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Dangerous Goods Tank Car Marshalling Analysis: Phase 1 Literature Search, Jurisdictional Review

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1 INTRODUCTION

This letter report summarizes the results of Phase 1 of a project for Transport Canada (TC) Transportation of Dangerous Goods (TDG) directorate. TC-TDG had requested that the National Research Council Canada (NRC) review the existing regulations surrounding how dangerous goods cars are placed within a train, and the impact of this placement on safety. Specifically, TC-TDG requested the following:

1. An assessment of the effectiveness of the current dangerous goods car placement guidelines in Section 10.6 of the Transportation of Dangerous Goods Regulations (TDGR);
2. A comparison of the requirements from Section 10.6 of the TDGR with:
    a. Regulatory requirements from other jurisdictions for dangerous goods car placement in a train; and
    b. Other rail industry practices or guidelines for the marshalling requirements for train makeup;
3. An assessment of whether the presence of buffer cars results in an increased level of safety over dangerous goods trains without buffer cars;
4. Confirmation of whether other dangerous goods car placement rules should be considered for inclusion in Section 10 of the TDG Regulations; and
5. An assessment of whether dangerous goods cars in a train have any impact on in-train forces that should be considered when evaluating long train marshalling guidelines.

To reduce the project risk, NRC proposed to conduct the work to answer the above questions in two phases, where the results of Phase 1 would guide what the requirements would be for Phase 2. Therefore, Phase 1 was planned to be a jurisdictional scan of regulations and a search for related literature concerning the regulations within Canada and similar jurisdictions. The details of Phase 2 would be dependent on the outcomes of Phase 1.

1.1 Scope: Phase 1

This first phase of the work consisted of a jurisdictional scan of existing dangerous goods segregation rules from Canada and other jurisdictions including the United States (US), the United Kingdom (UK), European Union (EU) and Australia, as well as a literature search for documents supporting or related to DG transportation regulations. NRC conducted a search of publicly available documents using Knowledge, Information and Technology Services (KITS) branch, internet searches for relevant papers and documents, and through correspondence with key stakeholders in these jurisdictions.

A search of academic and industry publications in the open literature related to segregation rules and marshalling practices of the placement of dangerous goods cars in a train consist was also undertaken. As well, TC-TDG provided a list of known publications related to DG transportation. NRC conducted an assessment of the findings of the jurisdictional scan and literature review, where the following points of interest were of importance in reviewing the works found in the literature scan:

1. Does the literature provide the rationale for segregation decisions, in Canada or in other jurisdictions;

2. Does the literature provide rationale for the decisions made in selecting segregation rules in these other jurisdictions;
3. Does the literature inform TC-TDG whether current segregation requirements outlined in Section 10.6 of the Transportation of Dangerous Goods Regulations (TDGR) interfere with other recommended practices of train makeup for safe handling; and
4. Does the literature inform TC-TDG whether the current segregation requirements outlined in Section 10.6 of the TDGR reduce the possibility of combining dangerous goods that could cause chemical reaction, propensity for fire or toxic impacts;

The findings from the jurisdictional scan and literature search, as well as the assessment of these findings, are summarized in this letter report. This report also recommends appropriate next steps for future work to be conducted in Phase 2, as well as a proposed technical approach for each of the recommended actions.

2 JURISDICTIONAL SCAN AND LITERATURE SEARCH

2.1 Jurisdictional Scan

Regulatory documents related to Canada, US, UK, and EU jurisdictions were provided to NRC by TC for review. As well, a literature search was conducted by Knowledge, Information and Technology Services (KITS) branch of the NRC at the request of Automotive Surface Transportation (AST) to also locate regulations or supporting documents that govern the transportation of dangerous goods by rail in Canada, US, UK, the EU and Australia.

2.1.1 *Canadian vs. US Regulations*

The Canadian regulations are outlined in Transport Canada Regulations (SOR/2008-34: Section 10.6), most recently updated in 2008. These regulations formed the basis for which all other sets of regulations would be compared. The United States (US) regulations are described in the Code of Regulations (CFR) 174.84 and 174.85, which was most recently updated in 2001.

It was found that in general the regulations concerning the marshalling of dangerous goods cars in Canada have not significantly changed since approximately 1990. However, it was noted by TC-TDG that the Canadian regulations closely matched the US regulations until they were slightly modified in August of 2002 following the Clear Language amendments. A notable change was that the number of buffer cars between the locomotive and dangerous goods (DG) cars was reduced from 5 cars to 1. Reference to this change was made in TSB Report R02W0063[1] where it was stated that;

> *… new TDG (Clear Language) regulations came into effect on 15 August 2002. The new regulations require a minimum of one buffer car to separate the locomotive from DG cars located in the train. …*

and that;

> *The change in regulations was based primarily on consultants reports on the marshalling of DG railway cars. These reports included the Bowring Protection Consultants study completed for the British Railways Board, the Battelle study carried out for the Federal Railroad Administration, and the Canadian Institute of Guided Ground Transport (CIGGT) Working Paper completed for TC[2]. The objective of the CIGGT study was to summarize the work of the other two reports, in addition to providing the institutes own analysis. The CIGGT report concluded that there was not sufficient evidence at that time to suggest that*

[1] Railway Investigation Report R02W0063. Crossing accident and derailment of Canadian National freight train no. E20251b30, Mile 88.83, Rivers subdivision, near Firdale Manitoba, 02-May-2002. https://www.tsb.gc.ca/eng/rapports-reports/rail/2002/r02w0063/r02w0063.pdf

[2] Assessment of Dangerous Goods Regulations in Railway Train Marshalling. G.W. English, T.K. Cattani, C. Schwier. Canadian Institute of Guided Ground Transport (CIGGT), Project No. PRO-005 CIGGT Document No. 90-8. March 1991. Prepared for: Transportation Development Centre, Policy and Coordination Group. Transport Canada

overall railway safety could be improved through modifications of the existing regulations. The report also noted that the existing regulatory requirement for a five-car separation between an occupied locomotive and DG would likely reduce the risk of injury to crews in the event of a derailment, but that the magnitude of the reduction was difficult to quantify. The report further noted that the switching required to meet the train marshalling requirements of the TDG regulations is an activity that has its own risks for employee injury and equipment derailment.

A review of the CIGGT study referred to in TSB Report R02W0063 confirms that even at that point in time (1991) the justification for a 5 car buffer car regulation was not well understood, and that the overall risk of regulatory requirements needed to be addressed.

From the literature found to date, it appears that the conclusion drawn in the TSB Report R02W0063, that the Clear Language changes to the rules which took effect on 15 August 2002 also changed the requirements for the number of buffer cars from 5 to 1. NRC did not find other literature or reports directly supporting the past or current regulations, and it is assumed that the original supporting documents or justifications are not archived or date too far back to be contained in online documents. A review of the recent amendments (accessible online) did not reveal any significant details on the origins of the current set of regulations in any of the jurisdictions.

2.1.2 *Jurisdictional Comparison*

The jurisdictional scan conducted by the NRC included a review of regulations in Canada, USA, EU/UK and Australia. The regulations of the various jurisdictions are summarized in an Excel file referenced in Appendix A.

2.1.3 *Canada*

The Canadian regulations start with the opening statement “Unless it is likely to have a serious impact on train dynamics” one should follow these regulations. This provides a means of preventing the build-up of a train consist that could be dangerous in terms of longitudinal vehicle dynamics in order to satisfy the requirements for safe DG transportation. The regulations then indicate the requirement for a single buffer car to separate placarded cars from engines, cabooses, tenders, occupied cars, or other placarded cars. The regulations call for a buffer car between placarded cars and cars with a continual source of ignition, any open railway vehicle, or other cars where an accident could cause a puncture with loose or protruding lading. The regulations then describe which classes should not be placed next to each other and the incompatibility of specific chemicals. The regulations conclude by stating that any DG being transported from the United States can be marshalled in accordance with CFR 174.84 and 174.85.

2.1.4 *United States*

The United States regulations are similar to the Canadian regulations, and until Canada made changes to the regulations in 2002 with the Clear Language Amendment, they were essentially the same. Currently, the US regulations have a different format, using a table to specify which placarded groups can be placed near others, compared to a more descriptive approach as in the Canadian regulations. The primary difference between the two jurisdictions is the requirement for five buffer cars between a DG car and the engine or caboose, while Canada only specifies one.

The following are the other differences identified between the US and Canadian regulations:

- In 174.84 of the US Regulations, there is a specification for a 3 car buffer between division 1.1 or 1.2 cars and a rail car occupied by guards or technical escorts that has temperature control equipment in operation.
- 174.85 specifies that a tank car containing "residue" of a hazardous material also needs to be separated by one buffer car from a locomotive or occupied caboose[3].
- The US regulations specify radioactive material separate from other DG and includes a spacing requirement from undeveloped film.
- Certain cars such as division 1.1, 1.2, 2.3 and 6.1 "*must be next to and ahead of any car occupied by the guards or technical escorts accompanying the placarded rail car.*" The US regulations distinguish between tank cars and rail cars throughout the regulations, and uses the terms "*placarded car*" and "*hazardous materials*" rather than "*dangerous goods*".

2.1.5 *Europe/UK*

The regulations for the UK and the EU is the Regulation Concerning the International Carriage of Dangerous Goods by Rail commonly referred to as RID. This is an all-encompassing eight hundred page document that does not compare well with the concise format of the US or Canadian Regulations. For this reason, the Working Manual for Rail Staff – Handling and Carriage of Dangerous goods (GO/RT3053) published by the Rail Safety and Standards Board (RSSB) in the UK, which references the RID was used to compare regulations in the UK and Europe with those in Canada. This document, updated in 2018, lines up much closer to the regulations of both the US and Canada.

The main differences between these regulations and those in Canada are the following:

- The UK standard highlights physical condition of the cars, section C1.2 states "Wagons and containers used to carry dangerous goods, must be in good condition" and C1.3 b) Defective brake after goods are loaded states "if possible the defect must be repaired."
- The regulations also specify looser rules for "trip working" or lower speeds as seen in C1.5 D and E of the standard.
- Appendix 2 of GO/RT3053 provides a detailed table of separation requirements for the marshalling of dangerous goods.

2.1.6 *Australia*

It was found that Australia has separate regulations for each of its six states and one territory. Reviewing these seven sets of regulations indicated that they all refer to the Australian Code for the Transportation of Dangerous Goods by Road and Rail or ADGC, currently at edition 7.6 which was released in 2018. Chapter 9 of the ADGC has many similarities with Canadian regulations, and was the source used for the comparison between Australian and Canadian jurisdictions.

Some notable differences in the Australian regulations are that they include provisions for food and food packaging requirements to be separated from class 8 dangerous goods. The Australian

[3] In the Canadian regulations, a residue car is considered a placarded dangerous goods car. Placards cannot be removed until a means of containment has been cleaned and purged.

regulations also specify requirements with respect to radioactive materials similar to those in the US regulations. The Australian regulations also have similar provisions as the UK regulations for low speed or "not more than 15 kilometres per hour" limits that are not included in the Canadian regulations.

One difference particular to the Australian regulations is 9.2.4.6 which specifies that "*Dangerous goods must not be transported by rail in a bi-modal (road/rail) tank wagon unless approved by the Competent Authority and agreed by the rail track owner*."

2.2 Literature Search: marshalling, train make-up, dangerous goods transport.

The results of the literature search completed by KITS is listed in the documents referred to in Appendix A. NRC reviewed the titles and abstracts of the literature identified by KITS, and selected sources to be reviewed more fully in Phase 2 of the study. The selected literature was divided into two groups: literature of primary interest, and literature of secondary interest. Primary interest literature are listings where the title or abstract descriptions look to be a promising source of information that may have been used in the past to guide the writing of regulations, or could have been used to support opinions formed concerning the transport of DG regulations. Sources of secondary interest are those seen to have titles and abstract descriptions that are related to the transport of dangerous goods by rail, but do not appear to be directly related to the marshalling of DGs. The secondary sources may also contain references that lead to further primary sources.

2.2.1 **Literature Identified to be of Primary Interest**

The following listing of literature is of primary interest for review as it may be a source of justification for current or past regulations regarding dangerous goods marshalling rules. It is expected that these literature sources may also contain further references that may also be of interest. (The listing is not in any particular order.)

Assessment of Dangerous Goods Regulations in Railway Train Marshalling, Working Paper. G.W. English et al, Canadian Institute of Guided Ground Transport, March 1991

Event Probability and Impact Zones for Hazardous Material Accidents on Railroads
Nayak, et al., A.D. Little and Associates. Report DOT/FRA/ORD-83/20, 1983.

Hazardous Materials Car Placement in a Train Consist, Final Report, Volume 1 and 2, Battelle, Columbus, Ohio, Technical Task No. 6, Contract No. DTFR53-86-C-00006, September 7, 1989 (document available through the Technical Information Service, Springfield, Virginia 33262

A Risk Based Approach to the Segregation of Dangerous Goods on the Railways, M. Considine, Bowring Protection Consultants, prepared for British Railways Board, Contract NO. RE 21090, March 1988. [confidential report: available from Transport Canada]

Effective placement of dangerous goods cars in rail yard marshaling operation
Bagheri, M., Saccomanno, F.F., Fu, L.
(2010) Canadian Journal of Civil Engineering, 37 (5), pp. 753-762.

Dangerous goods railway car placement model
Bagheri, M., Saccomanno, F., Fu, L., (2009) Proceedings - 9th International Heavy Haul Conference: "Heavy Haul and Innovation Development", pp. 863-871.

Hazmat transport: A methodological framework for the risk analysis of marshalling yards
Cozzani, V., Bonvicini, S., Spadoni, G., Zanelli, S., (2007) Journal of Hazardous Materials, 147 (1-2), pp. 412-423.

Modeling hazardous materials risks for different train make-up plans
Bagheri, M. , Saccomanno, F. , Fu, L. (2012) Transportation Research Part E: Logistics and Transportation Review, 48 (5), pp. 907-918.

Reducing the threat of in-transit derailments involving dangerous goods through effective placement along the train consist. Bagheri, M., Saccomanno, F., Chenouri, S., Fu, L. (2011) Accident Analysis and Prevention, 43 (3), pp. 613-620.

Dangerous goods railway car placement model Bagheri, M., Saccomanno, F., Fu, L. (2009) Proceedings - 9th International Heavy Haul Conference: "Heavy Haul and Innovation Development", pp. 863-871.

Establishing derailment profiles by position for corridor shipments of dangerous goods
Saccomanno, F.F., El-Hage, S.M. (1991) Canadian journal of civil engineering, 18 (1), pp. 67-75.

An Appraisal of the Problem of the Handling, Transportation, and Disposal of Toxic and Other Hazardous Materials (1970) Booz-Allen and Hamilton, Inc., Washington, D.C. Department of Transportation, Washington, D.C.; Council on Environmental Quality, Washington, D.C. Council on Environmental Quality, 30 Jan 1970, 180 p.

Hazardous Materials Car Placement in a Train Consist. Volume 1. Review and Analysis. R. E. Thompson; E. R. Zamejc; D. R. Ahlbeck. Battelle, Columbus, OH. Corporate author code(s): 098156000 Federal Railroad Administration, Washington, DC. Office of Research and Development. Federal Railroad Administration, Jun 1992, 157 p.

Hazardous Materials Car Placement in a Train Consist. Volume 2. Appendices. R. E. Thompson; E. R. Zamejc; D. R. Ahlbeck. Battelle, Columbus, OH. Corporate author code(s): 098156000 Federal Railroad Administration, Washington, DC. Office of Research and Development. Federal Railroad Administration, Jun 1992, 310 p.

Railroad Accident Report - Derailment of Illinois Central Gulf Railroad Freight Train Extra 9629 East (GS-2-28) and Release of Hazardous Materials at Livingston, Louisiana, September 28, 1982. National Transportation Safety Board, Washington, DC. Bureau of Technology. Corporate author code(s): 022327003, National Transportation Safety Board, Report number(s): NTSB/RAR-83/05, 10 Aug 1983, 88 p.

Special Investigation Report - Railroad Yard Safety: Hazardous Materials and Emergency Preparedness. National Transportation Safety Board, Washington, DC. Bureau of Accident Investigation. Corporate author code(s): 022327001, National Transportation Safety Board, Report number(s): NTSB/SIR-85/02, 30 Apr 1985, 65 p.

Special Investigation Report - The Accident Performance of Tank Car Safeguards. National Transportation Safety Board, Washington, DC. Bureau of Technology. Corporate author code(s): 022327003, National Transportation Safety Board, Report number(s): NTSB-HZM-80-1, 8 Mar 1980, 26 p.

Hazardous Materials: A Guide for State and Local Officials. Bierlein, L.W., Washington, DC. Corporate author code(s): 075542000 Department of Transportation, Washington, DC. Office of the Secretary, Feb 1982, 81 p.

Safe Placement of Train Cars: A Report. Report to the Senate Committee on Commerce, Science and Transportation and the House Committee on Transportation and Infrastructure. Federal Railroad Administration, Washington, DC. Corporate author code(s): 035623000 Federal Railroad Administration, Jun 2005, 32 p.

Research on Marshalling Number of Vehicles in a Train for Gas-type Dangerous Goods Transport Based on Minimum Risk Gan, C., Yang, Y. (2018) Tiedao Xuebao/Journal of the China Railway Society, 40 (5), pp. 26-30.

Transportation of Hazardous Materials 1988. A. Saccomanno.
Transportation Research Board, Washington, DC. Corporate author code(s): 044780000 National Academy of Science Transportation Research Board, Report number(s): TRB/TRR-1193; ISBN-0-309-04764-1, 1988, 46 p.
Abstract: Locating emergency response capability for dangerous goods incidents on a road network; Knowledge-based classification scheme for regulating the flow of hazardous materials through tunnels and on bridges; Benchmark estimates of release accident rates in hazardous materials transportation by rail and truck; Hazardous materials transportation rules and regulations at bridge-tunnel facilities.

Transportation of Hazardous Materials 1989. F. F. Saccomanno; J. H. Shortreed; M. Van Aerde; J. Higgs; M. Abkowitz. Transportation Research Board, Washington, DC. Corporate author code(s): 044780000 National Academy of Science Transportation Research Board, Report number(s): TRB/TRR-1245; ISBN-0-309-04967-9, 1989, 74 p.

Formation of a model for the rational placement of cars with dangerous goods in a freight train Lavrukhin, O., Kovalov, A., Kulova, D., Panchenko, A. (2019) Procedia Computer Science, 149, pp. 28-35.

Accident-Cause-Specific Risk Analysis of Rail Transport of Hazardous Materials Liu, X., Turla, T., Zhang, Z., (2018) Transportation Research Record, 2672 (10), pp. 176-187.

Impact of train makeup on hazmat risk in a transport corridor Cheng, J., Verma, M., Verter, V. (2017) Journal of Transportation Safety and Security, 9 (2), pp. 167-194.

Risk comparison of transporting hazardous materials in unit trains versus mixed trains Liu, X., (2017) Transportation Research Record, 2608 (1), pp. 134-142.

Probability analysis of multiple-tank-car release incidents in railway hazardous materials transportation Liu, X., Saat, M.R., Barkan, C.P.L. (2014) Journal of Hazardous Materials, 276, pp. 442-451.

Hazardous Materials Car Placement in a Train Consist. Volume 1. Review and Analysis.
R. E. Thompson; E. R. Zamejc; D. R. Ahlbeck.
Battelle, Columbus, OH. Corporate author code(s): 098156000
Federal Railroad Administration, Washington, DC. Office of Research and Development.
Federal Railroad Administration, Jun 1992, 157 p.
Abstract: In response to major derailments involving hazardous materials cars, the Federal Railroad Administration (FRA) initiated the review of the consequences of hazardous materials car placement in a train consist. The review and analysis consisted of six task items: (1) review of accident trends and regulations, (2) an analysis of hazardous materials compatibility, (3) railroad operational constraints, (4) a cost/benefit analysis, (5) recommendations, and (6) preparation of a final report. A review of the 1982-1985 Railroad Accident/Icident Reporting System (RAIRS) data showed the rear quarter to be statistically the 'safest' location in a mainline freight train. Also, the top 101 hazardous commodities (by volume movement) plus fuming nitric acid were analyzed for chemical incompatibility, a total of 5,151 binary combinations. Consequence-based and risk-based rankings were established. Calculations established a post-derailment separation distance of 40 meters minimum to prevent mixing of incompatible chemicals. It was noted that mixing of hazmat materials was not cited in any NTSB accident report as a specific problem.

Hazardous Materials Transportation in Tank Cars: Analysis of Risks, Part 1.
P. K. Raj; C. K. Turner. Technology and Management Systems, Inc., Burlington, MA. Corporate author code(s): 077179000
Federal Railroad Administration, Washington, DC., Federal Railroad Administration, Report number(s): REPT-1991-64, 15 May 1993, 244 p.
Abstract: The report covers the development of a methodology to evaluate the potential national public risk arising from the transportation of hazardous materials in tank cars on the US Railroads. The analysis is intended to assess the relative changes in the overall risk when (structural) safety devices are provided on tank cars. Also the relative risks of transporting different chemicals in a specified DOT class tank car can also be determined. An analysis of tank car accident data (maintained by the Railway Progress Institute and the Association of American Railroads) was made and statistics on tank car puncture sizes were developed. The risk model developed takes into account the characteristics of tank cars, the puncture probability, properties of the hazardous material released and its behavior in the environment, occurrence of the accident in different population density areas under different types of weather conditions at the time of the accident, etc. Toxicity, fire and explosion behavior of the chemicals have been considered. The focus of application of the model has been to the transporation of poison-by-inhalation (PIH) and flammable materials. The results of the risk assessment model have been presented as a matrix of frequency and consequence classes indicated by MIL standard 882 B.

Hazardous Materials Transportation in Tank Cars: Analysis of Risks, Part II.
P. K. Raj. Technology and Management Systems, Inc., Burlington, MA. Corporate author code(s): 077179000
Federal Railroad Administration, Washington, DC. Office of Research and Development.
Federal Railroad Administration, Report number(s): REPT-1994-74, 31 Dec 1994, 160 p.

Abstract: In a previous study, sponsored by the Federal Railroad Administration (FRA) and performed by Technology & Management Systems, Inc. (TMS), the risk to the U.S. population arising from potential rail accidents involving hazardous materials transported on rail was analyzed. The focus of this study was the development of a risk assessment methodology which considered the differences in structure and strength of different DOT specification tank cars (i.e., their puncture resistance characteristics in accidents), improvements resulting from the provision of increased shell and head thickness, shell head protection, shelf couplers, thermal jacket insulation, etc. The risk analysis methodology also considered the physical and chemical characteristics and the hazardous nature of a number of commonly transported chemicals. The overall risks were calculated and plotted as annual frequencies of hazardous material exposure from mainline rail accidents against the severity of exposure (in terms of number of people being potentially exposed). The frequencies and severities were expressed in the (semi-quantitative) categories identified in MIL-Std-882B. The primary purpose of the above study was to review the compatibility of chemicals and tank cars authorized by HM 181 amendment to the Title 49 of the Code of Federal Regulations (49 CFR) and to evaluate (i) whether certain DOT specifications tank cars then authorized to transport certain specific chemicals needed to be strengthened or prohibited fiom transporting those chemicals because of the 'sigruficant' risks such a chemical-tank car combination posed to the population at large, and (i) the magnitude of reduction in risk if a better protected tank car were used to transport the same chemical(s) .

Realistic Characterization of Severe Railroad Accidents. Case Study: Tank Cars.

R. T. Anderson. Allied-General Nuclear Services, Barnwell, S.C. Corporate author code(s): 9500546

Department of Energy., Technical Information Center Oak Ridge Tennessee, Report number(s): CONF-780506-15, 1978, 17 p.

Abstract: The objective of the paper is not to state that one can accurately define the exact nature of all railroad accidents, nor to state that accident data can easily be translated into regulations and design criteria. History has shown this to be a difficult task for even those who have frequently been involved with railroad accidents. Rather, the intent is to show that upper limits for accident frequencies, physical forces, and fire effects, etc., can be established. These limits can be based on analysis of past accidents and the equipment involved. In simple language, no force is infinite no matter how long the train is and how fast it is going. Similarly, flame temperatures and fire durations are finite. Boundaries can be placed on the loadings imposed on a package. A direct comparison is made with the programs and regulations established by the Federal Railroad Administration and the railroad industry to make tank car movement of hazardous materials safer. These are compared with the regulations and design criteria used for radioactive material packages.

2.2.2 Literature Identified to be of Secondary Interest

The following list of literature is of secondary interest to the study, as it may contain information leading to literature related to the justification for current or past regulations. (The listing is not in any particular order.)

RISK ANALYSIS OF REGULATORY OPTIONS FOR THE TRANSPORT OF DANGEROUS COMMODITIES BY RAIL

Swoveland, Cary, (1987) Interfaces, 17 (4), pp. 90-107. Quantalytics Inc, Vancouver, BC, Can, Quantalytics Inc, Vancouver, BC, Canada

Abstract: A Canadian transport Commission hearing was held to consider the recommendations of an inquiry into the train derailment in Mississauga, Ontario, from which

nearly a quarter of a million people were evacuated because of the threat posed by a release of chlorine gas. A risk analysis study showed that the inquiry's principal recommendation would have resulted in an almost imperceptible improvement in safety at a cost that some estimates put at more than one billion dollars. Furthermore, the study demonstrated that the regulatory option favored by the railways, while superficially attractive, actually would have increased the risks of dangerous commodity spills. The commission rejected both proposals, in part because of the findings of the study.

Where are we going?

Baker, R. (2005) Petroleum Review, 59 (696), pp. 16-17. , Knight Support Fire, Rescue/A. S., Dar es Salaam, Tanzania.

Abstract: The regulations covering the transport of dangerous goods in the UK are discussed. A range of exemptions in the UK has led to confusion, unsafe practices and unfair competition. The majority of European hauliers leave most UK companies standing when it comes to compliance and standards. According to the industrial sources, any exemptions are entirely due to general inefficiency and the trade association's lack of readiness.

Hazardous materials transportation on U.S. railroads: Application of risk analysis methods to decision making in development of regulations

Raj, P.K., Pritchard, E.W., (2000) Transportation Research Record, (1707), pp. 22-26.

Rail safety in the carriage of dangerous goods

Abbott, Paul, (1995) Environmental Engineering, 8 (4), pp. 25-28. Railtrack HQ

Abstract: This paper addresses the safe carriage of dangerous goods by rail from a Railtrack point of view. Railtrack are committed to running a safe railway. A continuous programme of improvement in safety performance includes the need to regularly review the requirements for acceptance and carriage of dangerous goods. Railtrack and the rail industry in general are of course also involved in times of considerable change given privatisation. As far as dangerous goods are concerned this change gives added impetus to the need for harmonisation of transport requirements both nationally and internationally by road and rail. British Rail (BR) always supported this intention and so do Railtrack, as long as all modes are dealt with consistently particularly given the intermodal and international nature of many movements. This paper was presented at the EnviroMan '94 Conference in St Albans, England, 28-30 June 1994, organised by International Labmate Ltd.

Safety in the transport of dangerous goods

Mitschi, Jean, (1995) Rail International, (5), pp. 65-67.

Abstract :Dangerous goods make up a considerable share of industrial production and of the volume of freight carried by rail (around 13% of SNCF freight traffic), often in block trains. They therefore have major strategic implications for the railways' freight business and indeed for competition between modes of transport.

A Comprehensive Railroad Safety Report (Including an Analysis of the State Participation Program).

Federal Railroad Administration, Washington, D.C. Office of Safety.

Federal Railroad Administration, Report number(s): FRA/RSS-7601, 17 Mar 1976, 359 p.

An Evaluation of Railroad Safety.

Office of Technology Assessment, Washington, D.C.

Office of Technology Assessment US Congress, Report number(s): OTA-T-61, May 1978, 224p.

Burlington Northern Inc., Monomethylamine Nitrate Explosion, Wenatchee, Washington, August 6, 1974. National Transportation Safety Board, Washington, D.C. Bureau of Surface Transportation Safety. National Transportation Safety Board, Report number(s): NTSB-RAR-76-1, 2 Feb 1976, 72 p.

Computer Simulation of Tank Car Head Puncture Mechanisms. Classification Yard Accidents. K. H. Hohenemser; W. B. Diboll; S. K. Yin; B. A. Szabo. Washington Univ., St. Louis, Mo. School of Engineering and Applied Science. Federal Railroad Administration, Washington, D.C. Office of Research and Development. Federal Railroad Administration, Feb 1975, 86 p.

Control of Spillage of Hazardous Polluting Substances. G. W. Dawson; A. J. Shuckrow; W. H. Swift. Battelle Memorial Inst., Richland, Wash. Pacific Northwest Labs. Corporate author code(s): 387060 1 Nov 1970, 409 p.

Emergencies in the Overland Transportation of Hazardous Materials. R. Pipatti; R. Lautkaski; J. Fiet.
Valtion Teknillinen Tutkimuskeskus, Espoo (Finland). Corporate author code(s): 067526000 6658300, TIC Foreign Exchange Reports, Report number(s): VTT-TUTK-380, Mar 1985, 111 p.

National Transportation Safety Board Railroad Accident Report: Derailment of Norfolk Southern Railway Company Train 68QB119 with Release of Hazardous Materials and Fire, New Brighton, Pennsylvania, on October 20, 2006. National Transportation Safety Board, Washington, DC. Corporate author code(s): 022327000, National Transportation Safety Board, Report number(s): NTSB/RAR-08/02, 13 May 2008, 56 p.
Tank Car Head Puncture Mechanisms. D. A. Peters; B. A. Szabo; W. B. Diboll. Washington Univ., St. Louis, MO. School of Engineering and Applied Science. Corporate author code(s): 010065085, Federal Railroad Administration, Washington, DC. Federal Railroad Administration, Apr 1980, 107 p.

Risk Analysis in Hazardous Materials Transportation. Volume I. G. P. Jones; R. W. Barrow; L. C. Stuckenbruck; E. L. Holt; R. P. Keller. University of Southern California, Los Angeles. Inst. of Aerospace Safety and Management. Report number(s): RAPO-73-7, Mar 1973, 297 p.

Lac-mégantic accident: What we learned
Lacoursière, J.-P., Dastous, P.-A., Lacoursière, S., (2015)
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3 RECOMMENDATIONS FOR PHASE 2

Based on the results of Phase 1, the proposed work for Phase 2 is summarized in this section.

It is recommended that Phase 2 proceed in two separate but related activities:

i. Detailed review of the literature identified in Phase 1 (above).
ii. Comparison of accidents in US and Canada before and after 2002.

As well, the two activities above are to be used to guide and plan a third activity:

iii. A larger modelling study looking at the effect of in-train forces, train lengths and weights and other characteristics on derailment risk.

3.1 Detailed Review of Literature Identified in Phase 1

The literature listed in Section 2.2 would be compiled and reviewed in depth. As a primary goal, the key literature would be summarized as to the influence it had, or may have had, on the regulations regarding marshalling of DG cars. However, the review would go beyond identifying literature that may have been used to support past regulation changes, but will also identify literature that can be used to guide future regulation reviews and updates concerning DG transport. Given these broader requirements, the review will be guided by understanding that the final outcome of a derailment is affected by two separate but related groups:

i. What factors affect the probability of an accident?
ii. What factors affect the outcome of an accident?

Factors affecting the probability and outcome of an accident are numerous[4], but from the point of view of their effect on or being influenced by regulations under control of TDG and other groups within TC, they include;

1. the marshalling activities within a train yard to build up a train into the desired final condition that meets both the train makeup guidelines recommended by industry and/or government (affecting total length, total weight, locomotive position, etc.), and the regulatory requirements such as the location and number of buffer cars or other rail cars in relation to DG cars;
2. the train operating and handling characteristics of the train on the route, combined with the route characteristics, such as track class, and track curvature and grade; and
3. the location within a train of the DG cars.

The final train makeup is controlled by the movement of cars in the yard prior to a train departing, and there is risk to workers involved in these marshalling activities. The final outcome of the marshalling activity is the complete train, which once in operation on the route now contributes risk to the crew operating the train and to the public where the train passes. As well, the marshalling of the train has an effect on the severity of outcome of an accident, as the position of a car in the train determines what happens to that car should an accident occur. The industry recognizes that a balance must be struck between the efforts needed in a yard to makeup a train

[4] Study on the Factors that Increase the Severity of the Outcomes for Derailments Involving Dangerous Goods and Identification of Mitigation Measures. Elton Toma, Alok Jahagirdar, Zach Schenk. NRC-AST Report ST-R-TR-0118. Prepared for Transport Canada. 2019-12-15

into the ideal "low-risk" and regulation compliant train for the goods being transported and the route being travelled on, and the cost and safety risk to workers involved in the effort to move the cars into this ideal or preferred makeup.

For the above reasons, the literature will be reviewed and discussed along the lines of the following three topics. Literature that discusses or assesse:

1. the effect of DG car placement and the use of buffer cars or separation requirements within a train (marshalling) on derailment risk and accident outcome severity;
2. the effects of yard switching moves and risk to yard workers; and
3. the effect of dangerous goods cars characteristics and placement on in-train forces.

Item 1 above will continue to the main focus of interest in the literature review and summary, with items 2 and 3 being secondary focus to be discussed depending on the availability of the literature.

3.2 Comparison of derailments involving multiple cars: Did buffer cars create differences in outcomes in US and Canadian accidents?

In August of 2002, the rules regarding segregation of DG cars from the locomotives in Canada diverged from the counterpart rules in the US. It is proposed that a review of accident reports from the NTSB and the TSB be completed, which would investigate whether any differences in outcomes had occurred due to the different buffer-car rules. The project would involve the collection of accident reports and other relevant data from NTSB and TSB data before and after August 2002, from possibly as far back as 1980, up to the current time.

The review of the reports would result in the creation of a database to be used for the analysis. The database would require (as a minimum) the following information to be available from the accident reports: car position for start of derailment; length of train; number of cars following the initial car to derail; train makeup near the initial car to derail; train speed; track grade; a terrain description (flat/open; canyon/constricted, bridge/Cliffside); the climate conditions (temperature, season); location of all DG cars on the train; track class.

The collection of these characteristics, if possible, would be used to determine if there was a difference in outcome between accidents occurring in Canada and the US before and after August 2002. As well, the compilation and review of the accidents and the creation of a database would have larger positive benefits for TC as a whole, as the data could then be used for other similar or related research topics within TC or other government departments (OGDs).

3.3 Modelling of in-train forces: the effect of car placement and train operations on in-train forces and derailment risk.

Another goal of this project is to better understand the effects of dangerous goods car placement, weights, and conditions on the effect of in-train forces and other factors that affect derailment risk. The review of accident data described above in Section 3.2 is one method to better understand this, however a second method of understanding the complex system that is a train in operation, is to use modelling. The modelling would involve the use of commercially available software to model the longitudinal train dynamics of trains in operation. The software proposed for this modelling is the Train Energy Dynamics Simulator (TEDS), made available by the FRA.

The literature review and accident results analysis as described above in Section 3.1 and Section 3.2 would guide the final planning of the modelling exercise. However, the overall goal would be to model many train configurations over many track and operating conditions (amounting to several thousand simulated conditions) in order to determine what factors or configurations produce higher in-train forces and where these in-train forces predominantly occur within the train. Guiding this is the knowledge that high in-train forces can cause a derailment in several manners:

- High draft (tensile) longitudinal in-train forces can cause a string-lining derailment (without train separation);
- High draft forces can cause a broken coupler knuckle, separating the train and breaking the air brake pipe continuity, causing an undesired emergency (UE) brake application which can then result in a derailment of the trailing portion of the train; and
- High buff (compressive) longitudinal in-train forces can cause a buckling derailment, which may also result in a brake pipe separation causing a UE brake application, which can then result in a more severe type of derailment.

As the detailed plan for this modelling exercise would be guided by the literature review as described above in Section 3.1 and Section 3.2, the final description of this is left for a future proposal of work. However, as the scope is potentially fairly large and broad, it is recommended that other Transport Canada groups be considered for involvement in this effort such that the modelling work could be made to align with other research interests within TC for similar or related activities.

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5 ACRONYMS AND ABBREVIATIONS

AAR	The Association of American Railroads
AST	Automotive and Surface Transportation
DG	Dangerous Goods
EU	European Union
KITS	Knowledge, Information and Technology Services (NRC)
NRC	National Research Council Canada
NTSB	National Transportation Safety Board (US)
TDG	Transportation of Dangerous Goods
TDGR	Transportation of Dangerous Goods Regulations
TRB	Transportation Research Board (US)
TSB	Transportation Safety Board (Canada)
UK	United Kingdom
US	United States

Appendix A Jurisdictional Review

The jurisdictional review is summarized in the Excel spreadsheet file:

Marshalling Regulations Matrix.xlsx

Appendix B KITS Literature Search Results

The search strategy used by KITS is summarized in the following document:

Transportation of Dangerous Goods by Rail - Regulations and Literature Search FINAL.docx

The following files contain the full results of the KITS literature search:

Scopus Citations - Marshalling.docx
Scopus Citations - Regulations.docx
NTIS Citations - Marshalling.docx
NTIS Citations - Regulations.docx