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Tanker Truck Loading Platform Fall Protection Accident Reconstruction Analysis

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Abstract: A human factors accident reconstruction was conducted to determine the cause of a fall accident in which a tanker truck driver sustained injuries when he fell to the ground from an elevation during a loading operation. Testing was performed using an anthropomorphic dummy and a human surrogate to investigate the potential of the tanker truck driver slipping, tripping, and falling on the loading platform. Results of this accident reconstruction analysis indicate that the tanker truck driver more than likely fell from his tanker trailer. Fall protection devices and safety practices for the loading platform and the tanker truck are explored as fall injury prevention strategies.

Keywords: accident reconstruction, fall protection, tanker truck loading platform

1. Tanker Truck Loading Platform System Description

The tanker truck loading platform studied in this research is displayed in Figure 1. Plant personnel climb stairs to gain access to the multi-level loading platform with a hinged platform located at the end. Figure 1A shows the hinged platform in the vertical position for loading tanker trucks with a chain running horizontally to act as a fall protection barrier. Figure 1B demonstrates the hinged platform in the horizontal orientation with the fall protection barrier chain removed in a vertical position for accessing rail tank cars. In the loading configuration, the loading arm is positioned horizontally with a chute located above the tanker trailer hatch as illustrated in Figure 1B. During the tanker truck loading process, the tanker truck driver climbs to the top of the trailer using the fixed vertical ladder attached to the side of the trailer, opens the trailer hatch, and then climbs down the trailer ladder. Then plant personnel move the loading arm chute into the trailer hatch opening and start the process of loading the trailer. The plant personnel can safely stand on the loading platform with the fall protection chain secured horizontally and maneuver the loading arm chute into the trailer hatch opening. At the conclusion of the loading process, the plant personnel while standing on the loading platform remove the loading arm chute from the trailer hatch opening and then the tanker truck driver closes the trailer hatch. The loading platform system shown in Figure 1 can be utilized to load tanker trucks as well as rail tank cars that typically have fixed railings around the hatch. During the rail tank car loading process, the rail tank car hatch is accessed by the horizontal hinged platform with its side railings mating with the rail tank car railing system.

2. Fall Accident Description

A human factors accident investigation was conducted to determine the cause of a fall where a tanker truck driver sustained injuries when he fell to the ground from an elevation. Two distinctly different injury scenarios are presented. One accident scenario involves the tanker truck driver falling from the loading platform with the hinged platform deployed in the horizontal position and the fall protection chain unsecured as depicted in Figure 1B. Another injury scenario involves the tanker truck driver falling from his trailer. At the time of the accident, the loading arm chute had been placed in the trailer hatch opening and the loading process had started. Eyewitnesses and investigators accounted for various final resting positions of the tanker truck driver on the ground, including to the south of the loading platform, under the loading platform, and to the north of the loading platform. In addition, some witness accounts have the tanker truck cab facing north while other witnesses describe the tanker truck cab facing south at the time of the accident.

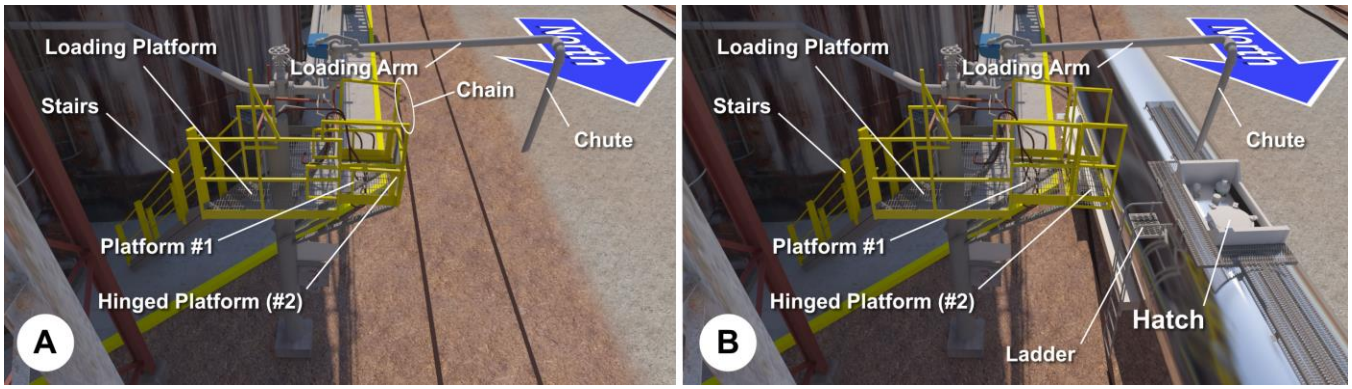

Figure 1. Tanker Truck Loading Platform

3. Fall Accident Reconstruction

3.1 Anthropomorphic Dummy Testing

Testing followed published methods that utilize the scientific method as a framework for accident reconstruction analysis (Knox, 2015). Preliminary investigation findings guided the development laboratory test protocols that included an anthropomorphic dummy to simulate various truck driver fall scenarios from the loading platform and from the tanker truck. The test dummy was 72 inches tall and weighed 192 pounds.

3.1.1 Dummy Falling From Loading Platform

Figure 2 sequence 1 demonstrates a fall test sequence where the dummy is standing on the loading platform facing the tanker truck and falls onto the horizontal chain at the end of the platform. The results of this test indicate that the horizontal secured chain prevented the dummy from falling off the end of the loading platform. The same result occurred during all test falls into a horizontal chain. Figure 2 sequence 2 displays a fall test sequence where the dummy is standing on the loading platform facing the tanker truck and falls from the end of the loading platform onto the tanker truck. The dummy's body forms a bridge between the platform and trailer without falling to the ground. Although the results varied slightly between different test falls, no fall resulted in the dummy falling to the ground. Figure 2 sequence 3 illustrates a fall test sequence where the dummy is stepping off the loading platform onto the top of the tanker truck. After the dummy is released, the dummy lands face down on top of the tanker truck. The forward momentum of the dummy during the simulated step resulted in a final rest position on the hatch and tanker ladder area.

3.1.2 Dummy Falling From Tanker onto Ground

Figure 3 sequence 4 shows a fall test sequence where the dummy is positioned on the tanker fixed ladder underneath the loading platform. The dummy is released from the ladder and lands on the ground underneath the loading platform. All fall tests from the ladder resulted in a final rest position underneath the loading platform, even though there were slight differences in body orientation and limb positions. Figure 3 sequence 5 exhibits a fall test sequence where the dummy is standing adjacent to the hatch on top of the tanker truck and falls to the ground to the side of the loading platform. In all test falls from a standing position on top of the tanker the final rest position of the dummy on the ground was a result of the starting position on top of the tanker and the fall direction.

3.2 Human Surrogate Force Plate Testing

Testing was conducted to assess the potential to slip on the loading platform surface during maneuvers such as walking, turning around and stopping and starting. The surface of the loading platform was welded metal bar grating. Exemplar grating was mounted to the top of two Bertec 6-axis force plates (model 4060-05-PT) and forces were measured while a human surrogate performed various maneuvers. The force data was processed to determine the amount of friction required to prevent slipping, and the likelihood of slipping during the specific action of turning around. The results of this test indicate that the action of turning around on the platform generates lower forces than either the action of walking along the platform or starting/stopping on the platform. Furthermore, if an individual does not slip while walking to or stopping at

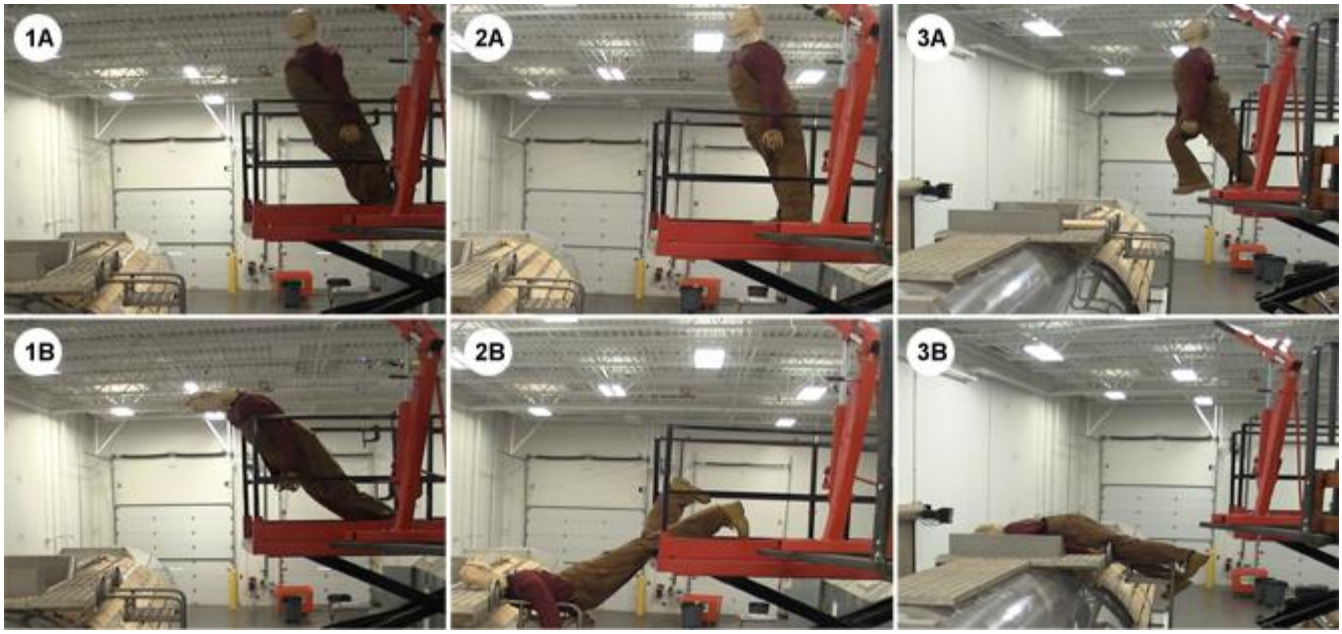

Figure 2. Loading Platform Dummy Fall Sequences

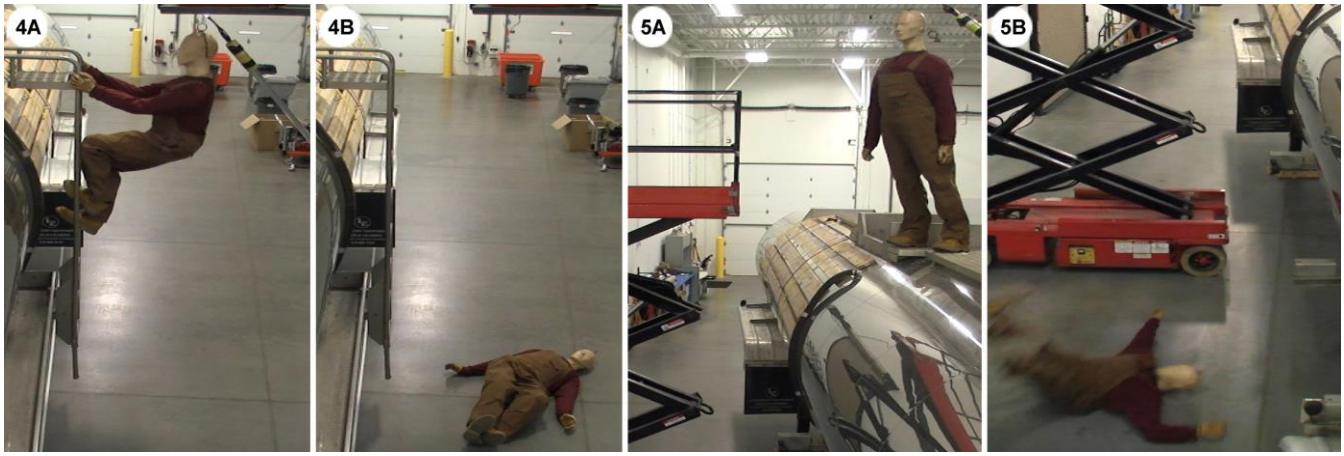

Figure 3. Tanker Truck Dummy Fall Sequences

a location on the metal bar grating, it is highly improbable that they will slip while turning around. The measured data are consistent with published literature (Redfern, 2001, Vanitchatchavan, 2009).

3.3 Human Surrogate Platform Testing

Testing and examination of the subject loading platform was conducted by a human surrogate doing various maneuvers on the platform after donning exemplar boots. The surrogate did not slip during any actions, and examination showed the grating to have aggressive slip resistant features that interacted with the bottom surface of the boots to create mechanical interference between the grate and boot sole in addition to the friction between the two surfaces.

Further testing was conducted in the laboratory with the same human surrogate and exemplar boots on the exemplar loading platform grating. The surface of both the grating and the boots were heavily contaminated with a sample of the viscous liquid material being loaded into the tanker, although this circumstance is highly unlikely because the geometry of the loading arm does not allow it. The results indicate that the surrogate was able to perform all maneuvers (unaided by handrails) on the grating without slipping. This further demonstrates the aggressive slip resistance of the metal grating.

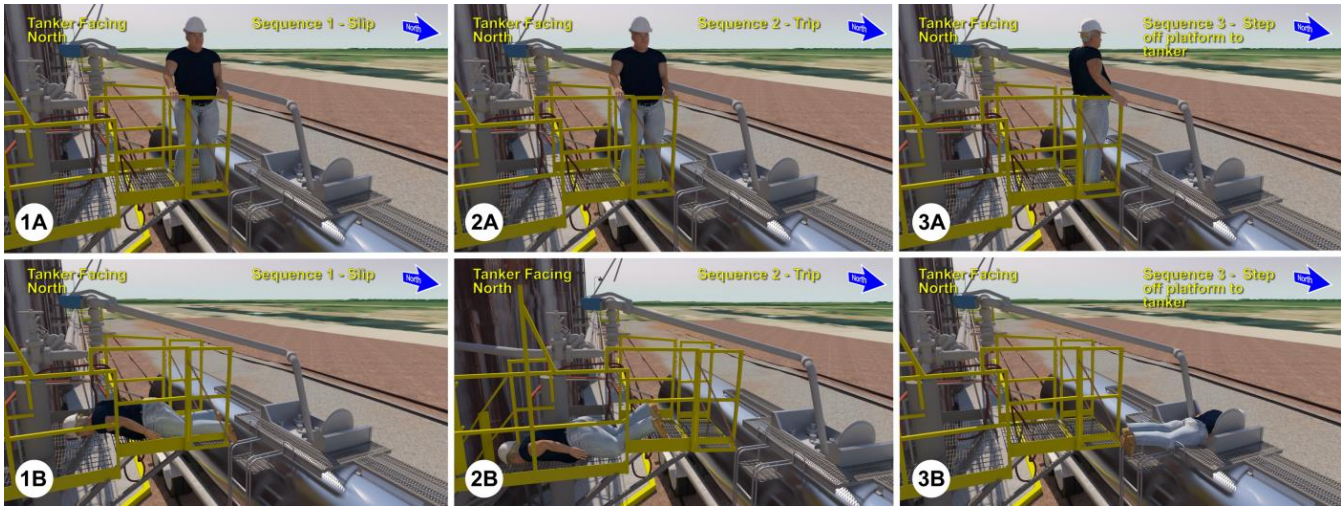

Figure 4. Animated Truck Driver Loading Platform Fall Sequences

3.4 Fall Scenario Analysis

Six separate fall scenarios were analyzed as part of the accident reconstruction based upon the witness accounts, anthropomorphic dummy testing, human surrogate platform testing, and the laws of physics. Animated truck driver fall sequences from the loading platform and from the tanker truck are presented and analyzed below. The tanker truck is facing north in the first four truck driver fall sequences associated with the loading platform and the tanker ladder. The tanker truck is facing south in the sequences where the truck driver falls off the top of the tanker.

3.4.1 Truck Driver Falling from Loading Platform

Figure 4 sequence 1 demonstrates a slip fall scenario where the truck driver starts from a standing position at the end of the loading platform and initiates a turn toward the stairs. The scenario finishes with the truck driver in a prone position on the loading platform with his head facing the stairs and his feet at the end of the loading platform. This slip fall sequence is highly unlikely because of the physics described previously, but also does not result in the truck driver falling to the ground. Figure 4 sequence 2 shows a trip fall scenario with the truck driver positioned at the end of the loading platform and then landing face down with his head at the top of the stairs and his feet on the loading platform. This trip sequence does not result in the truck driver falling to the ground. Figure 4 sequence 3 illustrates a scenario where the truck driver steps off the loading platform onto the tanker in a similar manner as the anthropomorphic dummy testing. The truck driver's forward momentum moves him over the top of the trailer and he lands face down in the area of the open trailer hatch. This stepping fall sequence does not result in the truck driver falling to the ground.

3.4.2 Truck Driver Falling from Tanker Truck

Figure 5 sequence 4 depicts a ladder fall scenario where the truck driver is climbing the trailer fixed ladder and his head contacts the underside of the hinged platform in a horizontal orientation. The landing zone for the truck driver is indicated by a blue shaded circle on the ground under the loading platform. This ladder fall scenario is consistent with the anthropomorphic dummy testing and some witness accounts of the final resting place of the truck driver. Figure 5 sequence 5 displays a fall scenario where the truck driver is standing on top of the tanker to the north of the open hatch and lands in the purple shaded circle located to the north of the loading platform. This fall sequence from the top of the tanker is consistent with the anthropomorphic dummy testing and some witness accounts of the truck driver's final rest position. Figure 5 sequence 6 portrays a similar fall scenario as sequence 5 except the truck driver is standing on top of the tanker to the south of the open hatch and lands in the green shaded circle located to the south of the loading platform. This fall sequence from the top of the tanker is consistent with the anthropomorphic dummy testing and some witness accounts of the truck driver's final rest position.

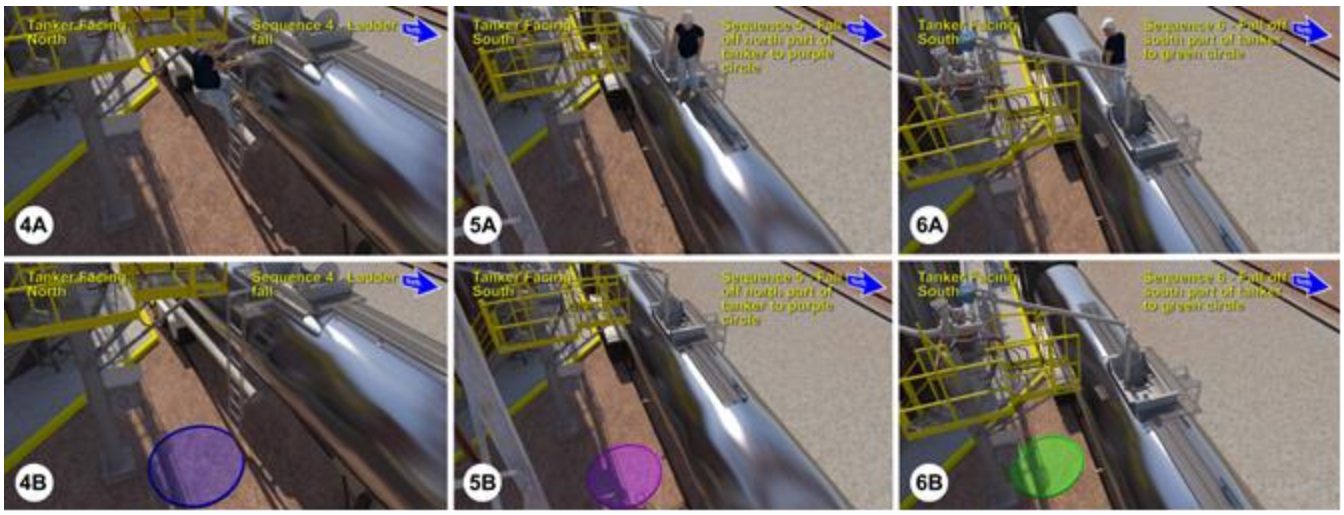

Figure 5. Animated Truck Driver Tanker Truck Fall Sequences

4. Tanker Truck – Loading Platform Safety Standards and Recommended Practices

The Truck Trailer Manufacturers Association (TTMA) has produced a recommended practice intended to serve as a guide for the uniform design and construction of ladders and walkways on tank trailers (TTMA, 1987). In general industry, OSHA issued a program directive to clarify regulations regarding loading rack platform protection (OSHA, 1978). This OSHA instruction indicates that guardrails on the outside edge of the loading platform above the top of the tank truck are impractical because tank trucks are of different configurations and the several loading hatches make it necessary for employees to be able to step from the platform (or use a runway from the platform onto the tank) at any place in order to go onto the tank.

5. Tanker Truck Fall Protection Safety Practices

The Cargo Tank Risk Management Committee (CTRMC) has developed minimum suggested standards for driver training to reduce the potential for falls while climbing cargo tank motor vehicles (CTRMC, 2011 and U.S. DOT, 2011). According to the CTRMC, falls are the number 1 cause of worker injuries for trucking companies based upon a 2010 trucker survey on injury frequency. Training program elements include: developing written policies that outline climbing and working on tanker task expectations, providing training based on the type of equipment being used and tasks drivers are expected to perform, and conducting evaluations to verify tasks are being performed as expected on an on-going basis. CTRMC recommends the following cargo tank driver fall prevention measures: maintain three points of contact as you climb the ladder (Figure 6A), stay low once you reach the top (Figure 6B), don't take chances/jump (Figure 6C), and follow your company procedures.

6. Tanker Truck Fall Protection Systems

The Cargo Tank Risk Management Committee (CTRMC) has presented several different cargo tank truck fall protection railing systems (Vaughn, 2011). Some of these fall protection railing systems remain fixed on the cargo tank trucks and others have collapsible railing systems that are deployed into the protective state when needed by a control system. Standfast offers a tanker truck total restrain access module - fall protection system (TRAM) where the driver wears a fall protection harness that attaches to a movable TRAM located on top of the tanker truck (Standfast, 2017).

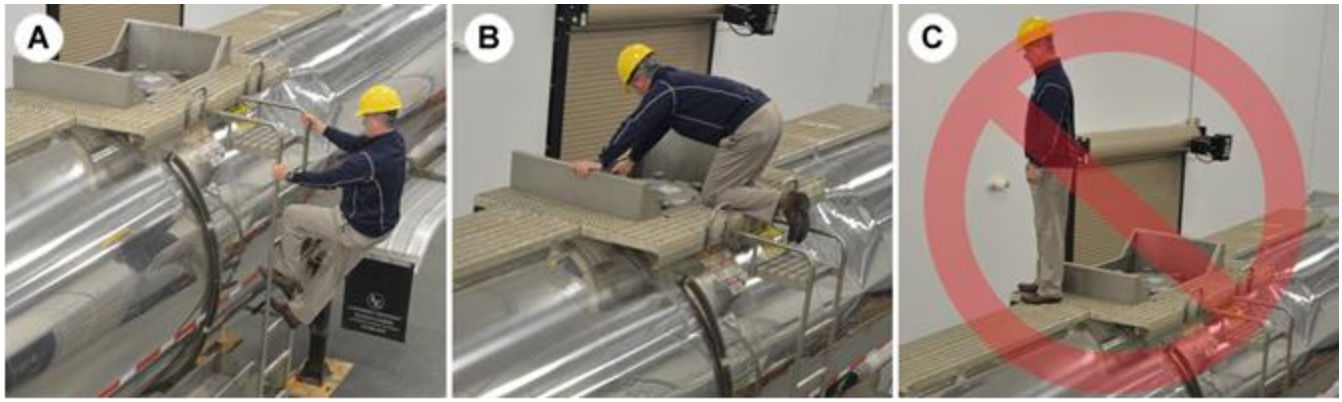

Figure 6. Cargo Tank Driver Fall Prevention Measures

7. Conclusions

Results of the accident reconstruction analysis determined that the tanker truck driver more than likely fell from his trailer during the loading process. Testing indicates that the tanker truck driver would have landed on the loading platform or on the top of the trailer during a fall event initiating from the loading platform. Fall scenarios initiating from the top of the tanker trailer and from the trailer ladder are consistent with witness accounts of the truck driver's final resting position on the ground. Fall prevention safety strategies include maintaining the hinged platform in the vertical position with the chain fall protection secured horizontally across the end of the loading platform, following CTRMC recommended fall protection driver safety training practices, and utilizing commercially available tanker truck fall protection systems. Incorporating a fixed railing at the end of the loading platform presents functional downsides associated with universal loading of various rail tank car and tanker truck systems and creates safety dangers by encouraging worker chance taking maneuvers in violation of CTRMC recommended fall protection safety training practices.

8. References

CTRMC. (2011). *Minimum Suggested Standards for Driver Training to Reduce the Potential for Falls While Climbing Cargo Tank Motor Vehicles*. Retrieved from http://www.cargotanksafety.org.

Knox, E.H. et al. (2015). *Methods of Accident Reconstruction: Biomechanical and Human Factors Considerations*. Proceedings of the ASME 2015 International Mechanical Engineering Congress and Exposition, IMECE2015-53666, 1-11.

OSHA. (1978). *29 CFR 1910.23(c)(1), Protection of Open-sided Floors, Platforms and Runways: Guardrails – Loading Rack Platforms*. OSHA Directive Number STD 01-01-005, 1978.

Redfern, M.S. et al. (2001). *Biomechanics of Slips.* Ergonomics, Vol. 44, No. 13, 1138-1166.

Standfast. (2017). *TRAM-Total Restrain Access Module-Fall Protection*. Retrieved from http://www.standfastusa.com.

TTMA. (1987). *Tank Trailer Ladders and Walkways*. TTMA Recommended Practice No. 59-87, 1987.

U.S. DOT. (2011). *Cargo Tank Motor Vehicle (CTMV) Loading/Unloading Operations: Recommended Best Practices Guide*. Retrieved from https://phmsa.dot.gov.

Vanitchatchavan, P. (2009). *Termination of Human Gait.* Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics, 3169-3174.

Vaughn, R. and Wright, D. (2011). *Workers on the Top of Tanks: An Update on the Journey of the CTRMC*. Retrieved from http://nttc-web.s3.amazonaws.com.