate and the time the pool is on fire. Both surface and depth have repercussions on the fire fighting possibilities for example how much foam should be used for repression or how to access the emergency. In 1994 and for the Betuweline, fire brigades guaranteed that they would be able to repress a $600m^2$ pool fire. At that moment, they did not reckon for noise shield alongside the track. That is why it is important to find out if designed noise shields influence the pool shape and surface, and to what extent.

The instantaneous release test

To asses the influence of the noise shield, a full scale test was conducted on an already constructed part of the Betuweline (Nibra, 2005). A $50m^3$ rail tanker was filled with a red-colored liquid from the nearby ditch. We used water instead of a flammable liquid for safety reasons, environmental aspects and costs. At 20 degrees Celsius, water has almost the same viscosity as flammable liquids[2]. This viscosity is important because it determines the flow pattern of the liquid. The table below shows some design aspects of the rail tanker that was used in the full scale test.

[2] The nominal viscosity of water is 1,0mm2/sec and is in the range of viscosity numbers of flammable liquids like gasoline (Verkerk, 1986).

Table 1: Design characteristics of the rail tanker.

Aspect	Specification
Type:	Tanoos 896
Maximum volume:	75 m^3
Release jaws (2):	80 cm x 20 cm
Height release jaw - rail:	40 cm

The test was hold near the villages of Leerdam and Vuren very close to highway 15, hectometer 34,5. The test location was relatively horizontal (hardly any elevation). This flat location prevents the liquid for flowing in one dominant direction (the lowest point). On one side of the rail tanker, a noise shield, including a door in the shield is apparent. The shield is dug in a small sand dike of 60 centimeters high. The door is important because its frame and sill is not dug in a small sand dike. During the test, the door is closed. At the test location, markers were positioned and connected with red-white striped ribbon. This ribbon is used as an iso-distance line and assists observers in making their observations of the pool size. The mutual distance between the ribbons is 5 meters, and starts from the centre of the rail tanker.

The picture below shows the test location, including the rail tanker, the noise shield, the door in the shield and the ribbons.

Figure 1: Test site photograph.

The test was realized with the cooperation of many stakeholders: ProRail (providing the rail track), fire region Zuid-Holland Zuid (preparation and logistics), fire brigades of Lingewaal/Lingewaal Zuid, Sliedrecht, Lingewaal/ Asperen en Papendrecht (filling the rail tanker), NedTrain (providing the rail tanker), the national police ((KLPD) for photography and video observations), Ministry of Transport (traffic management at highway 15) and the dike reeve Vierstromengebied (ditches).

The liquid (50m^3) was instantaneous released. The results were observed in two ways:

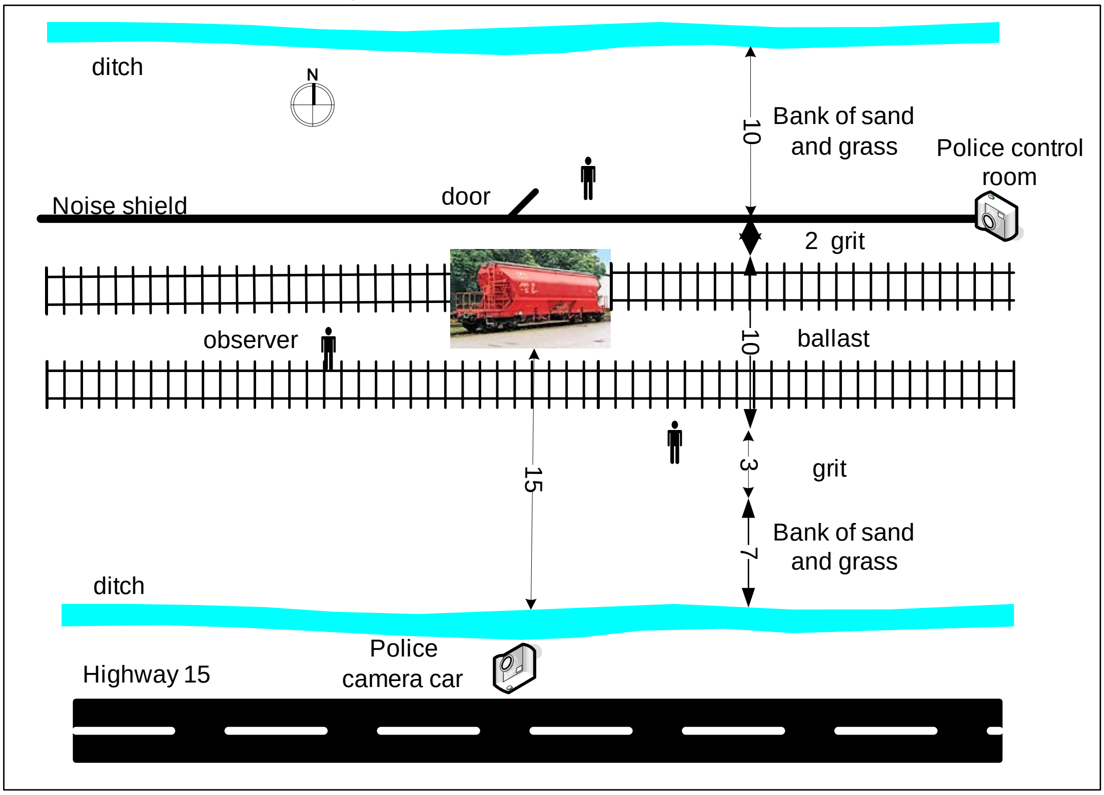
- Three police camera's (1 helicopter, and 2 police cars)
- Three observers (2 at each side of the rail tanker, and 1 behind the noise shield)

An observation protocol was developed. The three police cameras were coordinated by the police control room near the test site. One liaison of the test team was apparent in the police control room. The test leader was in contact with the liaison and the observers. The observers were in contact using the Dutch new emergency response communications system C2000. The test leader coordinated the observations by indicating the start of the release. Using C2000, the test leader requested the observers to indicate the pool shape at the below specified moments.

Each of the observers had his own observation map. The observers were asked to indicate the pool size on the papers by marking the size on a pre specified raster. Four observations were made by each observer: after 2 minutes 30 seconds, 5 minutes, 7 minutes 30 seconds and after 20 minutes.

Both observers and policemen were instructed before the test. This instruction was meant to clarify the goal of the test and the aspects the observers should take notice of. The figure below shows the test arrangement.

Figure 2: Test site schematic overview.



The table below shows the relevant test data.

Table 2: Test site data.

Aspect	Specification
Date and time	24 June 2005, 11.00 am
Temperature	30 degrees Celsius
Weather conditions during test	Dry and sunny, hardly any wind
Weather conditions 1 week before test	Heat wave: 5 days, 30 degrees Celsius
Location ditch (north) behind noise shield	10 meters from noise shield
Ground conditions noise shield-ditch	Sandy and covered by grass, dry

Ditch (north) behind noise shield	Cleaned 1 week before test, 1-side dammed, hardly any current
Width ditch (north) behind noise shield	3 meters
Location noise shield	4,75 meters from the centre of the rail track
Location noise shield	2 meters from ballast
noise shield	60 cm earth dike outside the noise shield, except for the doors
Width door in noise shield	1 meter
Width ballast rail track 1	5 meter
Width ballast 2 tracks	10 meter
Width grit along side tracks	3 meter
Width grit-ditch (south)	7 meter
Ground conditions grit- noise shield (south)	Sandy and covered by grass, dry
Location ditch (south)	15 meters from rail tanker
Ditch (south)	Not cleaned, connected to open water, hardly any current
Width ditch (south)	3 meter

Results

The pool shape and surface did not develop significantly different between 2 minutes 30 seconds, 5 minutes, and 7 minutes 30 seconds from the release moment. After 20 minutes, the liquid still flew underneath the ballast and grit. The latter could only be observed by observers at the test location. Cameras did not record this liquid flow. The mechanism causing this delayed liquid flow is that the liquid initially is stored in the ballast and grit. Later, when the ballast and grit are saturated, the liquid is 'released' from the ballast and grit and flows to the lower points. Figure 3 and 4 show the pool shape after 7 minutes 30 seconds respectively 20 minutes from the release moment. As can be seen from figure 3 and 4, the total pool is consists of several characteristic sub parts of the pool.

Figure 3: Pool size after 7 minutes and 30 seconds (is the same for 2 minutes and 30 seconds and 5 minutes).

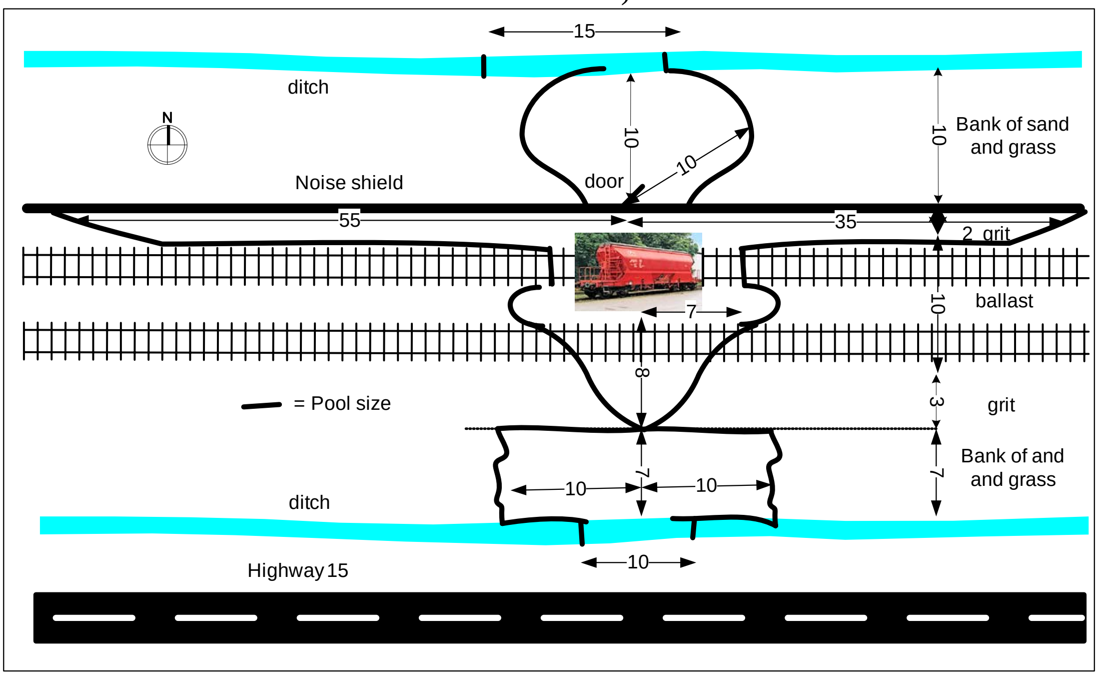
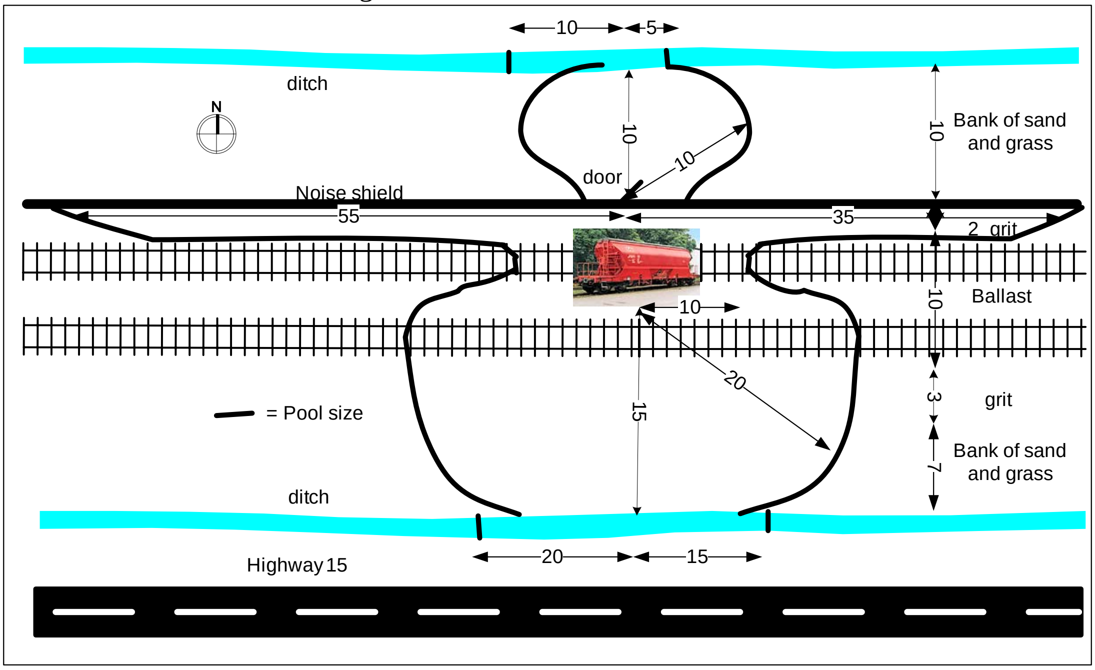


Figure 4: Pool size after 20 minutes.



The table below summarizes the observations as made by observers and cameras. In this table, the characteristic pool parts are presented in the most left column (in sequence from north to south). The upper 2 rows indicate the moment at which the pool shape is observed. The cells that originate are filled with test results. For the pool surface, the cells contain square meters. For the dispersion of the liquid in the ditch, the cells indicate the length in meters over which liquid spots appeared.

Table 3: Results instantaneous release.

	Observation after ... minutes					
Characteristic part of the pool	Pool shape (7,5)	2,5	5	7,5	Pool shape (20)	20
Behind noise shield	Half circle	160 m^2	160 m^2	160 m^2	Half circle	160 m^2
Grit along noise shield (west)	Ditch	110 m^2	110 m^2	110 m^2	Ditch	110 m^2
Grit along noise shield (east)	Ditch	70 m^2	70 m^2	70 m^2	Ditch	70 m^2
Ballast rail track	Rectangle	15 m^2	15 m^2	15 m^2	Rectangle	20 m^2
Ballast between 2 tracks	Ditch	20 m^2	20 m^2	20 m^2	Ditch	40 m^2
Ballast and grit	Triangle	55 m^2	55 m^2	55 m^2	Rectangle	150 m^2
Pool south (A15)	Rectangle	140 m^2	140 m^2	140 m^2	Rectangle	210 m^2
Total surface	-	570 m^2	570 m^2	570 m^2	-	760 m^2
Ditch behind noise shield (north)	Spots	15 m	15 m	15 m	Spots	15 m
Ditch (south)	Spots	10 m	10 m	10 m	Spots	35 m

The difference between the observations after 7 minutes 30 seconds and 20 minutes is about 200 square meters (about 550 respectively 750). The liquid buffer in the ballast and grit causes this delayed increase after 20 minutes. At that moment liquid flows underneath the ballast and grit. This delayed flow also influences the pool shape in the ballast and grit zone: after 7 minutes 30 seconds the pool was like a triangle where it is a rectangle after 20 minutes.

A very peculiar pool shape results due to the noise shield. A ditch is created between the rail track and the noise shield (2 meters wide and 90 meters long) is within 2 to 3 minutes filled with 15 centimeters of liquid. The total pool surface was about 750m^2. Due to the noise shield, both pool shape and surface deviate substantially from the traditional figures.

In addition, the following aspects were observed during the test:

- The developed ditch (15 centimeters deep) between rail track and noise shield stretches in western direction (about 55 meters) a bit more that eastwards (35 meters) due to a small elevation
- The remaining parts of the pool are at maximum several centimeters deep
- Already during filling activities small leakages caused liquid to flow under the rail tanker and under the door frame
- The pool stretches about 10 meters on the rail track in the transport direction, meaning that the liquid only flows under the 2 direct adjacent other rail cars.
- The earth below the door frame is completely washed out
- The dispersion in the ditch behind the noise shield is hampered by vegetation in the ditch and therefore spots originate instead of a continuous surface
- Five railway sleepers were washed out involving a hole of 75 centimeters deep
- The ballast stones were launched over a distance of 5 meters from the rail tanker

The insights regarding pool size and pool shape are both relevant to emergency responders for disaster abatement purposes and to risk analysts for effect modeling purposes. For emergency responders because it determines:

- The amount of foam to repress the emergency
- The accessibility of the emergency scene
- Heat radiation to other rail cars and hence possible domino effects

For risk analysts because it determines:

- Heat release rate
- Possible evaporation
- Heat radiation to other rail cars and hence possible domino effects

Conclusions and recommendations

The following conclusions are drawn:

1. The pool surface is about 550 square meters after 7 minutes 30 seconds and about 750 square meters after 20 minutes
2. Along the noise shield, over 90 meters a 2 meter wide ditch originates, being about 15 centimeters deep
3. The noise shield blocks the liquid flows in lateral direction, except for the door in the noise shield
4. The released liquid reaches the parallel ditches relatively fast (within 2 to 3 minutes)
5. Underneath the ballast and grit, liquid flows, without being clearly visible from above

The following recommendations were made:

1. Develop a pool fire repression strategy, thereby reckoning for the pool shape and surface as a result of the noise shield. In addition, take care of the length of the ditch parallel to the noise shield and the liquid flow underneath the ballast and grit.
2. Reconsider the door frame construction
3. Reconsider the primary direction for repression activities with respect to the noise shield presence
4. Calculate the burning time of the resulting pool and the effect of the noise shield on the heat release rate
5. Assess the influence of noise shields on both sides of the track.

Discussion

The results are based upon one single instantaneous release test. Still, we argue that similar tests would result in similar pool shapes and surfaces. The reason therefore is that most important variables were controlled and that unexpected variables, such as weather conditions, hardly affect the outcomes.

Opposite an instantaneous release, most of the railway leakages are continuous. In general, continuous releases have a smaller release volume but last longer. Therefore, it is interesting to find out what the pool shape and surface would be in case of a continuous release from the rail tanker near a noise shield, for example 100 liters per minute.

The rail tanker was positioned before a (closed) door in the noise shield. Substantial amounts of liquid flew underneath the door frame. It is interesting to find out what the pool shape en surface would be when locating the rail tanker not for a door but only for the noise shield. In addition, it is interesting to find out if in that situation, the liquid will also wash out the earth underneath the door frame.

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Author Biography

Nils Rosmuller has a PhD in transport safety at Delft University of Technology. Since 2001, he is working at the Netherlands Institute for Fire Service and Disaster Management, at the research department. His main fields of interests are transport safety, tunnel safety and the safety of fire fighters.