INF.9

ECONOMIC COMMISSION FOR EUROPE

INLAND TRANSPORT COMMITTEE

Working Party on the Transport of Dangerous Goods

Joint Meeting of the RID Committee of Experts and
the Working Party on the Transport of Dangerous Goods

Geneva, 11-21 September 2007
Item 7 of the provisional agenda

REPORTS OF INFORMAL WORKING GROUPS

Report of the informal working group on the reduction of the risk of a BLEVE

Transmitted by the Government of the Norway on behalf of the working group

1. The working group held a second session from 20 to 22 June 2007 in Tønsberg, Norway under the chairmanship of Mr. Arne Johansen (Norway). The meeting was attended by representatives of Canada, France, Germany, Italy, the Netherlands, Norway, Poland, United Kingdom and the United States of America as well as the following non-governmental organisations: European Liquefied Petroleum Gas Association (AEGPL), European Industrial Gas Association (EIGA) and International Union of Private Wagons (UIP).

2. The documents on the agenda were as follows:

- Report Joint Meeting March 2006, ECE/TRANS/WP.15/AC.1/102 (OCTI/RID/GT-III/2006-A), para. 5-12, 20 and 21;

- Report Joint Meeting working group on tanks, ECE/TRANS/WP.15/ AC.1/102/Add. 1 (OCTI/RID/GT-III/2006-A/Add.1), item 4.

- ECE/TRANS/WP.15/AC.1/2006/8 (OCTI/RID/GT-III/2006/8) (Netherlands),

- Informal document March 06/ INF.3 (Netherlands)

- Informal document March 06/ INF.26 (AEGPL)

- ECE/TRANS/WP.15/AC.1/2007/11 - (The Netherlands) Report of the informal working group on the reduction of the risk of a BLEVE

- Informal document March 07/INF.22 (AEGPL)

- Report Joint Meeting March 2007 ECE/TRANS/WP.15/AC.1/106, para. 62.

3. The meeting was welcomed by Mr. Arne Johansen, who was subsequently elected Chairman of the working group session. The Chairman referred to the key elements of the mandate given by the RID/ADR/ADN Joint Meeting:

(a) Prevention of a BLEVE;

(b) Reduction of the effect of a BLEVE;

(c) Hot BLEVE and cold BLEVE should be considered;

(d) Technical and other measures should be taken into account;

(e) Other matters of principle.

4. The meeting continued on the work agreed upon at the first session of refining, amending and restructuring the list of possible measures that had been set up at the first meeting of the working group.

5. The result of the discussions can be found in annex 1. The revised list of measures can be found in Annex 2 and the revised list of advantages and disadvantages can be found in Annex 3.

6. The meeting made progress in refining and amending the list of measures, and sees the potential of this work leading to reduced risks of BLEVEs and increased safety in the transport of dangerous goods as a whole.

7. The informal working group therefore recommends that an additional session be held. The work of this session will be to finish the work of refining and amending the list of measures and, if possible, prioritise the measures in order to present firm proposals for changes in the texts of RID/ADR.

8. AEGPL invites the working group for the next meeting in Rome. The meeting will be held on 27 and 28 November 2007.

Annex 1 of the report of the working group on BLEVE, Tønsberg, June 2007

- Discussion on measures.

Presentation by AEGPL

The representative of AEGPL presented an analysis of LPG BLEVE incidents recorded in the TNO database. The TNO database has details of 6 LPG road tanker BLEVE incidents occurring in Europe in the last 50 years. AEGPL looks at the root causes of these accidents and attempts to allocate appropriate measures that could have reduced the likelihood of the BLEVE occurring. AEGPL concluded that in 5 out of 6 incidents the tanker was involved in a collision. Therefore the focus should be on preventing the initial accident. Already many measures are taken by the industry to insure safety at transporting LPG by road. AEGPL acknowledges that in 4 out of 6 incidents the performance of the driver was contributory to the incident. According to AEGPL thermal insulation might have prevented one out of 6 BLEVEs in the past. AEGPL does not consider thermal insulation to be a very reliable measure to prevent a BLEVE.

Reactions:
The representative of the Netherlands points out that there are also a lot of near BLEVEs like the accident in Lillestrøm. TNO has data of 40 near misses of a BLEVE from all over the world based on public information. Beside that the database of TNO is not complete on accidents. Therefore the Netherlands is interested in AEGPL statistics on accidents with road tankers carrying LPG to complete the statistics. More data will make the risk calculations more reliable. The AEGPL agrees there is more to look at than accidents resulting in a BLEVE. The TNO database was earlier presented to the working group and therefore AEGPL reacted on this information. The AEGPL information on road accidents involving an LPG-tanker can be made available to the working group.
The representative of Germany says the working group has to decide on whether to cover this kind of low chance, high consequence accidents. . The accident in Los Alfaques, Spain, is an example for that.
The representative of France tells about an accident near Lyon a month ago where three road tankers with some LPG took fire on a parking place. The fire caused a BLEVE of two tankers within a short time. The third tanker was destroyed by the BLEVE and blown away. The accident is investigated, but the results are not yet available. The chance that three road tankers take fire at the same time is very low, therefore criminal actions may have caused this accident. It happened in a fenced area that was not guarded. Fortunately there were no people injured by the accident. A thermal coating would have delayed the BLEVE in this case. But a coating is an expensive measure and valves and smaller fuel tanks are measures more easily to take.
The representative of Norway worries about the rupture of the tanks and is especially interested in train accidents and near accidents. In Norway a cold BLEVE occurred some years ago with an overfilled tank containing ammonia.
The representative of the United Kingdom says that safety valves are recommended in UK against overfilling. Safety valves are not mandatory.

Assessment scheme by the Netherlands

In a document made available to the working group, the representative of the Netherlands suggests to make a choice of criteria to asses the measures resulting in an advice to the Joint Meeting on measures to prevent a BLEVE. The Netherlands uses criteria (reduction of frequency and consequence of a BLEVE) related to calculations on societal risk near transport routes. An explanation on how these calculations are made is transmitted to the participants of the working group. The Netherlands also

considers the costs of measures as a criterion, and the measures have to be feasible and enforceable to be effective.
The representative of AEGPL says that the reduction of frequency will exclude the risk completely.
The representative of the Netherlands agrees on that, but the human factor cannot be excluded in real life and some factors are not controllable. The Dutch calculations on societal risk assume that 50% of the BLEVEs are hot and 50% are cold. In fact there are too little data available for statistics. A sensitivity analysis could correct this basic assumption.
The representative of Germany wants to define a hot and a cold BLEVE before discussing the Dutch calculations on societal risk.
The representative of Canada point at the time-factor for reaction. In case of a cold BLEVE there is no time for action because the BLEVE is instantaneous. In case of a hot BLEVE measures are possible to delay and prevent a BLEVE.
The representative of France thinks the assumptions in the calculation are not correct, in practice the accident in Spain at Los Alfaques was a cold BLEVE with the most casualties ever. Therefore it seems strange that a cold BLEVE has less effect than a hot BLEVE.
The chairman concludes that the difference between a hot and a cold BLEVE is an academic matter and that the mandate of the working group covers both.
The representative of the Netherlands says the transmitted document only shows how the Dutch calculate the risks of a BLEVE. The 35 kW/m^2 heat radiation contour is accepted by risk experts as a model to predict fatalities. The difference in effect between a cold and a hot BLEVE is caused by the difference in pressure level in the tank, 6 bar and 19 bar.
The representative of France objects to the summation of probabilities and is of the opinion that the scheme is very complicated and should be checked by risk experts first before discussing in this working group.
The representative of AEGPL says the quantification is not correct and the effectiveness is unknown.
The chairman concludes there is no agreement on the method of the Netherlands. However there is a need for something to weight the measures. Some prioritising is necessary later on.
The representative of Canada suggests scoring in a matrix on frequency reduction and on consequence reduction.
The representative of France supports the suggestion made by Canada.

Presentation by USA

The representative of the USA shows a short film of a collision test with a coated rail tank wagon normally used for the carriage of chlorine. The tested tank was filled with a non-dangerous gas on the same pressure level as chlorine. The test showed some protective effect of the coating, because the impact area on the tank was larger than the size of the impact tool. There will be further tests with higher speed to know what impact is critical. The USA and Canada also have plans to investigate coating materials that can absorb the energy of an impact.

Discussions on measures

In Annex 2 the advantages and disadvantages of measures are listed.
In this Annex discussions on advantages and disadvantages of measures and the reason to delete certain measures from the list of measures are reported.
Pressure relief valve
More than one PRV on a tank is listed as a disadvantage, because every hole in the tank is considered to be an extra chance for a leak, therefore holes in tanks should be minimised.

Complete thermal protection

On a question how effective a coating is when damaged, the representative of Canada says to consider a defect sized 40 by 120 cm as critical. Canada is planning fire tests tot get data for this critical point.

Sunshield

The representative of the Netherlands remarks that a sunshield does not prevent a BLEVE. The representative of AEGPL says a sunshield can contribute tot the prevention of a cold BLEVE.

Aluminium foils/balls inside tank

This technique is proven for fuel tanks to prevent fire. It is used in Formula 1 cars and military aviation. TNO asked for prove from the industry that this technique also works to prevent a BLEVE with a liquefied gas like LPG. Till now no reaction has been received on this question.
The representative of UIP points out that this technique will require an extra hole in the tank to get the balls in and to get them out for inspections.

Use of integrated telematics system

Early information can be helpful to know which strategy for fire fighting is useful. However there will be no certainty when the tank will fail, especially when the tank is damaged. This system may be required for other dangerous goods in the near future. For security reasons the information shall be protected.

Additional checks during periodic inspection

The representative of Canada mentioned the existence of additional regulations for the checks on possible cracks in the bottom of a tank.

The representative of Germany recalled the difference between the pressure vessel codes of North America and Europe. The subject is already covered by ADR and RID.

Additional periodic inspections

Are the intervals for periodic inspections appropriate? Difference exists between RID and ADR: road vehicles are inspected yearly.

Modal shift

Removed from the list because it is no measure to be part of ADR or RID regulations. It falls outside the scope of this working group. ADR cannot regulate transport by rail or waterway.

However there is a discussion whether the treaty and/or the European directive allows modal shift or not. The representative of the UK mentioned that for those dangerous goods not permitted through the Channel Tunnel there were no alternative road or rail routes and the goods had to go by sea (or air). Norway may forbid the transport of dangerous goods on certain roads, regardless of the alternative. The representative of France says modal shift is not allowed in general according to article 1.9.3 ADR. An alternative route should be available. It is only allowed in specific cases and should be reported to the Joint Meeting. The representative of Germany is of the opinion that it is forbidden to exclude transport when the rules for that mode of transport are followed. Germany has a legal possibility for modal shift.

Transport in daytime or night-time

Removed from the list because this is no solution in general. There may be fewer accidents during night-time, because of low traffic. On the other hand drivers may be less alert at night-time and restrictions of this kind will bring considerable higher costs of transport.

Tank size limitations

In Finland, Sweden and the Netherlands a road tanker with a total weight of 50 tons is allowed. In the other countries the total weight is maximised on 44 tons.
TNO has studied the effect area of the different tanks and does not see advantage in smaller tanks combined with a higher number of transport movements. The representative of Germany is interested in the relation between these variations. TNO has figures on this matter and will send it to the chairman for distribution to the working group.

Speed limitation

This subject cannot be regulated in general terms in ADR and RID. It is a subject to be arranged by national authorities.

Safety management system

In some countries a safety management system is mandatory. In the regulations ADR/RID/ADN the requirement for a safety management system is not very clear. The safety adviser has to deal with safety and should monitor and report the functioning of the safety management system of a transport company. The management of the company is responsible for the functioning of the safety management system. The representative of AEGPL is prepared to make a list of elements to monitor a safety management system. The list can be discussed in the next meeting.
Specific measures identified by the working group such as journey/route management, company control of rule violation, pre-start alcohol control, driver health, company audit program and maintenance are to be arranged within the framework of a safety management system.

Emergency planning and preparedness

There is a company responsibility to inform the fire brigade adequately after an accident but there is also a need for the company to have procedures to deal adequately with any incident that may occur. This is not fully regulated in ADR/RID and can be part of a safety management system.

Fire brigade education and training

Removed from the list because it is not an ADR/RID regulating matter. However the capabilities of the fire brigade are a matter of consideration for the transport company in dealing with incidents.

Vehicle design

Removed from the list because it is too general and already covered by more specific measures.

Research in progress and next meeting

France does research on spontaneous fires with brakes, engines, tires, etc. There were 100 spontaneous fires in 6 months with all kinds of trucks (not only dangerous goods). When the research is ready France will share the information. There is also research done in USA about fires on trucks.
The representative of the Netherlands presents a list of research on some feasibility questions with respect to thermal coatings. The research is planned for this year and some results will be presented in the next meeting of the working group.
AEGPL invites the working group for the next meeting in Rome. The meeting will be held on 27 and 28 November 2007. Arne Johansen offers to chair the next meeting. Anneke Raap offers to make the report.

Annex 2 to the report from the BLEVE-working group

(Items still not considered by the WG are indicated in red text)

Identified technical and operational measures to reduce risk / avoid BLEVEs during road and rail transport.

Table A1	Road and rail - technical measures
A1. 1	Pressure Relief Valve
A1. 2	Complete thermal protection
A1. 3	Sun shield
A1. 4	Aluminium foils / balls inside tank to prevent BLEVE
A1. 5	Protection against overfilling
A1. 6	Additional impact protection
A1. 7	Apply normalised carbon steel
A1. 8	Heat treatment after welding
A1. 9	Excess flow valves
A1.10	Use of telematics
A1.11	Sufficient water supply at loading/unloading sites
A1.12	Tank size limitations

Table A2	Road and rail - Organisational measures
	Operational measures
A2. 1	Additional periodic inspection
A2. 2	Routeing
A2. 3	Speed limitation
A2. 4	Safety management system
A2. 5	Journey management / route management
A2. 6	Company control of rule violation
A2. 7	Pre-start alcohol control
A2. 8	Driver health/drugs/alcohol abuse
A2. 9	Maintenance
A2.10	(Near) accident investigation / reporting
A2.11	Emergency planning and preparedness

Table B	Road measures

B1	**Technical measures**
B1. 1	Accept only single Rigid tank vehicle or semi-trailer for transport of gases
B1. 2	Improve Bumper/Side/Rear impact resistance
B1. 3	Electronic vehicle stability control to avoid overturning
B1. 4	Monitoring systems for brakes/bearings
B1.5	Protection of fuel tank
B1. 6	Automatic engine fire extinguisher
B1. 7	Limit capacity fuel tank
B1. 8	Aluminium foils/balls inside fuel tank
B1.9	Design and construction of fuel tanks
B1.10	Avoiding of sources of heat and ignition
B1.11	Tyre control + inflate with nitrogen
B1.12	Automatic battery master switch
B1.13	Higher integrity (foot-valve) vessel closure; interlocked transfer
B1.14	Non-return valves
B1.15	On Board fire extinguishing equipment
B2	**Operational measures**
B2.1	Lane departure warning / distance warning
B2.2	Defensive driver training

Table C	**Rail measures**
C1	**Technical measures**
C1.1	Wagon design
C1.2	Improve Side/End impact resistance
C1.3	Over buffering tank wagons flammable gases/flammable liquids
C1.4	Crash elements tank wagons flammable liquids/flammable gases
C1.5	Derailment detection
C1.6	Hot box detection
C1. 7	Control systems for brakes
C2	**Operational measures**
C2.1	Dedicated trains for flammable gases only
C2.2	On train segregation / protection wagons

Annex 3 of the report of the working group on BLEVE, Tønsberg, June 2007

- Discussion of advantages and disadvantages of the identified measures

A1.1 Pressure relief valve

Advantages:
- Limitation of the burst pressure (at PRV set point)
- Delays burst
- Protection against overpressure e.g. in case of overfilling
- Some cooling during venting
- Less contents in the tank at BLEVE
- Warning signal to emergency service

Disadvantages:
- In case of overturning limited cooling tank wall in vapour space
- Wrenching off in case of accidents?
- Potential source of leakage due to malfunctioning (especially in tunnels + flammable gases) + ignition source of fire
- Potential negative effects overturning (e.g. torch fire)
- In case overturning lower cooling effect but better than no PRV
- PRV does not prevent overheating vapour space wall (limited delay time to prevent hot BLEVE)
- More than one PRV may be needed?
- Risk from vented gas, especially in tunnels (fire + toxicity + etc). Bursting discs will reduce the risk.

Remarks:

A1.2 Complete thermal protection

Advantages:
- Protection for at least 100 min (pool fire) 30 min (torch fire) if combined with PRV and other tank features (figures derived from US/CAN standard)
- Smaller size of safety valves needed
- Sufficient time for safe fire brigade response to pool fire
- Cost benefit
- Additional mechanical protection for some systems
- Improved emergency evacuation
- Sunshield not required?
- Reduced effect zone due to vented LPG gas

Disadvantages:
- Reduced effect if damaged or degraded
- Reduced external tank inspection
- Water cooling after extinguishing fire hindered
- For existing tanks maximum allowed width exceeded
- May increase corrosion risk
- Efficiency in case of small tanks unknown (torch fires?)
- Reduced pay-load increase in trips increase risks
- Higher centre of gravity
- Rail decrease of pay load due to more wall thickness
- Cost benefit
- 30 min torch fire not enough for fire brigade response
- Reduces the possibility to use thermal cameras during normal emergency actions
- Makes use of ultrasonic filling control devices impossible

Remarks:

A1.3 Sunshield

Advantages:
- Limits the heat input from solar radiation
- Increase in pay load

Disadvantages:
- Problems in cooling down tank under fire
- Risk of cold BLEVE increases if damaged (because of reduced wall thickness)

Remarks:

A1.4 Aluminium foils / balls inside tank to prevent BLEVE

Advantages:
- Redistributes the heat load from outside (cooling effect)

Disadvantages:
- Reduces the payload
- Uncertainty whether it works in the context of BLEVE prevention
- Makes internal inspection of the tank difficult
- Difficulties in obtaining contact with the inner walls of the tank
- May be a problem with traces of sodium hydroxide in tanks

Remarks:
Needs to be checked further if it is suitable for use in liquid gass

A1.5 Protection against overfilling

Advantages:
- Reduces the possibility for cold BLEVE

Disadvantages:

Remarks:
- Procedural
- Electronic control
- Mechanical
- Already exists in RID

A1.6 Additional impact protection

Advantages:
- Better impact strength / puncture resistance

Disadvantages:
- Increased weight

Remarks:
- Tank / service equipment
- Includes measures, B1.2, C1.1, C1.2, C1.3, C1.4

A1.7 Apply normalised carbon steel

Advantages:
- Improving impact strength
- Improve cold temperature properties of steel

Disadvantages:
1. Impossible to retrofit old tanks

Remarks:
Use carbon steel that has been normalized by heat treatment

A1.8 Heat treatment after welding

Advantages:
- Removes manufacturing induced stresses in the tank shell
- Reduces the likelihood of stress induced cracks

Disadvantages:

Remarks:
- Stress relief measure for carbon steel tanks
- RID requires that water quenched steels are not to be used for welded tanks

A1.9 Excess flow valves

Advantages:
- Prevents the release of the substance if the pipework or valve is sheared

Disadvantages:
- Not effective if the pipework or valve is slightly damaged and only has a small leak

Remarks:

A1.10 Use of intergrated telematics system

Advantages:
- Early information on problems before an accident
- Information may be available on the contents
- Information on the tank and its equipment
- “Pinpoints” the place of accident
- Allows for “in-house” fleet management (driver compliance)

Disadvantages:
- Overall coverage not readily available today
- Overall coverage needs expensive infrastructure (Galileo ?) / maintenance

Remarks:
“In-house”-systems already in use
May be required for other dangerous goods in the near future
Security issues

A1.11 Water supply near loading/unloading sites

Advantages:
- Cooling the tank during a fire

Disadvantages:
- Needs sufficient delivering capacity from the water supply system (60 m^3 pr. Hour to cool 100 m^2)

Remarks:

A1. 12 Tank size limitations

Advantages:
- Reduce the consequence of a BLEVE

Disadvantages:
- May increase number of road transports
- May increase the number of possible leakages
- Will increase number of rail transports

Remarks:
Situation vary in Europe today
Optimal size?

A2. 1 Additional checks during periodic inspection

Advantages:
- Makes sure that the critical equipment is working

Disadvantages:

Remarks:
Also includes equipment on the load carrier, e.g. “King Pin”

A2. 2 Routeing

Advantages:
- Avoid areas of large consequence in case of BLEVE

Disadvantages:
-

Remarks:
Similarity exists in RID/ADR Chapter 1.10

A2. 3 Speed limitation

Advantages:
- May reduce the possibility or severity of an accident

Disadvantages:
- May create dangerous situations by overtaking of vehicles
- Problems with enforcement

Remarks:
Already applied in a few European countries
Has been considered for rail, but not pursued

A2. 4 Safety management system

Advantages:
- Additional assures that the company follows the regulations plus appropriate safety measures

Disadvantages:
- Dependant on the quality of the system as set up

Remarks:
- General requirement in Chapter 1.4 for the undertaking to set up the system?
- The Safety adviser monitor and reports?
- For the goods mentioned in Chapter 1.10?
- Goods of Transport Category 0 and 1?
- Goods mentioned in RID/ADR/ADN Directive?
- Shall this comprise all participants?

A2. 5 Journey management / route management

Advantages:
-

Disadvantages:

Remarks:
Part of the Safety management system? (AEGPL)

A2. 6 Company control of rule violation

Advantages:
-

Disadvantages:

Remarks:
Part of the Safety management system? (AEGPL)

A2. 7 Pre-start alcohol control

Advantages:
-

Disadvantages:

Remarks:
Part of the Safety management system? (AEGPL)

A2. 8 Driver healt/drugs or alcohol abuse

Advantages:
-

Disadvantages:

Remarks:
Part of the Safety management system? (AEGPL)

A2. 9 Maintenance

Advantages:

- Assures that the vehicle/wagon is properly maintained

Disadvantages:

Remarks:

Introduce provisions for the carrier similar to the ones for the tank-container 1(.4.3.4(b)) and tank-wagon operator (1.4.3.5(b)) in for road tank vehicles. Text regarding vehicle/wagon maintenance will have to be added.

Part of the Safety management system? (AEGPL)

A2. 10 (Near) accident investigation / reporting

Advantages:

- Catching the incidents makes it possible to implement corrections before a systematic problem escalates into an serious accident

Disadvantages:

Remarks:

SAFEX?

Promote the use of the existing RID/ADR system

A2. 11 Emergency planning and preparedness

Advantages:

- May reduce the effect of an BLEVE by informing and preparing involved parties beforehand

Disadvantages:

Remarks:

Included in the Safety management plan?

RID has regulations for marshalling yards

Fire brigade education and training has to be dealt with in relation to the emergency planning

B1.1 Accept only single Rigid tank vehicle or semi-trailer for transport of gases

Advantages:
- Eliminates domino effects between vehicles of a transport unit with liquefied gases

Disadvantages:
- Not possible to transport tank containers on drawbar vehicles
- More journeys

Remarks:
- Drawbar vehicles are used in some countries today

B1.2 Improve Bumper/Side/Rear impact resistance

Advantages:
- Lower the risk of puncture

Disadvantages:
- Loss of payload

Remarks:
- Standard for side impact protection?
- Recessed valve gear
- Already in place for certain gasses

B1.3 Electronic vehicle stability control

Advantages:
- Reduces risk of rolling-over in curves

Disadvantages:

Remarks:
Work already going on in WP.15/WP.29

B1.4 Monitoring systems for brakes / bearings

Advantages:
- Gives early warning of fire hazard
- Gives information on disc status

Disadvantages:

Remarks:
Work already going on in WP.15/WP.29

B1.5 Protection of fuel tank

Advantages:
- Reduce probability of external fire

Disadvantages:

Remarks:
- Should be applied to all vehicles (WP.29)?
- Assess in combination with measures B1.7, B1.8, B1.9
- Tank material
-

B1.6 Automatic engine fire extinguisher
Advantages: - Reduces the possibility of transfer of an engine fire to the load
Disadvantages:
Remarks: - Established technology - May be retrofitted

B1.7 Limit capacity of fuel tanks
Advantages: - Reduces the size of the pool fire - Increases the payload
Disadvantages:
Remarks: - Change 1.1.3.3?

B1.8 Aluminium foils/balls inside fuel tank
Advantages:
Disadvantages:
Remarks: Needs to be checked further if it is suitable for use in liquid gass

B1.9 Design and construction of fuel tanks
Advantages: -
Disadvantages:
Remarks:

B1.10 Avoiding sources of ignition
Advantages: -
Disadvantages:
Remarks:

B1.11 Tyre control and inflate with nitrogen

Advantages:

Disadvantages:

Remarks:

1. Nitrogen results in lower tyre temperatures than air
2. This measure should include requirements for tyre quality

B1.12 Automatic battery master switch

Advantages:

-

Disadvantages:

-

Remarks:

B1.13 Higher integrity (foot-valve) vessel closure; interlocked transfer

Advantages:

- Keeping the substance in the tank
- Vehicle can not travel without the valve closed

Disadvantages:

Remarks:

- Makes sure that the valve is closed while moving (self closing)

B1.14 Non-return valves

Advantages:

- Prevents the release of the substance if the filling pipework or valve is damaged

Disadvantages:

-

Remarks:

B1.15 On-Board fire extinguishing equipment

Advantages:

- Could prevent escalation of small fire

Disadvantages:

- Systems for wheel fire suppression may be unreliable

Remarks:

On board automatic systems for engine fires see B1. 6

B2 Operational measures

B2. 1 Lane departure warning / distance warning

Advantages:
-

Disadvantages:

Remarks:

B2. 2 Defensive driving training

Advantages:
-

Disadvantages:

Remarks:

C1. 1 Wagon design

Advantages:
-

Disadvantages:

Remarks:

C1. 2 Improve Side/End impact resistance

Advantages:
-

Disadvantages:

Remarks:

C1. 3 Over- buffering, tank wagons for flammable gasses / flammable liquids

Advantages:
-

Disadvantages:

Remarks:

C1. 4 Crash elements, tank wagons for flammable gasses / flammable liquids

Advantages:
-

Disadvantages:

Remarks:

C1. 5 Derailment detection
Advantages: -
Disadvantages:
Remarks:

C1. 6 Hot box detection
Advantages: -
Disadvantages:
Remarks:

C1. 7 Control systems for brakes
Advantages: -
Disadvantages:
Remarks:

C2. Operational measures

C2. 1 Dedicated trains for flammable gasses only
Advantages: -
Disadvantages:
Remarks:

C2. 2 On train segregation / protection wagons
Advantages: -
Disadvantages:
Remarks: