Falls From Cargo Tankers

Keeping Workers on the Ground

By Albert Weaver III and Cynthia H. Sink

Fall injuries, both on the same level and to a lower level, remain among the most disabling injuries in the U.S. Researchers at Liberty Mutual Research Institute for Safety (2014) examined Bureau of Labor Statistics (BLS) injury data of all workplace injuries to determine which events caused an employee to miss 6 or more days of work, then ranked those events by total workers' compensation costs. The results of their examination showed that the leading causes and direct costs of the most disabling workplace injuries in 2012 were:

1) overexertion involving an outside source;
2) falls on the same level;
3) struck by an object or equipment;
4) falls to a lower level.

Falls to a lower level accounted for $5.12 billion in costs in 2012. According to Federal Highway Administration (FHWA, 2014) 2,643,567 million ton-miles of freight were transported in the U.S. during 2011 (a ton-mile is a single ton of goods that is transported for 1 mile). Collecting the following data involving semis, tractor-trailers and tanker trucks due to falls to a lower level, BLS (2016) reports that between 2011 and 2013, 7,450 nonfatal occupational injuries and illnesses occurred involving days away from work and 44 fatalities. This is BLS category code 8421 including tanker trucks and flatbed trucks except straight trucks, logging trucks and car haulers. It also excludes fire trucks, which are category 8425. Federal Motor Carrier Safety Administration defines *semitrailer* as "any motor vehicle, other than a pole trailer, which is designed to be drawn by another motor vehicle and is constructed so that some part of its weight rests upon the self-propelled towing motor vehicle" (Federal Motor Carrier Safety Regulations).

IN BRIEF
- Working on top of cargo tankers presents risks such as falling and exposure to hazardous materials.
- Using a fill-level gauge to determine the fill level can eliminate the need for personnel to be on top of a cargo tanker.
- Considerations for installing a fill-level gauge include pricing, safety and applicability to the material being transported.
- With the cost of fill-level gauges starting at $40, their addition to cargo tankers increases worker safety without placing an undue cost burden on the transporter.

Cargo Tank Truck Falling Hazards

When loading a cargo tanker, climbing on top to observe the fill level creates a fall hazard. Adding to the possibility of having a fall, certain cargo can create hazardous gases or slick surfaces. According to Cargo Tank Risk Management Committee (CTRMC, 2014), the top 10 reasons (not ranked) that workers climb atop transportation tanks are to:

1) ensure security;
2) check equipment;
3) extract samples;
4) load/unload product;
5) assess liquid content levels;
6) initiate air unloading or vapor recovery;
7) perform maintenance and inspections;
8) wash tanks;
9) remove snow;
10) discharge heel (any material remaining in a tank following unloading, delivery or discharge of the transported cargo).

Case Studies

The following case studies exemplify falls from tanker trucks where the cargo transported fell outside DOT regulations for gauges on tankers.

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The addition of a fill-level gauge to a cargo tanker increases the safety of the workers filling the tank without placing an undue cost burden on the transporter.

Table 1

Gauge Types Quick Reference

Type	Physical basis/principle	Advantages	Constraints/limitations	Cost range
Sight eye (type of sight glass)	Visual indication	Simplicity; can retrofit	Volume known only to level visible; may need cleaning after each use; subject to breakage; should carry a spare glass.	≈ $40 for 5-in. diameter part plus cost to install
Threaded rod gauge	Visual indication	Simplicity; can retrofit	Worker must be at cargo tanker opening to see the fill level.	≈ $30 for nuts, fender washer, and threaded rod plus cost to install
Sight tube	Hydrostatic head	Simplicity; can retrofit; can manufacture with parts from plumbing supply store	Subject to breakage, should install with a cut-off valve; viscosity is an issue, may clog with thicker substances; may freeze with certain substances in cold weather.	≈ $170 for materials plus labor to assemble and install
Float gauge	Visual indication	Simplicity; can retrofit	Certain product characteristics, such as a sticky coating forming on the float, can make this gauge inaccurate.	≈ $230 for part plus cost to install
Load cell (a.k.a. strain gauge device)	Essentially a mechanical support member or bracket equipped with one or more sensors that detect small distortions in the support member	Weighing system requirements must be a paramount consideration throughout initial vessel support and piping design, or performance is quickly degraded (Hambrice & Hopper, 2004).	Cost; not conducive to retrofitting; vessel support structure and connecting piping must be designed around requirements of floating substructure; need to know specific gravity of liquid hauling.	≈ $10,000
Ultrasonic level sensor	Measure the time required for a sound wave to travel from the emitter to the object's surface and return to the detector	Not subject to deterioration due to corrosive, viscous, coating and scaling liquids; accuracy.	Do not work well with liquids with foam, heavy vapor, turbulence.	≈ $760 plus cost to install
Radar	Uses guided wave radar to measure the liquid level or volume in mobile tanks	Precise; for bulk solids, slurries, and opaque liquids such as dirty sumps, milk and liquid styrene, even in vapor and foam; can retrofit; ideal for vessels with numerous obstructions.	Cost	≈ $1,393

Case Study #1

During the process of loading blood and discarded turkey parts at a turkey processing plant, the driver climbed the truck-mounted ladder on the side of the truck to check the fill level of the blood tank as it was being loaded. The driver needed to stand on top of the truck to hold onto the blood pipe while looking down into the tank to determine when it was full or if the weight limit had been reached. The truck was not equipped with a fill gauge.

When the tank was full, he instructed a processing plant employee to cut off the blood flow into the tank. After bending over the tank as if he were sick, he fell approximately 10 ft onto a concrete floor, striking his head. He died 2 days later. The autopsy report noted that the cause of death was aspiration pneumonia with contributing causes of blunt force trauma to the head.

The decedent was working in an environment with the potential of producing hydrogen sulfide. Although it is a recognized hazard in the meat processing industry, it is unknown whether the processing plant personnel involved in the loading process or the driver who was fatally injured knew of the hazard.

Case Study #2

A wastewater management employee at a hog processing plant was transferring hog waste sludge containing decayed and fermented pig parts, urine, feces, fat, grease and hair from an overhead storage tank to a tanker truck for shipment off-site. After starting the gravity flow of the waste into the tanker, the employee remained on top of the tanker truck. In accordance with company policy, he was wearing a personal fall arrest system (PFAS) anchored overhead. The transport company was aware of the possible production of hydrogen sulfide gas by the anaerobic breakdown of waste.

Due to the cool outside temperature and the warmth of the sludge being loaded, a thick fog was generated, hindering visibility. Within minutes of starting the loading process, the truck driver noticed a lack of motion by the employee on top of the tanker. The driver found the employee motionless and slumped over, his head in the tanker's hatch opening and the sludge still running. Another worker noted that employees were unhooking the harness so that they could bend over the hatch opening to check the tank fill level. The wastewater employee suffered a fatal injury from inhalation of hydrogen sulfide gas. The truck was not equipped with a fill gauge.

Case Study #3

A fuel oil tank truck delivery employee was loading fuel at a transfer station. The truck held approximately 3,200 gallons, the typical size for home delivery vehicles. The employee had parked his tank truck beside the fuel loading rack at the oil company and climbed the steps of a 48-in.-high platform. After removing the tank hatch and setting the downspout into the tank to load fuel oil, the driver climbed to the top of the fuel truck and onto the fuel spill reservoir/platform to observe the filling process.

After an unusually long period, plant workers noticed the truck still at the platform. After searching the truck, workers found the delivery employee in the driver's side cab of his truck, leaning against the

Figure 1
Threaded Rod

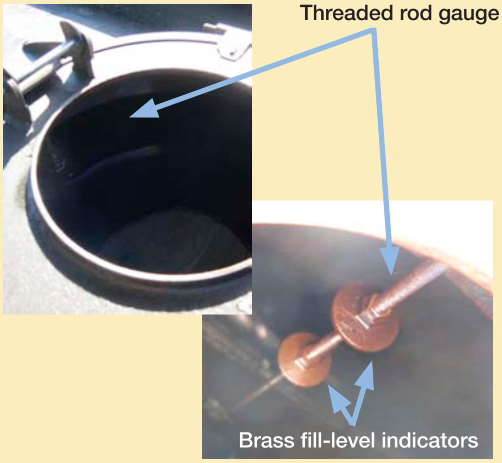


Figure 2
Sight Eye

glass, bleeding and incoherent. Hair and blood on the ground on the passenger side of the truck indicated the site of the employee's landing after falling from the top of the truck. The employee suffered a broken left shoulder, broken ribs, broken back and head injuries.

A threaded rod with brass washers acting as a fill gauge (Figure 1 shows an exemplar) mounted to the inside of the hatch allowed the employee to view the fill level while standing on the loading platform (loading rack). The side of the truck, pulled alongside the loading platform, acted as a barrier, which would have protected him from falling from the platform. However, the employee claimed he was too short to see the gauge while standing on the platform, so he climbed on top of the truck for a better view.

In these case studies, the injuries occurred after the employee climbed onto the cargo tanker to determine the fill level. Knowing the fill level of the tank is important for safety. Although this article discusses the types of gauges that could be used to avoid the aboveground exposure, other usual and customary injury prevention controls could be employed, such as pretask assessments for evaluation of confined space hazards, respiratory hazard assessments, use of personal and area hydrogen sulfide monitoring, personal worker-down alarm systems, automatic fill line shut-off technologies and hermetical seals at the junction of the waste discharge and tank hatch openings.

Although not applicable to the type of tank trucks and loading racks in these three cases, other loss prevention technologies are employed at some tank loading facilities. Railings can be constructed that surround the work area on the top of the tank. Gantry systems, designed for the type of cargo tankers used, can be moveable or permanently installed to prevent falls. Cargo tankers can have catwalks or tank top walkways with railings installed to prevent falls, and overhead anchored fall arrest systems can be used to reduce the severity of falls.

PHOTOS BY ALBERT WEAVER III

Determining Fill Levels in Tank Trucks

Various types of systems are used to determine the fill level of tankers of which the gauges covered here are only part. More complex methods include metering skids, weight systems and bottom loading. Composed of one or more flowmeters, a metering skid is a framed device on which various assemblies are installed to aid in custody transfer, that is gallons of product (Petropedia, 2016).

Top loading and bottom loading involve tankers being filled at loading gantries either by loading from the top or from the bottom, with or without vapor recovery systems. Top loading uses an articulating arm inserted into the tank compartment through a hatch on top of the truck. A long fill pipe extends to the bottom of the compartment. Liquid level rapidly covers the bottom opening of the fill pipe resulting in low vapor generation. Bottom loading uses a hose or flexible arm attached to the bottom of the tanker. Vapor generation is minimized by the introduction of liquid through the bottom of the tanker compartment (BP Safety Group, 2008).

Equipping tankers or the source of the cargo with an automatic shut-off valve allows the operator to monitor the fill level from the ground. Automatic shut-off technology has been in use since the early 1940s (U.S. Patent No. US2316934 A, 1943) and has been used in many different industries. By using an automatic shut-off system, the worker no longer needs to stand on top of the tanker while the tank is filling.

Automatic shut-off valves work with an electronic gauging system. The gauge measures the fill level and when the tank is filled to a predetermined level, the filling system automatically shuts off (W. Graham, personal communication, July 7, 2014). The system requires companies to alter the filling process by using a power take off (PTO) pump to fill the tankers rather than gravity. The PTO pump is powered from the running engine of the tanker truck. Another type of system is an overflow prevention system that uses a gauging system to control the automatic shut off. Once the liquid level reaches the desired shut off point, the engine will automatically turn off, thus removing the power to the pump. This eliminates the need for workers to be on top of the tanker to manually shut off a filling mechanism.

Gauges Reviewed

Keeping personnel on the ground while loading can be facilitated by the use of fill-level gauges. Many types of gauges ranging in price and complexity are available. Cargo tankers can be retrofitted with low-tech and less expensive gauges, or high-tech gauges that provide greater accuracy

Figure 3
Sight Tube

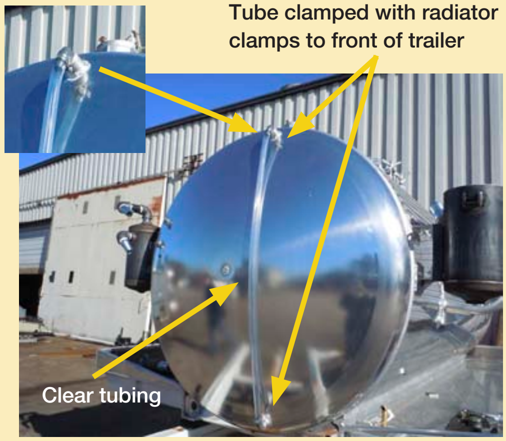
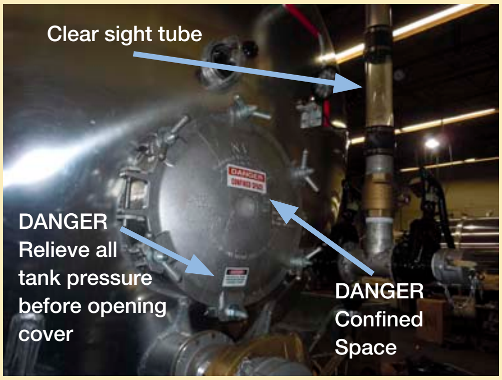


Figure 4
Sight Tube



and convenience. Following are several examples of these gauges. Table 1 (p. 30) lists common types of gauges and their characteristics.

Sight Eye

One of the simplest and lowest cost gauges is a sight eye gauge. This is a glass or plastic bowl design with an aluminum or metal framework to support the bowl that can be retrofitted to a cargo tanker (Figure 2, p. 31). The bowl of the sight eye provides a visual indication of the fluid level in the tank. Sight eyes are usually attached to the cargo tank at the rear of the tank where the surface of the tank is less curved. A hole is cut into the cargo tank the size of the circumference of the sight eye base, then the sight eye is welded to the cargo tank.

Typically three sight eyes are used to indicate a low, medium and maximum level in the cargo tank by installing them at the different corresponding heights. Once installed, the sight eyes can be used to view the fluid level in a tanker without having to access the top of the tanker.

The cost of a 5-in. sight eye is approximately $40 plus the cost of installation. Fill-level information received from the sight eyes is limited since the volume is known only to the extent of the level of the sight eye. The bowl can break or become dirty making the fill level no longer visible. Also, the consistency of the liquid must be such that the bowl can fill. A semiliquid substance such as a sludge with large semisolids may block the 5-in. bowl and the bowl may not fill correctly.

A sight eye should not be confused with a sight glass. A sight glass is a glass tube, or a glass-faced section of a process line, used for sighting liquid levels or taking manometer readings.

Sight Tube

Another inexpensive liquid fill-level gauge for cargo tankers is a sight tube. A sight tube, like the one shown in Figure 3, is a glass tube used for sighting liquid levels or taking manometer readings. As the liquid level in a vessel rises or falls the liquid in the glass tube will also rise or fall. The gauges are made of glass, plastic or combination of the two materials (Tomsic & Hodder, 2000).

Sight tubes are simple and can be retrofitted to cargo tankers. As the liquid fills the tanker, the sight tube will maintain the same level of fluid, thus giving a visual indicator of the tanker's fill level (Figure 4). Parts to assemble a sight tube cost approximately $170; installation, cutting holes into the cargo tank, welding the pipe-fittings and assembling the parts are additional costs. Use of a sight tube is hampered by severe cold weather, which may cause the contents of the tube to freeze. Also viscosity of the liquid may be an issue. If the liquid is too thick or contains semisolids, it may not fill the tube. Another concern is the gauge's ability to withstand impact; since the tube stands out or away from the tank, the tube is subject to breaking.

Threaded Rod

A threaded rod gauge is also used in some cargo tank trucks. The gauge is a threaded rod welded to the top lip of the tank hatch with brass or other nonsparking, nonferrous metal washers threaded onto the rod at the height(s) the cargo is to be loaded (Figure 1, p. 31).

Float Gauge

Similarly low tech, a float gauge can be retrofitted to a cargo tank. Floats are buoyed on the liquid's surface; therefore, the density of the float must be less than the density of the liquid. The position of the float is observed visually by an indicator arm, which is external to the tank. A float gauge consists of a ball float at the end of a rod (Figure 5). The rod is placed through the side of a cargo tank and an arrow is attached to the rod's exterior end. As the liquid level rises, so does the float and the arrow attached to the exterior end of the float, indicating the tanker's fill level. Float gauges cost approximately $230 plus installation. Liquids that may form a sticky coating on the float, such as a resin, could interfere with the accuracy of the gauge (Emerson Process Management, 2006).

Load Cells

Alternatively, load cells are complex and expensive, but provide greater accuracy when determining the fill volume (Figure 6). As explained by Webster and Eren (2014), "The strain-gauge load cell consists of a structure that elastically deforms when subjected to a force and a strain-gauge network that produces an electric signal proportional to this deformation" (pp. 41-44). Load cells, also known as strain gauges, are essentially sensors that

Figure 5
Float Gauge

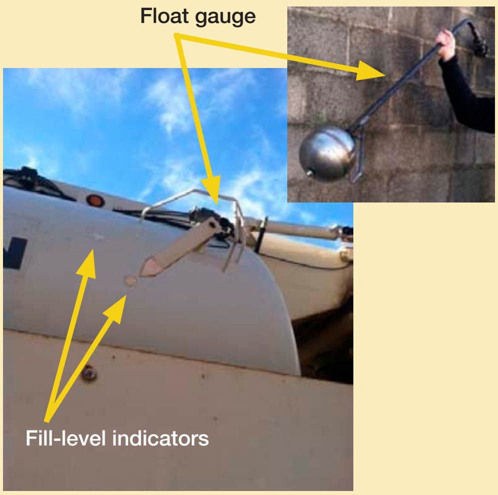


Figure 6
Load Cell

measure the strain or distortions of the framework supporting the tank (Hambrice & Hopper, 2004). Not conducive to retrofitting, load cell systems must be part of the vessel support and piping design. Also, the specific gravity of the liquid cargo must be known to calibrate the system. Load cells cost approximately $10,000.

Similar to using a load cell, the amount of fill can be determined by weight. Tanker trucks can be weighed empty and then weighed full. A gallon estimate can be made by subtracting the before weight from the after weight and using a one-pound-per-gallon conversion. This can be done with traditional truck scales or portable truck scales.

Ultrasonic Level Transmitters

Ultrasonic level sensors measure the time required for a sound wave to travel from the emitter to the object's surface and return to the detector (Figure 7). Then the information is sent to a receiver located in the cab of the truck. By using sound waves, the ultrasonic level sensors are not subject to deterioration due to corrosivity, viscosity, or being coated or scaled by liquids as would a float gauge or sight tube. Liquids with foam, heavy vapor or turbulence do not work well with ultrasonic level sensors since those characteristics can absorb and/or deflect away a substantial portion of the return signal (Flowline, 2016).

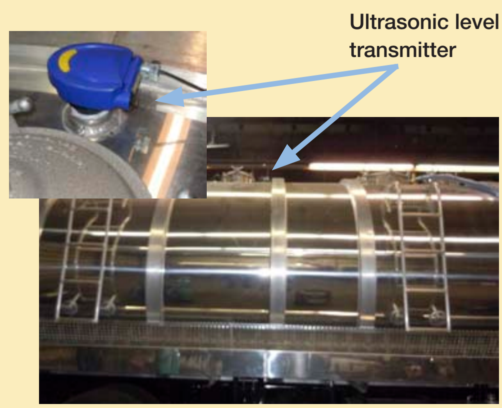
Guided Wave Radar

First used in the early 1990s for measuring the level of liquids, guided wave radar level sensors utilize a continuously suspended cable or rod (wave guide) inside the cargo tank. Guided wave radar may also be known as micro-impulse radar.

Guided wave radar level sensors operate by generating electromagnetic energy of approximately 1 GHz, which is at the low end of what is considered by RF engineering to be microwaves. The radar energy pulses are guided toward the surface of the liquid through a suspended cable or rod that runs the length of the desired measuring range. Using the reflected radar pulses and time-of-flight, guided wave radar units measure the empty space (Lewis, 2012).

PHOTOS BY ALBERT WEAVER III

Figure 7
Ultrasonic Level Transmitter



Costs & Benefits

The expenditure to fit a cargo tanker with a fill-level gauge is offset by the safety of keeping personnel on the ground, away from noxious and toxic contaminants, and possible injury. Fluids need not be toxic to create a hazard. Overfilling can create slippery surfaces and cause exposure to contaminants, while spills that feed insects and vermin can spread disease at food plants.

OSHA (2016) states that by implementing an effective safety and health management system, employers may expect to significantly reduce injuries and illnesses and thus reduce the associated costs. ASSE (2002) states, "There is a direct positive correlation between investment in safety, health and environmental performance and its subsequent return on investment." Employers can also benefit in avoiding costly litigation. Between 2013 and 2015, of the nine work injury lawsuits reported by North Carolina Lawyers Weekly (2016), the average settlement reached was $1.6 million.

Another incentive to protect workers is the memorandum of understanding (MOU) between the Department of Justice (DOJ) and OSHA. The MOU moves the OSH Act into DOJ's Environment and Natural Resource Division and that division's Environmental Crimes Section. The U.S. Attorney's offices works with OSHA to investigate and prosecute worker endangerment violations (Smith, 2015). Not only could an incident be a financial cost to a com-

Figure 8

Example Using DOT Hazardous Materials Table

Symbols	Hazardous materials descriptions and proper shipping names	Hazard class or Division	Identification Numbers	PG	Label Codes	Special provisions (§172.102)	(8) Packaging (§173.***) Exceptions	Non-bulk	Bulk	(9) Quantity limitations (see §§173.27 and 175.75) Passenger aircraft/rail	Cargo aircraft only	(10) Vessel stowage Location	Other
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8A)	(8B)	(8C)	(9A)	(9B)	(10A)	(10B)
	Hexafluoropropylene compressed *or* Refrigerant gas R 1216	2.2	UN1858		2.2	T50	306	304	314, 315	75 kg	150 kg	A	

Figure 8: Example using DOT hazardous materials table (excerpt). For hexafluoropropylene compressed or refrigerant gas R 1216, 49 CFR 173.314 or 49 CFR 173.315 bulk cargo tanker standards would apply.

pany, it could also mean criminal charges for an owner. OSHA Administrator David Michaels notes that employers now face prison terms of 25 years instead of 6 months if convicted of crimes that contribute to employee fatalities.

Smith (2015) notes that one firm's owner was charged in June 2015 with four counts of making false statements, one count of obstruction of justice and one count of willfully violating an OSHA regulation causing death to an employee. He pleaded guilty to all charges and faces a maximum sentence of 25 years in prison, 3 years of supervised release, $1.5 million in fines and a $510 special assessment for the criminal conviction.

The cost for installing gauges on tank trucks range from approximately $40 for sight eyes and sight tubes to about $10,000 for load level gauges (Table 1). Even the $10,000 more sophisticated gauges are substantially less than the cost for litigated incidents.

DOT Guidance

Following are details of the requirements under DOT for which gauges are required. Using cargo tankers for bulk transport presents hazards to personnel while loading and unloading, including exposure to confined spaces and falling, among other risks. Bulk packaging is defined by DOT in 49 CFR 171.8 (transportation regulations) as a packaging, other than a vessel or a barge, including a transport vehicle or freight container, in which hazardous materials are loaded with no intermediate form of containment. Defined by volume, it has:

1) maximum capacity greater than 450 L (119 gallons) as a receptacle for a liquid;

2) maximum net mass greater than 400 kg (882 lb) and a maximum capacity greater than 450 L (119 gallons) as a receptacle for a solid; or

3) water capacity greater than 454 kg (1,000 lb) as a receptacle for a gas.

Cargo tankers have manufacturing designs, gauges and loading procedures specified by DOT regulations in 49 CFR as well as American Society of Mechanical Engineers' technical documents and other consensus standards. Tank specifications are given based on the material being transported. Some cargo tank trucks are not required by DOT to have fill-level gauges. Typically, these vehicles haul nonhazardous materials and even though the cargo may be considered nonhazardous, the process of loading, unloading and hauling with a cargo tanker presents hazards. As noted in the case studies, one hazard is falling from the top of the cargo tanker. Eliminating the need to be on top of the cargo tanker reduces this risk and improves worker safety. For the type of tanker that DOT specifies for a specific material, fill-level gauge specifications for the different type of cargo tanks also depend on the type of material transported. Fill-level gauges offer the opportunity to keep workers on the ground and should be used regardless of regulatory mandates to employ them.

The following discussion and example explain the sequential steps needed to determine the type of tanker and fill gauge necessary for DOT-defined hazardous materials. The type of tanker and gauge that can be used is listed in the hazardous materials table in 49 CFR 172.101. The bulk transport column (8C) of that table lists the type of cargo tanker that can be used for transport, with the three digits listed designating the appropriate section of part 173 (Figure 8).

Once the type of cargo tanker that can be used is determined, then the specifications of the gauge needed can be found under the standards for that type of tanker. As an example, hexafluoropropylene compressed or refrigerant gas R 1216, the standards listed for bulk transport are 49 CFR 173.314 and 173.315. The latter lists an MC-331-type cargo tanker, which is primarily for transportation of compressed gases.

Next, the type of gauge must be determined for that type of cargo tanker. A search of the transportation code gives 49 CFR 178.337-14, Gauging Devices, and addresses the requirements. That subchapter references 49 CFR 173.315(h), which is a listing for the different compressed gases and the gauging device permitted for filling purposes.

For an MC 338, which is an insulated cargo tank motor vehicle, the DOT specification in 49 CFR 178.338-14 for gauging devices requires that the tanker have an accurate fixed-length dip tube, fixed trycock line or differential pressure liquid level gauge that indicates the maximum permitted level, which is 2% outage below the inlet of the pressure control valve or pressure relief valve and with a design pressure at least that of the tank for the primary control for filling. The standard requires that the gauge be designed and installed to accurately indicate the maximum filling level at the point midway of the tank both longitudinally and laterally.

Section 178.345 includes the general design and construction requirements applicable to specification DOT 406, DOT 407 and DOT 412 cargo tank motor vehicles. Section 178.345-12 specifies for gauging devices that:

> Each cargo tank, except a cargo tank intended to be filled by weight, must be equipped with a gauging device that indicates the maximum permitted liquid level to within 0.5% of the nominal capacity as measured by volume or liquid level. Gauge glasses are not permitted.

A gauge glass is a glass or plastic tube for measuring liquid level in a tank or pressure vessel, usually by direct sight (Tomsic & Hodder, 2000).

Conclusion

Cargo tank owners/operators should install gauges to keep workers grounded, whether or not doing so is mandated by DOT or other regulations. Not only do gauges and other fill-level devices keep workers safe, but they also decrease the cost associated with injuries while delivering a positive return on investment. The type of gauge to use may be in part a financial decision but it should also be based on the type of load to be transported. Gauge suppliers can provide selection guidance as well as advice on the efficacy of the fit between the cargo and the gauge or sensor. Another source of feedback is firms that use the gauge with a similar cargo. **PS**

Fill-level gauges offer the opportunity to keep workers on the ground and should be used regardless of regulatory mandates to employ them.

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