TECHNICAL TRANSACTIONS 12/2019
MECHANICS

DOI: 10.4467/2353737XCT.19.129.11454
SUBMISSION OF THE FINAL VERSION: 11/12/2019

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Risk minimization methods for loading dangerous goods into tanker trains

Sposoby minimalizacji ryzyka podczas załadunku materiałów niebezpiecznych do cystern kolejowych

Abstract

The paper focuses attention on the problem of increased risks during the loading and unloading of railway tankers. To evaluate the risk which may occur during loading dangerous goods into tanker trains, the loading processes have been divided into seven stages. Based on HIRA risk analysis, for each stage of improvements, Quick Kaizen tasks were proposed. Special attention was paid to possible improvements in technical means, tools and processes. Thanks to the proposed improvements, it is possible to increase safety, not only during the loading of dangerous goods, but also in cases of loading and transportation of standard cargoes.

Keywords: risk evaluation, tanker train loading, HIRA analysis, dangerous goods

Streszczenie

W artykule zwrócono uwagę na problem zwiększonego poziomu ryzyka powstającego podczas załadunku i rozładunku cystern kolejowych. W celu jego oceny dokonano podziału procesu załadunku na siedem etapów oraz uwzględniono dodatkowo prace konserwacyjne i sytuacje nietypowe, które mogą wystąpić podczas załadunku materiałów niebezpiecznych. Na podstawie przeprowadzonej oceny ryzyka w każdym z poszczególnych etapów utworzono zbiór zaleceń pozwalających na zwiększenie bezpieczeństwa pracowników. Zwrócono szczególną uwagę na możliwe usprawnienia wykorzystywanych środków technicznych, narzędzi oraz sposobu postępowania. Dzięki przedstawionym w artykule zaleceniom możliwe jest zwiększenie poziomu bezpieczeństwa nie tylko podczas załadunku materiałów niebezpiecznych, ale także w przypadku przewozu ładunków standardowych.

Słowa kluczowe: ocena ryzyka, załadunek cystern, analiza HIRA, materiały niebezpieczne

1. Introduction

During loading process of dangerous goods into a tanker train, employees are exposed to vapours and concentrations of the substance being transported. These cargoes are transported in Z type railway wagons (Fig. 1) [9]. Transportation of dangerous goods is regulated by international regulations called RID (Fr. Règlement concernant le transport international ferroviaire des marchandises dangereuses) constituting annex C to the Convention on International Carriage by Rail (COTIF) of 9.05.1980 [11]. COTIF 1999 regulations apply strictly in railway transport in the case where the location of the cargo shipment is located in two countries-signatories of COTIF. These regulations are also used if the place of shipment or reception is located in one signatory country and if rail transport is to be dealt with as one of the elements of the transport process (transport chain) [4, 7].

Fig. 1. Rain wagon, type Zaces [12]

The Minister of Labour and Social Policy Regulation of 23 June 2014 determines the concentrations of harmful factors of chemical and particulate pollutants in the work environment [5]. It determines the highest acceptable concentration of harmful factors for healthy, established as [3]:

- **highest acceptable concentration (NDS)** – weighted value of average concentration, which can impact on the employee during an 8-hour daily and average weekly working time during its activity should not cause negative changes in his state of health and the health of his future generations; working time is defined in the Act of 26 June 1974 – Labour Code;
- **highest acceptable instantaneous concentration (NDSCh)** – average concentration which would not cause negative changes in employee health, if it is present in working

environment for no more than 15 minutes and no more than twice during a work shift, in an interval of not less than 1 hour;

- **highest acceptable ceiling concentration (NDSP)** – the concentration value which due to the risk to the health or life of the employee cannot be exceeded in the work environment at any time.

For the case presented in this paper, during the loading process, employees are exposed to vapours and harmful concentrations of the substances being loaded above the maximum acceptable concentration (NDS) for approximately 110 minutes at a distance of 5 m from the loading funnel. At a distance of 15–50 m, it is possible to smell the odour, which creates extreme discomfort [6, 1]the paper addressed a fuzzy extended fault tree analysis (FFTA).

The stages of the process of loading a tanker train are shown in Figure 2.

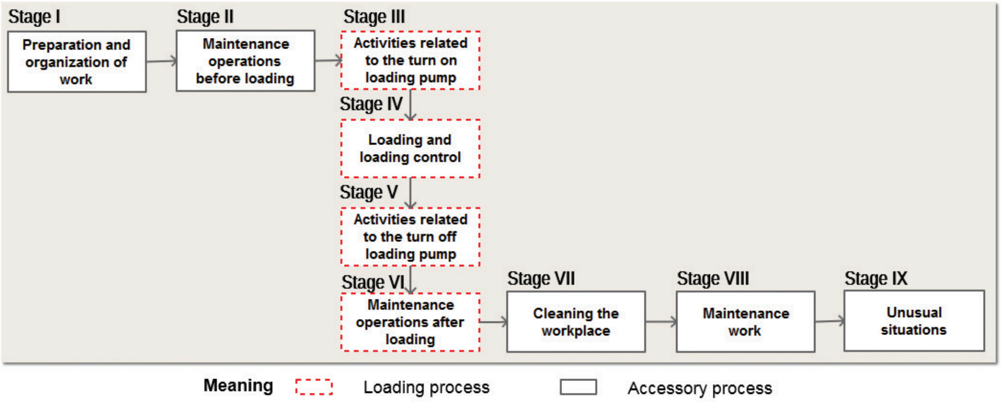

Fig. 2. Stages of the process of loading a tanker train

The process of loading a tanker train can be divided into stages. The risk to human safety in regard of the loading process occurs in steps III–VI.

Under Stage I (Preparation and organisation of work), the following sub activities have been separated out: participation in the briefing shift, moving to workplace, tool preparation, checking exceedances of the concentration on the central gas detection system, checking tanker, handles checking the validity of the revision of the tank and checking the temperature of the tank.

Under Stage II (Maintenance operations before loading), the following sub activities have been separated out: connecting the grounding of the tanker, moving around platforms in the region of loading, checking breathing valve on the tanker, unscrewing the hatches of the tanker, inserting loading funnel to the tanker, and checking the encapsulation.

Under Stage III (Activities related to the turn on loading pump), the following sub activities have been separated out: checking the status of devices for loading, valve manipulation (setting the path), setting the amount of product loading, starting the pump.

Under Stage IV (Loading and loading control), the following sub activity has been separated out: controlling the quantity of goods loaded.

Under Stage V (Activities related to the turn off the loading pump), the following sub activities have been separated out: turning off the pump, manipulation of valves (closing the path), removal loading funnel from the tanker, and closing the hatch of the tanker.

Under Stage VI (Maintenance operations after loading), the following sub activities have been separated out: taking a sample, closing the hatch of the tanker, sealing of all valves, gate valves and top hatch (after taking samples for analysis), raising the loading platform, securing loading funnel, and detaching the grounding connection of the loaded tanker.

Under Stage VII (Cleaning the workplace), the following sub activities have been separated out: cleaning the tray, cleaning the operator's room, cleaning the area of the loading facility.

Under Stage VIII (Maintenance work), the following sub activities have been separated out: maintenance of valves, maintenance of fittings, maintenance of wires.

Under Stage IX (Unusual situations) the following sub activities have been separated out: unsealing standard valves or valves completely emptying the tanker, unloading the tanker.

2. HIRA hazard identification and risk analysis

Securing and proper loading of cargo have a significant impact on human safety. Loading should be done in such way as to minimize the risk of potential danger situations and their results [8].

Risk analysis and determination of the value of safety indicators allows possible risks and their consequences to be visualized [6]. The most common types of risk analyses are HIRA and FMEA, which are performed prior to the planned implementation of improvements [10, 2].

For the stages listed in chapter 1, the identification of risk and its consequences has been conducted. For the identification of risk and its analysis, a HIRA (*Hazard Identification and Risk Analysis*) analysis has been performed. This allowed all potential risks which may occur during the loading or unloading of the tanker to be identified. For analysis, the matrix evaluation in accordance with table 1 has been constructed.

For the calculation of the risk assessment the following formula has been used:

$$R = w_c \cdot p_c + w_p \cdot p_r + w_e \cdot e + w_{sp} \cdot s_p + w_i \cdot i_r \tag{1}$$

where:

- R – coefficient of risk,
- w_c – weight of potential severity of injury,
- w_p – weight of risk perception,
- w_e – weight of ergonomics,
- w_{sp} – weight of working environment,
- w_i – weight of other risk,
- p_c – potential severity of injury,
- p_r – risk perception,

e – ergonomics,
s_p – working environment,
i_r – other risk.

The weights are established as constant for this method and the values are presented in Table 1. The value of a factor is dependent on the importance (e.g. the potential severity of injury for importance: heavy, deadly $p_c = 3$).

Table 1. Matrix evaluation of risk for HIRA analyze

	The potential severity of injury	The perception of risk (risk awareness by people)	Ergonomics	Working environment	Others eg.: The risk to external staff	Value (p)
Importance	Heavy, deadly	Careless	Not natural	Wrong	Big	3
	Serious	Normal	Slightly unnatural	Problematic	Average	2
	Light	Very important	Normal	No problem	Low	1
	No impact	Safe	Natural	Comfortable	Absence	0
Weight (w)	$w_c = 2$	$w_p = 2$	$w_e = 1$	$w_{sp} = 1$	$w_i = 1$	

If the value of a risk coefficient is in the range 1–6, it is classified as low risk. If the value equals 7, the risk is considered as normal. Whereas, if the value is in the range 8–21, it is classified as average. In the case when this value exceeds 16, the risk is classified as high.

When analyzing all the activities carried during the loading of tankers, the following were identified:

- 248 activities of low risk,
- 44 activities of normal risk,
- 5 activities of average risk,
- 0 activities of high risk.

Based on this analysis, it was found that low risk activities do not require improvements. Table 2 shows groups of activities of normal and average risk level. No high risk activities were identified. For each activity, improvements in the form of Quick Kaizen (QK) have been assigned.

The Kaizen method for processes is characterized by a high quantity of small improvements, which require little effort. Due to this there can be many improvements, and they are easy to implement [1, 2].

In the case analyzed, Kaizen methods were used to adjust the technical elements of the system.

Table 2. Identification of risk taking into account the activities performed by employees

Description of the risk (hazard)	Consequence	Activity	Quant.	QK
uncontrolled movement loading funnel	bruises, sprains	Maintenance operations before loading	2	6
vapours caused by leaks around the cone	poisoning	Maintenance operations before loading	4	5
		Loading and loading control	4	5
		Activities related to the turn off loading pump	4	5
difference in platforms levels	contusion	Maintenance operations before loading	2	7
moving parts	contusion	Maintenance operations after loading	2	6
corroded elements of the thermal insulation of the collector at the height of the loading	contusion, wound	Preparation and organization of work	14	1
		Maintenance operations before loading	4	1
		Activities related to the turn on loading pump	7	1
		Loading and loading control	4	1
		Activities related to the turn off loading pump	2	1
		Maintenance operations after loading	7	1
		Cleaning the workplace	7	1
		Maintenance work	7	1
		Unusual situations	14	1
corroded entrance stairs	sprains, breaks	Maintenance operations before loading	2	2
		Activities related to the turn on loading pump	9	2
		Loading and loading control	4	2
		Activities related to the turn off loading pump	12	2
		Maintenance operations after loading	12	2
		Cleaning the workplace	2	2
		Maintenance work	7	2
		Unusual situations	2	2
height	breaks, contusion	Maintenance operations before loading	2	4
protruding arm of bolts on the intake manifold	bruises, sprains	Maintenance operations before loading	4	3
		Maintenance operations after loading	2	3

3. Possible improvements using Quick Kaizen

Based on the HIRA analysis, seven small improvements (planned as Quick Kaizen) have been proposed. Their description, causes of risk, and corrective actions have been shown above. The part of the tanker used in the loading process is shown in Figure 3.

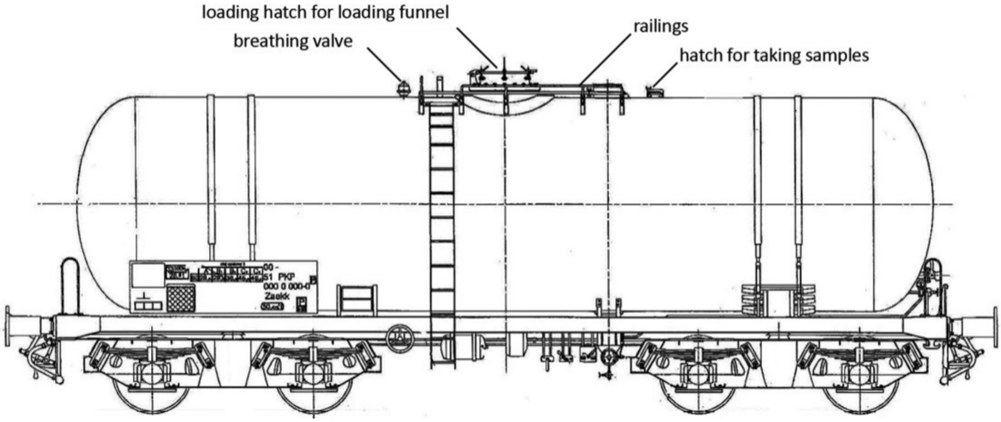

Fig. 3. Selected part of tanker used in the loading process

QK 1 – Vapour collector. Workers are exposed to risk during activities like: checking handle tanker, checking the validity of the revision of the tank and checking the temperature of the tank, grounding the connection of the tanker, cleaning the area of the loading facility, maintenance of fittings, and loading and sealing of the tanker. They are exposed to the risk of insulation falling with the vaporcollector and striking the employee operating the loading station. Possible causes of corrosion include the following: adverse weather conditions, lack of periodic inspections, leak on the pipe suction vapor, incorrectly matched material and incorrectly matched thermal insulation.

As part of the corrective action, it is justified to replace corroded parts of the heat shield of the vapour collector.

QK 2 – Corrosion and anti-corrosion coating. Workers are exposed to the risk of stumbling or falling when entering the loading platform to perform such tasks as: pressing the breathing valve, securing the loading funnel, moving and inserting the funnel into the tanker, checking and controlling the pipe of the hopper and the tank, manipulating valves, maintenance of fittings, and unloading or sealing the tanker. As possible corrosion causes, the following can be listed: adverse weather conditions, lack of periodic inspections, leak on the pipe suction vapour, incorrectly matched material, and incorrectly matched thermal insulation.

As part of the corrective action, replacement of corroded parts of the heat shield of the vapour collector is justified.

QK 3 – Valve of the intake manifold vapour. During the performance of all actions on the loading platform, workers are exposed to being struck by the protruding bolts arm on the vapour intake manifold, which is extended in the closed position on the loading platform. Possible causes are: a protruding flap in the closed position, a too long arm of the valve, and the vertical position of the valve.

Within the corrective actions, it is possible to rotate the valve in the vapour intake manifold toward the platform by 90 degrees and change the valve arm by 180 degrees.

QK 4 – Picking the tanker. Sometimes, the breathing valve is positioned on the tanker approximately 70 cm from the loading platform railing. Workers inspecting the breathing valve on the tanker must lean out of the loading platform railings, which is associated with the risk of falling. As possible causes, the following may be mentioned: incorrect manner of picking the tanker to control breathing valve, or too small loading platforms.

As a corrective action, it is possible, in the case of a tanker in which breathing valves are located at a considerable distance from the loading platform, to make organizational changes in the manner of picking the tanker train.

QK 5 – Leakage of the vapour of transported substances into the atmosphere. During loading the tanker, part of the vapours comes out via the gap between the hatch and the cone to the atmosphere. The worker who is loading it is exposed to harmful vapours. At the same time, the vapours make an irritating smell despite the absence exceedance of NDS, smelt at a distance of several metres from the loading. Possible causes include: inefficient pneumatic pressure cone, defective gum seal on the cone, low manifold vapour vacuum intake, and clogged vapour intake manifold.

Corrective actions include: replacement of the pneumatic valve pressuring the cone, replacement gum seal on the cone, mount vacuum gauge for measuring the vapour intake in the intake manifold, performing a pairing of vapour intake manifold, executing the adapter cone leveling differences between the hatches of tanks, bringing the vapours to the vapour intake manifold.

QK 6 – Moving funnel. While the employee unfastens the funnel of the railings, he or she is exposed to uncontrolled movement of the loading hopper. In addition, uncontrolled movement of the funnel can be caused by weather conditions such as a strong wind. Causes of this situation can be listed as: the possibility of free movement of the funnel in the fixed position and the lack of locking of funnel in the fixed position.

As a corrective action, it is possible to fix the devices of the loading funnel.

QK 7 – Loading funnel hampers the landing platform on the tanker. Some railway cisterns are equipped with additional railings next to the tanker loading platform, enlarging the platform by about 8 cm. This prevents the movement of the loading funnel over the hatch of the tanker. This forces the workers to lift the funnel above the level of the platform, which creates an additional risk for workers by exposing them to the vapours of the transported substances. Possible causes of this problem include: the inability to complete descent of the platform, the funnel hampers the step of the platform, and a wrongly selected tanker.

As a corrective action is possible to make cutouts in the movable platform.

4. Planned results of implementations

Thanks to the planned implementation of Quick Kaizen, it is possible to make small improvements which will greatly help to reduce the level of risk. For tanker loading, 297 activities have been identified as steps in the loading process. Before the implementation of improvements, 44 activities were classified at a normal risk level, whereas another 5 were classified at the average risk level. After the implementations of improvements and HIRA re-analysis, both normal and average level of risk activities were classified as low risk activities. These changes are shown in Figure 4.

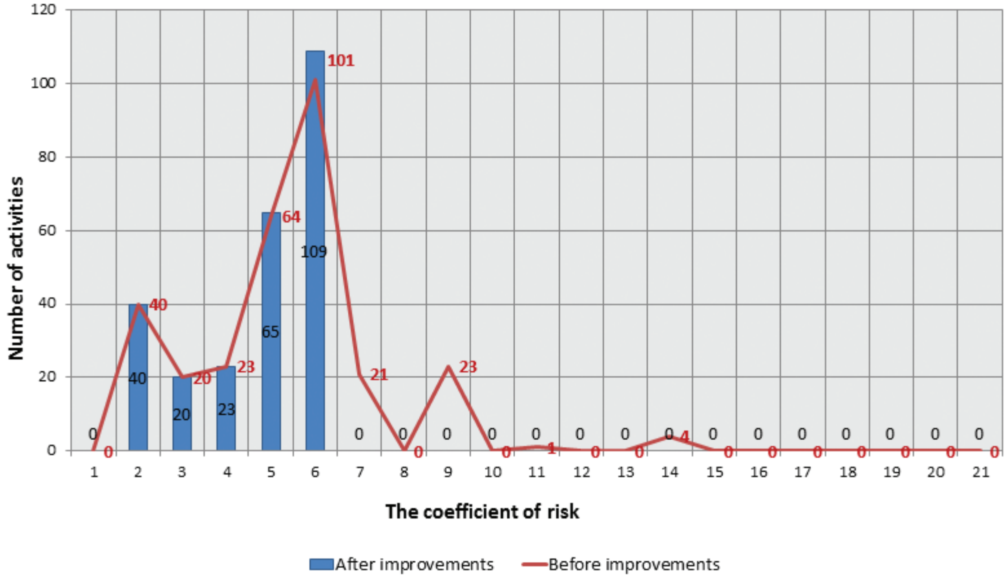

Fig. 4. Changing the values of risk assessment as a result of implementation of Quick Kaizen tasks

5. Conclusions

The problem of increased risks during the loading and unloading of railway tanks is an important issue for the safety of employees. In this case, in order to evaluate the risks which may occur during loading dangerous goods into tankers, the loading processes have been divided into seven stages. Thanks to the HIRA analysis, it was possible to identify and classify activities according to risk criterion. This analysis allowed us to determine which of the activities performed were the most risky and should be improved first. Base on this risk identification and HIRA risk analysis for each stage of improvement, Quick Kaizen tasks were planned. Thanks to this, it was possible in to improve those activities a clear and simple way. Special attention was paid to possible improvements in technical means, tools and processes. HIRA risk analysis can be used not only during loading of dangerous goods, but also in cases of loading and transportation of standard cargoes. In this case, with the planned improvements, it is expected to reduce the level of risk to low level.

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If you want to quote this article, its proper bibliographic entry is as follow: Kuźnar M., Lorenc A., *Risk minimization methods for loading dangerous goods into tanker trains*, Technical Transactions, Vol. 12/2019, pp. 163–172.