Derailment of LPG tank-wagons followed by a UVCE explosion and an intense fire

29 June 2009

Viareggio

Italy

Freight transport
Derailment
LPG
Maintenance
Tanker-wagon
Explosion (UVCE)

THE FACILITIES INVOLVED

The site :

The accident happened nearby an Italian railway station, in June 2009. The station serves the city of Viareggio, in the region of Tuscany, central Italy. Opened in 1936, it is along the Pisa–La Spezia–Genoa railway line (Tyrrenic coast line), and is also a junction for a secondary railway line to Lucca. The station is currently managed by the infrastructure manager *Rete Ferroviaria Italiana (RFI)*. Train services to and from the station are operated by different railway undertakings, the most important of them being *Trenitalia,* authorized by *RFI* (now by *ANSF - Agenzia Nazionale per la Sicurezza Ferroviaria*).

Due to its position, the station is one of the most important in the north-centre-west coast of Italy and in particular in the Province of Lucca, and it is an important junction connecting Pisa, Livorno and Rome with La Spezia, Genoa, Parma and Milan, providing interchange for passengers to and from all of these cities.

On the 29th of June 2009 (day of the accident), the 50325 train was transporting LPG from the oil refinery of Trecate, near Milan, to a LPG storage depot located in Gricignano, near Naples. The train was crossing the Viareggio's railway station shortly before midnight.

The involved unit :

The train was composed of fourteen rail tankers loaded with LPG, each one with a nominal capacity of 110 m^3 and loaded with 45 t of LPG [2] [5].

The tankers were all leased by *GATX Europe* to the Italian company *FS Logistica* and were built between 2003 and 2006. The lead rail tanker was registered to the Polish railway undertaking *PKP* and the other 13 to the German rail and distribution group *Deutsche Bahn*. Each wagon was equipped with 4 wheel-axes, 2 in front and 2 at the rear (fig. 1) [5] .

The first rail tanker, which derailment created the LPG release, was a cylindrical tank model 462R (fig. 1), 15,95 m long and 3,04 m of diameter [5]. The derailment was probably caused by the rupture of one of the wheels axes.

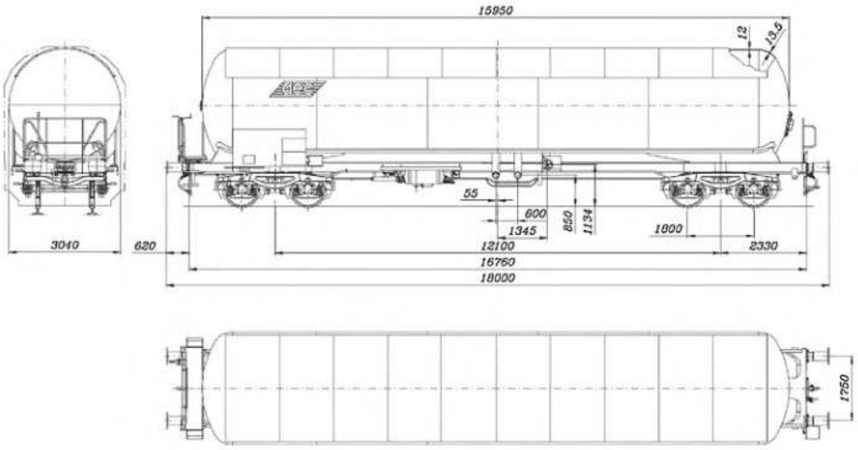

Fig. 1: Rail-tanker 462 R geometrical characteristics (mm)

Tare [t]	33,5
Max speed loaded [km/h]	100
Max speed unloaded [km/h]	120
Max loading per axe [t]	20
Max loading [t] at operative speed of 100 km/h	A=30,5, B=38,5, C=46,5
Total capacity [m3]	110
Design pressure [bar]	25
Working pressure [bar]	25
Test pressure [bar]	25
External overpressure [bar]	1

Tab 1: Rail-tanker 462 R technical form (GATX). Categories A, B, C are referred to the International Wagon Regulations (RIV).

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident :

On the 29th of June 2009, shortly before midnight, the 50325 train derailed while crossing the station of Viareggio and five of fourteen rail tankers overturned (fig. 2) [4]. The train was travelling at about 90 km/h (below the speed limit set at 100 km/h) [1] [5]. The first rail tanker plowed the ground and breached probably after the hit with a signaling stake beside the railway or with a rail switch (this point is at the time of writing under investigation during the trial) : the impact caused a hole, about 40 cm long and about 2 to 5 cm wide [3] [2], from which all the LPG escaped (45 t). No loss of containment occurred from the other 13 rail tankers vessels.

The LPG was released: the liquid phase formed a boiling pool on the ballast while the dense gas started spreading and evaporating in the atmosphere. Some people living in the surrounding could hear a loud noise like a gas emitted by a valve, and went to the open windows to see what was going on. They could see a white and short cloud of gas that was moving towards their houses. The dense gas cloud moved radially from the derailed tank mainly across the railway line, due to the rather calm weather conditions. Meteorological conditions at the moment of the release were: 22°C, 92% relative humidity, stability class F, wind almost absent (on the seaside, wind at 0.3 m/s blowing towards the E-SE direction was recorded at the moment of the accident) [4].

The gas cloud found its way towards via Ponchielli, which is a narrow and long street parallel to the railway line with more than forty-two houses facing on it. A rather loose cement fence divided via Ponchielli from the station and the gas cloud went through it. Finally, the LPG cloud, also due to the hot night that forced people to leave their windows open, entered the ground floors and basements and accumulated up to flammable limits. According to the report of the engine drivers, no immediate ignition followed the release. It is not clear if the first ignition source was nearby the railway or among the surrounding houses (more probable), however when it occurred a fire propagated through the flammable portion of the cloud (FLASHFIRE), reached the houses and caused some deflagrations (VCE) [2].

No BLEVE occurred as the LPG cloud did not involve the other wagons and also due to the subsequent heavy cooling operations made by the firefighters.

Some witnesses reported 2 min, others 5 min, as the time elapsed between the crack opening and the first explosion. A short time later, two further explosions were heard [2].

Buildings up to 200 m from the release point were damaged due to the collapse of some of the apartments and glasses were projected over an extended area. A large-scale fire developed near the damaged rail tanker. Thirty-two people died (the last one died exactly two months after the accident); more than thirty people were seriously injured. About 1100 people were evacuated for safety reasons [3].

The national and regional fire Emergency Centers dispatched support fire teams, which came from all of the Provincial Fire Departments of Tuscany and neighbouring regions. About 300 firefighters were involved in the operations. At early dawn, all fires were extinguished and brought under control. Fire operations continued during the night and all day on June 30. Early in the morning on June 30, clean-up of the collapsed buildings debris and rescue operations for injured people were started. The firefighters removed the LPG load from the undamaged derailed tankers working 24 hours a day with no interruptions from the morning of June 30 to the evening of July 2 [3] [4].

The main cause of the accident seems to be a mechanical failure in the first LPG tanker of the train. One of the axles was found broken probably due to a fatigue crack (also under investigation).

Fig. 2

The drivers felt a strong jerk on the traction; they went to the window and saw the first tank car gone off the rails. The drivers applied immediately the emergency brakes and they started to smell the gas. Before the ignition of the gas cloud, the drivers had sufficient time to shut-down the engine (e.g., lowering the pantograph), remove some documents and run about 150-200m away from the railway line. They took shelter behind a wall of the station and immediately after, the explosions and the fire occurred [2] [4].

The railway accident investigation branch of RFI (that is the state owned railway infrastructure manager) opened a technical investigation to find out the cause of the accident, in parallel and independently from the investigation aimed to identify any possible responsibilities in the lawsuit.

Consequences of the accident :

The accident caused serious damages to people and generated distress in the population, which was taken into account by the media and the public authorities.

The scenarios occurred were FLASHFIRE followed by VCEs, while BLEVEs did not occur due to the LPG cloud spreading around without involving the other rail tankers.

Immediately after occurrence, other trains (intercity and regional) which were arriving at the Viareggio station were stopped.

The buildings along via Ponchielli, and the neighbouring streets were on fire, with approximately 200 metres of flames on both sides of the road. Five houses collapsed due to inner explosions. Almost all the remaining houses of via Ponchielli burned due to the subsequent fires that engulfed also other areas surrounding the station (fig. 3) [4] including trees in a small public children's park some bushes and parked cars and trucks (fig. 4) [4]. The poolfire from the liquid-phase LPG could be noticed far away with flames as high as 20-25 m [2] [3].

Fourteen people died immediately: some under the collapse of buildings or suffocated by the smoke inside their houses ; some burned because standing inside the flash area. The fatalities rose to 22 people the day of the state funerals. Finally, there were 32 fatalities (one woman had a heart attack), the last person died exactly two months after the accident. More than thirty people were seriously injured. About 1100 people had to evacuate their homes for safety reasons.

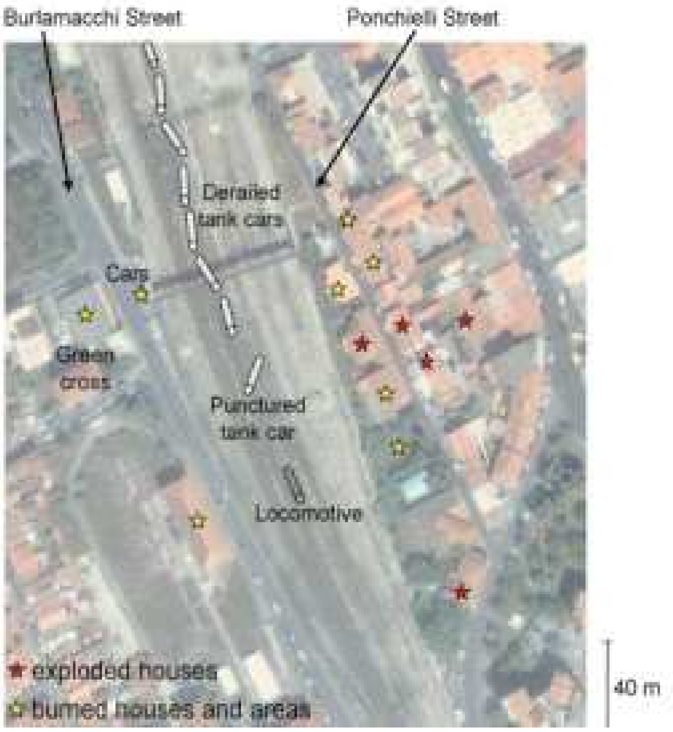

Fig. 3

The overall damages for the population and the infrastructures have been preliminarily estimated to a few tens of millions euros, [2].

Though the accident is not a Seveso accident, it has been analysed because it results to be the worst railway accident ever happened in Italy related to the transportation of dangerous substances, and the most serious accident in Italy involving LPG.

Fig. 4

The European scale of industrial accidents

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in February 1994 by the Member States' Competent Authority Committee for implementing the '*SEVESO II*' directive on handling hazardous substances, and in light of the information available, this accident can be characterised by the four following indices:

The parameters composing these indices and their corresponding rating protocol are available from the following Website : http://www.aria.developpement-durable.gouv.fr

The full content of the crashed LPG tank was released and burnt. These 45 t (22.5 % of the upper-tier Seveso threshold) made the "dangerous material released" index climb up to 4.

In total, 32 people with no relation to rail freight lost their life and more than 50 were severely wounded : the human impact index raises at 6.

Finally, the total economic loss incurred to third parties stands at several tens of million €. The "economic consequences" are rated 6.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The accident is still under investigation and the trial is not concluded, so until now we can only assume on the basis of a preliminary analysis, some direct causes :

1) Mechanical failure of the front axle of the first wagon. The failure occurred exactly between the wheel and the axle (fig. 5) [7] probably when the train was at the entrance of the station, and the train derailed after about 700-800 m [7], then the truck (the whole complex wheels-axle) was projected at about 70-80 m away [7], and the first wagon overturned (fig. 6a). The section of the rupture looks smooth on more than 90% of the surface (fig. 6b and 6c) [4], the other part of the section appears instead coarse and corrugated. These elements seem to suggest a fatigue-type rupture [1] [4], that developed in a relatively medium - long period, and consequently raise questions about identification of the problem, control inspection procedures and adequacy of verification techniques applied: is there any evidence that this kind of rupture happened in the past ? Was a risk analysis conducted identifying this kind of failure and possible consequences? Do tanker control inspection procedures require specific attention to the system wheels - axle? What is required in terms of integrity test of that specific part? Is the kind of test required sufficient to identify the potential problems ? Is the time period between controls short enough to prevent that kind of failure? In case of transportation of dangerous substances are these controls sufficiently stressed?

2) Train speed at about 90 km/h: it was below speed limit set at 100 km/h [1] [2] ; we believe that a specific risk analysis could be helpful to establish if more restrictive speed limits, time of transit or any other particular additional precaution are required when dangerous substances are in transit nearby densely populated areas.

3) A breach, about 40cm long and 2-5 cm wide (fig. 8) [4], was produced in the first rail tanker after the derailment. The cause of the breach is still under discussion, highly suspected are either the I-shaped stakes disposed close to the railway line (fig. 7) [4], used as references to control rail stability, or the "common crossing" (or "frog") of a rail switch [1].

Fig. 5

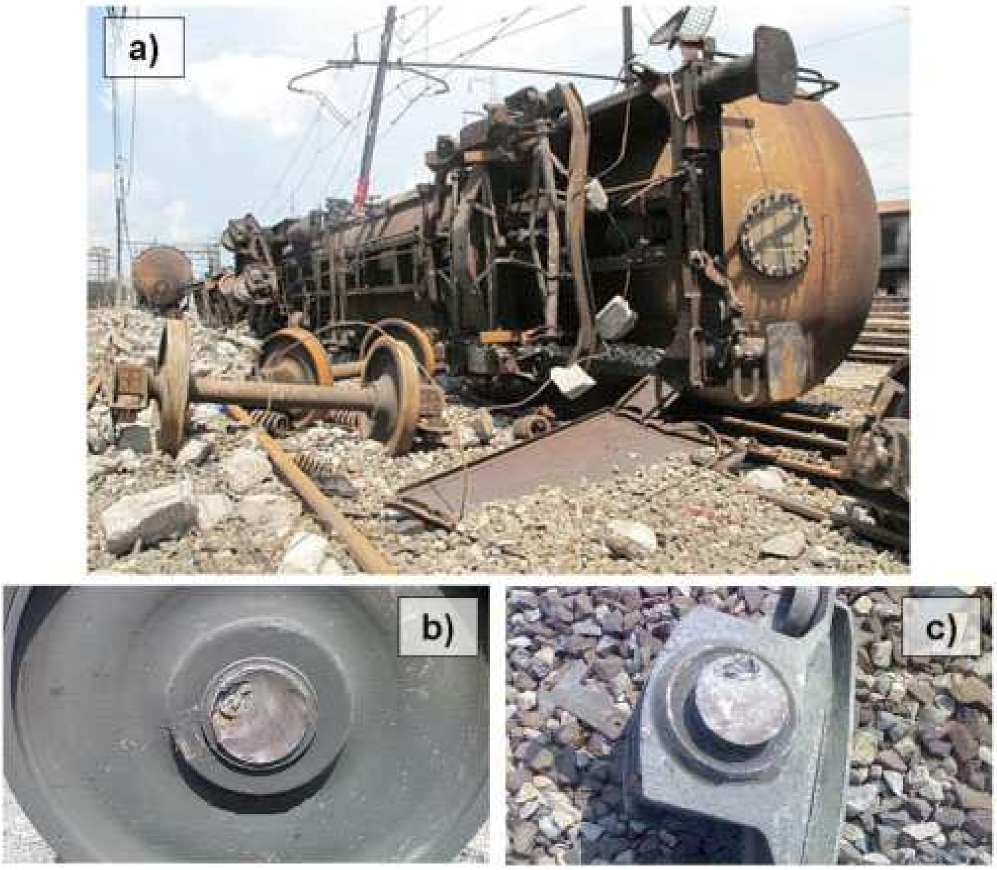

Fig. 6

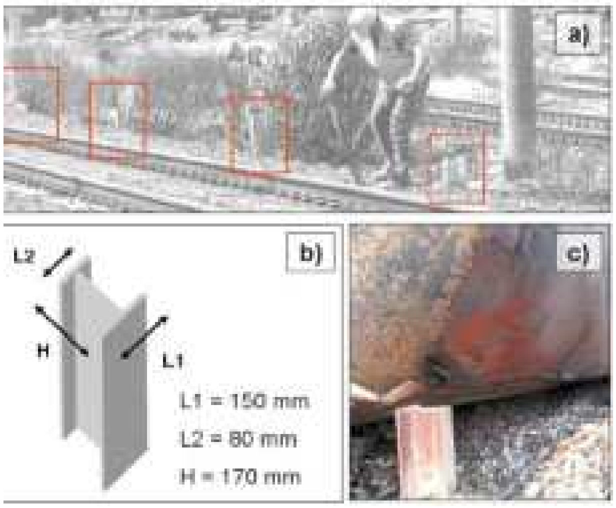

Fig. 7

Fig. 8

ACTIONS TAKEN

Emergency measures :

After the accident a joint emergency centre (COM) for rescue coordination and an advanced medical post (PMA) were set up. The national and regional fire emergency Centres dispatched support fire teams, which came from all of the Provincial Fire Departments of Tuscany and neighbouring regions. About 4 hours later, early at dawn, all fires were brought under control.

The fire teams had to face difficult scenarios. On the north side of the railway, the buildings along via Ponchielli and the neighbouring streets were on fire, with approximately 200 metres of flames on both sides of the road. The trees in a small public children's park were also burning, as well as some bushes and cars and trucks parked along the road. Making their way through the flames, the firefighters encountered people lying down who were engulfed in flames while trying to escape from the area; crews extinguished the flames and handed the injured over to the Emergency Health Services. Firefighters rescued people from burning houses, having to access some buildings through first floor bedroom windows to reach injured people and take them to safety. Besides these rescues, three buildings collapsed, and several victims were trapped under the rubble. Even wearing the complete required personal protective equipment, firefighters needed additional protective cover from their colleagues' hoses in order to endure the strong thermal radiation.

In the railway area, in order to avoid flames threatening the other intact LPG tankers, fire teams proceeded to cool the tankers closest to the one on fire. The other fires, were kept under control in order to ensure a complete combustion of the gas released. Wooden sleepers were burning, as well as electrical and transmission cables, brushwood, shrubs and various other combustible materials along the railway [3] [4].

An Advanced Command Post (PCA) for the operation command was activated immediately in a safe zone close to the intervention area. All fire teams arriving on site were sent to the PCA where they received instructions for positioning and tasks to be carried out. Fire operations in via Ponchielli and along the railway line continued during the night and all day on June 30. Early in the morning on June 30, clean-up of the collapsed buildings debris was started in order to search for people trapped under the rubble, and to remove unsafe building elements.

The National Fire Emergency Centre immediately alerted and deployed the regional advanced CBRN (Chemical-Biologic-Radiological-Nuclear) units to the site in order to carry out the LPG transfer operations from derailed tankers to other tankers and allow its removal to a safe place. CBRN units from the provincial fire departments of Tuscany, as well as the Regional Advanced Unit of Tuscany, were called to the site to detect any trace of LPG gas and constantly monitor the derailed tankers. CBRN units from the provincial fire departments of Venice, Milan and Rome reached the incident site during June 30, to start preliminary operations – the setting up of special safety and gas transfer equipment and the deployment of fire teams in charge of ensuring support and assistance to operations (fig. 9) [3] [4]. From the morning of June 30 to the evening of July 2, working 24 hours a day with no interruptions, about 700 tons of LPG were transferred to a total of nine tank lorries [3] [4].

Fig. 9

Official action taken :

The railway accident investigation branch of RFI has opened an investigation about the cause of the accident, in parallel with an official public inquiry. A detailed investigation is still open, and involves 349 inquired parts, 8 companies and 38 inquired persons [7]. The trial started in the beginning of 2011.

LESSONS LEARNT

The *European Directive on rail transport* was adopted in Italy with the D.Lgs. 162/2007 (2004/49/CE e 2004/51/CE Directives). The decree introduces the obligation of adoption of a Safety Management System (SMS) in rail transport. The SMS is required to cover safety requirements on the system, including safe management of infrastructure and of traffic operation and the interaction between railway undertakings and infrastructure managers.

Art. 13 of the Decree says that :

- the SMS shall meet the requirements and contain the elements (listed in Annex III of the Decree), adapted to the character, extent and other conditions of the activity pursued. The SMS shall ensure the control of all risks associated with the activity of the infrastructure manager or railway undertaking, including the supply of maintenance and material and the use of contractors.
- It shall also take into account, where appropriate and reasonable, the risks arising as a result of activities by other parties.
- The SMS of any infrastructure manager shall take into account the effects of operations by different railway undertakings on the network and make provisions to allow all railway undertakings to operate in accordance with Technical Specifications for Interoperability (TSIs) and national safety rules and with conditions laid down in their safety certificate. The SMS shall furthermore be developed with the aim of coordinating the emergency procedures of the infrastructure manager with all railway undertakings that operate on its infrastructure.

The basic elements of the SMS, specified in Annex III of the Decree, are :

- a safety policy approved by the organisation chief executive and communicated to all staff; qualitative and quantitative targets of the organisation for the maintenance and enhancement of safety, and plans and procedures for reaching these targets ;
- procedures to meet existing, new and altered technical and operational standards or other prescriptive conditions in TSIs, or in national safety rules referred to in Article 11 and Annex II, or in other relevant rules, or in authority decisions; and procedures to assure compliance with the standards and other prescriptive conditions throughout the lifecycle of equipment and operations ;
- procedures and methods for carrying out risk evaluation and implementing risk control measures whenever a change of the operating conditions or new material imposes new risks on the infrastructure or on operations ;
- provision of programmes for training of staff personnel and measures to ensure that the staff's competence is maintained and tasks are carried out accordingly ;
- arrangements for the provision of sufficient information within the organisation and, where appropriate, between organisations operating on the same infrastructure ;
- procedures and formats for how safety information is to be documented and designation of procedure for configuration control of vital safety information ;
- procedures to ensure that accidents, incidents, near misses and other dangerous occurrences are reported, investigated and analysed and that necessary preventive measures are taken ;
- provision of plans for action and alerts and information in case of emergency, agreed upon with the appropriate public authorities ;
- provisions for recurrent internal auditing of the safety management system.

Comparing the above elements with the *Seveso* SMSs ones, applied to the fixed installations, it is possible to put in evidence that the general SMS frameworks could be compared and have different elements in common, but :

- the Seveso SMS looks more logically structured, starting from the safety policy and ending to the audit, dealing with different issues logically ordered: personnel organization/training, risk assessment, operational control, management of change, emergency planning

- risk assessment does not appear enough stressed as in the *Seveso* Directive, which considers the identification of substances and processes hazards ; the definition of safety requirements and criteria, and the identification of possible accidental events, safety analysis and residual risk. The rail transport SMS seems, instead, to consider the risk assessment only in case of change of the operating conditions, and provides general criteria to do it.

European Directives on rail transport of dangerous substances (90/EC Directive of November 2006 and 68/EC Directive of June 2008), implemented in Italy by Ministerial Decrees, seem not to consider, in the opinion of the authors, in a appropriate way the risk assessment issues, if compared with fixed industrial establishments storing similar quantities of hazardous substances. These Directives are essentially aimed at improving the safety measures and harmonizing the European standards in this field, also by application of the 2009 edition of ADR/RID/ADN regulation. The ADR/RID/ADN regulation itself drives Member States to a stricter and binding safety technical requirements for transport of dangerous substances, but does not still consider risk assessment issues and a more well-structured SMS, at the same level developed according to Seveso Directives.

Though the Viareggio accident is not a Seveso accident, it result to be the worst railway accident ever happened in Italy related to the transportation of dangerous substances, and the most serious accident occurred in Italy involving LPG.

For the reasons explained above, it could be very important to analyse this accident (and the similar ones) by applying a well-structured SMS, starting from the critical safety issues appeared and summarized below, which can considered as first comments-remarks after accident analysis :

a) fatigue-type rupture of the axle, if confirmed by the conclusion of the investigation, will point out the need to reinforce the check-inspections, in particular in terms of :

    o efficiency of the inspections-controls actually in force for the mechanical device origin of the accident (axle-wheels system) ;

    o review of techniques and procedures for this type of mechanical device, and if needed addition of new and more specific control tests ;

    o review of the specific requirements to be established (responsibilities, technical specifications, procedures, etc.) for regulating the case of involvement of more contractors and the use of subcontractors (in particular for maintenance activities).

b) train speed at about 90 km/h and presence of structures (stakes/switches) along the railroad line: a specific risk assessment should have been used to assess their compatibility. A risk assessment study, in particular for transport of dangerous substances, should consider all the risk factors present along the railroad line (i.e. allowable speed of the train, presence of nearby structures, level of vulnerability and urbanization of crossed areas, etc.) and its results could consequently useful to identify, if needed, additional technical/managerial measures to adopt, for example :

    o speed limitations to trains carrying dangerous substances when crossing populated areas ;

    o additional safety devices like RTB installation (temperature-detectors of the truck), Derailment Detection Device (DDD) [1] ;

    o adoption of different types of stakes/switches in the rail (plastic or metal-alloy stakes with low mechanical resistance) or possible prohibition of them ;

    o etc.

On the basis of the elements indicated above, even if the rail transport is excluded from the Seveso scope, it can be useful, also as an exercise, to refer to Seveso SMS elements for the analysis of the accident, especially considering that the large quantities of dangerous substances carried by the rail tankers can be of the same order as that present in the storage depots located in the industrial establishments.

We experienced the SMS faults analysis used by the Seveso inspectors in Italy, which makes reference to a check list of SMS elements (see Annex 1), consistent with the SMS structure given in the Annex III of Seveso Directive. The analysis aims to point out the SMS faults identified as root causes of the accidents ; in Viareggio accident the main elements available seem to highlight the following SMS faults:

- faults in identification of possible accidental events, safety analysis and residual risk; faults in planning and updating of technical and/or managerial solutions for the reduction of risks (Seveso inspectors check list elements 3.i, 3.ii, 3.iii) ;

- faults in identification of plants and equipment to be subject to inspection plans, and in maintenance procedures; faults in clear definition of maintenance activities responsibilities, and in communication of accomplishment of the maintenance-work, re-examination to assure the proper recovery of correct operational standard (elements 4.i, 4.ii, 4.iii, 4.iv, 4.v).

In conclusion, all the management faults previously identified as hypothetical critical issues causing the Viareggio accident could probably, if confirmed after the conclusion of the trial, show the need to put more emphasis on risk assessment procedures in the rail transport of dangerous substances and on consequent actions more similar to those already required for the operators subjected to the Seveso Directives. The authors believe worth to consider this issue together with the need of a higher level of harmonisation of the maintenance regimes existing across Europe, in the European regulation for transport of dangerous substances.

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Annex 1: Elements of SMS Seveso inspectors check-list

1. The document on prevention policy
1.i Definition of prevention policy
1.ii Verification of the SMS structure and its integration with the establishment organization
1.iii Policy Document Contents

2. Organization and personnel
2.i Definition of responsibilities, resources and planning of activities
2.ii Information activity
2.iii Training and formation activities
2.iv Human factors, operator/plant interfaces

3. Evaluation and identification of major hazards
3.i Identification of substances and processes hazards; definition of safety requirements and criteria.
3.ii Identification of possible accidental events, safety analysis and residual risk
3.iii Planning and updating of technical and/or managerial solutions for the reduction of risks

4. Operational control
4.i Identification of plants and equipment to be subject to inspection plans
4.ii Process documentation
4.iii Operating procedures and instructions in normal, abnormal and emergency conditions
4.iv Maintenance procedures
4.v Materials and services procurement

5. Management of change
5.i Technical and organizational plant modifications
5.ii Documentation updating

6. Emergency planning
6.i Accident analysis, planning and documentation
6.ii Roles and responsibilities
6.iii Controls and verifications of the management of emergency situations
6.iv Alarm and communication systems and support to the external intervention

7. Monitoring performance
7.ii Performance evaluation
7.ii Accident and near-accident analysis

8. Audit and review
8.i Safety audits
8.ii Review of safety policy and of Safety Management System.