Guidelines for the Operation, Assembly, Repair, Testing and Inspection of Hazardous Material Cargo Tanks

FINAL REPORT

Submitted to:

U.S Department of Transportation
Federal Motor Carrier Safety Administration

June 2009

Virginia Tech Transportation Institute

FOREWORD

The purpose of this report is to assist the Federal Motor Carrier Safety Administration (FMCSA) in identifying factors that affect the service life of a cargo tank and to assist in the development of industry-informed guidelines to provide methods, programs, processes, and procedures that will minimize the effects of factors that reduce the service life of a cargo tank. The basis for these guidelines includes industry comments, regulatory documents, and professional organizations' guidance.

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This program was administered through the Federal Motor Carrier Safety Administration (FMCSA) and the Virginia Transportation Research Council (VTRC). The FMCSA Authorized Organizational Technical Representative (AOTR) is James Simmons and the VTRC Principal Investigator (PI) is Mike Perfater.</td></tr>
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This document consists of guidelines and recommendations related to operations, assembly, repair, testing and inspection of cargo tanks hauling hazardous materials. This document is the result of research findings from the project titled: Research to Identify the Factors that Affect the Service Life of Cargo Tanks [VTRC # 08-0669-10, FMCSA # TMC75-07-H-00008 Task Order # 2].</td></tr>
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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ACKNOWLEDGEMENTS

The authors of this report wish to thank James Simmons and Felix Gonzalez of the Federal Motor Carrier Safety Administration (FMCSA) for their constructive comments throughout this project. Mr. Simmons served as the Authorized Organizational Technical Representative (AOTR) and Mr. Gonzalez served as the project manager. The authors also wish to thank other staff members at FMCSA who provided comments during the course of this work, and also Mike Perfater, Cynthia Perfater, and other members of the Virginia Transportation Research Council (VTRC) for their support and oversight.

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ACRONYMS

AI	Authorized Inspector
AOTR	Authorized Organizational Technical Representative
ASME	American Society of Mechanical Engineers
BPV	Boiler and Pressure Vessel
CFR	Code of Federal Regulations
CI	Certified Inspector
CGA	Compressed Gas Association
CMV	Commercial Motor Vehicle
CT	Cargo Tank
CTMV mfr.	Cargo Tank Motor Vehicle Manufacturer
DCE	Design Certifying Engineer
DOT	Department of Transportation
EPA	Environmental Protection Agency
FMCSA	Federal Motor Carrier Safety Administration
HM	Hazardous Materials
HMR	Hazardous Materials Regulations (49 CFR Parts 171-180)
I	Internal Visual Inspection
IGSCC	Intergranular Stress Corrosion Cracking
K	Leakage Test
L	Lining Test
LPG	Liquefied Petroleum Gas
MAWP	Maximum Allowable Working Pressure
NBIC	National Board Inspection Code
NPT	National Pipe Thread
NQT	Non-Quenched and Tempered
NTTC	National Tank Truck Carrier
OSHA	Occupational Safety and Health Administration
P	Pressure Retest
PHMSA	Pipeline and Hazardous Materials Safety Administration
Psig	Pound-force per square inch gauge
QI	Qualified Inspector

QT	Quenched and Tempered
RI	Registered Inspector
SCFH	Standard ft^3/hour
T	Thickness Test
TTMA	Tank Truck Manufacturers Association
U.S.	United States
USDOT	United States Department of Transportation
V	Visual External Inspection
VTTI	Virginia Tech Transportation Institute
WFMPT	Wet Fluorescent Magnetic Particle Testing

1. Introduction

These guidelines are based on cargo tank (CT) industry input gathered by Virginia Tech Transportation Institute (VTTI) during the Virginia Transportation Research Council (VTRC)/Federal Motor Carrier Safety Administration (FMCSA)-sponsored project titled Research to Identify Factors that Affect the Service Life of Cargo Tanks.

1.1 THE CARGO TANK INDUSTRY

The CT industry is a varied group of transportation providers who specialize in the transport of fluid hazardous materials. To adequately transport these unique substances, specific tanks have been designed and fabricated according to the Hazardous Materials Regulations, which fall within the regulatory oversight of the U.S. Department of Transportation (USDOT).

The DOT Specification 406, 407, and 412 CTs replace the MC 306, 307, and 312 tanks, which are no longer manufactured but are still in operation. HM 183[1] replaced the use of the prefix "MC" with the prefix "DOT" for use on CTs built to the newest requirements. Although the MC series CTs are still legal to operate, they must conform to the requirements of the current code. Typically, the DOT 406 CT is used for gasoline, fuel oil, alcohol, and other liquid flammables. The DOT 406 CT is typically constructed of aluminum, is designed for atmospheric pressure, and has an elliptical cross section.

The DOT 407 CT is characteristically used for solvents, plasticizers, casing head gas, etc. It is typically constructed of stainless steel, designed for a pressure of at least 172 kPa (25 psig), and has a circular cross section.

The DOT 412 CT is characteristically used for corrosive materials. It is typically constructed of stainless or carbon steel, is designed for a pressure of 241kPa (35 psig), and has a circular cross section.

The MC 330, MC 331, and MC 338 CTs are high-pressure vessels designed and constructed according to ASME Section VIII, Division 1. These tanks are typically used for atmospheric gases or cryogenics. The MC 330 and MC 331 CTs are designed for pressures anywhere from 689kPa to 3447kPa (100 psig to 500 psig), whereas the MC 338 CT is designed for pressures from 174kPa to 3447kpa (25.3 psig to 500 psig).

1.2 CARGO TANK REGULATIONS, STANDARDS, AND CODES

There are several organizations involved in the procedures and practices of repairing, inspection, and testing of specification CTs. These agencies include two USDOT agencies (i.e., Pipeline and Hazardous Materials Safety Administration [PHMSA] and Federal Motor Carrier Safety Administration [FMCSA]) and two professional organizations (i.e., American Society of

[1] "Requirements for Cargo Tanks; Final Rule," 54 Federal Register 111 (12 June 1989), pp. 24982 - 24990.

Mechanical Engineers [ASME] and National Board of Boiler and Pressure Vessel Inspectors). The USDOT publishes CT regulations in Section 49 of the Code of Federal Regulations (CFR). The following provide guidance documents:

- An electronic copy of the CFR: U.S. Government Printing Office (GPO) Access (http://ecfr.gpoaccess.gov/).
- The ASME provides guidance through rules of safety governing the design, fabrication, and inspection of boilers and pressure vessels. This Boiler and Pressure Vessel Code – 2007 Edition can be obtained through the ASME Web site: http://www.asme.org/Codes/International_Boiler_Pressure.cfm.
- The National Board of Boiler and Pressure Vessel Inspectors publishes the National Board Inspection Code (NBIC), which provides standards for the repair and/or alteration of pressure vessels and pressure relief devices (National Board, 2009). A copy of the NBIC can be obtained through the National Board's Web site: http://www.nationalboard.org.

1.3 METHODS

This methods section is specific to the guidelines document. Participants, data collection, and analysis are described in detail.

1.3.1 Participants

The subject pool for this study consisted of 63 administrators and maintenance/inspection personnel of commercial fleets carrying hazardous material (HM) and inspection and repair facilities qualified to inspect, test, and repair HM CTs. The commercial fleets included eight motor carriers that represented a cross section of the carrier population meeting the following general requirements:

- Two of the motor carriers selected operate insulated MC 307/DOT 407 specification CTs transporting chemicals.
- Two of the motor carriers selected operate MC330/MC331 (compressed gases) specification CTs constructed in accordance with Part UHT in Section VIII of the ASME Code.
- Two of the motor carriers selected operate MC330/MC331 (compressed gases) specification CT bobtails (CTs, typically less than 3,500-gallon water capacity, mounted directly to the vehicle chassis).
- Two of the motor carriers selected operate MC306/DOT 406 (flammable liquids with low vapor pressure) specification CTs.

The inspection, test, and repair facilities included 10 companies that represented a cross section of inspection, test, and repair facilities. The facilities involved in this study specifically conducted the following:

- Two of the facilities selected perform repairs on MC 331 specification CTs constructed in accordance with Part UHT of Section VIII of the ASME Code and perform wet fluorescent magnetic particle testing in accordance with Section V of the ASME Code.
- Two of the facilities selected perform repairs on insulated CTs transporting chemicals.
- Two of the facilities selected perform rechassis operations on MC 330/MC 331 specification CTs.
- Two of the facilities selected perform testing and inspection of specification CTs.
- Two of the facilities selected performed mobile test and inspections of specification CTs.

1.3.2 Data Collection

For the guidelines document, the VTTI team used a variety of survey tools and techniques to identify and explore the HM fleets' and maintenance facilities' recommendations related to CT assembly, testing and inspection, repair, and operations. These methods included interviews with senior fleet and facility maintenance personnel, focus groups with key fleet and facility maintenance personnel, and direct observation of inspection and repair procedures.

1.3.3 Data Analysis

The approach that was used to analyze the results of the interviews and focus groups was an adaptation of framework analysis, a methodology developed in the 1980s at the National Centre for Social Research in Britain.[2] The steps that were taken to carry out the framework analysis were as follows:

1. **Determining Analysis Focus:** Researchers determined that the focus of the framework analysis would be on industry recommendations related to the four key areas of importance to the development of the guidelines document: CT assembly, testing and inspection, repair, and operations.

2. **Identifying and Transcribing Key Audio Clips:** Each interview and focus group audio recording was reviewed to determine the location of any discussions related to the four key areas of interest. Key segments of each audio file were then transcribed in full.

3. **Familiarization:** A researcher read over each of the transcripts to become familiar with the dataset.

4. **Identifying a Thematic Framework:** A researcher conducted a review of the dataset and identified for each theme (e.g., Operations, Test and Inspection, etc.) a list of key subthemes. The themes and subthemes were then arranged in a logical order and an index was created. For instance, under the theme Operations was the subtheme Driver.

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[2] Ritchie, J., Spencer, L., and O'Conner, W. (2003). Carrying out Qualitative Analysis. In J. Ritchie & J. Lewis (Eds.), *Qualitative Research Practice* (pp. 220). London: Sage.

5. **Indexing:** The index was systematically applied to the dataset and comments were identified and marked in the transcripts by theme and subtheme (e.g., Operations: Driver). Multiple subthemes were assigned to the statements if necessary.

6. **Charting:** A researcher arranged all of the indexed comments into one Microsoft® Excel® spreadsheet. The spreadsheet was then sorted by theme (e.g., Operations, Test and Inspection, etc.). Individual spreadsheets were then created for each theme. These spreadsheets or thematic charts were further sorted by subtheme (e.g., Operations: Driver). Finally, within subthemes categories were created. For example, under Driver two categories (e.g., Driver Training and Driver Inspections) emerged from the data.

7. **Interpretation:** As a last step in the framework analysis process, the themes, subthemes, and categories captured and detailed in the charts were used by the research team to better understand industry perspectives related to key areas (i.e., operations, assembly, repair, test and inspection). Regulations related to each of the industry recommendations were also reviewed. A listing of these recommendations and related regulations is included in each section of the guidelines document along with supporting quotes from industry where applicable. These industry recommendations and related regulations provided the foundation for this guidelines document.

1.4 RESULTS AND DISCUSSION

From the analyzed industry comments, the industry-recommended practices were identified and grouped according to type of CT activity (i.e., operations, repair, assembly, test and inspection). These industry-recommended practices are supplemented by recommended procedures from industry-related associations (e.g., National Tank Truck Carriers, Compressed Gas Association, State propane associations, etc.) and engineering societies (e.g., ASME, The National Board of Boiler and Pressure Vessel Inspectors).

1.5 STRUCTURE OF THE GUIDELINES DOCUMENT

This guidelines document will be divided into five separate chapters:

1. Introduction
2. Cargo Tank Fleet/Facility Operations
3. Cargo Tank Assembly
4. Cargo Tank Repair
5. Cargo Tank Test and Inspection

2. Cargo Tank Fleet/Facility Operations

2.1 INTRODUCTION

During the course of this study, the research team found that participants often spoke about the lifespan of a CT in terms of how the company that owned the tank was operated. Researchers felt that some interesting and worthwhile findings could be gleaned by looking in more depth at what participants had to say about operations. This chapter is not an exhaustive look at operations; rather it provides a focused list of recommendations related to the comments that participants made about operations as they were discussing the factors that affect the service life of CTs.

The analysis of participant comments regarding operations can be broken down into three areas: Fleet Management, Driver, and Maintenance. Within each area of operations there are several categories. For instance, one area of operations analyzed was maintenance. Comments gathered from participants and analyzed suggested that preventative maintenance (PM), proper coating of the tank, and tank cleaning are ways to potentially extend the service life of a CT. The research team pulled together participant comments about each of these these maintenance practices as well as current regulations related to required maintenance. These inputs were used in the development of industry recommendations. A list of industry recommendations is included within each section (e.g., Maintenance) by category (e.g., Protective Coating). In most cases a quote from industry is provided for each recommendation.

2.2 FLEET MANAGEMENT

A fleet's management approach is very important to the service life of a CT. Tanks are likely to last longer when fleets are careful about understanding and managing the lading transported in their tanks, when they keep good records on each tank and use those records to track changes in the condition of each tank, when they are safety-focused in terms of how they operate their business, and when they invest resources in good drivers and regular maintenance. Each of these areas (i.e., Lading Management, Record Keeping/Condition Tracking, Safety Policies and Procedures, and Investment) is described in this section along with industry recommendations for each area, related regulations, and supporting quotes from participants in this study.

Readers may want to reference some of the Web sites that were useful in the development of this section, including the following:

- How to Comply with Federal Hazardous Materials Regulations:
    - http://www.fmcsa.dot.gov/safety-security/hazmat/complyhmregs.htm
- Loading/Unloading Inspection:
    - http://www.fmcsa.dot.gov/facts-research/research-technology/publications/accidenthm/inspect.htm

2.2.1 Lading Management

It is critical that a fleet hauling hazardous material understands whether or not the products they are hauling are compatible with their tank. 49 CFR 173.24(e) states, "Even though certain packagings are specified in this part, it is, nevertheless, the responsibility of the person offering a hazardous material for transportation to ensure that such packagings are compatible with their lading. This particularly applies to corrosivity, permeability, softening, premature aging and embrittlement."

Though it is the responsibility of the shipper to determine compatibility with the type of CT being used for shipment, FMCSA[3] notes that the "carrier must check to insure that the material offered by the shipper is properly described and packaged." The fleets and facilities interviewed stressed the importance of carriers rigorously managing this aspect of their business (i.e., lading compatibility) because if communication breaks down between the shipper and the carrier, the results can be detrimental to the service life of the CT. For example, participants mentioned that transporting a load that is incompatible with a tank can lead to, among other things, changes in barrel thickness due to corrosion.

Related Regulations
To determine the regulatory requirements for shippers and carriers, it is important to review the most current copy of the Code of Federal Regulations Parts 100-180. Some of the key regulations within Parts 100-180 that cover compatibility include:

- 49 CFR 172.101
- 49 CFR 173.22
- 49 CFR 173.24
- 49 CFR 177.848

Industry Recommendation

- **Verify that the lading being offered is compatible with the cargo tank before accepting the shipment.**

Industry Supporting Quotes

- *You want to make sure the stuff you are putting in will work with the steel or the container, the tank that you are putting it in as far as corrosion or stress or whatever.* (MC 330/ MC 331 and Wet Fluorescent Magnetic Particle Testing)
- *We're proactive and we review every product that goes into our tank. So we know what is going in and if we have some that are damaged we will go back and run a product history to see what products we've hauled before and research those out.* (Repair Insulated CTs)

2.2.2 Record Keeping/Tracking Key Measures

CT owners should maintain CT-specific records of all shipments, maintenance, tests/inspections, and repairs. These records will enable the fleet to identify and track changes or problems with a CT over time (e.g., corrosion, fatigue, etc.). Designating someone to be in charge of keeping these records is recommended.

[3] http://www.fmcsa.dot.gov/safety-security/hazmat/complyhmregs.htm

Related Regulations

- 49 CFR 172.201
- 49 CFR 177.817
- 49 CFR 396.3
- 49 CFR 396.11
- 49 CFR 396.21

Industry Recommendations

- **Maintain detailed records on each tank so that issues with a particular tank can be tracked over time.**
- **Establish accountability for maintaining records on all of the CTs.**
- **Use records from past years to help identify problems (such as thinning over time).**

Industry Supporting Quotes

- *I will give the guy, the mechanic, last year's, or 2 years ago, thickness chart for comparison. So if he seeing any thinning or notices any problems then, "OK, he had this, then all of a sudden now we're down to this." So they can alert me to it.* (MC 330/MC 331 and Wet Fluorescent Magnetic Particle Testing)
- *….He keeps track of every time that particular trailer's been in here for service. So at the top of the name plate sheet it will have all of the different shop order numbers so at any point in time if we want to do what it is you're talking about* [track key measures of corrosion, fatigue, etc.] *we can pull all the shop orders and find out, "okay it was in here in '89, what did we do in '89? We have a repair tech here, was that something we did in 1989?" And we can pull those documents up.* (MC 330/MC 331 and Wet Fluorescent Magnetic Particle Testing)
- *We are keeping the record of what we've done to date and that is how I will be able to know that when one of my customers will call I'll be able to go in there and look on the computer and say "okay, we were there 3 months ago, we did this."* (Mobile Test and Inspection)
- [NAME REDACTED] *keeps service records on everything we're doing. He has service records on everything that he does. Everything that we do, we put in a folder and he documents it. So he can pull that particular trailer up, he can tell you everything they done to the trailer since it's been in service.* (MC 307/DOT 407)
- *….We continue to look at safety devices and analyze what's happened in the past, some accidents, things like that*. (MC 330/MC 331)

2.2.3 Safety Policies/Procedures

Companies operating and inspecting CTs should have policies and operating procedures in place that ensure the safety and security of employees and equipment. Proactively identifying and addressing safety risks, making sure equipment is in safe operating condition, and using safer equipment when possible are some of the ways participants said their companies try to maintain a safe operating environment. A safe operating environment can lead to a decrease in costs associated with equipment replacement or repair and lengthen the overall service life of that equipment.

Participants also described how important it is to create a culture that affirms driving decisions that avoid operating in adverse weather conditions. This company policy is supported in 49 CFR 392.14, which states that:

> Extreme caution in the operation of a commercial motor vehicle shall be exercised when hazardous conditions, such as those caused by snow, ice, sleet, fog, mist, rain, dust, or smoke, adversely affect visibility or traction. Speed shall be reduced when such conditions exist. If conditions become sufficiently dangerous, the operation of the commercial motor vehicle shall be discontinued and shall not be resumed until the commercial motor vehicle can be safely operated.

Related Regulations

- 49 CFR 172
- 49 CFR 392.14
- 49 CFR 393
- 49 CFR 396.7

Industry Recommendations

- **Establish policies and standard operating procedures (SOPs) that ensure safety in the operation, maintenance, and inspection of specification CTs.**
- **Proactively identify and address safety risks.**
- **Use equipment that increases safety when operating the truck and CT.**

Industry Supporting Quotes

- *….I have a policy here – when it's snowing and the roads are really bad, our trucks sit.* (MC 306/DOT 406)
- *Safety is a big thing. Got a load of this resin, it's probably worth 50,000 dollars worth of material, maybe more, could be 100,000 dollars of material in that load. Got to get it there safe, not have it run on the ground coming up there. That's why maintenance, to us, is really important. Our tire program, we don't put any recaps on these trailers. The recaps go on the old, the fly ash, the cement.* (MC 307/DOT 407)
- [NAME REDACTED] *knows the whole deal. If there's something that's not safe, he's not going to play it; he's going to take it right out.* (MC 307/DOT 407)

2.2.4 Fleet/Facility Investment

Investing in drivers and maintenance is an important way to extend the life of a CT. Human capital theory[4] suggests that more experience is expected to lead to greater safety. Therefore, the service life of a CT will likely be longer if it is operated by an experienced and skilled driver and if it is properly maintained. Since pay can be considered a function of different levels of driver

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[4] Becker, G. (1964). *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education*. New York: Columbia University Press.

experience, higher pay, in a competitive market, would enable companies to recruit and retain drivers with certain behavioral characteristics (e.g., skills) that would contribute to better safety.[5]

Related Regulations

- None found

Industry Recommendations

- **Considering that drivers are an important investment because their experience and sense of ownership may have a direct impact on the use and care of the equipment:**
    - **Hire skilled drivers.**
    - **Provide fair and competitive compensation.**
- **Consider maintenance as a worthwhile investment. Proactive maintenance ensures that major problems will be caught early and/or avoided.**

Industry Supporting Quotes

- *So you've got to put money in to keep it. I don't have enough facts on that, but yeah. If you don't spend money on truck expense, the maintenance, then your tank will go downhill.* (MC 330/MC 331 Bobtail)
- *…I guess they don't pay enough to get experienced drivers. No matter what, whether you were going to be a good driver or not, you are better after you've done it for 10 years.* (Test and Inspection)
- *Oh yeah,* [driver experience] *would be the number one. The number one way to increase safety and useful life of vehicles—if they could restructure their pay plans so they could hire good drivers.* (Test and Inspection)
- *The number one way* [to extend the life of specification CTs] *is obviously the way the industry is structured where drivers don't get paid enough and where larger and larger companies own the fleets of trucks so there is less and less motivation for any one operator to take care of equipment. That is the main reason stuff gets broken. So there is almost no motivation for the operator of the equipment to take care of it.* (Test and Inspection)
- *I pay in a different way than most common carriers pay, I pay by the hour. I do that to enhance, people take their time and do things right.* (MC 306/DOT 406)
- *And drivers like* [COMPANY NAME REDACTED] *will tie the hoses up off the ground just to keep them from wearing. Hardly ever fail a hose for those guys.* (MC 330/MC 331 and Wet Fluorescent Magnetic Particle Testing)
- *We'll have customers that are mom and pop organizations that have five or six trucks in one location. When the guy makes the delivery he has an extra 15 minutes he's out there with some wax and cleaning the thing up and in 10 years from now you can get in the cab of that truck and, wow this looks like it's brand new.* (MC 330/MC 331 and Wet Fluorescent Magnetic Particle Testing)

2.3 DRIVER MANAGEMENT

Participants noted the impact that drivers have on the service life of CTs. Drivers of HM CTs must be well trained and they must be rigorous about the inspections that they are required to

[5] Rodr´ıguez, D. A., Rocha, M., Khattak, A., & Belzer, M. H. (2003). The effects of truck driver wages and working conditions on highway safety: A case study. *Transportation Research Record*, *1883*, 95–102.

perform on their commercial motor vehicle (CMV) before and after driving. This section outlines the regulations related to driver training and inspections and provides insight from the fleets and facilities interviewed regarding these important topics.

2.3.1 Driver Training

Companies that transport HM should ensure that their drivers have training that is both specific to the operation of DOT specification CTs and that covers the handling of HM. Having clear company policies on these training areas and an instructional manual for drivers is suggested.

In terms of the operation of DOT specification CTs, driver training requirements are described in §177.816, which states:

> In addition to the training requirements of §177.800, no carrier may transport, or cause to be transported, a hazardous material unless each HM employee who will operate a motor vehicle has been trained in the applicable requirements of 49 CFR parts 390 through 397 and the procedures necessary for the safe operation of that motor vehicle.

§177.816 provides a thorough list of the topics that the driver training must cover as well as the specialized requirements for the operation of CTs.

Training of drivers operating HM CTs must also cover the HM employee training requirements outlined in §172.704. The PHMSA Web site[6] provides a helpful summary of the training requirements, which include: general awareness/familiarization, function-specific training, safety, security awareness, in-depth security training (if security plan is required), and driver training (for each HM employee who will operate a motor vehicle).

As §172.704 describes, HM employee training is an on-going process that requires that HM employees receive training at least once every 3 years. Records of current training must also be created and retained by each HM employer for the duration of the HM employee's employment and for 90 days thereafter. Details of what needs to be included in these records is found in §172.704.

The PHMSA Web site offers several free publications on HM safety and training. For instance, there is one publication that deals specifically with HM Transportation Security Awareness Training, a requirement of §172.704. These free publications can be found at: https://hazmatonline.phmsa.dot.gov/services/Pub_Free.aspx.

Also, FMCSA provides educational and training materials for drivers online at: http://www.fmcsa.dot.gov/spanish/english/tm_index_training.htm.

Along with the required training regarding HM, many participants mentioned the need to increase driver awareness through training specific to the operation of their CTMV (CTMV).

[6] http://www.phmsa.dot.gov/hazmat/training/requirements

This training would entail subject matter specific to collision avoidance techniques to prevent dents, scraping, and gouges to the tank. Although individually minor, many participants agreed that the occasional collision of the tank with a street sign, building edge, bridge abutment, etc. would play a significant role in decreasing the service life of the CT.

Related Regulations

- 49 CFR 172.704
- 49 CFR 173
- 49 CFR 177
- 49 CFR 380
- 49 CFR 383

Industry Recommendations

- **Establish a thorough training process for new hires.**
- **Provide regular and ongoing education/training for current drivers.**
- **Set forth clear policies and provide a training manual. The manual could cover company policies as well as details of the specific tasks related to the CT that the drivers must perform.**
- **Include training on a variety of important topics pertaining to DOT specification CTs, including but not limited to inspection, equipment operation, driving/vehicle operation, loading/unloading, and safety.**
- **Relay clear expectations to drivers about the manner in which equipment should be taken care of and what to do if there is a problem.**

Industry Supporting Quotes

- *I think the more training you can get the better off your people will be whether it be in-house training. We don't want you to learn by experience.* (MC 330/MC 331 Bobtail)
- *…you've got to train your personnel properly.* (MC 330/MC 331 Bobtail)
- *Better driver training would probably help with* [CT] *abuse.* (MC 307/DOT 407)
- *…training is an ongoing issue with new people, as your plate grows adding on additions. You can get your company, everybody trained, everybody understanding, and then you hire a couple/three people and you might miss relaying some of the information to the new hire. That comes down to me. I have to stay really on top of it. "Have I shortchanged this guy? Have I handicapped or set up one of my own men?" And that's an issue we talk about in our driver's meetings – "Don't set up the guy behind you or your co-worker." Don't set him up.* (MC 306/DOT 406)
- *They go through the* [training] *video then I personally give my road test to warm up drivers. Then driver trainers. And we give them a road test. And they're generally in training up to 3 to 4 weeks of riding with a driver because in the past, being in management with highway transport stuff, we made the mistake of ushering men out too fast for the sake of trying to cover loads—which is a huge issue—the driver shortage everybody's heard about. So we try to make sure our driver understands everything. We want a driver to be helpful when he is turned out. 'Cause if you don't take that time, trust me, I can tell you first hand it will come back and get you. So the best thing to do is be patient.* (MC 306/DOT 406)

- *We do a safety meeting once a month* [in order to train the driver]. *And then during the spring and summer months we go over things to look for. And that's kind of what we train. We use this several times a year as a training mechanism for safety meetings. I know, friends, it's boring, but we're going to have to do it again. And that's, yes it's redundant, but we have to continue to make sure we don't have anything that's wrong.* (MC 330/MC 331 Bobtail)
- *….. So we train them on that* [how to brake properly, especially on big mountains], *on how to stab the brake and how to do those things not to burn up the brakes on a trailer. So we have safety meetings here all the time and some of that stuff we'll go over. From time to time if I see things out there—like on brakes—then I'll hold a little session and we'll come in here and I'll talk with them or I'll bring them out in the shop. I'll show them the brake shoes. Show them why a drum cracked or broke or whatever. That's the big thing – training. To get them to understand because sometimes they just forget. Especially with some of the newer guys.* (MC 307/DOT 407)
- *We have safety videos; we have a risk and safety department* [which provides training to drivers so that they can recognize the need for immediate maintenance of the CTs]. (MC 330/MC 331)
- *Yeah training; state your policies. We're getting ready develop a company manual; we're having to take this a step at a time, that way there's no gray areas of what I expect and what I want. We're trying to do controlled growth, stair step everything in. It's training your drivers, training your mechanic, learning from your mistakes, "What did we do wrong?"* (MC 306/DOT 406)

2.3.2 Driver Inspection

Drivers of HM CTs have two very important tasks that can impact the service life of the CT: (1) the preparation of vehicle inspection reports and (2) pre- and post-trip inspections. Drivers are required by §396.11 to prepare vehicle inspection reports at the completion of each day for each vehicle operated. These reports should identify the vehicle and list any defect or deficiency discovered by or reported to the driver that would affect the safety of operation of the vehicle or result in its mechanical breakdown.[7]

§396.11(a) lists the parts and accessories that a driver must check when completing their vehicle inspection report. Many companies may choose a more comprehensive checklist, but at minimum the inspection should include:

- Service brakes (including trailer brake connections).
- Parking (hand) brake.
- Steering mechanism.
- Lighting devices and reflectors.
- Tires.
- Horn.
- Windshield wipers.
- Rear-vision mirrors.

[7] §396.11(b)

- Coupling devices.
- Wheels and rims.
- Emergency equipment.

These inspection reports, as noted in §396.13, must be reviewed and signed off on by the driver at the start of each work day to ensure that all problems that may affect the operation of the CMV have been addressed before the vehicle is operated again. A copy of the *Driver's Vehicle Inspection Report* can be found at:
http://www.fmcsa.dot.gov/documents/forms/sec396_form1.pdf

Drivers are also required by §396.13 to conduct driver inspections. The purpose of the driver inspection is to ensure the CMV is in safe operating condition. Making sure that drivers conduct these inspections regularly and properly is important to the life of a CT. §396.13 outlines what a driver must do before driving:

- Be satisfied that the motor vehicle is in safe operating condition.
- Review the last driver vehicle inspection report.
- Sign the report, only if defects or deficiencies were noted by the driver who prepared the report, to acknowledge that the driver has reviewed it and that there is a certification that the required repairs have been performed. The signature requirement does not apply to listed defects on a towed unit which is no longer part of the vehicle combination.

This regulation is reinforced in §396.7(a), which forbids the operation of a motor vehicle "in such a condition as to likely cause an accident or breakdown of the vehicle."

A more specific area of driver inspection discussed by participants who operate MC 330/MC 331 CTs was the important role that drivers play in the inspection of delivery hoses. This finding is also discussed in §180.416(c), which requires that after each unloading is completed operators visually check the portion of delivery hose assembly deployed during the unloading.

Related Regulations

- 49 CFR 172
- 49 CFR 180.416
- 49 CFR 392.7
- 49 CFR 392.8
- 49 CFR 396.11
- 49 CFR 396.13

Industry Recommendations

- **Develop a pre- and post-trip inspection for CTs and train drivers to complete these daily inspections and identify potential CT problems.**
- **Train drivers on how to properly communicate any CT discrepancies back to either maintenance or fleet management (e.g., written reports, safety meetings, or direct conversation).**
- **Ensure that drivers are consistently and properly doing their pre-trip inspections and post-trip driver inspection reports.**

- **For drivers of MC 330/MC 331 CTs, check CT hoses regularly.**

Industry Supporting Quotes

- *The lifespan of equipment is based upon how well the driver does in taking care of the equipment when they're out there!* (MC 307/DOT 407)
- *You need to know how to operate that cargo tank. If you don't, the life can be definitely shortened. You can shorten the life of a cargo tank in seconds if you don't know what you're doing.* (MC 307/DOT 407)
- *That's your quickest way to catch a problem is your driver: pre-trip / post-trip.* (MC 330/MC 331)
- [In response to whether drivers are trained to look for potential maintenance items:] *Federal law requires a pre-trip inspection and then there's a post-trip inspection at the end of every day. Every trucking company, anybody that possesses a CDL, has a truck, has to do that, that's a requirement. And that's what they do. We encourage our drivers when you're loading or unloading, standing around waiting on your truck, "Check your trucks. Look under trucks, see if you see anything."* (MC 306/DOT 406)
- *You do check your truck every day and you're constantly doing everything to check it. And then when you pull a hose and you put it back or whatever, there's things you look for. Basically, you check hoses once a month. Basically, you check the truck every day; it's a constant, ongoing thing. … You get out there and you're delivering gas and you pull a hose out and you look for nicks or whatever. Make sure there are no leaks; you don't put leaks in it like that. It's just obvious things.* (MC 330/MC 331 Bobtail)

2.4 MAINTENANCE

For this section of the guidelines document, "maintenance" refers to any service action related to the operation of the CT that does not fall within the 49 CFR 107.502(a)(1) definition of assembly or the NBIC definition of repair. See both chapters 3 and 4 of this document for detailed definitions of assembly and repair.

Maintenance was an important area of discussion to the participants in this study. This section details some of the areas of maintenance that participants discussed, including: preventative maintenance (PM), protective coating, and cleaning. A few of the helpful references from the FMCSA on maintenance include:

- Loading/Unloading Equipment Maintenance: http://www.fmcsa.dot.gov/facts-research/research-technology/publications/accidenthm/maintena.htm.
- Preventive Maintenance and Inspection Procedures: http://www.fmcsa.dot.gov/facts-research/research-technology/publications/accidenthm/vehicle.htm.

2.4.1 Preventative Maintenance

Preventative maintenance (PM) can help extend the life of a CT and will help ensure that equipment is in proper operating condition. FMCSA[8] notes that "preventive maintenance and periodic inspection procedures help to prevent failures from occurring while the vehicle is being

[8] http://www.fmcsa.dot.gov/facts-research/research-technology/publications/accidenthm/vehicle.htm

operated." Study findings support this by suggesting that one way to extend the life of a CT is to be proactive about maintenance. To be proactive, companies should perform inspections regularly (see section 2.3.2 and chapter 5) and make repairs when necessary. For instance, good communication is necessary between the driver and those who are responsible for ensuring that the problems identified during pre- and post-trip inspections are repaired before the CMV is operated.

Along with performing regular tests and inspections, several of the companies participating in this study spoke of the importance of conducting monthly PM. Getting the CMV and tank into the shop each month and servicing it is a key way to locate problems early and to keep equipment in good working order. Following a maintenance form or checklist, documenting problems, and making necessary repairs also was recommended.

In §396.3(a)(1), the FMCSA outlines the parts and accessories that should be in safe and proper operating condition at all times. Parts and accessories specified in 49 CFR 393 and any additional parts and accessories that may affect safety of operation, including but not limited to frame and frame assemblies, suspension systems, axles and attaching parts, wheels and rims, and steering systems, must be kept in safe and proper operating conditions at all time.

Related Regulations

- 49 CFR 180.416
- 49 CFR 393
- 49 CFR 396.3
- 49 CFR 396.5
- For regulations related to inspections see the Driver and Inspection section.

Industry Recommendations

- **Be proactive and preventative about maintenance.**
- **Perform (at least) monthly PM as a means to extend the service life a CT.**
- **Use a checklist as a guide when conducting maintenance so nothing is missed.**
- **Replace damaged parts before they become a problem.**
- **Document problems once they are found.**

Industry Supporting Quotes

- *Well, continually running a tank without actually doing preventive maintenance on it as far as the tandem, the equalizers, the springs, the hubs, they all wear if you don't do the preventive maintenance on them. When you do the preventive maintenance, you extend the life of the tank. But if it is not done everything wears out and therefore it'll cause you a lot of problems down the road.* (Repair Insulated CTs)
- [When checking the trailer]*...put grease in it where everything needs greasing; check air in the tires, oil reserves, visual check—walk around and check everything—make sure everything rusted/needs to be changed gets changed. And leaks. Different things like that.* (MC 307/DOT 407)
- *That trailer was built in 1957. It has nothing to do with how it lasts; it has to do with how it is maintained, the inspection done right as far as if you catch that stuff when it starts. If*

you see a problem maybe try to correct it, see what you can do to keep it from happening again. (MC 330/MC 331and Wet Fluorescent Magnetic Particle Testing)

- *It seems since they went to yearly* [inspection intervals] *it has gotten better. And not everybody follows up on that. Some you will see that are out of inspection and you see the fleets and the owner operators that actually do what they are supposed to and you'll see less deficiencies less often because they are caught quicker.* (MC 330/MC 331 and Wet Fluorescent Magnetic Particle Testing)
- *A factor in this* [age of the CT affecting service life] *is that we are always doing preventative maintenance so it's not like something ought to be on there 20 years. Even the frame if it's severely bad, we'll replace it. So things that are common to being changed out, they don't have a chance to run 20 to 30 years without any maintenance.* (Repair Insulated CTs)
- *Actually if you go through your PM form, like I said, your lights, everything is going to be covered on that I think. Go to the top, it would take care of the whole thing.* (Repair Insulated CTs)
- *…we have a monthly PM schedule* [to determine when a CT requires maintenance beyond the 1- and 5-year inspections]. *What we do, it's an inspection that we perform on our trucks checking maybe the welds on the tank, checking your undercarriage, your plumbing, your piping, your wiring. It's a real thorough checklist that we go through and we do that every 30 days.* (MC 306/DOT 406)
- *We do our trailers on monthly PM. They roll in the shop every 30 days and we go into one end and out the other. We check everything on it. We've got a big sheet that we fill out—you go over everything from a dome lid right on down to the belly valves to adjusting or checking brakes all the way to the whole piece of equipment every 30 days. And that really makes a difference. We see equipment come out of* [STATE NAME REDACTED] *and* [STATE NAME REDACTED] *that we work on, of other people's, that have no PM schedule and it's a different world.* (MC 306/DOT 406)
- *We try to check the trailer once a month. Sometimes it doesn't happen. But if you check it once a month and keep ahead of it you're good.* (MC 307/DOT 407)
- [In regards to the types of repairs and inspections that lend themselves to mobile settings] *Well, that is why I stuck with the 306/406 because I have been doing it so long. I know the procedures I have been doing and I can do them in my sleep. I am actually going to make a manual that you could actually hand somebody that never did it before and they can actually do it and do it safely. I was in the military and they have such things as called planned maintenance systems so being that my customers tankers are required for an annual test every year we take their pressure relief devices and replace them because the pressure relief device fails they destroy their tank. So we make sure that we use the planned maintenance systems so that they know every 2 years we are going to replace this gasket, every 3 years we are going to replace this. And we get them to agree to it, which they've actually, the customers themselves, have helped me with my plan of maintenance system because they know how long stuff lasts on their vehicle. I have a good idea, but they know because they keep records of everything. The repairs, when they were done, what was done, so they keep a really, really good record of it. We are keeping the record of what we've done to date and that is how I will be able to know that when one of my customers will call I'll be able to go in there and look on the computer and say "Okay, we were there 3 months ago, we did this."* (Mobile Test and Inspection)

2.4.2 Maintenance: Protective Coating

Applying a protective coating to the exterior tank wall (for non-insulated CTs) is suggested by participants as a way to prevent the deterioration of the tank shell. Participants also suggested that having a good coating material and process for application (e.g., blast, prime, and paint/coat) is a way to help extend the life of a CT. Checking the protective coating regularly and repairing it when necessary is important if the coating is to serve its intended purpose. Some specific areas mentioned by participants as important for coating included tank shell (in particular underneath the tank), suspension, and frame.

Related Regulations

- **None found**

Industry Recommendations

- **Have a good coating process: blast, prime, and paint/coat.**
- **Use a quality, proven coating material.**
- **Check protective coating regularly and repair the coating when necessary.**
- **Consider the following cargo tank parts as potential areas for these protective coatings: underside of tank, supporting structures, tank shell, frame, suspension.**

Industry Supporting Quotes

- *We use a standard Imron paint when we paint our trailers, which is automobile-grade paint. It seems to hold up better than some of the others.* (Repair Insulated CTs)
- *Of course this* [as a process of repainting using Imron paint] *may be standard procedure but we almost always blast it down to the bare metal and then prime it and then apply the paint.* (Repair Insulated CTs)
- [We see corrosion on] *the welds in the corner, salt will accumulate there. You'll see a bubble of paint come up and that's when you scrape them down and paint them between the 5-year paint jobs. We try to do everything on a 5-year deal. We know it's going to be pulled down, and thus they sandblast and paint them, prime and paint them, and send them back.* (MC 330/MC 331 Bobtail)
- *I really personally think* [Alumaclear is] *one of the greatest ideas that somebody's come up with in a long time for the aluminum barrel of a tank, aluminum components. But it's subject to pitting, road pitting. You have to maintain.* (MC 306/DOT 406)
- *The paint job is every 5 years. We just make sure everything's painted underneath and on top where you can't see it. And that's the main thing, you want to make sure you do keep an eye on that.* (MC 330/MC 331 Bobtail)
- *In other words, it doesn't last very long before you got to paint it, we have to do it. That's done here too; they'll just tear it down, needle-scale it, and then paint it all back up. Check everything for pitting and paint it back up.* (MC 307/DOT 407)
- *If you put a good paint job on it, and keep it maintained like we were saying with washing it and stuff, then you are not chancing the rust and corrosion because like a few jobs I've done or we've all done where they have been out there for a while upwards of suspension, fifth wheel, or the landing gear, especially under the suspension because the*

2.4.3 Cleaning

Cleaning the inside and outside of the tank when necessary is an important part of the maintenance process. In terms of external cleaning, participant comments continually mentioned that salt (typically when used as a de-icing agent in the winter months) should be cleaned off as soon as practical to prevent corrosion where possible. Cleaning should specifically target those areas on the CT and frame that can accumulate both salt and road debris, such as gusset connections, frame corners, etc.

Washing the inside of the tank is also important. Internal cleaning should be done between loads especially in cases where the CT is not in dedicated service. Thorough cleaning of the inside of the CT can help prevent accidental mixing of two ladings, which may chemically combine to create a mixture harmful (potentially corrosive) to the CT material. Care should be taken to follow proper cleaning procedures for the particular type of tank being cleaned. When cleaning the inside of the tank, the regulations regarding confined space safety precautions and personal protective equipment as outlined by the Occupational Safety and Health Administration (OSHA)[9] must also be taken into consideration and followed if applicable to protect the employees who are cleaning the tank.

Companies that are cleaning CTs must be aware that the Environmental Protection Agency (EPA) holds the right to enforce the 1972 Clean Water Act. The Clean Water Act set the standard for eliminating sewage and industrial waste in groundwater supplies. State EPA offices[10] should be referenced for information on treating and conducting wastewater disposal before it enters the public water system or is absorbed into groundwater supplies. It is good business practice to have a wastewater disposal recovery plan in place and to adhere to any and all applicable regulations for the disposal of wastewater.

Upon completion of internal CT washing, ensure the tank is dried thoroughly. Remaining moisture and subsequent bacteria can lead to significant corrosion of the tank wall. Moisture in the CT prior to loading may also cause issues with the incoming product and should be avoided for safety and product integrity reasons.

Related Regulations

- 49 CFR 180.413
- 49 CFR 172.704
- 29 CFR 1910.146
- 40 CFR 442

[9] See 29 CFR 1910 for additional information regarding applicable OSHA safety standards.
[10] State offices can be located using the EPA Web site: http://www.epa.gov/lawsregs/where/index.html

Industry Recommendations

- **Clean the inside of the tank between loads, especially when the CT is not in dedicated service. Once washing is completed, dry out the tank to prevent moisture and bacteria from building up inside, as this too can lead to corrosion.**
- **Regularly and thoroughly wash the outside of the tank, paying careful attention to areas where salt and grime accumulate. Cleaning the outside of the tank will help to prevent corrosion.**
- **Follow proper cleaning procedures. The type of tank being cleaned and the product being cleaned out should be considered.**

Industry Supporting Quotes

- *Keeping them washed and stuff comes in with the corrosion part of it. I mean, especially up here where there is a lot of salt. If you do keep them clean it will help cut down on the corrosion factor.* (MC 330/MC 331 and Wet Fluorescent Magnetic Particle Testing)
- *If they could get the road salt washed out from under some way after every load. Over time, that would make a big difference, but it's hard to do.* (MC 307/DOT 407)
- [Cleaning the road salt from under the tanks]*…really needs to be done, especially when the weather is bad.* (MC 307/DOT 407)
- *I guess wash out is pretty important…on corrosives. You know when they take them in and have them washed out* [after unloading]*.… Yeah. Between loads I should say.* (Rechassis MC 330/MC 331 Bobtail)
- *That's the tough part now if you're dealing with the 306s like the gasoline tankers where they're going to the biofuels. We're not hauling that yet. You take these aluminum tanks that you're hauling diesel fuel and gasoline in them. The inside of them will look like sort of a dark stain which is like a varnish. To me, that's what it looks like. When you haul a biofuel like ethanol, it will attack that coating. If you don't wash those tanks out and get them dried, there's bacteria that'll grow on the walls, and then if you haul something else in it's going to come out and fill up the filters and get in the tanks.* (MC 307/DOT 407)
- *Different products that we haul take different processes to clean. A resin, we have resins and rosins, we have one way of cleaning that. Acid, we have one way of neutralizing that and cleaning it. Each product has its own cleaning standard. And we have a cleaning manual to know how to clean each product and what will clean it and what won't clean it.* (Repair Insulated CTs)

2.4.4 Maintenance Training

Providing training for maintenance staff is important to ensure that the employees who are working on an HM CT are properly trained to handle the requirements of their job. One suggestion made by participants was to provide continuing education/training to maintenance staff, in particular directors of maintenance, as a way to keep employee skills and knowledge current. An FMCSA Web site that provides educational materials for maintenance staff can be found at http://www.fmcsa.dot.gov/spanish/english/tm_index_training.htm.

Related Regulations

- 49 CFR 172.704

Industry Recommendations

- **Hold regular training sessions and discuss previous maintenance challenges and what can be done to make improvements.**
- **Provide ongoing training for maintenance staff.**

Industry Supporting Quotes

- *Well* [the most important training that needs to happen is] *actually more of the training of the maintenance, to help protect everything else.* (MC 330/MC 331 Bobtail)
- *Maintenance and then training is so much of our business that you can pretty much divide anything into maintenance and training. We're continually training and we have safety meetings and all this brings up: What do you do? What happened? It's usually an issue that brings it up and it's a main issue of the safety meeting. And that helps us train.* (MC 330/MC 331 Bobtail)
- *Training, state your policies. We're getting ready to develop a company manual; we're having to take this a step at a time, that way there's no gray areas of what I expect and what I want. We're trying to do controlled growth, stair step everything in. It's training your drivers, training your mechanic, learning from your mistakes; "What did we do wrong? What hit it up?"* (MC 306/DOT 406)
- *I think that as a company, if you are proactive with things, like going to these National Tank Truck Maintenance Seminars, I've gone there every year. I think if every company would send their people that are involved with their maintenance to these seminars, there's so much information and new stuff that keeps coming out. There's loads of stuff I've started here that came out of these seminars. So I think training/education for maintenance personnel, especially the directors of maintenance, those that are responsible for those tank inspections, to be trained. A lot of times people will do things and they don't know. They just say, "I didn't know anything about that!" That's an important thing.* (MC 307/DOT 407)

3. Cargo Tank Assembly

3.1 INTRODUCTION

The Assembly chapter of the guidelines document covers three key areas: mounting of CTs, installation of equipment and components, and installation of linings and coatings. Each section provides a high-level overview of these key areas to offer the user industry recommendations and code requirements pertaining to CT assembly procedures. 49 CFR 107.502(a)(1) provides a definition of assembly:

> *Assembly* means the performance of any of the following functions when the function does not involve welding on the cargo tank wall: (i) The mounting of one or more tanks or cargo tanks on a motor vehicle or to a motor vehicle suspension component; (ii) The installation of equipment or components necessary to meet the specification requirements prior to the certification of the cargo tank motor vehicle; or (iii) The installation of linings, coatings, or other materials to the inside of a cargo tank wall.

This chapter includes material related to CT design to provide the assembler with the reasoning behind some of the recommended practices given below.

3.2 MOUNTING OF CARGO TANKS ON FRAMES

CTs can be mounted to three types of frames: a full-sized semi-trailer frame or when the CT itself serves as the structure carrying the load of the tank; a front, fifth-wheel mounting frame and a rear, wheel-mounting frame or bogie; and a straight truck chassis commonly referred to as a bobtail. When mounting a CT to any frame there are several considerations detailed below.

3.2.1 Mounting

Mounting a CT on a CTMV must "meet the requirements of the specification in effect at the time such work is performed, and all applicable structural integrity requirements."[11] Furthermore, such mounting must be

> certified by a Design Certifying Engineer (DCE) if the mounting of a cargo tank on a motor vehicle chassis involves welding on the cargo tank head or shell or any change or modification of the methods of attachment; or
>
> In accordance with the original specification for attachment to the chassis or the specification for attachment to the chassis in effect at the time of the mounting, and performed under the supervision of a Registered Inspector (RI) if the mounting of a cargo tank on a motor vehicle chassis does not involve welding on the cargo tank head or shell or a change or modification of the methods of attachment.[12]

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[11] 180.413(d)
[12] 180.413(e)

3.2.2 Attachments

A tank will have concentrated loads imposed where connections are made to the chassis. Stresses due to other loadings, such as the weight of water present for hydrostatic testing, or vertical, lateral and longitudinal loadings caused by acceleration or deceleration of the vehicle, must be accounted for. The details of supports should conform to good structural practice. An important reference is Appendix G of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel (BPV) Code.[13] The following considerations should be emphasized.

(a) All connections between the tank and its supports must be designed to prevent excessive localized stresses due to mechanical loads as cited above, due to temperature changes in the CT, or due to internal pressure or the hydrostatic pressure from fluid contents.

(b) Round, oval, or rectangular reinforcing plates with rounded corners must be used between a support or the chassis and the tank. They should be welded all around and should be provided with a weep-hole at the bottom of the reinforcing plate. The reinforcing plates should have dimensions and thickness selected to minimize flexing of the plate under forces normal to the surface of the CT.

CTs may also be supported by means of saddles. The contact surface of the saddles shall extend over at least one-third of the circumference of the shell. Supports should be as few in number as possible, preferably two over the length of the CT. The CT may be reinforced by stiffening rings at intermediate sections, or by longitudinal stringers, typically at the top of the tank. CTs designed for gases under pressure (MC 330/MC 331) may be supported by any combination of ring girders, stiffeners, and such other reinforcement as may be necessary to prevent stresses in the shell in excess of those allowed by the ASME Code, Section VIII, Division 1, paragraph UG-23.

Certain attachments may serve to mount a pump, compressor, motor, internal combustion engine, mixer, or any other rotating or reciprocating equipment on a CTMV. For such cyclic loading, the mounting practices advocated in (b) above are of particular importance. It is important to avoid resonance between the cyclic forces imposed by the equipment and the natural frequencies of the CT with equipment in place. Such equipment can excite resonances or directly cause cyclic forces to act upon the attachment, the CT, and/or the CT supports. Resonant frequencies must be determined by testing or by analysis.

Industry Recommendation

- **Ensure material compatibility to avoid galvanic corrosion.**

The Repair section describes galvanic corrosion and how to avoid it. This material is useful to assemblers as well. From the Repair chapter:

> **Galvanic corrosion -** typically occurs at a juncture of dissimilar metals or dissimilar alloy content of the same metals in the presence of an electrolyte. An

[13] When Section XII of the ASME Code is adopted by the USDOT, the proper reference will be Appendix VIII of Section XII.

example of an electrolyte is a film of water containing dissolved oxygen, nitrogen, or carbon dioxide, making up an electrolytic cell. The difference in galvanic potential between the two dissimilar materials creates a local electrical cell that may cause rapid corrosion of the less noble metal. This corrosion mechanism becomes more active when there are large differences between the electrode potentials of the two metals. Galvanic corrosion may even occur with relatively minor changes of alloy composition, as between weld metal and base metal. Repair must follow elimination of the cause of the galvanic attack by redesign or other neutralizing of the offending material pair.

Galvanic corrosion is a common cause of corrosion to the frame or the CT at the frame supports. CTs made of aluminum with a mild steel or alloy steel may show galvanic corrosion where the frame or chassis is connected to the CT. Galvanic corrosion is generally manifested by localized pitting of the less noble metal in the region where the two materials are joined mechanically or by welding or brazing.

Gussets are sometimes required as part of the structure between the frame and the support pads. When gussets are used, they should be of the same material as the frame and the pads to avoid galvanic interaction. They can be designed using standard structural design rules and can be up to three-eighths inch in thickness.

§178.345–6 sets forth the regulatory requirements for support and anchoring of the CT for DOT specification 406, 407, or 412 CTMVs, as follows:

(a) CTs with non-integral frames must be secured by restraining devices (typically snubbers). The restraining devices eliminate motion between the tank and frame which may abrade the tank shell due to the stopping, starting, or turning of the CTMV. Restraining devices must be readily accessible for inspection and maintenance, except in those cases where insulation and jacketing is permitted to cover the devices.

(b) CTs designed and constructed so that they constitute, in whole or in part, the structural member used in lieu of a frame must be supported in such a manner that the resulting stress levels in the CT do not exceed those specified in §178.345–3(a). The design calculations of the support elements must include the stresses indicated in §178.345–3(b) and as generated by the loads described in §178.345–3(c).

3.3 INSTALLATION OF EQUIPMENT AND COMPONENTS (DOT 406/DOT 407/ DOT 412)

There are certain articles of equipment and components that are required by 49 CFR §178.345 for DOT 406/407/412 specification CTs. These include but are not limited to manholes, pressure relief valves, tank outlets, and emergency discharge controls. Although this chapter is specific to assembly as defined by USDOT, the following guidelines and regulations apply to the equipment regardless of type of attachment.

3.3.1 Manhole Assemblies

The interior of each CT with a capacity greater than 400 gallons must be accessible through a manhole at least 15 inches in diameter. Each manhole must be structurally capable of withstanding, without leaking or permanent deformation that would affect its structural integrity, a static internal fluid pressure of at least 248kPa (36 psig) or the CT test pressure, whichever is greater. The manhole must have a way to relieve internal pressure without fully opening the manhole cover and fasteners that prevent the cover from opening due to road vibrations or shock impacts including a rollover accident. In tanks constructed after October 1, 2004, all manholes are required to permanently state the manufacturer's name, test pressure, and compliance with the requirements of §178.345-5 on the outside of the assembly. Moreover, any fittings or devices mounted on the manhole assembly potentially contacting the lading must be marked in the same fashion, readable outside of the CT. These fittings and devices must also withstand the same static internal fluid pressure as the manhole cover itself.[14] This simply means that the overall integrity of the CT *including* equipment and components must remain constant.

3.3.2 Accident Damage Protection

Outlets, valves, closures, piping, or any device that if damaged in an accident could result in a loss of lading from the CT must be protected by accident damage protection devices.[15] Each outlet, projection or piping located in the lower one-third of the CT circumference (or cross section perimeter for noncircular CTs) that could be damaged in an accident and that may result in the loss of lading must be protected by a bottom damage protection device. Outlets, projections, and piping may be grouped or clustered together and protected by a single protection device.[16] There are two exceptions provided:

§178.345-8(a)(1), which states:

> Any dome, sump, or washout cover plate projecting from the cargo tank wall that retains lading in any tank orientation must be as strong and tough as the cargo tank wall and have a thickness at least equal to that specified by the appropriate cargo tank specification. Any such projection located in the lower 1/3 of the tank circumference (or cross section perimeter for non-circular cargo tanks) that extends more than half its diameter at the point of attachment to the tank or more than 4 inches from the cargo tank wall, or located in the upper 2/3 of the tank circumference (or cross section perimeter for non-circular cargo tanks) that extends more than 1/4 its diameter or more than 2 inches from the point of attachment to the tank must have accident damage protection devices that are: 125 percent as strong as the otherwise required accident damage protection device; or attached to the cargo tank in accordance with the requirements §178.345-8(a)(3).

[14] §178.345-5
[15] §178.345-8(a)(2)
[16] §178.345-8(b)

And §173.33(e), which states:

> DOT specification cargo tanks used for the transportation of any material that is a Division 6.1 (poisonous liquid) material, oxidizer liquid, liquid organic peroxide or corrosive liquid (corrosive to skin only) may not be transported with hazardous materials lading retained in the piping, unless the cargo tank motor vehicle is equipped with bottom damage protection devices meeting the requirements of §178.337–10 (outlined in section 3.4.4) or as described in section 3.3.2, or the accident damage protection requirements of the specification under which it was manufactured. This requirement does not apply to a residue which remains after the piping is drained. A sacrificial device may not be used to satisfy the accident damage protection requirements of this paragraph.

A lading discharge opening equipped with an internal self-closing stop-valve need not be as strong as the CT wall, nor have a thickness equal to or greater than that specified by the appropriate CT specification, provided it is protected so as to reasonably assure against the accidental loss of lading. This protection must be provided by a sacrificial device located outboard of each internal self-closing stop-valve and within 4 inches of the major radius of the CT shell or within 4 inches of a sump, but in no case more than 8 inches from the major radius of the tank shell. (The shape of a tank with an elliptical cross section, for example, is formed with two radii, a major, or larger radius, and a minor, or smaller radius).

The sacrificial device must break at no more than 70 percent of the load that would be required to cause the failure of the protected lading retention device, part, or CT wall. The failure of the sacrificial device must leave the protected lading retention device or part and its attachment to the CT wall intact and capable of retaining product.[17] Each closure for openings, including but not limited to the manhole, filling or inspection openings, and each valve, fitting, pressure relief device, vapor recovery stop valve, or lading retaining fitting located in the upper two-thirds of a CT's circumference (or cross section perimeter for non-circular tanks) must be protected by being located within or between adjacent rollover damage protection devices, or by being 125 percent of the strength that would be provided by the otherwise required damage protection device.[18] Thus, equipment or components must be adequately protected by an accident damage protection device or must be strong enough to prevent a loss of lading if involved in an accident.

3.3.3 Pressure Relief

Each CT must be equipped to relieve excessive pressure or vacuum conditions with pressure relief devices including valves, frangible (rupture) disks, vacuum vents, and combination devices. Pressure differences can cause anything from minor deformations of the CT to catastrophic mechanical failure of the CT itself. DOT 406 specification CTs must have at least one vacuum relief device.[19] This will help facilitate more complete unloading and prevent collapse due to an unsafe negative pressure situation, usually caused by condensation of vapor inside a sealed tank. DOT 407 and DOT 412 specification CTs are not required to have vacuum

[17] §178.345-8(b)(2)
[18] §178.345-8(c)
[19] §178.346-3(b)(1)

relief devices when designed to be loaded by vacuum or built to withstand full vacuum.[20] The pressure relief system must have the capacity to prevent CT rupture or collapse while loading, unloading, or heating and cooling of the lading.[21] Each CT must have a primary pressure relief device consisting of at least one **reclosing** pressure relief valve. A secondary pressure relief system is authorized if it functions in parallel with the first and augments the venting capacity of the CT. A non-reclosing pressure relief device is not authorized **unless** it functions in series with a reclosing pressure relief device. The pressure relief device should cease venting upon mitigation of the differential pressure situation to avoid loss of lading beyond that necessary to alleviate pressure. CTs may not have a gravity-actuated relief device.[22]

When DOT 406 specification CTs are intended for use only with lading meet the requirements of the following paragraph, the CT may be equipped with a normal vent. Such vents must be set to open at 6.89kPa (1 psig) and must be designed to prevent loss of lading through the device in case of vehicle upset.[23] Vehicle upset occurs any time the vehicle is oriented in a manner inconsistent with normal operation (e.g., rollover, on side, etc).

For liquid HM loaded in a DOT specification CT with a 1-psig normal vent, the maximum allowable working pressure must be greater than or equal to the sum of the tank static head plus 6.89kPa (1 psig). Additionally, the vapor pressure of the lading at 115°F (46.1°C) must not be greater than 6.89kPa (1 psig), except for gasoline transported in accordance with table 1 below.[24]

Table 1. Maximum ambient temperature – gasoline.

ASTM D439 Volatility Class		Maximum Lading and Ambient Temperature (see note 1)
A	(RVP<=9.0 psia)	131°F
B	(RVP<=9.0 psia)	124°F
C	(RVP<=10.0 psia)	116°F
D	(RVP<=13.5 psia)	107°F
E	(RVP<=15.0 psia)	100°F

Note 1: Based on maximum lading pressure of 1 psig at top of CT.

Each pressure relief system must be able to handle dynamic pressure surges up to 30 psig above the design set pressure for 60 milliseconds without releasing more than 1 liter (1 gallon if manufactured prior to September 1, 1995) of liquid before reclosing to a leak-tight condition. This requirement is effective regardless of vehicle orientation, and the pressure relief device capability must be demonstrated by testing (see TTMA Recommended Practice No. 81).[25] When installing a pressure relief valve, it must be tamper proof to prevent unauthorized adjustment of the relieve valve setting, it may not have a shutoff valve or other device that could prevent

[20] §178.347-4(b) and §178.348-4(b)
[21] §178.345-10(a)
[22] §178.345-10(b)(1)
[23] §178.346-3(b)(2)
[24] §178.345-10(b)(2), §173.33(c)(1)(iii), and §172.102(c)(3)(B33)
[25] §178.345-10(b)(3)

venting, and it must be shielded and drainable to minimize the accumulation of material that may impede operation or discharge capability.[26]

The location of each pressure relief system should be as close to the center of the vapor space as possible while still maintaining communication with the vapor space above the lading. The discharge from any pressure relief device must be unrestricted; however, it may have protective devices that deflect the flow of vapor, provided the required vent capacity is maintained.[27]

The pressure at which a pressure relief device starts to open allowing discharge (*set pressure*) must be no less than 120 percent of the maximum allowable working pressure of the CT. The primary pressure relief valve must have a set pressure of no greater than 132 percent of the maximum allowable working pressure and must reclose at 108 percent of the maximum allowable working pressure, remaining closed at lower pressures.[28]

The pressure relief system must have sufficient venting capacity to limit the CT internal pressure to not more than the CT test pressure. This ensures that tank pressure never exceeds the max pressure at which the CT has been tested. The total venting capacity, rated at not more than the CT test pressure, must be at least that specified in §178.345-10(e), unless the CT is used in dedicated service for corrosives with no secondary hazard. These CTs may have a total venting capacity that is less than required by §178.345-10(e). The minimum total venting capacity for these tanks must be determined in accordance with the formula contained in §178.270-11(d)(3). Use of the approximate values given for the formula in §178.270-11(d)(3) are acceptable.

DOT 407 and DOT 412 specification CTs with vacuum relief devices must limit the vacuum to less than 80 percent of the design vacuum capability of the CT.[29] For both DOT 407 and DOT 412 specification CTs designed for loading and unloading by pressure, the relief system must have adequate vapor and liquid capacity to limit the tank pressure to the CT test pressure at maximum loading or unloading rate. The maximum loading or unloading rate must be on the specification plate.[30]

The primary pressure relief device must have a minimum venting capacity of 12,000 standard ft^3/hour (SCFH) per 350 ft^2 of exposed CT area unless otherwise specified in the applicable individual specification. For DOT 406 CTs, the venting capacity must be at least 6,000 SCFH. In either case, the minimum venting capacity must be at least one-fourth the total venting capacity for the CT.[31] If the primary pressure relief device does not provide venting capacity equal to the total required for a given CT, additional capacity must be provided by a secondary pressure relief device.[32]

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[26] §178.345-10(b)(4) through [§178.345-10(b)(6)
[27] §178.345-10(c)
[28] §178.345-10(d)
[29] §178.347-4(d)(1) and §178.348-4(d)(1)
[30] §178.347-4(d)(2) and §178.348-4(d)(2)
[31] §178.345-10(e)(1)
[32] §178.345-10(e)(2)

3.3.4 Tank Outlets

CT outlets are openings in the CT used for loading or unloading of lading, as distinguished from openings such as manhole covers, vents, vapor recovery devices, and similar openings. Each CT loading/unloading outlet must be equipped with either an internal self-closing or an external stop-valve, and be capable of closing outlets in an emergency within 30 seconds of actuation.[33] External self-closing stop-valves are **not** authorized as an alternative to internal self-closing stop-valves for DOT 406 specification CT loading/unloading outlets.[34] These tank outlets must possess accident protection as described in the Accident Damage Protection section.

Each self-closing system must include a remotely actuated means of closure located more than 10 feet from the loading/unloading outlet where vehicle length allows, or on the end of the CT farthest away from the loading/unloading outlet. The actuating mechanism must be corrosion-resistant and effective in all types of environments and weather. If the actuating system is accidentally damaged or sheared off during transportation, each loading/unloading outlet must remain securely closed and capable of retaining lading. When required for materials that are flammable, pyrophoric, oxidizing, or Division 6.1 (poisonous liquid) materials (see 49 CFR Part 173), the remote means of closure must be capable of thermal activation. The means by which the self-closing system is thermally activated must be located as close as practicable to the primary loading/unloading connection and must actuate the system at a temperature not over 250°F (121°C). In addition, outlets on these CTs must be capable of being remotely closed manually or mechanically.[35] It is not necessary to have a self-closing system when the outlet is bottom-loading (discharge lading into CT) through fixed piping above the maximum liquid level of the CT.[36]

Any loading/unloading outlet that extends beyond the internal self-closing stop-valve or innermost external stop-valve that is part of a self-closing system must be fitted with another stop-valve or other leak-tight closure at the end of such connection. CT outlets not used for loading and unloading must be equipped with a stop valve or leak-tight closure as close as practicable to the CT outlet. Any connection extending beyond this closure must be fitted with another stop-valve or leak-tight closure at the end of such connection.[37]

3.3.5 Gauges

Each CT, except a CT intended to be filled by weight, must be equipped with a gauging device that indicates the maximum permitted liquid level to within 0.5 percent of the nominal capacity as measured by volume or liquid level. Gauge glasses are not permitted.[38]

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[33] §178.345-11(b), §178.345-11(b)(1)
[34] §178.346-4(b)
[35] §178.345-11(b)(1)(i) through §178.345-11(b)(1)(iii)
[36] §178.345-11(b)(2)
[37] §178.345-11(c), and §178.345-11(d)
[38] §178.345-12

3.4 INSTALLATION OF EQUIPMENT AND COMPONENTS (MC 330/MC 331)

There are certain articles of equipment and components that are required by 49 CFR §178.337 for MC 330 and MC 331 specification CTs. These include but are not limited to manholes, pressure relief devices, tank outlets, and emergency discharge controls. Although this section is specific to assembly as defined by the USDOT, the following guidelines and regulations apply to the equipment regardless of type of attachment.

3.4.1 Closure for Manhole

Any CT marked or certified after April 21, 1994, must have a manhole conforming to UG-46(g)(1) and other applicable requirements in Section VIII of the ASME Code. If the CT is constructed of non-quenched and tempered (NQT) steel, and has a capacity of 3,500 gallons or less, it may have an inspection opening conforming to UG-46 and other applicable requirements of the ASME Code instead of a manhole. The manhole must not be located on the front head of the CT, unless it was constructed prior to July 1, 1979.[39]

3.4.2 Openings, Inlets, and Outlets

The following applies to MC331 CTs, **except** those used in chlorine service. Each CT must have at least one opening that facilitates complete drainage. Except for gauging devices, thermometer wells, pressure relief devices, manhole openings, product inlet openings, and product discharge openings, all openings in a CT must be closed with a lug, cap, or bolted flange. Each product inlet opening, including vapor recovery lines, must be fitted with a back-check valve or internal self-closing stop valve located in either the CT itself or a welded nozzle that is an integral part of the CT. The valve seat must be inside the CT or within 1 inch of the external face of the welded flange.[40] However, a discharge outlet on a CT used to transport carbon dioxide, refrigerated liquid is **not** required to have an internal self-closing stop valve.[41]

Each liquid or vapor discharge outlet must be fitted with a primary discharge control system, which must be capable of stopping a CT unloading operation in the event of an unintentional release.[42] Each CT must have two means of remote closure installed at diagonally opposite corners of the tank. For CTs with more than a 3,500-gallon capacity, a thermal and a mechanical means of remote closure must be installed in both locations. If neither location is within close proximity of the loading and unloading connection, then an additional thermal means of remote closure must be installed so that heat from a fire at the loading/unloading connection or discharge pump will activate the primary discharge control system. The thermal means of remote closure must activate at a temperature of 250°F (121°C). For a CT of 3,500-gallons or less, a mechanical means of remote closure must be installed on the end of the CT farthest from the loading or unloading location, and a thermal means of remote closure must be installed at or near the internal self-closing stop valve.[43] An integral excess flow valve or the excess flow feature of

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[39] §178.337-6(a) and §178.337-6(b)

[40] §178.337-8(a)(1) through §178.337-8(a)(3)

[41] §178.337-8(c)

[42] §178.337-8(a)(4), §178.337-1(g)

[43] §178.337-8(a)(4), §178.337-8(a)(4)(i), and §178.337-8(a)(4)(ii)

an internal self-closing stop valve may be designed with a bypass, having an opening diameter not to exceed 0.040 inches (0.1016 centimeters), to allow equalization of pressure.[44]

A primary discharge control system is not required on the following:[45]

- A vapor or liquid discharge opening of less than 1.25 national pipe thread (NPT) equipped with an excess flow valve together with a manually operated external stop valve in place of an internal self-closing stop valve.
- An engine fuel line on a truck-mounted CT of not more than 0.75 NPT equipped with a valve having an integral excess flow valve or excess flow feature.
- A CTMV used to transport refrigerated liquids such as argon, carbon dioxide, helium, krypton, neon, nitrogen, and xenon, or mixtures thereof.

In addition to the internal self-closing stop valve, each filling and discharge line must be fitted with a stop valve located in the line between the internal self-closing stop valve and the hose connection. A back flow check valve or excess flow valve may not be used to satisfy this requirement.[46]

3.4.2.1 Cargo Tanks in Chlorine Service

A chlorine CT shall have only one opening. That opening shall be in the top of the CT and shall be fitted with a nozzle that meets the following requirements:

- On a CT manufactured on or before December 31, 1974, the nozzle shall be protected by a dome cover plate which conforms to either the standard of The Chlorine Institute, Inc., Dwg. 103–3, dated January 23, 1958.
- On a CT manufactured on or after January 1, 1975, the nozzle shall be protected by a manway cover that conforms to the standard of The Chlorine Institute, Inc., Dwg. 103–4, dated September 1, 1971.

In addition, the inlets and outlets of a CT used to transport chlorine must be fitted with an internal excess flow valve. The inlet and outlets must also be equipped with an external stop valve (angle valve). Excess flow valves must conform to the standards of The Chlorine Institute, Inc., as follows:[47]

- A valve conforming to The Chlorine Institute, Inc., Dwg. 101–7 must be installed under each liquid angle valve.
- A valve conforming to The Chlorine Institute, Inc., Dwg. 106–6 must be installed under each gas angle valve.

[44] §178.337-8(a)(4)(vi)
[45] §178.337-8(a)(5)
[46] §178.337-8(a)(6)
[47] §178.337-8(b)

3.4.3 Pressure Relief Devices, Piping, Valves, Hoses, and Fittings

3.4.3.1 Pressure Relief Devices

The total relieving capacity, as determined by the flow formulas contained in Section 5 of Compressed Gas Association (CGA) S–1.2, must be sufficient to prevent a maximum pressure in the tank of more than 120 percent of the design pressure.

On CTs for carbon dioxide or nitrous oxide, each safety relief device must be installed and located so that the cooling effect of the contents will not prevent the effective operation of the device. In addition to the required safety relief valves, these tanks may be equipped with one or more pressure controlling devices.[48] Each tank for refrigerated liquid carbon dioxide may also be equipped with one or more non-reclosing pressure relief devices set to function at a pressure not more than 2 times nor less than 1.5 times the design pressure of the tank.[49]

3.4.3.2 Piping, Valves, Hose, and Fittings

The burst pressure of all piping, pipe fittings, hose, and other pressure parts, except for pump seals and pressure relief devices, must be at least four times the design pressure of the CT. Additionally, the burst pressure may not be less than four times any higher pressure to which each pipe, pipe fitting, hose, or other pressure part may be subjected to in service. Pipe joints must be threaded, welded, or flanged. If threaded pipe is used, the pipe and fittings must be Schedule 80 weight or heavier, except for sacrificial devices.[50] Piping must be protected from damage due to thermal expansion and contraction, jarring, and vibration. Slip joints are not authorized for this purpose.[51] CT manufacturers and fabricators must demonstrate that all piping, valves, and fittings on a CT are free from leaks. To meet this requirement, the piping, valves, and fittings must be tested after installation at not less than 80 percent of the design pressure marked on the CT.[52]

3.4.3.3 CTs in Chlorine Service

Angle valves on CTs intended for chlorine service must conform to the standards of The Chlorine Institute, Inc., Dwg. 104–8. Before installation, each angle valve must be tested for leakage at not less than 225 psig using dry air or inert gas.[53]

3.4.3.4 Marking Inlets and Outlets

Except for gauging devices, thermometer wells, and pressure relief valves, each CT inlet and outlet must be marked ‘‘liquid’’ or ‘‘vapor’’ to designate whether it communicates with liquid or vapor when the CT is filled to the maximum permitted filling density. A filling line that communicates with vapor may be marked ‘‘spray-fill’’ instead of ‘‘vapor.’’[54]

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[48] §173.315(i)
[49] §173.315(i)(9), §173.315(i)(10), §178.337-9(a)(1), §178.337-9(a)(2)
[50] §178.337-9(b)(2)
[51] §178.337-9(b)(4)
[52] §178.337-9(b)(6)
[53] §178.337-9(b)(8)
[54] §178.337-9(c)

3.4.3.5 Refrigeration and Heating Coils

Refrigeration and heating coils must be securely anchored with provisions for thermal expansion. The coils must be pressure tested externally to at least the CT test pressure, and internally to either the tank test pressure or twice the working pressure of the heating/refrigeration system, whichever is higher. A CT may not be placed in service if any leakage occurs or other evidence of damage is found. The refrigerant or heating medium to be circulated through the coils must not be capable of causing any adverse chemical reaction with the CT lading in the event of leakage. The unit furnishing refrigeration may be mounted on the motor vehicle. Where any liquid susceptible to freezing, or the vapor of any such liquid, is used for heating or refrigeration, the heating or refrigeration system shall be arranged to permit complete drainage.[55]

3.4.4 Accident Damage Protection

3.4.4.1 Valves, Fittings, Pressure Relief Devices, and Other Accessories

All valves, fittings, pressure relief devices, and other accessories to the tank proper shall be protected in accordance with the following paragraph against such damage as could be caused by collision with other vehicles or objects, jack-knifing, and overturning. In addition, pressure relief valves shall be so protected that in the event of overturn of the vehicle onto a hard surface, their opening will not be prevented and their discharge will not be restricted.[56] The protective devices or housing must be designed to withstand static loading in any direction equal to twice the weight of the tank and attachments when filled with the lading, using a safety factor of not less than four, based on the ultimate strength of the material to be used, without damage to the fittings protected, and must be made of metal at least 3⁄16-inch thick.[57] Piping and fittings must be grouped in the smallest practicable space and protected from damage as required in this section.[58]

A shear section or sacrificial device is required for the valves specified in the following locations:

- A section that will break under strain must be provided adjacent to or outboard of each valve specified in §178.337–8(a)(3) and (4).[59]
- Each internal self-closing stop valve, excess flow valve, and check valve must be protected by a shear section or other sacrificial device. The sacrificial device must be located in the piping system outboard of the stop valve and within the accident damage protection to prevent any accidental loss of lading. The failure of the sacrificial device must leave the protected lading protection device and its attachment to the CT wall intact and capable of retaining product.[60]

[55] §178.337-9(d)(1), §178.337-9(d)(2)
[56] §178.337-10(a)
[57] §178.337-10(b)
[58] §178.337-10(e)
[59] §178.337-10(f)(1)
[60] §178.337-10(f)(2)

3.4.4.2 Cargo Tanks in Chlorine Service

A chlorine tank must be equipped with a protective housing and a manway cover to permit the use of standard emergency kits for controlling leaks in fittings on the dome cover plate. The housing and manway cover must conform to the Chlorine Institute's standards as follows:[61]

- Tanks manufactured on or before December 31, 1974: Dwg. 137–1 or Dwg. 137– 2.
- Tanks manufactured on or after January 1, 1975: Dwg. 137–2, dated September 1, 1971.

3.5 EMERGENCY DISCHARGE CONTROL

3.5.1 Emergency Discharge Control Equipment

Emergency discharge control equipment must be installed in a liquid discharge line as specified by product and service in table 2 below. The performance and certification requirements for emergency discharge control equipment are specified in §173.315(n).[62]

Table 2. Required emergency discharge control capability.

§173.315(n)(1)(*)	Material	Delivery Service	Required Emergency Discharge Control Capability
(i)	Division 2.2 materials with no subsidiary hazard, excluding anhydrous ammonia	All	None
(ii)	Division 2.3 materials	All	Paragraph (n)(2) of this section
(ii)	Division 2.2 materials with a subsidiary hazard, Division 2.1 materials, and anhydrous ammonia	Other than metered delivery service	Paragraph (n)(2) of this section
(iv)	Division 2.2 materials with a subsidiary hazard, Division 2.1 materials, and anhydrous ammonia in a CTMV with a capacity of 13,247.5 liters (3,500 water gallons) or less	Metered delivery service	Paragraph (n)(3) of this section
(v)	Division 2.2 materials with a subsidiary hazard, Division 2.1 materials, and anhydrous ammonia in a CTMV with a capacity greater than 13,247.5 liters (3,500 water gallons)	Metered delivery service	Paragraph (n)(3) of this section, and, for obstructed view deliveries where permitted by §177.840(p) of this subchapter, paragraph (n)(2) or (n)(4) of this section
(vi)	Division 2.2 materials with a subsidiary hazard, Division 2.1 materials, and anhydrous ammonia in a CTMV with a capacity greater than 13,247.5 liters (3,500 water gallons)	Both metered delivery and other than metered delivery service	Paragraph (n)(2) of this section, provided the system operates for both metered and other than metered deliveries; otherwise, paragraphs (n)(2) and (n)(3) of this section

[61] §178.337-10(d)

[62] §178.337-11(a)

3.5.2 Engine Fuel Lines

On a truck-mounted CT, emergency discharge control equipment is not required on an engine fuel line of not more than 3/4 NPT equipped with a valve having an integral excess flow valve or excess flow feature.[63]

3.6 GAUGING DEVICES

3.6.1 Liquid Level Gauging Devices

Each CT, except a tank filled by weight, must be equipped with one or more of the gauging devices described in table 3 below, which indicate accurately the maximum permitted liquid level. Additional gauging devices may be installed but may not be used as primary controls for filling of CTs and portable tanks. Gauge glasses are not permitted on any CT or portable tank.[64]

Table 3. Acceptable gauging devices.

Kind of Gas	Gauging Device Permitted for Filling Purposes
Anhydrous Ammonia	Rotary tube, adjustable slip tube, fixed-length dip tube
Anhydrous dimethylamine	None
Anhydrous monomethylamine	Do.
Anhydrous trimethylamine	Do.
Aqua ammonia solution containing anhydrous ammonia	Rotary tube, adjustable slip tube, fixed-length dip tube
Butadiene stabilized	Do.
Carbon dioxide, refrigerated liquid	Do.
Chlorine	None
Dichlorodifluoromethane	Do.
Difluoroethane	Do.
Difluoromonochloroethane	Do.
Dimethyl ether	Do.
Ethane, refrigerated liquid	Rotary tube, adjustable slip tube, fixed-length dip tube
Ethane-propane mixture, refrigerated liquid	Do.
Hexafluoropropylene	None
Hydrogen chloride, refrigerated liquid	Do.
Liquefied petroleum gases	Rotary tube, adjustable slip tube, fixed-length dip tube
Methyl chloride	Fixed-length dip tube
Methyl mercaptan	Rotary tube, adjustable slip tube, fixed-length dip tube
Monochlorodifluoromethane	None
Nitrous oxide, refrigerated liquid	Rotary tube, adjustable slip tube, fixed-length dip tube
Methylacetylenepropadiene, stabilized	Do.
Refrigerant gas, n.o.s. or dispersant gas, n.o.s.	None
Sulfur dioxide	Fixed-length dip tube
Vinyl chloride	None
Vinyl fluoride, inhibited	Do.

Each CT used in carbon dioxide, refrigerated liquid or nitrous oxide, refrigerated liquid service must be provided with a suitable pressure gauge. A shut-off valve must be installed between the pressure gauge and the CT.

[63] §178.337-11(b)
[64] §178.337-14(a) and §173.315(h)

3.7 PUMPS AND COMPRESSORS

Liquid pumps or gas compressors, if used, must be of suitable design, adequately protected against breakage by collision, and kept in good condition. They may be driven by motor vehicle power take-off or other mechanical, electrical, or hydraulic means. Unless they are of the centrifugal type, they shall be equipped with suitable pressure actuated by-pass valves permitting flow from discharge to suction or to the CT. A liquid chlorine pump may not be installed on a CT intended for the transportation of chlorine.[65]

3.8 INSTALLATION OF LININGS AND COATINGS

Lining material must consist of a nonporous, homogeneous material not less elastic than the parent metal and substantially immune to attack by the lading. The lining material must be bonded or attached by other appropriate means to the CT wall and must be imperforate when applied.

Any joint or seam in the lining must be made by fusing the materials together or by other satisfactory means.[66] For testing of the integrity of the lining see the Testing and Inspection chapter of this guidelines document.

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[65] §178.337-15 (a) and §178.337-15 (b)

[66] §178.345-2(c)(2)

4. Cargo Tank Repair

4.1 INTRODUCTION

This chapter of the guidelines document will provide recommended practices for the repair of specification CTs. The specific recommended practices will address the following areas: requirements for administration, personnel, and conditions requiring repair. This chapter will describe best practices for repair of defects in CTs conforming to DOT Specifications MC 306, MC 307, MC 312, MC 330, MC 331, MC 312, DOT 406, DOT 407, and DOT 412. While industry input was analyzed for recommended practices, CT repair is more thoroughly covered in regulations, codes, and standards; therefore, the recommendations presented in this chapter will be based primarily on these sources rather than participant input. In a few instances, industry comments will be provided to support the recommended practices.

Repair of CTs is narrowly defined in 49 CFR 180 as any welding done on a CT wall done to return a CT or a CTMV to its original specification or a later equivalent specification. Part 3 of the 2007 Edition of the National Board Inspection Code (NBIC) defines repair more broadly as the work necessary to restore pressure-retaining items to a safe and satisfactory operating condition. This industry-recommended guidelines document will use the broader definition contained in the NBIC, which includes repair methods in addition to welding.

Accepted practices for the repair of specification CTs are informed by the CFR, the ASME Code, and the NBIC. Regulatory support for repair practices can be found in the following sections:

- 49 CFR 107.501-504 (Subpart F)
- 49 CFR 178.337-16
- 49 CFR 178.337-3, 178.338-3, or 178.345-3
- 49 CFR 180.405(d)
- 49 CFR 180.407
- 49 CFR 180.407(g)(1)(iv)
- 49 CFR 180.413

Additional support can be found in the codes and standards established by the ASME Code and NBIC. In 1996, Section XII, Rules for Construction and Continued Service of Transport Tanks of the ASME Boiler and Pressure Vessel Code, was created at the request of the USDOT. The USDOT and the ASME involved the National Board of Boiler and Pressure Vessel Inspectors in the in-service inspection, repair, and alteration requirements to be included in the new code. As a result of this collaboration, the first edition of Section XII was released in 2004, and a new edition of the NBIC was released in 2007.

The USDOT is currently working to publish a rulemaking that will formally adopt Section XII and the NBIC into the Federal regulations and expects that this will take place in 2009. This rulemaking will mean that in-service inspection, maintenance, repair, and alteration of CTs will utilize the NBIC and its system of Authorized Inspectors (AI); Qualified Inspectors (QI), and the newly created category of Certified Individuals (CI) to oversee this work. Table 5, shown below, clarifies these categories of personnel and their responsibilities.

Table 4. Inspector requirements for various CT classes.

Tank Class	Insp. Description	Qualifications	CT Type
1	Authorized Inspector (AI)	National Board Certification	407 with MAWP>35 psig; 412 with MAWP>15 psig; all 331; 338 inner tanks
2	Qualified Inspector (QI)	Similar to National Board Certification	406, 407, 412 except see above; also others not yet defined
3	Certified Individual (CI)	Certified by Manufacturer	406, 407, 412 except see above

An AI can perform the duties of a QI or a CI, and a QI can perform the duties of a CI.

USDOT regulations require that any ASME Code-stamped vessel must be repaired or altered only by organizations holding a National Board "R" Certificate of Authorization. Currently, ASME code-stamped vessels (tanks) in transport service are stamped as Section VIII (U-stamped) vessels. Once Section XII is formally adopted by the USDOT, new vessels will bear a "T" Stamp, and repairs or alterations will need to be performed by a holder of a National Board "TR" Certificate of Authorization.

NBIC-2007, Part 2, Inspection, Supplement 6, and NBIC-2007, Part 3, Repairs and Alterations, Supplement 6, also recognize Registered Inspectors (RI) who are registered with and qualified by the USDOT.

4.2 ADMINISTRATION REQUIREMENTS

Certain administrative requirements apply to a repair organization and its practices. A repair organization must be accredited in accordance with the National Board "TR" Program. It must have a quality assurance program in place that will document and control repair activities. Welding procedures must be established according to the requirements of ASME BPV Code Section IX, Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators. Other procedures associated with repair must be written and must be formally approved by the repair organization.

Industry Recommendation

- **Implement proper welding procedures.**

4.3 PERSONNEL REQUIREMENTS

Welding personnel must be certified welders meeting the certification requirements of ASME Section IX for the appropriate welding procedures. Repair facilities should ensure that all welders meet these requirements. Often times, repair facilities may find it beneficial to implement their own training programs for welders as there may not be a training facility in the region. Through the use of qualified weld procedures, facilities should ensure that high quality welding standards are maintained by each welder responsible for the repair of specification CTs. This can be done by continued quality assurance programs that require the welders to periodically test their weld techniques against a standard weld procedure for a specific function.

Industry Recommendation

- **Ensure welding personnel retain necessary qualifications through ongoing quality control and training processes.**

Industry Supporting Quote

- *It's* [the quality control procedures]*, a written procedure based on the NBIC quality control. It's just customer specific. It's not just one manual. Each company has to make their own specific to your company.… It's certified by the NBIC.* (Repair Insulated CTs)

4.4 CONDITIONS REQUIRING REPAIR

4.4.1 Corrosion

Corrosion is defined as the breaking down or destruction of a material, especially a metal, through chemical reactions. The longevity of a CT is directly related to corrosion. The first line of defense against corrosion is avoiding corrosive situations with the tank. For more information on corrosion see chapter 2: Operations – section 2.4.1, which provides several industry-recommended practices for preventing corrosion. Diligence alone will not prevent all corrosion, and thus it is very important to identify areas of corrosion on the CT as soon as possible. Upon identifying the corrosion, one can plan a course of action to repair the affected area. Listed below are common types of corrosion found in CTs and their definitions. This list is not exhaustive, but should enable one to identify types of corrosion and how best to proceeded with repairs.

Industry Recommendations

- **Be aware of various types of corrosion that can affect a DOT-specification CT.**
- **Develop a corrosion mitigation plan that establishes the processes for determining root cause of corrosion and proper repair procedures for each type of corrosion.**

Industry Supporting Quotes

- *In my opinion, the main problems with corrosion is the products that we haul. Say we haul one product this way and we back-haul another product that way. What if the tank isn't …if the tank isn't cleaned perfectly or if there is already pitting in there that is holding little tiny parts of the previous product, well it might mix with another chemical and cause a reaction. Therefore making the pitting worse.* (Repair Insulated Tanks)
- *Welding pits* [is the number one repair that if not completed would affect the service life of CTs]. (Repair Insulated Tanks)

- *Corrosion in general is the pitting and etching of the barrel, which thins the barrel over the years. Like he said we have to remove that corrosion and etching and repair the pitting.* (Repair Insulated Tanks)
- *If we get a job and say it's a remodel. When a truck comes in, if we've got to cut the skirting off and we see any corrosion underneath it, then we'll do an ultrasound test on it and it's basically during that job that that gets repaired and re-skirted and put on a new chassis.* (Rechassis MC 330/MC 331 Bobtails)

Pitting corrosion – The formation of through or partially through holes in an otherwise unattacked surface. It can be caused by microbiological activity or microbial induced corrosion. Crevice corrosion (figure 1) also can be a cause. Rules in Section VIII, Division 1, Mandatory Appendix 30, Rules for Drilled Holes Not Penetrating Through Vessel Wall, are available to determine whether a pit is acceptable or whether repair is required. If repair is not indicated, the pit must be cleaned and the cause must be eliminated.

Line corrosion – A condition where pits are connected or nearly connected with one another in a narrow band or line. It typically occurs in the interior of the tank at the liquid-vapor interface or along the tank bottom. The affected areas must be inspected to make sure that the minimum wall thickness has not been compromised. If it has been compromised, the repair will generally consist of a flush patch. General weld overlay repair, seen in figure 1, is possible only if the original tank wall thickness is substantial, at least three-eighths of an inch.

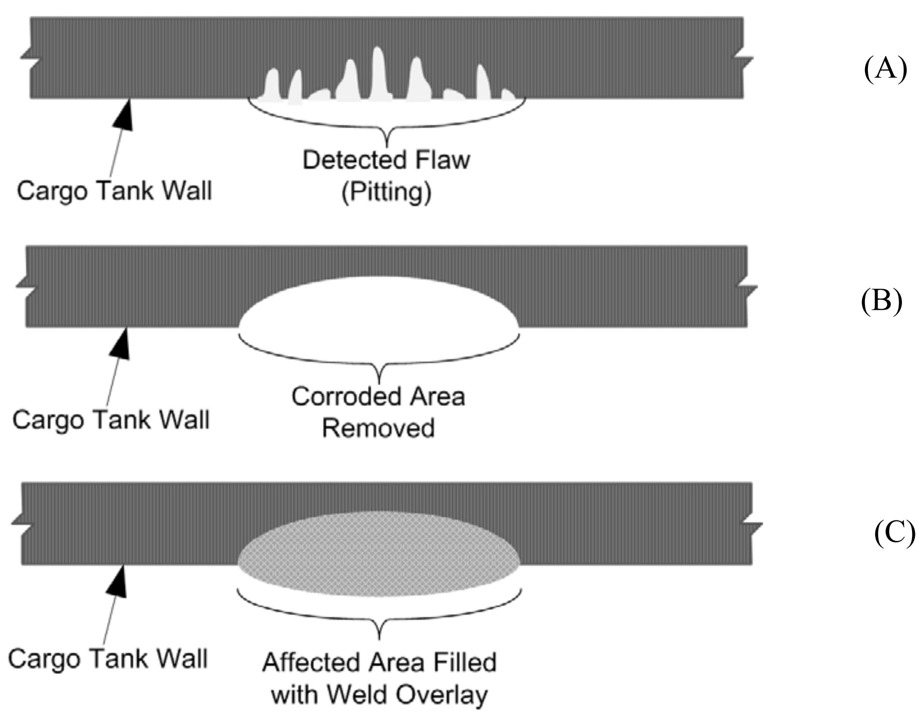

Figure 1. Diagram. Example of weld overlay repair process.

General corrosion – Corrosion that covers a considerable area of the tank surface. The affected areas must be inspected to make sure that the minimum thickness has not been compromised. If it has been compromised, the repair will generally consist of a flush patch. General weld overlay repair is possible only if the original tank wall thickness is substantial, at least three-eighths of an inch.

When addressing general corrosion areas, bear in mind that the repair should return the CT to its original state. Lap patching, seen in figure 2, is not allowed for this purpose, so flush patches must be used for this type of repair. The patch material must be of the same material as the CT, and all standard welding procedures should be observed.

Grooving corrosion – Typically occurs adjacent to a weld joining the shell and reinforcement or in the shell, adjacent to a saddle. This can occur externally or internally. If it has been compromised, the repair will generally consist of a flush patch. General weld overlay repair is possible only if the original tank wall thickness is substantial, at least three-eighths of an inch.

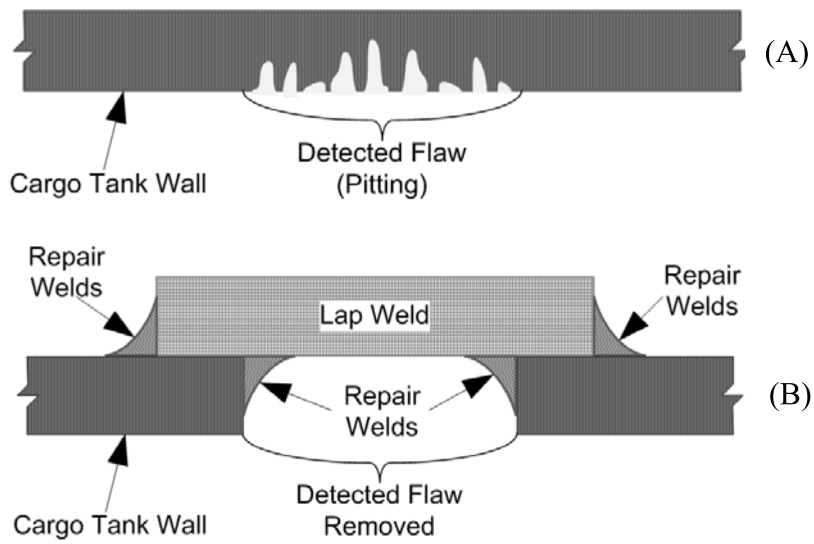

Figure 2. Diagram. Example of lap weld process.

Galvanic corrosion **–** Typically occurs at a juncture of dissimilar metals or dissimilar alloy content of the same metals in the presence of an electrolyte. An example is a film of water containing dissolved oxygen, nitrogen, or carbon dioxide, making up an electrolytic cell. The difference in galvanic potential between the two dissimilar materials creates a local electrical cell that may cause rapid corrosion of the less noble metal. This corrosion mechanism becomes more active when there are large differences between the electrode potentials of the two metals. Galvanic corrosion may occur even with relatively minor changes of alloy composition, as between weld metal and base metal. Repair follows elimination of the cause of the galvanic attack by redesign or other removal of the offending material pair.

Erosion/corrosion – Typically occurs with movement of a corrodent over a metal surface that increases the rate of attack due to mechanical wear combined with corrosion or by mechanical removal of a protective layer (typically an oxide layer) combined with subsequent corrosion of the unprotected surface. This type of damage mechanism is generally characterized as having the appearance of a smooth-bottomed shallow pit depression, and it may also exhibit a directional pattern related to the path taken by the corrodent. It would normally be expected to occur at locations where the transport tank is filled or emptied.

***Crevice corrosion* –** Typically occurs at gasket surfaces, lap joints, and the interface between bolts, nuts, washers, and flanges. It is caused by the differential environment within and outside the crevice. An electrolytic cell is created, and the corrosion mechanism is similar to galvanic corrosion. Pits can also develop. Repair is only effective after correction of the offending design detail.

***Passivation* –** Consists of applying a solution of nitric acid or citric acid without oxidizing salts. The solution will dissolve embedded iron residue and restore the original corrosion-resistant film by forming a thin, transparent oxide film. However, passivating is not a failsafe; it will reduce, but not eliminate, the chemical reactivity of the tank material.

4.4.2 Weld Defects

Weld quality is very important to the longevity of a CT and paramount to its lading retention capability. In general, butt-welds and fillet welds must meet the thickness requirements of the thinner of the two members joined. In the case of fillet welds, weld size is of particular importance. Some guidance for treatment of particular defects is given below.

Industry Recommendation

- **Establish welding quality control policies and procedures to (1) ensure consistent welding techniques throughout company personnel and (2) identify all weld defects and procedures for rectifying such defects before placing cargo tank back into service.**

Industry Supporting Quotes

- [If a bubble on a weld is not addressed] *you'll get a pit in the tank and that will question the integrity of the tank itself, or the structure holding it to the body, or the chassis.* (MC 330/MC 331 Bobtail)
- *You'll see a weld sometimes of ungodly thickness. What they will do is they will keep welding over a crack. They won't gouge it out or go down to the root of the problem and fix it. They'll just keep welding over it and it will get* [this] *wide and thick.* (MC 330/MC 331 and Wet Fluorescent Magnetic Particle Testing)

***Weld cracking* –** Generally detected by visual examination, but more sensitivity can be obtained by magnetic particle examination, or for austenitic stainless steel or aluminum, by dye-penetrant examination. Repair is made by grinding to clean metal and repair-welding. Repeat occurrences in the same joint during repeat inspections must be evaluated to find and eliminate the cause.

Undercutting – Also called local reduction in thickness, it occurs at the interface between the weld and the base metal. It is generally detected by visual examination. Repair is made by grinding or power-bushing to clean metal and then repair-welding.

Excessive reinforcement – Rules for the permissible degree of reinforcement of butt-welds are given in Section VIII, Division 1, paragraphs UG-35 (c) and (d). Excess reinforcement must be removed by grinding because it produces a stress-concentration that can initiate fatigue failure.

Insufficient reinforcement – Rules for the minimum filling of weld grooves are given in Section VIII, Division 1, paragraphs UG-35 (b) and (c). Fillet welds must also meet the requirements of UG-35 (b). Insufficient filling can also produces a stress-concentration that can initiate fatigue failure. Repair is made by grinding or power-brushing to clean metal and repair-welding.

Incomplete fusion – Generally detected by visual examination. Greater sensitivity can be obtained by magnetic particle examination (see Wet Fluorescent Magnetic Particle Test [WFMPT]), or for austenitic stainless steel or aluminum, by dye-penetrant examination. Similarly to excessive reinforcement and insufficient reinforcement above, incomplete fusion produces a stress-concentration that can initiate fatigue failure. Repair is made by grinding to clean metal and repair-welding.

4.4.3 Cargo Tank Distortion

CT distortion can include both dents and gouges. Dents cannot exceed one-half inch when they include welds. Dents exceeding this value must be repaired with a flush patch, as in figure 3.

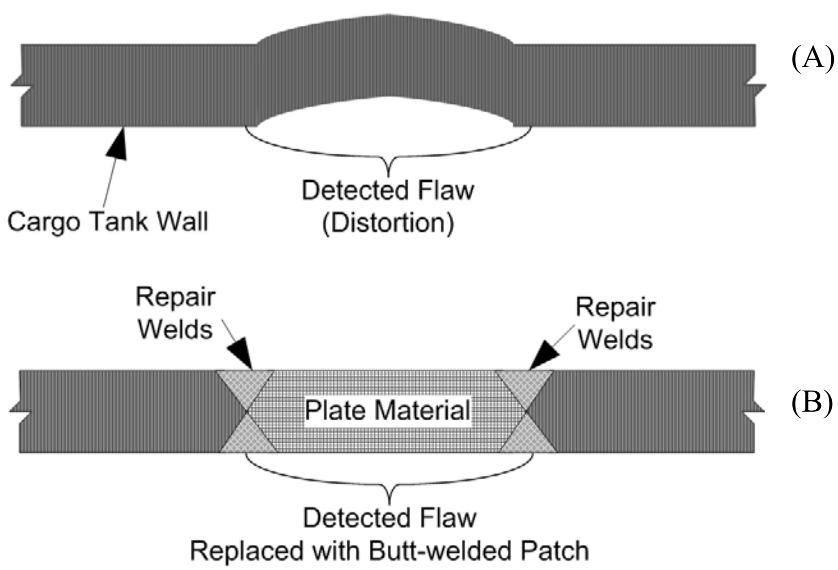

Figure 3. Diagram. Example of flush patch process.

For dents away from welds, the maximum allowable depth is one-tenth of the greatest dimension of the dent but cannot exceed 1 inch. Again, dents exceeding this value that cannot be removed without damaging the tank proper must be repaired with a flush patch.

Gouges – May be repaired by blending so the width of the blending is at least three times the maximum depth of the gouge around the full periphery. Gouges shall then be evaluated using Section VIII, Division 1, Mandatory Appendix 32, Local Thin Areas in Cylindrical Shells and in Spherical Segments of Shells. Alternatively, the guidance in API/ASME FFS-1, *Fitness for Service*, may be applied.

4.4.4 Cracking

Cracking is always a symptom of a structural overload, which is a repetitive, unaccounted-for, cyclic load causing a fatigue crack, a non-ductile fracture, weld embrittlement, or stress-corrosion cracking. It is recommended that a Design Specifying Engineer or equivalent be consulted in determining the cause for the crack and developing a repair.

Industry Recommendation

- **Establish policies for identifying and correcting material cracking, including properly trained personnel and proper procedures.**

Industry Supporting Quotes

- *We have an on-site engineer to work with us on those problems. A mechanical engineer. If we find cracks that are* [recurring]*…we try to find a fix, a better support for that structure to stop that from happening*. (Repair Insulated Tanks)
- *We've seen cracks in barrels that were not back welded. All repairs should be done to the highest standard to be sure that the replacement material restores the material to original integrity.* (Repair Insulated Tanks)

Fatigue cracks – Caused by repetitive cyclic loading. They often occur in the shell at the edges of mounting pads or saddles. Corners of mounting pads must be rounded, and welding around the pad should be continuous. (See Appendix A, paragraph A2(c) of ASME Section XII.) The cause and magnitude of the repetitive loading must be determined and mitigated. Usually, a simple grinding-out and welding of a crack will not remedy the problem. A simple weld repair will create a so-called metallurgical notch; the repaired structure will be less resistive to fatigue than the original structure, and the cracking will simply recur unless the cause is eliminated. To eliminate the cause, the cyclic stress input must be reduced to an acceptable level, either by strengthening the structure (e.g., strengthening or enlarging a pad) or by changing the load input.

Structural overload – Usually does not cause cracking in the ductile materials used in ASME Code construction of the tank. These ductile materials are intended to accept a certain amount of strain without cracking. This strain will generally manifest itself as distortion. The cause of the cracking must be determined. If cracking occurs due to structural overload, the repair weld must be carefully performed and finished to prevent stress-concentration, which would weaken the structure and increase the likelihood of recurrence.

Nonductile fracture (brittle fracture) – Can occur with materials that are low in notch-toughness. It is not an issue with stainless steel or aluminum construction. These materials do not suffer from low notch-toughness at all practical temperatures of operation. Notch-toughness in most carbon and alloy steels decreases with decreasing temperature. Therefore, brittle fractures have occurred in steel CTs at cold ambient temperatures. The remedy for this mode of failure is to either change the material of construction or avoid operation in the cold environment. Damage is generally catastrophic, so repair will almost always involve rebarrelling the CT.

Stress-corrosion cracking – Intergranular stress corrosion cracking (IGSCC) occurs in stainless steel tanks and components because austenitic stainless steels have become sensitized. During exposure to temperatures between about 900°F and 1,200°F, chromium carbides precipitate out of solid solution of the stainless steel at the grain boundaries. The chromium-depleted grain boundaries then become susceptible to cracking when exposed to even small amounts of chlorides and can crack under even low stress. The sensitization is a time-dependent process, so very short times in the critical temperature range may not cause sensitization. In low-carbon stainless steels (the L-grades, containing less than 0.04 percent carbon) the carbide precipitation is negligibly small.

The typical IGSCC is virtually invisible before rupture of a tank wall unless one is looking for it. It usually manifests itself as a failure. If it is suspected before failure, liquid penetrant examination near welds will detect it. Protection against IGSCC is most simply provided by avoiding the combination of sensitized stainless steel and halide compounds (those containing chlorine or bromine, or less commonly fluorine or iodine). Repair involves removing the generally cracked material and replacing it.

Transgranular stress – Also called ***corrosion cracking***, it can occur at low temperatures—about 104°F to 140°F, and does not require sensitization of the steel. It is not as common in cargo tank motor vehicle (CTMV) environments as IGSCC. Stainless steels crack in chloride environments but not in ammonia-containing environments. They do not crack in sulfuric acid, nitric acid, acetic acid, or pure water, but they do crack in chloride and caustic environments.

Hydrogen embrittlement – Can cause cracking and failure of high-strength steels. Dissolved hydrogen accumulates at the grain boundaries of the material, and the embrittled material fails at low stress. The hydrogen does not accumulate during operation of the CT because it operates at low pressure and temperature. However, welding with improperly treated, moisture-containing weld material can cause the problem. It manifests itself by cracking around a weld joint. Prevention is achieved by properly "baking" the weld material before use. Repair involves removing and replacing the cracked material.

4.4.5 Bulkhead and Baffles Defects

Defects in bulkheads and baffles typically occur at the welds joining these components to the shell. Bulkheads are pressure-tight separators within the tank. Baffles are not pressure-tight but resist sloshing in the tank and also act as stiffeners. Both bulkheads and baffles are joined to the shell with continuous welds. The desired construction is to flange (bend over) the edge of the baffle and fillet-weld the edge to the shell. A less desirable procedure is to weld the edge of the baffle without a flange directly to the shell.

Mandatory Appendix VIII of Section XII of the ASME Code states in part, "Pressure retaining heads and bulkheads in low pressure transport tanks can be inserted into the tank shell and fillet welded from one side, and each such pressure retaining part may have a formed flange providing a faying surface to the shell. The single fillet weld shall be made on the end of the formed flange. Heads, bulkheads, baffles and non-pressure-retaining elements can be installed without formed flanges, but such tanks shall require an annual inspection of the shell welds to them to verify their integrity if made from one side only."

Weld failures or cracking can often occur and must be repaired using the same guidance as provided in *Weld cracking* above.

Industry Recommendation

- **Bulkheads and baffles must be attached and joined appropriately to ensure structural integrity.**

Industry Supporting Quotes

- *Mostly what you will see is that the baffles do get loose, and then I don't know again how you'd know it other than at the 5-year. The cargo will start to move and it will actually almost* [act] *like a wave inside there, it will start hitting that baffle and eventually it will knock it down. And sometimes you will have damaged valve sacks ….(*MC 330/MC 331 and Wet Fluorescent Magnetic Particle Testing)
- [As far as baffles extending the service life of a tank,] *all depends on how they are put in too. Some people put them in like . . .they'll just weld a little clip in or something like that and the ones that are welded like two and a half feet have a clip all the way down on a section on this and another section up top and another one over here, like on the four corners like if it would have corners. And those usually last and hold up really well.* (MC 330/MC 331 and Wet Fluorescent Magnetic Particle Testing)
- *…. What we have done over the years is actually repaired tanks that customers did not want to have rebarrelled. They just wanted the wall re-supported and any cracks in them done so. Then they bring them in and say,"Well I want to make this tank legal to haul gasoline on it." As soon as you put air to it the bulkhead moves. You can't help it, it's the stress. We always recommend that they get rid of the tank and/or we recommend them to* [COMPANY NAME AND LOCATION REDACTED] *who will actually rebarrell their tank. They have a U stamp.* (Mobile Test and Inspection)

4.4.6 Omitted or Undersized Welding Pads

Defects in attachment of shell to frame or to rollover protection devices or rear-end protection structures are typically due to omitted or undersized pads. Mounting pads must be used and must be between 100 and 150 percent of the local wall thickness.[67] However, they are not required by the construction codes to be thicker than three-sixteenths of an inch. Pads must extend at least 2 inches in any direction from the point of appurtenance attachment. They must have rounded corners in order to minimize stress concentrations and must be welded to the shell all around, except for a small gap at the lowest point for drainage.

Industry Recommendation

- **Use welding pads appropriately to prevent cargo tank shell defects.**

Industry Supporting Quote

- *Everything that you weld to the vessel has to be done on a pad and there's a spec—a calculation and a spec of the pad that's going to be welded to the shell, and then any attachment on it has to be a certain size and distance from the pad or weld on the vessel.* (Rechassis MC 330/MC 331 Bobtails)

[67] 178.337-3(g)(3) and 178.345(f)(3)

4.5 REFERENCES

API/ASME FFS-1 (2006). *Fitness for Service*, New York, NY: American Society of Mechanical Engineers.

ASME Boiler and Pressure Vessel Code Section IX (2008). *Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators*, 2007 Edition, 2008 Addenda. New York, NY: American Society of Mechanical Engineers.

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"Transportation" Title 49, Code of Federal Regulations.

5. Test and Inspection Guidelines

5.1 INTRODUCTION

Federal Hazardous Materials Regulations (HMR) require that CTs constructed in accordance with a DOT specification or exemption and certain authorized nonspecification CTs are to be inspected, tested, and maintained in accordance with Title 49, Code of Federal Regulations (49 CFR) Part 180, "The Continuing Qualification and Maintenance of Packaging." The rules contained within Part 180 apply to any person who operates a CT, as well as facilities that manufacture, assemble, repair, certify, inspect, and test CTs and CTMVs whether or not the CT is intended to be used in the transportation of HM. 49 CFR 180 is supplemented by Appendices A and B of Part 180; Parts 107, 171, 172, 173, and 178; Appendix A to 40 CFR 60; 40 CFR 63.425; 29 CFR 1910.146; and CGA Technical Bulletin TB-2. Additional industry recommended practices can be found in the NTTC Users Manual: 2004.[68]

This chapter will discuss types of tests, test and inspection schedules, quality control procedures, acceptable results of tests and inspections, reporting and record retention requirements, and specific requirements for the test and inspection of specification CTs.

Part 180 sets forth six different tests and inspections to be used during the requalification of tanks:

1. **Visual external inspection** (V) – §180.407(d) requires a visual examination of a DOT CTMV for any condition that would render the tank unsafe for transportation service.
2. **Internal visual inspection** (I) – §180.407(e) requires an examination of the inside of the DOT CT for corroded areas, dents, distortions, weld defects, and any other condition that might render the tank unsafe for transportation service.
3. **Lining test** (L) – §180.407(f) requires a test of the integrity of the lining on all tanks, when lining is specifically required.
4. **Pressure retest** (P) – §180.407(g) requires the use of hydrostatic or pneumatic pressure methods to verify the structural integrity of the tank. Additionally, any tank out of HM service for more than 1 year must be pressure tested prior to a return to HM service.
5. **Leakage test** (K) – §180.407(h) requires a test for leaks.
6. **Thickness test** (T) – §180.407(i) requires a test of degraded or defective areas during which the degraded or defective areas are removed, the tank wall is inspected, and corroded areas are thickness tested.

Proper and timely tests and inspections are imperative to extending the service life of a CT. As such, tanks are required to be re-qualified on a regular basis. Requalification refers to the periodic testing and inspection required to be performed on a cylinder to determine its suitability for continued service. When tests and/or inspections required by §180 of 49 CFR are due, the owner or carrier may not fill the tank or ship product in the tank until the required tests and/or inspections have been completed.

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[68] National Tank Truck Carriers (2004). *Users Manual:2004* (3rd ed.). Arlington, VA: Author.

If a CT fails to pass the required tests and/or inspections, the tank must be repaired and retested. For CTs that fail the required tests and/or inspections and are not brought into conformance with the applicable specification requirements, the tank specification plate must be obliterated, removed, or covered (See §180.405). An owner or motor carrier who is aware that he or she is operating a CT that is marked with a DOT specification number or exemption that does not meet the applicable DOT specification yet continues to represent or use the CT is subject to severe penalties.

Per §107.329, in the event that the inspection of a hazardous materials operation discloses violations of the hazardous materials regulations, one may be subject to civil and/or criminal penalties. The minimum civil penalty per violation is $275.00, and the maximum civil penalty per violation is $32,500.00. Individual criminal penalties range to $250,000.00 while corporate penalties can range to $500,000. Criminal penalty fines are from 18 U.S.C., which includes a provision for imprisonment for not more than 5 years.

5.2 TEST AND INSPECTION SCHEDULES

§180.407(c) (table 5) provides the periodic test and inspection requirements that are to be followed by qualified inspectors. Testing and inspecting according to schedule can result in the early detection of tank problems which may result in a cost savings. Regardless of the schedule provided in the table below, additional tests or retests are required prior to use if the tank:

- Shows signs of bad dents, corroded areas, leakage, or any other condition which might render it unsafe in transporting hazardous materials.
- If a tank has been involved in an accident and damaged to the extent that it may have been rendered unsafe to transport products.
- If the tank has been out-of-service for a period of more than 1 year.
- If the tank has been modified from its original design.
- If the tank is determined to be unsafe by the DOT.

In these circumstances, the CT must be retested and/or re-inspected prior to use to ensure that it is within specification standards.

Table 5. Compliance dates – inspection and test under §180.407(c).

Test or Inspection (CT specification, configuration, and services)	Interval Period After First Test
External Visual Inspection All CTs designed to be loaded by vacuum with full opening rear heads	6 months
External Visual Inspection All other CTs	1 year
Internal Visual Inspection All insulated CTs, except MC 330, MC 331, MC 338 (see note 1)	1 year
Internal Visual Inspection All CTs transporting lading corrosive to the tank	1 year
Internal Visual Inspection All other CTs, except MC 338	5 years
Lining Inspection All lined CTs transporting lading corrosive to the tank	1 year
Leakage Test MC 330 and MC 331 in chlorine service	2 years
Leakage Test All other CTs except MC 338	1 year
Pressure Test (see notes 1 and 2) All CTs that are insulated with no manholes or insulated and lined, except MC338	1 year
Pressure Test (see notes 1 and 2) All CTs designed to be loaded by vacuum with full opening rear heads	2 years
Pressure Test (see notes 1 and 2) MC 330 and MC 331 CTs in chlorine service	2 years
Pressure Test (see notes 1 and 2) All other CTs	5 years
Thickness Test All unlined CTs transporting material corrosive to the tank, except MC 338	2 years

Note 1: Insulated CTs equipped with manholes or inspection openings may perform either an internal visual inspection in conjunction with the external visual inspection or pneumatic pressure test of the CT.

Note 2: Pressure testing is not required for MC 330 and MC 331 CTs in dedicated sodium metal service.

Note 3: Pressure testing is not required for un-insulated lined CTs with a design pressure or MAWP 15 psig or less, which receive an external visual inspection and lining inspection at least once a year.

Industry Recommendation

- **Ensure that tests and inspections are completed on time.**

Industry Supporting Quotes

- *A bad inspection would* [shorten the life of a CT]. *But not if you give thorough inspection – it's going to help prolong the life of the vessel.* (MC 330/MC 331 Bobtail)
- *I believe the inspections are an integral part of keeping your equipment up and running.* (MC 330/MC 331 Bobtail)
- *One of the big things is the proper inspection, proper repair, getting this testing and stuff done on time when it is supposed to be.* (MC 330/MC 331, Wet Fluorescent Magnetic Particle Testing)
- *I think that probably the best way* [to improve the service life of the CTs] *is to make sure that everybody is doing what they're supposed to do…. I'd just say more diligence in testing.* (Mobile Test and Inspection)

It is possible that tests and inspections may be done at the same time in order to minimize CT out-of-service time. Additionally, tests and inspections may be coordinated with PM schedules. For PM recommendations, see section 2.4.1. If tests and inspections are done at the same time, each inspector may have his or her own order for completing the test. However, at minimum, the tests and inspections need to cover the items specifically noted in the regulations for each test and inspection.

Industry Recommendation

- **Coordinate test and inspection schedules for improved efficiencies.**

Industry Supporting Quotes

- It will, however, make good sense to try to coordinate all maintenance requirements for items like running gear, lights, brakes, and etc. with the DOT mandated items. (NTTC Users Manual: 2004)
- Most of the time more than one inspection is going to be done during one shop visit, like external visual inspection, internal visual inspection and leakage test. The sequence of these jobs should be thought through so you don't spend a lot of time on one and then disqualify the tank quickly with the second test. For instance, an internal inspection might precede the external inspection for a single compartment clean bore tank. Any pressure testing should be done last. (NTTC Users Manual: 2004)

5.3 QUALITY CONTROL PROCEDURES

Quality control procedures play an important role in the test and inspection process. These procedures ensure that tests and inspections are completed fully and to specification. Also, completing the forms as the tests and inspections are performed streamlines the record preparation process. Industry recommends that inspectors follow a set of guidelines for completing the tests. Most companies have internally developed policies/procedures or guidelines modeled after those provided by the NTTC (e.g., the "Checklist/Inspection Report") or a third-party fleet management company. On its Web site,[69] the FMCSA provides a partial listing of sources for additional publications and training material. This list is replicated below and is provided as a courtesy, not as an endorsement for these companies or their products (table 6).

Table 6. Partial listing of sources providing additional publications and materials.[70]

J.J. Keller & Associates, Inc. 7273 State Road 76, Neenah, WI 54957-0368 (920) 722-2848 (800) 558-5011	Learncom, Inc. 38 Discovery, Suite 250 Irvine, CA 92618 (800) 969-2711 learncom.com
Scientech LLC 910 Clopper Rd Gaithersburg, MD 20877 (301) 258-2500 FAX (301) 258-1731	Mancomm 317 West 4th Street Davenport, IA 52801 (877) 626-2666 mancomm.com
American Trucking Association, Inc. 220 Mills Road Alexandria, VA 22314 (800) ATA-LINE (703) 838-1754	Compressed Gas Association 4221 Walney Road 5th Floor Chantilly, VA 20151 (703) 788-2700
LabelMaster 5724 North Pulaski Road Chicago, IL 60646 (312) 478-0900 (800) 621-5808	Emergency Film Group 140 Cooke Street Edgertown, MA 02539 (800) 842-0999
Idaho Dept. of Law Enforcement MCSAP Division Video Dept 700 South Stratford Drive Meridian, ID 83680	Dangerous Goods Advisory Council 1100 H Street NW, Suite 740 Washington DC 20005 (202) 289-4550 (800) 634-1598

Industry Recommendation

- **Establish quality control procedures for tests and inspection.**

Industry Supporting Quotes

- *I've been in this for a long time. You find people like to shortcut things sometimes. By having it a set guideline* [for inspections] *that they have to follow, they can't shortcut. They have to follow the program, the protocol.* (MC 330/MC 331 Bobtail)
- *You have to have a quality assurance manual that describes in general how your program works. Then you have to have the individual procedures outlining what you're*

[69] http://www.fmcsa.dot.gov/safety-security/hazmat/complyhmregs.htm
[70] http://www.fmcsa.dot.gov/safety-security/hazmat/complyhmregs.htm

going to do, and they include not only the procedures that say you're going to test it in this method, but how you're going to keep your equipment calibrated. (Mobile Test and Inspection)

- *After the test is performed, we go around and double check everything. Make sure we don't miss anything, make sure no gaskets need replaced. Everything's tested.* (Mobile Test and Inspection)
- *There are several items that are vague that's up to peoples' interpretations, but other than that it's pretty clear what the government says needs to be tested, and we formed our internal forms around what they say needs to be done along with some other things that we check.* (Repair of Insulated CTs)
- *The visual form we have here at* [COMPANY NAME REDACTED] *goes over each component of the tank. The landing gear, the king pin plate, the rails, the cross-members, the sub-frame, we check them for cracks. We check all the equalizers, the springs, the air brakes, I mean it is a complete list of everything that is on that trailer and it has to meet a certain specification or we replace it then.* (Repair of Insulated CTs)
- *The forms I have tell us what to check* [like external visual/internal visual]. *There's a procedure for each step of the way of what to look at and how to test them. Like taking valves off, for instance, and bench testing. You could test a valve on top of a tank, but it would be the lazy way to do it. But you take them off, put them in a vise, and you can have a chance to make sure it's clean and you can really inspect them. So we have a procedure for which I do all that.* (MC 307/DOT 407)

Individual company policies may encourage additional tests and/or inspections as part of the PM program. Company policies should serve to supplement the schedule provided. For example, the NTTC User's Manual 2004 provides guidance on non-DOT specification components, such as ladders, walkways, hose tubes, cabinets, etc., which are not required but that they have found to be essential to the safe operation of the vehicle. Additional discussion on the benefits of a PM program can be found in chapter 2 of this document.

Industry Recommendation

- **Establish a preventative maintenance program.**

Industry Supporting Quotes

- [We] *do our inspections. We try to do them as best as we possibly can. We go over them. We try to find and repair anything. We try to go above and beyond and repair everything we can possibly repair where there are other companies that to get them in and out they let stuff go. I think if you have good inspections on your tank it will last a lot longer.* (MC 330/MC 331, Wet Fluorescent Magnetic Particle Testing)
- *Regular testing and maintenance from a qualified mechanic or technician will prevent, I'd venture to say, most of these* [leaks]. (Test and Inspection of Specification CTs)
- [Age] *has nothing to do with how it lasts; it has to do with how it is maintained, the inspection done right as far as, if you catch that stuff when it starts. If you see a problem maybe try to correct it, see what you can do to keep it from happening again.* (MC 330/MC 331, Wet Fluorescent Magnetic Particle Testing)

5.4 SAFETY PRECAUTIONS

Safety is paramount to CT operations. Tanks must be able to operate in a safe manner—both over the road and during the loading and unloading of ladings. Testing and inspections play a critical role in ensuring the continued safe operations of a CT. However, safety should not be limited to tank operations. Safety should also be at the forefront during the test and inspection process.

5.4.1 Tank Cleaning

49 CFR 180.413(a)(2) requires that prior to each repair, modification, stretching, rebarrelling, or mounting, the CTMV must be emptied of any HM lading. Additionally, CTs used to transport flammable or toxic lading must be sufficiently cleaned of residue and purged of vapors so that any potential hazardous are removed—this includes void spaces between double bulkheads, piping, and vapor recovery systems.

Prior to test and inspection, CTs should be well cleaned and free from any debris. Ensure all liquid and vapor lines and any void areas on the CT have been purged. A clean tank will ensure that inspectors are not exposed to any dangerous materials. Additionally, a clean tank ensures that no defects in the tank are overlooked because they were obscured by residue, dirt, or debris. For further information on tank cleaning, see chapter 2 of this document.

Industry Recommendation

- **Ensure tanks are clean before performing any work.**

Industry Supporting Quotes

- Hazardous material cargo tanks can be dangerous to work on unless they are professionally cleaned and are free of any flammable, poisonous or otherwise harmful commodities. (NTTC Users Manual: 2004)
- *…definitely easier to see a leak on a clean tank.* (Test and Inspection of Specification CTs)

5.4.2 Confined Space Safety Precautions

Confined spaces are governed under OSHA. Regulatory guidelines can be found in 29 CFR 1910.146. A confined space is a space that:

1. Is large enough and so configured that an employee can bodily enter and perform assigned work.
2. Has limited or restricted means for entry or exit (for example, tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry).
3. Is not designed for continuous employee occupancy.

A CT is a confined space. As such, great care must be taken to make certain that inspectors are safe while inside the CT completing any necessary inspections, tests, or repairs. Inspectors should be trained in all company and government requirements and should be expected to abide by those standards in order to ensure their own personal safety as well as the safety of their co-workers.

Industry Recommendation

- **Establish and follow confined space safety requirements.**

Industry Supporting Quotes

- Work in confined spaces is often necessary and needs to be done in a manner that meets all company and government requirements. (NTTC Users Guide: 2004)
- *Because it is a confined space that is a challenge we've had over the years to educate the people that we work with. It's a confined space, which I mentioned, which is a controlled area. You must have the proper protection equipment and the space must be monitored to make sure that you've got enough oxygen to survive in there. There've been many, many deaths of people in confined spaces because they just went in and didn't check it to make sure that there was a sufficient amount of oxygen and no toxic remains in there because those tanker trucks carry a lot of different materials that are toxic. You must maintain positive air pressure and you must monitor that with a calibrated monitoring device to assure there's enough oxygen. Then you've got to have, as I mentioned, a hole watch—a person outside that's watching—to make sure that if you do lose oxygen, go down, that emergency personnel are there quickly enough to extract you and bring you back.* (Mobile Test and Inspection)
- *This* [education] *is the term that we hear often when we say, "Gee, we can't go in there until you've monitored it."* [And he or she will tell us,] *"Well, I've been doing this for 20 years and nobody's died on my watch!"*[And we'll reply,] *"Well, I understand that and that's important to some people, but that doesn't mean that somebody won't die on your watch if you don't do it correctly.* (Mobile Test and Inspection)

5.4.3 Pneumatic Pressure Testing Safety Precautions

Exercise caution when conducting pneumatic pressure testing. While the regulations allow for pneumatic pressure testing, many find hydrostatic pressure testing to be a safer alternative. Many facilities note that they believe hydrostatic testing is safer because a failure involving water pressure poses a less serious threat than does a failure which involves air pressure.

Industry Recommendation

- **Exercise caution when conducting pneumatic pressure testing.**

Industry Supporting Quote

- The disadvantage of pneumatic testing (particularly above 5 psi), is that if a failure occurs in the vessel it takes a longer time for the pressure to dissipate through the failure allowing that failure to propagate very quickly and (perhaps) catastrophically. In addition to damaging the vessel, these failures can be DANGEROUS TO PERSONNEL, who may be close to the failure while inspecting the vessel. (NTTC Users Manual: 2004)

5.5 REGISTRATION

CT inspection, testing, manufacturing, and repair facilities are required to be registered with the USDOT in accordance with 49 CFR Part 107, Subpart F (see §107.502, 503, and 504). The two types of qualified and registered facilities are: (1) a National Board of Boiler and Pressure Vessel R stamp facility or (2) a facility that holds an ASME Code symbol U stamp. Once a facility has registered, the registration is valid for 6 years. Inspectors or design certifying engineers are considered to be registered if their employers are registered, provided they are employed as a registered inspector or design-certifying engineer.

5.6 MINIMUM QUALIFICATIONS FOR INSPECTORS AND TESTERS

Tests and inspections are to be performed by qualified individuals as set forth in §180.409, Minimum Qualifications for Inspectors and Testers. Except as otherwise noted, any person performing or witnessing the tests must:

1. Be registered with the FMCSA in accordance with 49 CFR 107 subpart F.
2. Be familiar with DOT specification CTs and trained and experienced in use of the inspection and testing equipment needed.
3. Have the training and experience required to meet the definition of "Registered Inspector."

A ***Registered Inspector*** (RI) [See §171.8] is a person registered with the USDOT who has the knowledge and ability to determine whether a CT conforms to the applicable DOT specification. RIs can satisfy the knowledge and ability requirements if they are able to meet any one of the following requirements:

1. Has an engineering degree and 1 year of work experience relating to the testing and inspection of CTs.
2. Has an associate's degree in engineering and 2 years of work experience relating to the testing and inspection of CTs.
3. Has a high school diploma (or General Equivalency Diploma) and 3 years of work experience relating to the testing and inspection of CTs.
4. Has at least 3 years' experience performing the duties of an RI prior to September 1, 1991.

RIs are to inform CT owners or motor carriers in writing of any deficiencies found during the test and inspection of the CT. The tank owner, and motor carrier if different from the owner, is required to retain a copy of the test and inspection reports until the next test or inspection of the same type is successfully completed.[71]

Although CT inspectors are required to meet the qualifications above, many companies find it beneficial to provide their employees with additional training. Training ensures that everyone performs tests and inspections consistently and according to the most recent regulatory requirements. Additionally, training provides an opportunity for interaction and feedback regarding new test and inspection techniques, problems, or solutions relating to new technologies, the hauling of different ladings, changes in tank design or fittings, etc.

Industry Recommendation

- **Ensure that all cargo tank inspectors receive regular training.**

[71] This requirement does not apply to motor carriers who lease a cargo tank for less than 30 days.

Industry Supporting Quotes

- *The* [test and inspection process] *is good. I think what they have is pretty thorough. So I like the system that they have right now in place. I think their process is good. Training—I guess that's an important thing. As long as inspectors are trained or know what they're looking for, training would be a thing* [to improve the test and inspection process]. (MC 307/DOT 407)
- *The only other thing I can think of* [to improve testing and inspection] *is just having people who are better versed in the area besides just the people that come out to audit you. There should be some type of outsourced training programs.* (MC 330/MC 331 Bobtail)
- *As far as an industry, in whole* [to improve inspection and testing of CTs], *more qualified people as far as an RI. Just more as far as an individual who does it, as far as educating or training.* (Rechassis MC 330/MC 331 Bobtail)

Additional information about employee training can be found in chapter 2 of this document.

5.7 ACCEPTABLE RESULTS OF TESTS AND INSPECTIONS

§180.411 outlines the guidelines for acceptable results of tests and inspections. Company-specific policies may impose stricter requirements than listed below; however, at minimum, the following represents the regulation-defined acceptable results.

- Corroded or abraded areas: The minimum thickness may not be less than that prescribed in the applicable specification.
- Dents, cuts, digs, and gouges:[72] For dents at welds or that include a weld, the maximum allowable depth is one-half inch. For dents away from welds, the maximum allowable depth is one-tenth of the greatest dimension of the dent, but in no case may the depth exceed 1 inch. The minimum thickness remaining beneath a cut, dig, or gouge may not be less than that prescribed in the applicable specification.
- Weld or structural defects: Any CT with a weld defect such as a crack, pinhole, or incomplete fusion or a structural defect must be taken out of HM service until repaired.
- Leakage: All sources of leakage must be properly repaired prior to returning a tank to HM service.
- Relief valves: Any pressure relief valve that fails to open and reclose at the prescribed pressure must be repaired or replaced.
- Liner integrity: Any defect shown by the test must be properly repaired.
- Pressure test: Any tank that fails to meet the acceptance criteria found in the individual specification that applies must be properly repaired.

Industry Recommendations

- **Establish acceptable result criteria for tests and inspections.**
- **Train inspectors on established acceptable result criteria.**

[72] For evaluation procedures, reference CGA C-6: Standards for Visual Inspection of Steel Compressed Gas Cylinders.

Industry Supporting Quotes

- [We] *do our inspections. We try to do them as best as we possibly can. We go over them. We try to find and repair anything. We try to go above and beyond and repair everything we can possibly repair where there are other companies that to get them in and out they let stuff go. I think if you have good inspections on your tank it will last a lot longer.* (MC 330/MC 331, Wet Fluorescent Magnetic Particle Testing)
- *A lot of times they will have broken springs or sometimes even missing like half a spring when they come in and never even really mentioned it. They don't get inspected every day for certain. Probably don't even inspect them except for when they are getting fixed for something.* (Test and Inspection of Specification CTs)
- *You see that every year* [that the valves and emergency remotes haven't been maintained through the year] *and some of them it is the exact same unit. You'll come in and his controls won't work.* (MC 330/MC 331, Wet Fluorescent Magnetic Particle Testing)

5.8 REPORTING AND RECORD RETENTION REQUIREMENTS

§180.417 establishes reporting and record retention requirements. Keeping complete internal records makes it easier to track when tests and inspections are due. Detailed record-keeping also allows tank owners to track maintenance, repairs, and tank degradation over time. Specification CT owners are required to retain the manufacturer's certificate, the manufacturer's ASME U1A data report, where applicable, and related papers certifying that the tank was manufactured and tested in accordance with the applicable specification.[73] This would include any certification emergency discharge control systems required by §173.315(n) of this subchapter or §180.405(m).[74] These documents are to be retained for as long as the tank is owned and for one additional year. When a tank changes ownership, the prior owner must retain copies of the documents for 1 year. Motor carriers who lease or operate tanks they do not own are required to obtain copies of the manufacturer's certificate and related papers as well. These documents are to be retained for as long as the CT is used by that carrier and for one additional year. Documents should be kept at the company's principal place of business or the location where the vehicle is housed or maintained. If a tank is leased for a period of less than 30 days, this requirement does not apply. Each person offering a DOT-specification CT for sale or lease must provide the purchaser or lessee a copy of the CT certificate of compliance, records of repair, modification, stretching, or rebarrelling, as well as the most recent inspection and test reports. Copies of such reports must be provided to the lessee if the CT is leased for more than 30 days.

If an owner has a non-ASME code-stamped CT that was manufactured prior to September 1, 1995, and he or she wishes to certify it as a specification CT, the tank must pass all appropriate tests and inspections for the applicable specification as performed under the supervision of an RI. Both the owner and the RI must certify that the CT conforms to the specification.

[73] For example, see §178.345-10(f) and §178.345-10(g) for certification of pressure relief devices and rated flow capacity certification test requirements.

[74] See section below regarding emergency discharge control systems for additional information about those systems.

For ASME code-stamped CTs, an owner who does not have the manufacturer's certificate required by the DOT specification and the manufacturer's data report[75] required by the ASME may contact the National Board for a copy of the manufacturer's data report, if the CT was registered with the National Board, or copy the information contained on the CT's identification and ASME Code plate. Additionally, the owner and an RI must certify that the CT fully conforms to the specification. The owner must retain such documents as long as the CT is used by that carrier and for one additional year.[76]

§180.417(b) provides that written reports are to accompany tests and inspections. The owner and the motor carrier, if not the owner, must each retain a copy of the test and inspection reports until the next test or inspection of the same type is successfully completed. This requirement does not apply to a motor carrier leasing a CT for fewer than 30 days. These reports must be prepared in English and must include the following information:

- Owner's and manufacturer's unique serial number for the CT.
- Name of the CT manufacturer.
- CT DOT or MC specification number.
- Maximum allowable working pressure (MAWP) of the CT.
- Minimum thickness of the CT shell and heads when the CT is thickness tested in accordance with 180.407(d)(4), 180.407(e)(3), 180.407(f)(3), and 180.407(i).[77]
- Indication of whether the CT is lined, insulated, or both.
- Indication of special service of the CT (e.g., transports materials corrosive to the tank, dedicated service, etc.).

In addition, each test or inspection report must include the following specific information as appropriate for each individual type of inspection:

- Type of test or inspection performed.
- Date of test or inspection (month and year).
- Listing of all items tested or inspected, including information about pressure relief devices that are removed, inspected, and tested or replaced, when applicable (type of device set to discharge pressure, pressure at which device opened, pressure at which device reseated, and a statement of disposition of the device [e.g., reinstalled, repaired, or replaced]); information regarding the inspection of upper coupler assemblies, when applicable (visually examined in place or removed for examination); and information regarding leakage and pressure testing, when applicable (pneumatic or hydrostatic testing method, identification of the fluid used for the test, test pressure, and holding time of test).
- Location of defects found and method of repair.
- ASME or National Board Certificate of Authorization number of facility performing repairs, if applicable.
- Name and address of person performing test.

[75] See http://www.asme.org/Codes/Publications/BPVC/Data_Report_Forms.cfm for examples.
[76] See §180.417
[77] See Thickness Testing Section for additional information.

- Registration number of facility or person performing the test.
- Continued qualification statement, such as “CT Meets the Requirements of the DOT Specification Identified on this Report” or “CT Fails to Meet the Requirements of the DOT Specification Identified on this Report”.
- DOT registration number of the RI.
- Dated signature of the RI and the CT owner.

There are additional requirements for specification MC 330 and MC 331 CTs. After completion of the pressure test specified in §180.407(g)(3),[78] each motor carrier operating a specification MC 330 or MC 331 CT in anhydrous ammonia, liquefied petroleum gas, or any other service that may cause stress corrosion cracking must make a written report that contains the following information:

- Carrier’s name, address of principal place of business, and telephone number.
- Complete identification place data[79] required by Specification MC 330 and MC 331, including data required by the ASME Code.
- Carrier’s equipment number.
- A statement indicating whether or not the tank was stress relieved after fabrication.
- Name and address of the person performing the test and the date of the test.
- A statement of the nature and severity of any defects found—particularly, information must be furnished to indicate the location of the defects, such as such as in the weld, heat-affected zone, the liquid phase, the vapor phase, or the head-to-shell seam. If no defect or damage was discovered that fact must also be reported.
- A statement indicating the methods employed to make repairs, who made the repairs, and the date they were completed. Also a statement of whether or not the tank was stress relieved after repairs and, if so, whether full or local stress relieving was performed.
- A statement of the disposition of the CT, such as “CT scrapped” or “CT returned to service.”
- A statement of whether or not the CT is used in anhydrous ammonia, liquefied petroleum gas, or any other service that may cause stress corrosion cracking. Also, if the tank has been used in anhydrous ammonia service since the last report, a statement indicating whether each shipment of ammonia was certified by its shipper as containing 0.2 percent water by weight.

A copy of the report must be retained by the carrier at its principal place of business during the period the CT is in the carrier’s service and for 1 year thereafter. Upon a written request to, and with the approval of, the FMCSA’s Regional Service Center Field Administrator for the region in which a motor carrier has its principal place of business, the carrier may maintain the reports at a regional or terminal office.

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[78] See Pressure Test section for additional information about the pressure tests.

[79] See External Visual Inspection section for additional information about specification plate requirements and tank markings.

Industry Recommendations

- **Establish proper recording-keeping practices.**
- **Maintain detailed reports of the results of CT testing and inspection.**

Industry Supporting Quotes

- *I do all the tracking of it* [the scheduled maintenance]. *I'll give the dispatch a list every single month. At the beginning of the month I'll say, "These are the tanks I have to get here." So then they schedule them to get them in. What we've done now, is we have to have the State inspection (like on your cars).* [STATE REDACTED] *State inspection. We do the same thing to your car, tractors, and trailers. We've gone ahead and scheduled the* [STATE REDACTED] *State inspection the same time we do this annual hazmat inspection so that way it's sort of a failsafe thing. That if somebody forgets one of the hazmat inspections, they know the* [STATE REDACTED] *State inspection is due. So we've gone ahead and changed everything that we had on the hazmat tanks to have the* [STATE REDACTED] *State inspection at the same time.* (MC 307/DOT 407)
- *And then we track* [the results from the thickness tests] *from year to year so we can actually…you check the same. We do like a clock like 12:00, 6:00, 3:00, 9:00 right down the sides so we can keep track of it in the office so they can compare from year to year to make sure if it's wearing down the tank, the thickness.* (MC 330/MC 331)
- *A trailer comes in for inspection; the shop is given a worksheet. Here we include 5AS to do a BIT or an annual inspection, brake adjustment, external visual, internal visual, leakage, thickness, upper coupler, and pressure. Once that's done, when he starts doing running gear inspection, he's given the paperwork to follow it to conduct that. At that point he basically has to go through it top to bottom, identifying what problems we had, what problems we didn't have. And repair and identify. After he's done that, he gets, this is basically a running gear…. Once he turns around, he signs off that he's repaired it and a supervisor has to come over and double check it. Once a supervisor has verified the mechanic has done what he's done and the job is complete, a manager has to sign.* (MC 330/MC 331 Bobtail)
- *So I keep one copy, I give* [my customers] *two because they are required to give a copy of their tests to the facility and/or terminal they load their tankers at.* (Mobile Test and Inspection)

5.9 REQUIREMENTS FOR TEST AND INSPECTION OF SPECIFICATION CARGO TANKS

Requirements for the six tests and inspections can be found in §180.407. As noted above, these tests and inspections are: **external visual inspection** (V), **internal visual inspection** (I), **lining test** (L), **pressure retest** (P), **leakage test** (K), and **thickness test** (T). Prior to any test or inspection, the CT should be professionally cleaned. Cleaning has safety and practical implications. A clean tank will ensure that inspectors are not exposed to any dangerous materials. It is important prior to starting the tests to double check to make sure to purge all liquid and vapor lines and any void areas on the CT. Additionally, a clean tank ensures that no defects in the tank are overlooked because they were obscured by residue, dirt, or debris.

5.9.1 External Visual Inspection

The requirements for external visual inspections (V) are set forth in 49 CFR 180.407(d). If a full external visual inspection is precluded due to the presence of insulation, the CT must also be given an internal visual inspection. Results of the inspection must be recorded and must include any defects discovered and steps taken to remedy the defect. At minimum, the external visual inspection includes the following:

- Inspect the shell and head for corroded or abraded areas, dents, distortions, defects in welds, and any other conditions, including leakage that might render the tank unsafe.
- Inspect the piping, valves, and gaskets for corroded areas, defects in welds, and other conditions, including leakage, that might render the tank unsafe.
- Make sure that all devices for tightening manhole covers are operative. Make sure there is no evidence of leakage at the manhole covers or gaskets.
- Make sure that all emergency devices and valves, including self-closing stop valves, excess flow valves and remote closure devices are free from corrosion, distortion, erosion, and any external damage that will prevent safe operation.
- Operate remote closure devices and self-closing stop valves to demonstrate proper function.
- Replace any missing bolts, nuts, fusible links, or elements. Tighten any loose bolts and nuts.
- Make sure all required tank markings[80] are legible. Markings include the following:
    - Identification Numbers:[81] When required by §172.301, §172.302, §172.313, §172.326, §172.328, §172.330, or §172.331, identification number markings (denoting HM type) must be displayed on orange panels or placards as specified or on white square-on-point configurations as prescribed in §172.226(b).
    - Placard holders that will hold the required lading identification information should be present on both sides and ends of the CT and should be in working order.
    - Quenched and Tempered (QT) and NQT markings: Each MC 330 and MC 331 CT must be marked near the specification plate in letters no less than 50 mm (2 inches) in height, with "QT" if the CT is constructed of quenched and tempered steel or "NQT" if the CT is constructed of anything other than quenched and tempered steel.
    - Emergency Shutoff markings: After October 3, 2005, each on-vehicle manually activated remote shutoff device for closure of the internal self-closing stop valve must be identified by marking "Emergency Shutoff" in letters at least 0.75 inches in height in a color that contrasts with its background located in an area immediately adjacent to the means of closure.
    - Liquefied Petroleum Gas (LPG) markings: CTs for transporting LPG must be legibly marked "Non-Oderized" or "Not Odorized" on two opposing sides near the marked proper shipping name or near the placards.

[80] Those markings required by parts 172, 178 and 180 of CFR 49.

[81] See §172.332 Identification number markings

- Name Plate markings:[82] The corrosion-resistant metal name and specification plates are to be permanently attached to the CT or its integral supporting structure and affixed on the left side of the vehicle near the front of the CT (or the front-most CT of a multi-CTMV). The specification plate may be attached to the CTMV chassis rail by brazing, welding, or other suitable means on the left side near the front head, in a place accessible for inspection. If the specification plate is attached directly to the CT wall by welding, it must be welded to the tank before the CT is postweld heat treated. If the specification plate is attached to the chassis rail, then the CT serial number assigned by the CT manufacturer must be included on the plate. The markings are to be in English and measure at least three-sixteenths of an inch high. The information required for both the name and specification plate may be displayed on a single plate. If the information required below is displayed on a plate required by Section VIII of the ASME Code, the information need not be repeated on the name and specification plates. In addition to any information required by the ASME Code, the following information must be marked on the tank nameplate (parenthetical abbreviations may be used).
    - DOT-specification number DOT XXX (DOT XXX) where "XXX is replaced with the applicable specification number. For CTs having a variable specification plate, the DOT-specification number is replaced with the words "See variable specification plate."
    - Original test date, month, and year (Orig. Test Date).
    - Tank MAWP in psig.
    - CT test pressure (Test P) in psig.
    - CT design temperature range (Design temp. range), ___ °F to ___ °F.
    - Nominal capacity (Water cap.) in gallons.
    - Maximum design density of lading (Max. lading density) in pounds per gallon.
    - Material specification number – shell (Shell matl. yyy***), where "yyy" is replaced by the alloy designation and "***" by the alloy type.
    - Material specification number – heads (Head matl, yyy***), where "yyy" is replaced by the alloy designation and "***" by the alloy type.
    - When the shell and heads materials are the same thickness, they may be combined, (Shell & head matl. yyy***).
    - Weld material (Weld matl.).
    - Minimum thickness – shell (Min. shell-thick) in inches. When the minimum shell thicknesses are not the same for different areas, show (top ___, side ___, bottom ___) in inches.
    - Minimum thickness – heads (Min. heads thick.) in inches.

[82] §178.345-14 Marking

    - Manufactured thickness – shell (Mfd. shell thick.), top ___, side ___, bottom ___, in inches. (Required when additional thickness is provided for corrosion allowance.)
    - Manufactured thickness – heads (Mfd. heads thick) in inches. (Required when additional thickness is provided for corrosion allowance.)
    - Exposed surface area in square feet.
- Specification plate:[83] Each CTMV must have an additional corrosion-resistant metal specification plate attached to it. The specification plate must contain the following information (parenthetical abbreviations may be used):
    - CTMV manufacturer (CTMV mfr.).
    - CTMV certification date (CTMV cert. date), if different from the CT certification date.
    - CT manufacturer (CT mfr.).
    - CT date of manufacturer (CT date of mfr.), month and year.
    - Maximum weight of lading (Max. Payload) in pounds.
    - Maximum loading rate in gallons per minute (Max. Load rate, GPM).
    - Maximum unloading rate in gallons per minute (Max. Unload rate, GPM).
    - Lining material (Lining), if applicable.
    - Heating system design pressure (Heating sys. press.) in psig, if applicable.
    - Heating system design temperature (Heating sys. temp.) in °F, if applicable.
- Test and Inspection Markings:[84] CTs successfully completing the test and inspection requirements must be marked durably and legibly in English with the date (month and year) and the type of test or inspection performed. The date must be readily identifiable with the applicable test or inspection. The markings must be in letters and numbers at least 32 mm (1.25 inches) high near the specification plate or anywhere on the front head. The test or inspection may be abbreviated using the designations V for external visual inspection, I for internal visual inspection, P for pressure test, L for lining inspection, T for thickness test, K for leakage test, and K-EPA 27 for CTs inspected under 180.407(h)(2). For a CTMV composed of multiple CTs constructed to the same specification, which are tested

[83] For multi-CTMVMVs having their CTs not separated by any void, the name and specification plate information may be combined on one specification plate. When separated by a void, each CT must have an individual nameplate unless all CTs are made by the same manufacturer with the same materials, manufactured thickness, and minimum thickness and to the same specification. The CTMV may have a combined nameplate and specification plate. When only one plate is used, the plate must be visible and not covered by insulation. The required information must be listed on the plate from front to rear in the order of the corresponding CT location. For variable specification CTs, each variable specification CT must have a corrosion-resistant metal variable specification plate attached to it. The mounting of this variable specification plate must be such that only the plate identifying the applicable specification under which the tank is being operated is legible.

[84] §180.415

and inspected at the same time, one set of test and inspection markings may be used. For a CTMV composed of multiple CTs constructed to different specifications, which are tested and inspected at different intervals, the test and inspection markings must appear in the order of the CT's corresponding location, from front to rear.

- Inspect major appurtenances and structural attachments on the CT, including but not limited to suspension system, attachments, connecting structures, and those elements of the upper coupler (i.e., fifth wheel) assembly that can be inspected, without dismantling the upper coupler (i.e., fifth wheel), for any corrosion or damage that may prevent safe operation.
- For CTs transporting lading corrosive to the tank, areas covered by the upper coupler (i.e., fifth wheel) assembly must be inspected at least once in each 2-year period for corroded and abraded areas, dents, distortions, defects in the welds, and any other condition that might render the tank unsafe for transportation service. The upper coupler (i.e., fifth wheel) must be removed from the CT for this inspection.
- Inspect all reclosing pressure relief valves for any corrosion or damage that might prevent safe operation. All reclosing pressure relief valves on CTs carrying lading corrosive to the valve must be removed from the CT for inspection and testing.
    - Each reclosing pressure relief valve required to be removed and tested must open at the required set pressure and reseat to a leak-tight conditioner at 90 percent of the set-to-discharge pressure or the pressure prescribed for the applicable CT specification.
- Thickness test at least once every 2 years ring stiffeners or other appurtenances, installed on CTs constructed of mild steel or high-strength low-alloy steel, that create air cavities adjacent to the tank shell that do not allow for external visual inspection.[85] At least four symmetrically distributed readings must be taken to establish an average thickness for the ring stiffener or appurtenance. If any thickness reading is less than the average thickness by more than 10 percent, thickness testing must be conducted from the inside of the CT on the area of the tank covered by the appurtenance or ring stiffener.
- Thickness test any corroded or abraded areas of the CT wall.
- Visually inspect the gaskets on any full or opening rear head for cracks or splits caused by weather or wear.
- Replace any gaskets if cuts or cracks that are likely to cause leakage or are of a depth of one-half inch or more are found.

5.9.2 Internal Visual Inspection

The requirements for internal visual inspections are set forth in 49 CFR 180.407(e). At minimum, the internal visual inspection should include the following:

- Inspect the tank shell and heads for corroded and abraded areas, dents, distortions, defects in welds, and any other condition that might render the tank unsafe.
- Inspect tank liners using the lining test procedures.

[85] See thickness testing section below.

- Thickness test corroded or abraded areas of the CT wall according to thickness test procedures.

When the CT is not equipped with a manhole or inspection opening, or the CT design precludes an internal inspection, the CT must be either hydrostatically or pneumatically tested in accordance with the pressure test procedures. Results of the inspection must be recorded and include any defects discovered and steps taken to remedy the defect.

5.9.3 Lining Inspection

The requirements for lining inspections are set forth in 49 CFR 180.407(f). The integrity of the lining on all lined CTs, when lining is required by this subchapter, must be verified at least once a year. Rubber (elastomeric lining) must be tested for holes. This test requires equipment that consists of:

- A high-frequency spark tester capable of producing sufficient voltage to ensure proper calibration.
- A probe with an L–shaped, 2.4-mm (0.09-inch) diameter wire with up to a 30.5-cm (12-inch) bottom wire leg (end bent to a 12.7-mm [0.5-inch] radius), or equally sensitive probe.
- A steel calibration coupon 30.5 by 30.5 cm (12 by 12 inches) covered with the same material and thickness as that to be tested. The material on the coupon shall have a test hole to the metal substrate made by puncturing the material with a 22-gauge hypodermic needle or comparable piercing tool.

Begin the test by calibrating the probe. The probe must be passed over the surface of the calibration coupon in a constant, uninterrupted manner until the hole is found. The hole is detected by the white light or light blue spark formed. A sound lining causes a dark blue or purple spark. The voltage must be adjusted to the lowest setting that will produce a minimum 12.7-mm (0.5-inch) spark measured from the top of the lining to the probe. To assure that the setting on the probe has not changed, the spark tester must be calibrated periodically using the test calibration coupon and the same power source, probe, and cable length.

After calibration, the probe must be passed over the lining in an uninterrupted stroke. Holes that are found must be repaired using equipment and procedures prescribed by the lining manufacturer or lining installer. Linings made of anything other than rubber (elastometric material) must be tested using equipment and procedures prescribed by the lining manufacturer or lining installer.

Results of the inspection must be recorded and include any defects discovered and steps taken to remedy the defect. Degraded or defective areas of the CT liner must be removed, and the CT wall below the defect must be inspected. Corroded areas of the tank wall must be thickness tested.

Defects in the integrity of corrosion-resistant rubber, polymer, and similar linings are detected by visual examination and by high-frequency spark-testing equipment. Procedures for performing this testing and repair must be written using the lining manufacturer’s instructions. Personnel performing the testing and repair must be trained in the procedures and equipment used. Personnel qualifications must be certified by the employer.

Voids detected during inspection require removal of the lining at the defect and surrounding area and an inspection of the tank shell for corrosion and remaining metal thickness. Welded repairs must be accomplished in accordance with the requirements of the NBIC. The elastomeric lining must then be repaired and re-examined.

Industry Recommendation

- **Be proactive about checking the integrity of the cargo lining.**

Industry Supporting Quote

- *They check the lining and every now and then if the lining is split then they usually have it repaired because once that* [lading] *gets under the lining then it gets trapped in there and just, whew, right through the tank.* (MC 330/MC 331 and Wet Fluorescent Magnetic Particle Testing)

5.9.4 Pressure Test

The requirements for pressure tests are set forth in 49 CFR 180.407(g). All components of the CT wall must be pressure tested. "CT wall" means those parts of the CT that make up the primary lading retention structure, including shell, bulkheads, and fittings and, when closed, yield the minimum volume of the CT assembly.[86] As part of the pressure test, the inspector must perform an external and internal visual inspection, except in the case of an MC 338 CT or a CT not equipped with a manhole or inspection opening for which an internal inspection is not required. All self-closing pressure relief valves, including emergency relief vents and normal vents, must be removed from the CT for inspection and testing.

The pressure test includes the following:

- Open each self-closing pressure relief valve that is an emergency relief vent to the required set pressure and seat it to a leak-tight condition at 90 percent of the set-to-discharge pressure or the pressure prescribed for the applicable CT specification.
- Using the testing criteria established by the valve manufacturer, test the normal vents (1 psig vents).
- Replace all self-closing pressure relief devices not tested or failing the pressure tests.
- Except for CTs carrying lading corrosive to the tank, inspect areas covered by the upper coupler (i.e., fifth wheel) assembly for corroded and abraded areas, dents, distortions, defects in weld, and any other condition that might render the tank unsafe. Note: The upper coupler (i.e., fifth wheel) assembly must be removed from the CT for this inspection.
- Hydrostatically or pneumatically test the CT to the internal pressure specified in table 7. At no time during the pressure test may a CT be subject to pressures that exceed those identified in the following table:

[86] §178.320(a)

Table 7. 49 CFR 180.407(g)(1)(iv) internal test pressures for CT pressure tests.

Specification	Test Pressure
MC 300, 301, 302, 203, 305, 306	20.7 kPa (3 psig) or design pressure, whichever is greater
MC 304, 307	275.8 kPa (40 psig) or 1.5 times the design pressure, whichever is greater
MC 310, 311, 312	20.7 kPa (3 psig) or 1.5 times the design pressure, whichever is greater
MC 330, 331	1.5 times either the MAWP or the re-rated pressure, whichever is applicable
MC 338	1.25 times either the MAWP or the re-rated pressure, whichever is applicable
DOT 406	34.5 kPa (5 psig) or 1.5 times the MAWP, whichever is greater
DOT 407	275.8 kPa (40 psig) or 1.5 times the MAWP, whichever is greater
DOT 412	1.5 times the MAWP

When testing multitank CTs, the tank must be tested with the adjacent CTs empty and at atmospheric pressure.

All closures except pressure-relief devices must be in place during the test. All prescribed loading and unloading venting devices rated at less than test pressure may be removed during the test. If retained, the devices must be rendered inoperative by clamps, plugs, or other equally effective restraining devices. However, restraining devices may not prevent detection of leaks or damage the venting devices and must be removed immediately after the test is completed.

When testing an insulated CT, the insulation and jacketing does not need to be removed unless it is otherwise impossible to reach test pressure and maintain a condition of pressure equilibrium after test pressure is reached or the vacuum integrity cannot be maintained in the insulation space.

If an MC 338 CT used for the transportation of a flammable gas, oxygen, or refrigerated liquid is opened for any reason, the cleanliness must be verified prior to closure using the procedures contained in §178.338-15.[87]

All pressure-bearing portions of a CT heating system employing a medium such as, but not limited to, steam or hot water for heating the lading must be hydrostatically pressure tested at

[87] §178.338-15 Cleanliness. A cargo tank constructed for oxygen service must be thoroughly cleaned to remove all foreign material in accordance with CGA G-4.1. All loose particles from fabrication, such as weld beads, dirt, grinding wheel debris, and other loose materials, must be removed prior to the final closure of the manhole of the tank. Chemical or solvent cleaning with a material compatible with the intending lading must be performed to remove any contaminants likely to react with the lading.

least once every 5 years. The test pressure must be at least the maximum system design operating pressure and must be maintained for 5 minutes. A heating system employing flues for heating the lading must be tested to ensure against lading leakage into the flues or into the atmosphere. Exceptions are as follows:

- Pressure testing is not required for MC 330 and MC 331 CTs in dedicated sodium metal service.
- Pressure testing is not required for uninsulated lined CTs with a design pressure or MAWP of 15 psig or less, which receive an external visual inspection and a lining inspection at least once a year.

A CT that leaks, fails to retain test pressure or pneumatic inspection pressure, or shows distortion, excessive permanent expansion, or other evidence of weakness that might render the CT unsafe for transportation service may not be returned to service except as follows:

- A CT with a heating system that does not hold pressure may remain in service as an unheated CT if both:
  - The heating system remains in place and is structurally sound and no lading may leak into the heating system.
  - The specification plate heating system information is changed to indicate that the CT has no working heating system.

Results of the inspection must be recorded and include any defects discovered and steps taken to remedy the defect.

5.9.4.1 Hydrostatic Test Method

The NTTC Users Manual (2004) offers helpful insight as to the pros and cons of both the hydrostatic and pneumatic test method. NTTC notes that the primary benefit of hydrostatic testing is that if a failure in the vessel or fittings occurs during the test, a very small loss of fluid returns the pressure to atmospheric pressure almost instantaneously, and the failure will not propagate. However, water is heavy and requires that a tank be adequately supported throughout the test process.[88] Additionally, EPA requirements[89] as well as any applicable local ordinances must be complied with when water is disposed. Pneumatic testing does not require the tank to be filled with water, and the pressure can be applied more quickly than hydrostatic testing.[90]

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[88] National Tank Truck Carriers (2004). *Users Manual:2004* (3rd ed.). Arlington, VA: Author.

[89] The EPA holds the right to enforce the Clean Water Act, which was passed in 1972. The Clean Water Act set the standard for eliminating sewage and industrial waste into groundwater supplies. State EPA offices (which can be located using the EPA Web site: http://www.epa.gov/lawsregs/where/index.html) should be referenced for information on treating and conducting wastewater disposal before it enters the public water system or is absorbed into groundwater supplies. Local, State, and Federal agencies monitor the conditions of wastewater to endure the public's safety. Most level large fines to violators of clean water standards. It is good business practice to have a wastewater disposal recovery plan in place and to adhere to any and all applicable regulations for the disposal of wastewater.

[90] National Tank Truck Carriers (2004). *Users Manual:2004* (3rd ed.). Arlington, VA: Author.

However, if a failure occurs during pneumatic testing, it takes a longer time for the pressure to dissipate through the failure, allowing the failure to propagate very quickly and perhaps catastrophically. Additionally, NTTC notes that a failure during pneumatic testing, in addition to damaging the vessel, can be dangerous to personnel who may be close to the failure while inspecting the vessel. The benefits of hydrostatic testing and added safety this method provides should be considered when test pressures are above 5 psi and the vessel is new, has had extensive weld repairs, or has not been subjected to pressure for a long period of time.[91]

The regulatory procedure for conducting a hydrostatic pressure test is as follows:

- Fill the CT, including tank domes, with water or other liquid having similar viscosity, at a temperature not exceeding 100°F.
- Pressurize the CT to not less than the pressure specified. See table 2 of 49 CFR 180.407(g)(1)(iv), Internal Test Pressures for Cargo Tank Pressure Tests.
- The CT, including its closures, must hold the prescribed test pressure for at least 10 minutes.
- While the tank is holding the test pressure, inspect the tank for leaks, bulging, or any other defects.

Results of the inspection must be recorded and include any defects discovered and steps taken to remedy the defect.

5.9.4.2 Pneumatic Test Method

Pneumatic testing ***may involve higher risk*** *than hydrostatic testing. Therefore, suitable safeguards must be provided to protect personnel and facilities should failure occur during the test.*

1. Pressurize the CT using air or an inert gas. The pneumatic test pressure in the CT must be reached by gradually increasing the pressure to one-half the test pressure. Thereafter, the pressure must be increased in steps of approximately one-tenth of the test pressure until the required test pressure has been reached.
2. Hold the pressure for at least 5 minutes.
3. After 5 minutes, reduce the pressure to the MAWP, which must be maintained during the time the entire CT surface is inspected.
4. Inspect the tank for leaks using a suitable method for the detection of leaks. A suitable method consists of coating the entire surface of all joints under pressure with a solution of soap and water or other equally sensitive methods.

Results of the inspection must be recorded and include any defects discovered and steps taken to remedy the defect.

5.9.5 Wet Fluorescent Magnetic Particle Test (WFMPT)

Each MC 330 and MC 331 CT constructed of quenched and tempered (QT) steel in accordance with Part UHT in Section VIII of the ASME Code, or constructed of other than quenched and

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[91] National Tank Truck Carriers (2004). *Users Manual:2004* (3rd ed.). Arlington, VA: Author.

tempered steel but without post-weld heat treatment, used for the transportation of anhydrous ammonia or any other hazardous material that may cause corrosion stress cracking, must be internally inspected by the wet fluorescent magnetic particle (WFMPT) method immediately prior to and in conjunction with the performance of the pressure test. Each MC 330 and MC 331 CT constructed of QT steel in accordance with Part UHT in Section VIII of the ASME Code and used for the transportation of liquid petroleum gas must be internally inspected by the WFMPT method immediately prior to and in conjunction with the performance of the pressure test. The wet fluorescent particle inspection must be in accordance with Section V of the ASME Code and CGA Technical Bulletin P-26.[92] This paragraph does not apply to CTs that do not have manholes.

5.9.6 Leakage Test

The requirements for leakage tests are set forth in 49 CFR 180.407(h). When completing a leak test, suitable safeguards must be provided to protect personnel should a failure occur. Results of the inspection must be recorded and include any defects discovered and steps taken to remedy the defect.

The leakage tests include testing product in piping with all valves and accessories in place and operative, except that any venting devices set to discharge at less than the leakage test pressure must be removed or rendered inoperative during the test. CTs may be tested with HM contained in the CT during the test. CTs that fail to retain test pressure may not be returned to service as a specification CT until all sources of leakage are properly repaired.

For MC 330 and MC 331 tanks and non-specification CTs authorized under 173.315(k), visually inspect the delivery hose and piping system while the assembly is under leakage test pressure.[93] Delivery hose assemblies not permanently attached to the CTMV may be inspected separately. In addition to a written report of the inspection, the RI conducting the test must note the hose identification number, the date of the test, and the condition of the hose assembly and piping system tested.

Leakage test pressure must be no less than 80 percent of the MAWP marked on the specification plate except as follows:

- A CT with a MAWP of 690 kPa (100 psig) or more may be leakage tested at its maximum normal operating pressure provided it is in dedicated service.
- An MC 330 or MC 331 CT in dedicated liquefied petroleum gas service may be leakage tested at not less than 414 kPA (60 psig).
- An operator of a specification MC 330 or MC 331 CT authorized under §173.315(k)[94] of this subchapter equipped with a meter may check leak tightness of the internal self-closing stop valve by conducting a meter creep test (see appendix B to this part).

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[92] CGA Technical Bulletin P-26 supersedes the procedures formerly found in CGA Technical Bulletin TB-2: Guidelines for Inspection and Repair of MC 330-331 Cargo Tanks.

[93] See Discharge System Inspection and Maintenance Program for Cargo Tanks Transporting Liquefied Compressed Gasses section for additional information regarding rejection criteria.

[94] §173.315(k). A nonspecification cargo tank meeting, and marked in conformance with, the edition of Section VIII of the ASME Code in effect when it was fabricated may be used for the transportation of liquefied petroleum gas provided it meets all of the following conditions: (1) It must have a minimum design pressure no lower than

- An MC 330 or MC 331 CT in dedicated service for anhydrous ammonia may be leakage tested at not less than 414 kPa (60 psig).
- A non-specification CT required by 49 CFR 173.8(d)[95] of this subchapter to be leakage tested must be leakage tested at not less than 16.6 kPa (2.4 psig) or as specified in paragraph (h)(2).[96]
- CTs used to transport petroleum distillate fuels that are equipped with vapor collection equipment may be leak tested in accordance with the EPA's "Method 27 – Determination of Vapor Tightness of Gasoline Delivery Tank Using Pressure Vacuum Test," as set forth in Appendix A to 40 CFR part 60. Test methods and maximum allowable pressure and vacuum changes are in 40 CFR 63.425(e)(1). The hydrostatic test alternative, using liquid in Environmental Protection Agency's "Method 27 – Determination of Vapor Tightness of Gasoline Delivery Tank Using Pressure Vacuum Test," may not be used to satisfy the leak testing requirements of this paragraph. The test must be conducted using air.

During the test:

- Test all internal or external self-closing stop valves for leak tightness.
- Test each CT of a multi-CTMV with the adjacent CTs empty and at atmospheric pressure.

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250 psig. (2) It must have a capacity of 13,247.5 L (3,500 water gallons) or less. (3) It must have been manufactured in conformance with Section VIII of the ASME Code prior to January 1, 1981, according to its ASME name plate and manufacturer's data report. (4) It must conform to the applicable provisions of NFPA 58, except to the extent that provisions in NFPA 59 are inconsistent with the requirements in parts 178 and 180 of this subchapter. (5) It must be inspected, tested, and equipped in accordance with subpart E of part 180 of this subchapter as specified for MC 331 cargo tank motor vehicles. (6) Except as provided in this paragraph (k), it must be operated exclusively in intrastate commerce, including its operation by a motor carrier otherwise engaged in interstate commerce, in a state where its operation was permitted by law (not including the incorporation of this subchapter) prior to January 1, 1981. A cargo tank motor vehicle operating under authority of this section may cross state lines to travel to and from a qualified assembly, repair, maintenance, or requalification facility. The cargo tank need not be cleaned and purged, but it may not contain liquefied petroleum gas in excess of 5percent of the water capacity of the cargo tank. If the vehicle engine is supplied fuel from the cargo tank, enough fuel in excess of 5percent of the cargo tank's water capacity may be carried for the trip to or from the facility. (7) It must have been used to transport liquefied petroleum gas prior to January 1, 1981. (8) It must be operated in conformance with all other requirements of this subchapter.

[95] §173.8(d) Additional requirements. A packaging used under the provisions of paragraphs (a), (b) or (c) of this section must- (1) Be operated by an intrastate motor carrier and in use as a packaging for hazardous material before October 1, 1998; (2) Be operated in conformance with the requirements of the State in which it is authorized; (3) Be specifically authorized by a State statute or regulation in effect before October 1, 1998, for use as a packaging for the hazardous material being transported; (4) Be offered for transportation and transported in conformance with all other applicable requirements of this subchapter; (5) Not be used to transport a flammable cryogenic liquid, hazardous substance, hazardous waste, or a marine pollutant (except for gasoline); and (6) On and after July 1, 2000, for a tank authorized under paragraph (b) or (c) of this section, conform to all requirements in part 180 (except for §180.405(g)) of this subchapter in the same manner as required for a DOT specification MC 306 cargo tank motor vehicle.

[96] This requirement applies to tanks tested using the EPA's Method 27 – Determination of Vapor Tightness of Gasoline Delivery Tank Using Pressure Vacuum Test.

- Maintain the test pressure for at least 5 minutes.
- Inspect CTs in liquefied compressed gas service externally for leaks.
- If applicable, visually inspect the delivery hose and piping system.

Results of the inspection must be recorded and include any defects discovered and steps taken to remedy the defect.

5.9.7 Environmental Protection Agency's Method 27 – Determination of Vapor Tightness of Gasoline Delivery Tank Using Pressure Vacuum Test

Appendix A to 40 CFR 60 sets forth the requirements for the EPA's Method 27. This method is applicable for the determination of vapor tightness of gasoline delivery collection equipment (e.g., MC 306 and DOT 406 CTs). During a Method 27 test, pressure and vacuum are applied alternatively to the compartments of a gasoline delivery tank. The change in pressure or vacuum is recorded after a specified period of time. The following definitions apply to for this test.

- ***Allowable pressure change*** (Ap) means the allowable amount of decrease in pressure during the static pressure test, within the time period t, as specified in the appropriate regulation, in mm H_2O.
- ***Allowable vacuum change*** (Av) means the allowable amount of decrease in vacuum during the static vacuum test, within the time period *t*, as specified in the appropriate regulation, in mm H_2O.
- ***Compartment*** means a liquid-tight division of a delivery tank.
- ***Delivery tank*** means a container, including associated pipes and fittings that are attached to or form a part of any truck, trailer, or railcar used for the transport of gasoline.
- ***Delivery tank vapor collection equipment*** means any piping, hoses, and devices on the delivery tank used to collect and route gasoline vapors either from the tank to a bulk terminal vapor control system or from a bulk plant or service station into the tank.
- ***Gasoline*** means a petroleum distillate or petroleum distillate/alcohol blend having a Reid vapor pressure of 27.6 kilopascals or greater which is used as a fuel for internal combustion engines.
- ***Initial pressure*** (P_i) means the pressure applied to the delivery tank at the beginning of the static pressure test, as specified in the appropriate regulation, in mm H_2O.
- ***Initial vacuum*** (V_i) means the vacuum applied to the delivery tank at the beginning of the static vacuum test, as specified in the appropriate regulation, in mm H_2O.
- ***Time period of the pressure or vacuum test*** (t) means the time period of the test, as specified in the appropriate regulation, during which the change in pressure or vacuum is monitored, in minutes.

Results of the inspection must be recorded and include any defects discovered and steps taken to remedy the defect.

5.9.7.1 Method 27 Safety Precautions

Gasoline contains several volatile organic compounds (e.g., benzene and hexane) that present a potential for fire and/or explosions. It is advisable to take appropriate precautions when testing a gasoline vessel's vapor tightness, such as using explosion-proof equipment and refraining from smoking.

This method may involve hazardous materials, operations, and equipment. This test method may not address all of the safety problems associated with its use. It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to performing this test method.

5.9.7.2 Method 27 Equipment and Supplies

The following equipment and supplies are required for testing:

- Pressure source – a pump or compressed gas cylinder of air or inert gas sufficient to pressurize the delivery tank to 500 mm (20 inches) H_2O above atmospheric pressure.
- Regulator – a low-pressure regulator for controlling pressurization of the delivery tank.
- Vacuum source – a vacuum pump capable of evacuating the delivery tank to 250 mm (10 inches) H_2O below atmospheric pressure.
- Pressure-vacuum supply hose.
- Manometer – a liquid manometer, or equivalent instrument, capable of measuring up to 500 mm (20 inches) H_2O gauge pressure with ±2.5-mm (0.1-inch) H_2O precision.
- Pressure-Vacuum Relief Valves – the test apparatus shall be equipped with an inline pressure-vacuum relief valve set to activate at 675 mm (26.6 inches) H_2O above atmospheric pressure or 250 mm (10 inches) H_2O below atmospheric pressure, with a capacity equal to the pressurizing or evacuating pumps.
- Test Cap for Vapor Recovery Hose – this cap shall have a tap for manometer connection and a fitting with shut-off valve for connection to the pressure-vacuum supply hose.
- Caps for Liquid Delivery Hoses.

Testing problems may occur due to the presence of volatile vapors and/or temperature fluctuations inside the delivery tank. Under these conditions, it is often difficult to obtain a stable initial pressure at the beginning of a test, and erroneous test results may occur. To help prevent this, it is recommended that prior to testing, volatile vapors be removed from the tank and the temperature inside the tank be allowed to stabilize. Because it is not always possible to completely attain these pretest conditions, a provision to ensure reproducible results is included. The difference in results for two consecutive runs must meet the testing criteria.

5.9.7.3 Method 27 Preparation Procedures

The CT must be prepared for the test. The pretest preparations include the following:

- Emptying of Tank. The delivery tank shall be emptied of all liquid.
- Purging of Vapor. As much as possible the delivery tank shall be purged of all volatile vapors by any safe, acceptable method. One method is to carry a load of nonvolatile liquid fuel, such as diesel or heating oil, immediately prior to the test, thus flushing out all the volatile gasoline vapors. A second method is to remove the volatile vapors by blowing ambient air into each tank compartment for at least 20 min. **This second method is usually not as effective and often causes stabilization problems, requiring a much longer time for stabilization during the testing.**
- Temperature Stabilization. As much as possible, the test shall be conducted under isothermal conditions. The temperature of the delivery tank should be allowed to

equilibrate in the test environment. During the test, the tank should be protected from extreme environmental and temperature variability, such as direct sunlight.

In order to prepare for the test, complete the following steps:

1. Open and close each dome cover.
2. Connect static electrical ground connections to the tank. Attach the liquid delivery and vapor return hoses, remove the liquid delivery elbows, and plug the liquid delivery fittings. Note: The purpose of testing the liquid delivery hoses is to detect tears or holes that would allow liquid leakage during a delivery. Liquid delivery hoses are not considered to be possible sources of vapor leakage and thus do not have to be attached for a vapor leakage test. Instead, a liquid delivery hose could be either visually inspected or filled with water to detect any liquid leakage.
3. Attach the test cap to the end of the vapor recovery hose.
4. Connect the pressure-vacuum supply hose and the pressure-vacuum relief valve to the shut-off valve. Attach a manometer to the pressure tap.
5. Connect compartments of the tank internally to each other if possible. If not possible, each compartment must be tested separately, as if it were an individual delivery tank.

The annual certification test for gasoline CTs shall consists of a pressure test and a vacuum test, which are discussed below. Conduct the tests using a time period (t) of 5 minutes for the pressure and vacuum test. The initial pressure (P_i) for the pressure test shall be 460 mm (18 inches) H_2O gauge. The maximum allowable pressure and vacuum changes (Δp, Δv) are as shown in the table 8.[97]

Table 8. §63.425 Table 2 - allowable CT test pressure or vacuum change.

CT or compartment capacity, liters (gallons)	Annual certification-allowable pressure or vacuum change (Δp, Δv) in 5 minutes, mm H_2O (inches H_2O)	Allowable pressure change (Δp) in 5 minutes at any time, mm H_2O (inches H_2O)
9,464 or more (2,500 or more)	25 (1.0)	64 (2.5)
9,463 to 5,678 (2,499 to 1,500)	38 (1.5)	76 (3.0)
5,679 to 3,785 (1,499 to 1,000)	51 (2.0)	89 (3.5)
3,782 or less (999 or less)	64 (2.5)	102 (4.0)

Pressure test the CT's internal vapor valve as follows: After completing the tests in step 1 above, use the procedures in Method 27 to re-pressurize the tank to 460 mm (18 inches) H_2O gauge. Close the tank's internal vapor valve(s), thereby isolating the vapor return line and manifold from the tank. Relieve the pressure in the vapor return line to atmospheric pressure, and then reseal the line. After 5 minutes, record the gauge pressure in the vapor return line and manifold. The maximum allowable 5-minute pressure increase is 130 mm (5 inches) H_2O.[98]

[97] See 40 CFR 63.425(e).

[98] See 40 CFR 63.425(e)

5.9.7.4 Method 27 Pressure Test

1. Connect the pressure source to the pressure-vacuum supply hose.
2. Open the shutoff valve in the vapor recovery hose cap. Apply air pressure slowly; pressurize the tank to P_i, the initial pressure specified in the regulation.
3. Close the shut-off and allow the pressure in the tank to stabilize, adjusting the pressure if necessary to maintain pressure of P_i. When the pressure stabilizes, record the time and initial pressure.
4. At the end of the time period (t) specified in the regulation, record the time and final pressure.
5. Repeat the steps above until the change in pressure for two consecutive runs agrees within 12.5 mm (0.5 inches) H_2O. Calculate the arithmetic average of the two results.
6. Compare the average measured change in pressure to the allowable pressure change (Ap) specified in the regulation. If the delivery tank does not satisfy the vapor tightness criterion specified in the regulation, repair the sources of leakage and repeat the pressure test until the criterion is met.
7. Disconnect the pressure source from the pressure-vacuum supply hose, and slowly open the shut-off valve to bring the tank to atmospheric pressure.

5.9.7.5 Method 27 Vacuum Test

1. Connect the vacuum source to the pressure-vacuum supply hose.
2. Open the shut-off valve in the vapor recovery hose cap. Slowly evacuate the tank to V_i, the initial vacuum specified in the regulation.
3. Close the shut-off valve and allow the pressure in the tank to stabilize, adjusting the pressure if necessary to maintain a vacuum of V_i. When the pressure stabilizes, record the time and initial vacuum.
4. At the end of the time period specified in the regulation (t), record the time and final vacuum.
5. Repeat the steps above until the change in vacuum for two consecutive runs agree within 12.5 mm (0.5 inches) H_2O. Calculate the arithmetic average of the two results.
6. Compare the average measured change in vacuum to the allowable vacuum change (Av) as specified in the regulation. If the delivery tank does not satisfy the vapor tightness criterion specified in the regulation, repair the sources of leakage and repeat the vacuum test until the criterion is met.
7. Disconnect the vacuum source from the pressure-vacuum supply hose, and slowly open the shut-off valve to bring the tank to atmospheric pressure.

After the tests, disconnect all test equipment and return the delivery tank to its pretest condition. The vapor tightness of a gasoline delivery tank under positive or negative pressure, as measured by this method, is precise within 12.5 mm (0.5 inches) H_2O. No bias has been identified.

5.9.8 Thickness Testing

The requirements for thickness tests are set forth in 49 CFR 180.407(i). Additional requirements are found in §178.320(a), §178.345-2, §178.346-2, §178.347-2, and §178.348-2. The shell and head thickness of all unlined CTs used for the transport of materials corrosive to the tank must be measured at least once every 2 years, except CTs measuring less than the sum of the minimum prescribed thickness plus one-fifth of the original corrosion allowance, which must test annually.

Measurements must be made using a device capable of accurately measuring thickness to within ± 0.002 inches (0.0508 mm). Any person performing thickness testing must be trained in the proper use of the thickness testing device used in accordance with the manufacturer's instruction. A Design Certifying Engineer (DCE) must certify that the CT design and thickness are appropriate for the reduced loading conditions by issuance of a revised manufacturer's certificate, and the CTMV's nameplate must reflect the revised service limits. An owner of a CT that no longer conforms to the minimum thickness prescribed for the specification may not return the CT to HM service. The tank's specification plate must be removed, obliterated, or covered in a secure manner.

Thickness testing must be performed in the following areas of the CT wall, as a minimum:

- Areas of the tank shell and heads, and shell and head area around any piping that retains lading.
- Areas of high shell stress such as the bottom center of the tank.
- Areas near openings.
- Areas around joint welds.
- Areas around shell reinforcements.
- Areas around appurtenance attachments.
- Areas near suspension system attachments and connecting structures.
- Known thin areas in the tank shell and nominal liquid level lines.
- Connecting structures joining multiple CTs of carbon steel in a self-supporting CTMV.

Minimum thicknesses for MC 300, MC 302, MC 303, MC 304, MC 305, MC 306, MC 307, MC 310, MC 311, and MC 312 CTs are determined based on the definition of minimum thickness found in 49 CFR 178.320(a), which states that minimum thickness means the minimum required shell and head (and baffle and bulkhead when used as a tank reinforcement) thickness needed to meet the specification. The minimum thickness is the *greatest* of the following values:

1. For MC 330, MC 331 and MC 338 CTs, the specified minimum thickness found in the applicable specification(s).
2. The thickness necessary to meet with structural integrity and accident damage requirements of the applicable specification(s).
3. The thickness as computed per the ASME Code requirements (if applicable).

For MC 331 CTs constructed before October 1, 2003, minimum thickness shall be determined by the thickness indicated on the UIA forms minus any corrosion allowance. For MC 331 CTs constructed after October 1, 2003, the minimum thickness will be the value indicated on the specification plate. If no corrosion allowance is indicated on the UIA form, then the thickness of the tank shall be the thickness of the material of construction indicated on the UIA form with no corrosion allowance. In-Service minimum thickness for MC 300, MC 301, MC 302, MC 303, MC 304, MC 305, MC 306, MC 307, MC 310, MC 311, and MC 312 CTs is based on 90 percent of the manufactured thickness specified in the DOT specification, rounded to three places. Minimum thickness values for DOT 400 series CTs can be found in Tables I and II of §178.346-

2, §178.347-2, and §178.348-2. Thickness tables (table 9 through table 16) have been included below for reference.

Table 9. Table I – In-Service minimum thickness for MC 300, MC 303, MC 304, MC 306, MC 307, MC 310, MC 311, and MC 312 specification CTs constructed of steel and steel alloys.

Minimum Manufactured Thickness (U.S. gauge or inches)	Nominal Decimal Equivalent (inches)	In-service Minimum Thickness Reference (inches)
19	0.0418	0.038
18	0.0478	0.043
17	0.0538	0.048
16	0.0598	0.054
15	0.0673	0.061
14	0.0747	0.067
13	0.0897	0.081
12	0.1046	0.094
11	0.1196	0.108
10	0.1345	0.121
9	0.1495	0.135
8	0.1644	0.148
7	0.1793	0.161
$^{3}/_{16}$	0.1875	0.169
$^{1}/_{4}$	0.2500	0.225
$^{5}/_{16}$	0.3125	0.281
$^{3}/_{8}$	0.3750	0.338

Table 10. Table II – In-Service minimum thickness for MC 301, MC 302, MC 304, MC 305, MC 306, MC 307, MC 311, and MC 312 specification CTs constructed of aluminum and aluminum alloys.

Minimum Manufactured Thickness	In-service Minimum Thickness Reference (inches)
0.078	0.070
0.087	0.078
0.096	0.086
0.109	0.098
0.130	0.117
0.141	0.127
0.151	0.136
0.172	0.155
0.173	0.156
0.194	0.175
0.216	0.194
0.237	0.213
0.270	0.243
0.360	0.324
0.450	0.405
0.540	0.486

Table 11. §178.346-2. Specified minimum thickness of heads (or bulkheads and baffles when used as tank reinforcement) using mild steel (MS), high-strength low-alloy steel (HSLA), austenitic stainless steel (SS) or aluminum (AL) – expressed in decimals of an inch after forming for material volume capacity in gallons per inch of length

Volume capacity in gallons per inch of length	14 or Less	14 or Less	14 or Less	Over 14 to 23	Over 14 to 23	Over 14 to 23	Over 23	Over 23	Over 23
Material	MS	HSLA SS	AL	MS	HSLA SS	AL	MS	HSLA SS	AL
Thickness	.100	.100	.160	.115	.115	.173	.129	.129	.187

Table 12. §178.346-2. Specified minimum thickness of shell using mild steel, high-strength low-alloy steel, austenitic stainless steel, or aluminum – expressed in decimals of an inch after forming.[99]

CTMV Rated Capacity (Gallons)	Mild Steel	High-strength Low-alloy Steel or Austenitic Stainless Steel	Aluminum
More than 0 to at least 4,500	0.100	0.100	0.151
More than 4,500 to at least 8,000	0.115	0.100	0.160
More than 8,000 to at least 14,000	0.129	0.129	0.173
More than 14,000	0.143	0.143	0.187

Table 13. §178.347-2, Table I – Specified minimum thickness of heads (or bulkheads and baffles when used as tank reinforcement) using mild steel, high-strength low-alloy steel, austenitic stainless steel or aluminum – expressed in decimals of an inch after forming.

Volume capacity in gallons per inch	10 or less	Over 10 to 14	Over 14 to 18	Over 18 to 22	Over 22 to 26	Over 26 to 30	Over 30
Thickness – Mild Steel	0.100	0.100	0.115	0.129	0.129	0.143	0.156
Thickness – High-strength Low-alloy Steel	0.100	0.100	0.115	0.129	0.129	0.143	0.156
Thickness – Austenitic Stainless Steel	0.100	0.100	0.115	0.129	0.129	0.143	0.156
Thickness – Aluminum	0.160	0.160	0.173	0.187	0.194	0.216	0.237

Table 14. §178.347-2. Table II – Specified minimum thickness of shell using mild steel, high-strength low-alloy steel, austenitic stainless steel or aluminum – expressed in decimals of an inch after forming.

Volume capacity in gallons per inch	10 or less	Over 10 to 14	Over 14 to 18	Over 18 to 22	Over 22 to 26	Over 26 to 30	Over 30
Thickness – Mild Steel	0.100	0.100	0.115	0.129	0.129	0.143	0.156
Thickness – High-strength Low-alloy Steel	0.100	0.100	0.115	0.129	0.129	0.143	0.156
Thickness – Austenitic Stainless Steel	0.100	0.100	0.115	0.129	0.129	0.143	0.156
Thickness – Aluminum	0.151	0.151	0.160	0.173	0.194	0.216	0.237

[99] Maximum distance between bulkheads, baffles, or ring stiffeners shall not exceed 60 inches.

Table 15. §178.348-2, Table 1 – Specified minimum thickness of heads (or bulkheads and baffles when used as tank reinforcement) using mild steel, high-strength low-alloy steel, austenitic stainless steel, or aluminum – expressed in decimals of an inch after forming for volume capacity

Volume capacity (gallons per inch)	10 or less	10 or less	10 or less	10 or less	Over 10 to 14	Over 10 to 14	Over 10 to 14	Over 10 to 14	Over 14 to 18	Over 14 to 18	Over 14 to 18	18 and Over	18 and Over	18 and Over
Lading density at 60 °F in pounds per gallon	10 lbs and less	Over 10 to 13 lbs	Over 13 to 16 lbs	Over 16 lbs	10 lbs and less	Over 10 to 13 lbs	Over 13 to 16 lbs	Over 16 lbs	10 lbs and less	Over 10 to 13 lbs	Over 13 to 16 lbs	10 lbs and less	Over 10 to 13 lbs	Over 13 to 16 lbs
Thickness (inch), steel	0.100	0.129	0.157	0.187	0.129	0.157	0.187	0.250	0.157	0.250	0.250	0.157	0.250	0.312
Thickness (inch), aluminum	0.144	0.187	0.227	0.270	0.187	0.227	0.270	0.360	0.227	0.360	0.360	0.227	0.360	0.450

Table 16. §178.348-2, Table II – Specified minimum thickness of shell using mild steel, high strength low alloy steel, austenitic stainless steel, or aluminum – expressed in decimals of an inch after forming

Volume capacity in gallons per inch	10 or less	10 or less	10 or less	10 or less	Over 10 to 14	Over 10 to 14	Over 10 to 14	Over 10 to 14	Over 14 to 18	Over 14 to 18	Over 14 to 18	18 and Over	18 and Over	18 and Over
Lading density at 60 °F in pounds per gallon	10 lbs and less	Over 10 to 13 lbs	Over 13 to 16 lbs	Over 16 lbs	10 lbs and less	Over 10 to 13 lbs	Over 13 to 16 lbs	Over 16 lbs	10 lbs and less	Over 10 to 13 lbs	Over 13 to 16 lbs	10 lbs and less	Over 10 to 13 lbs	Over 13 to 16 lbs
Thickness (steel):														
Distances between heads (and bulkheads baffles and ring stiffeners when used as tank reinforcement):														
36 inches or less	0.100	0.129	0.157	0.187	0.100	0.129	0.157	0.187	0.100	0.129	0.157	0.129	0.157	0.187
Over 36 to 54 inches	0.100	0.129	0.157	0.187	0.100	0.129	0.157	0.187	0.129	0.157	0.187	0.157	0.250	0.250
Over 54 to 60 inches	0.100	0.129	0.157	0.187	0.129	0.157	0.187	0.250	0.157	0.250	0.250	0.187	0.250	0.312
Thickness (aluminum):														
Distances between heads (and bulkheads baffles and ring stiffeners when used as tank reinforcement):														
36 inches or less	0.144	0.187	0.227	0.270	0.144	0.187	0.227	0.270	0.144	0.187	0.227	0.187	0.227	0.270
Over 36 to 54 inches	0.144	0.187	0.227	0.270	0.144	0.187	0.227	0.270	0.187	0.227	0.270	0.157	0.360	0.360
Over 54 to 60 inches	0.144	0.187	0.227	0.270	0.187	0.227	0.270	0.360	0.227	0.360	0.360	0.270	0.360	0.450

5.10 DISCHARGE SYSTEM INSPECTION AND MAINTENANCE PROGRAM FOR CARGO TANKS TRANSPORTING LIQUEFIED COMPRESSED GASES

§180.416 is applicable to an operator using specification MC 330, MC 331, and nonspecification CTs authorized under §173.315(k) for the transportation of liquefied compressed gases other than carbon dioxide. Paragraphs (b), (c), (d)(1), (d)(5), (e), (f) and (g)(1)[100] apply only to hose assemblies installed or carried on the CT.

5.10.1 Hose Identification

The operator must assure that each delivery hose assembly is permanently marked with a unique identification number and maximum working pressure. After each unloading the operator must visually check that portion of the delivery hose assembly deployed during the unloading. Operators must also note each inspection in a record. That record must include:

- The inspection date.
- The name of person performing the inspection.
- The hose assembly identification number.
- The company name.
- The date the hose was assembled and tested.
- An indication that the delivery hose assembly and piping system passed or failed the tests and inspections.

A copy of each test and inspection record must be retained by the operator at its principal place of business or where the vehicle is housed or maintained until the next test of the same type is successfully completed.

5.10.2 Monthly Inspections and Tests

Each delivery hose assembly and piping system must be visually inspected at least once each month the delivery hose assembly is in service. The piping system inspection must include fusible elements and all other components of the piping system, including bolts, connections, and seals. Additionally, the emergency discharge control devices designed to close the internal self-closing stop valve must be actuated at least once each calendar month a CT is in service. This is done to assure that all linkages operate as designed. Section 5.11 of this chapter outlines acceptable procedures that may be used to test the emergency discharge control devices. The internal self-closing stop valve in the liquid discharge opening must also be checked for leakage through the valve at least once each month the CT is in service. On CTs equipped with a meter, the meter creep test as outlined in section 5.12 of this chapter or a test providing equivalent accuracy is acceptable. For CTs that are not equipped with a meter, section 5.11 of this chapter outlines one acceptable method that may be used to check internal self-closing stop valves for closure.

[100] Denoted by the asterisk (*) in the discussion below.

5.10.3 Annual Inspections and Tests

Each year, the owner of a delivery hose assembly that is not permanently attached must ensure that the hose assembly is tested in accordance with 180.407(h)(4).[101] For new or repaired delivery hose assemblies, the assembly is to be tested at a minimum of 120 percent of the maximum working pressure. While under pressure, the hose must be visually examined. Upon successful completion of the pressure test and inspection, the hose assembly is to be permanently marked with the month and year of the test. Additionally, a record documenting the test and inspection needs to be prepared by the registered inspector and retained at the principal place of business or where the vehicle is housed or maintained until the next test of the same type is successfully completed. The record must include:

- The date.
- The signature of the inspector.
- The hose owner.
- The hose identification number.
- The date of original delivery hose assembly and test.
- Notes of any defects observed and repairs made.
- An indication that the delivery hose assembly passed or failed the tests and inspections.

Delivery hose assemblies should be rejected and may not be used for unloading liquefied compressed gases if any condition identified below is found. An operator is permitted to remove and replace damaged sections or correct discovered defects. In cases of repairs, hose assemblies may be placed back in service if retested successfully in accordance with the requirements for new and repaired delivery hose assemblies. Defects include:

- Damage to the hose cover that exposes reinforcement.
- Wire braid reinforcement that has been kinked or flattened so as to permanently deform the wire braid.
- Soft spots when not under pressure, bulging under pressure, or loose outer covering.
- Damaged, slipping, or excessively worn hose couplings.
- Loose or missing bolts or fastenings on bolted hose coupling assemblies.

Similarly, no operator may use a CT with a piping system found to have any condition identified below for unloading liquefied compressed gases. Piping system defects include:

- Any external leak identifiable without the use of instruments.
- Bolts that are loose, missing, or severely corroded.
- Manual stop valves that will not actuate.
- Rubber hose flexible connectors with any condition outlined in the above section discussing hoses.
- Stainless steel flexible connectors with damaged reinforcement braid.
- Internal self-closing stop valves that fail to close or that permit leakage through the valve detectable without the use of instruments.
- Pipes or joints that are severely corroded.

[101] See Leakage Test above.

5.11 INTERNAL SELF-CLOSING STOP VALVE EMERGENCY CLOSURE TEST FOR LIQUEFIED COMPRESSED GASES

Appendix A to 49 CFR 180 presents the guidelines for the internal self-closing stop valve emergency closure test for liquefied compressed gases. This test is as follows:

1. In performing this test, all internal self-closing stop valves must be opened. Each emergency discharge control remote actuator (on-truck and off-truck) must be operated to ensure that each internal self-closing stop valve's lever, piston, or other valve indicator has moved to the closed position.
2. On pump-actuated pressure differential internal valves, the three-way toggle valve handle or its cable attachment must be activated to verify that the toggle handle moves to the closed position.

5.12 APPENDIX B TO PART 180 – ACCEPTABLE INTERNAL SELF-CLOSING STOP VALVE LEAKAGE TESTS FOR CARGO TANKS TRANSPORTING LIQUEFIED COMPRESSED GASES

Appendix B to 49 CFR 180 presents the guidelines for the acceptable internal self-closing stop valve leakage tests for CTs transporting liquefied compressed gases. For internal self-closing stop valve leakage testing, leakage is defined as any leakage through the internal self-closing valve or to the atmosphere that is detectable when the valve is in the closed position. On some valves this will require the closure of the pressure bypass port.

5.12.1 Meter Creep Test

1. An operator of a CT equipped with a calibrated meter may check the internal self-closing stop valve for leakage through the valve seat using the meter as a flow measurement indicator. The test is initiated by starting the delivery process or returning product to the CT through the delivery system. This may be performed at an idle. After the flow is established, the operator closes the internal self-closing stop valve and monitors the meter flow. The meter flow must stop within 5 seconds after the meter stops.
2. On pump-actuated pressure differential internal self-closing stop valves, the valve must be closed with the remote actuator to assure that it is functioning. On other types of internal self-closing stop valves, the valve(s) may be closed using either the normal valve control or the discharge control system (e.g., remote).
3. Rejection criteria: Any detectable meter creep within the first 5 seconds after initial meter stoppage.

5.12.2 Internal Self-Closing Stop Valve Test

An operator of a CT that is not equipped with a meter may check the internal self-closing stop valve(s) for leakage as follows:

1. The internal self-closing stop valve must be in the off position.
2. All of the material in the downstream piping must be evacuated, and the piping must be returned to atmospheric temperature and pressure.
3. The outlet must be monitored for 30 seconds for detectable leakage.
4. Rejection criteria: Any detectable leakage is considered unacceptable.

6. Additional Reference Material

6.1 49 CFR 173.315(N) – EMERGENCY DISCHARGE CONTROL FOR CARGO TANK MOTOR VEHICLES IN LIQUEFIED COMPRESSED GAS SERVICE

Each CTMV in liquefied compressed gas service[102] must have an emergency discharge control capability as specified in table 29:

Table 17. §173.315(n)(1) Required emergency discharge control capabilities.

§173.315(n)(1)(*)	Material	Delivery Service	Required Emergency Discharge Control Capabilities
(i)	Division 2.2 materials with no subsidiary hazard, excluding anhydrous ammonia	All	None
(ii)	Division 2.3 materials	All	Paragraph (n)(2) of §173.315
(iii)	Division 2.2 materials with a subsidiary hazard, Division 2.1 materials, and anhydrous ammonia	Other than metered delivery service	Paragraph (n)(2) of §173.315
(iv)	Division 2.2 materials with a subsidiary hazard, Division 2.1 materials, and anhydrous ammonia in a CTMV with a capacity of 13,247.5 liters (3,500 water gallons) or less	Metered delivery service	Paragraph (n)(3) of §173.315
(v)	Division 2.2 materials with a subsidiary hazard, Division 2.1 materials, and anhydrous ammonia in a CTMV with a capacity greater than 13,247.5 liters (3,500 water gallons)	Metered delivery service	Paragraph (n)(3) of §173.315, and, for obstructed view deliveries where permitted by 49 CFR 177.840(p), paragraph (n)(2) or (n)(4) of §173.315
(vi)	Division 2.2 materials with a subsidiary hazard, Division 2.1 materials, and anhydrous ammonia in a CT with a capacity of greater than 13,247.5 liters (3,500 water gallons)	Both metered delivery and other than metered delivery service	Paragraph (n)(2) of §173.315, provided the system operated for both metered and other than metered deliveries; otherwise, paragraphs (n)(2) and (n)(3) of §173.315

A CTMV in other than metered delivery service must have a means of automatically shutting off the flow of product without the need for human intervention within 2 seconds of an unintentional release caused by a complete separation of a liquid delivery hose (passive shutdown capability).[103] Designed flow of product through a bypass in the valve is acceptable when authorized by this subchapter.

The design for the means to automatically shut off product flow must be certified by a DCE. The certification must consider any specifications of the original component manufacturer and must

[102] §173.315(n)(5) Compliance Dates
[103] §173.315(n)(2) Cargo Tank Motor Vehicles in Other Than Metered Delivery Service

explain how the passive means to shut off the flow of product operates. It must also outline the parameters (e.g., temperature, pressure, types of product) within which the passive means to shut off the flow of product is designed to operate. All components of the discharge system that are integral to the design must be included in the certification. A copy of the design certification must be provided to the owner of the CTMV on which the equipment will be installed. Installation must be performed under the supervision of an RI unless the equipment is installed and removed as part of regular operation (e.g., a hose). The RI must certify that the equipment is installed and tested, if it is possible to do so without damaging the equipments, in accordance with the DCE's certification. The RI must provide the certification to the owner of the CTMV.

CTMVs in metered delivery service,[104] when required by the table above, must have an off-truck remote means to close the internal self-closing stop valve and shut off all motive and auxiliary power equipment upon activation by a qualified person attending the unloading of the CTMV (off-truck remote shut-off). It must function reliably at the distance of 45.72 m (150 ft). The off-truck remote shut-off activation device must not be capable of reopening the internal self-closing stop valve after emergency activation. The emergency discharge control equipment must be installed under the supervision of an RI. Each wireless transmitter/receiver must be tested to demonstrate that it will close the internal self-closing stop valve and shut off all motive and auxiliary power equipment at a distance of 91.44 m (300 ft) under optimum conditions. Emergency discharge control equipment that does not employ a wireless transmitter/receiver must be tested to demonstrate its functioning at the maximum length of the delivery hose. The RI must certify that the remote control equipment is installed in accordance with the original component manufacturer's specifications and is tested in accordance with the preceding paragraph. The RI must provide the owner of the CTMV with this certification.

When a transmitter/receiver is used to satisfy the requirements of paragraph §173.315(n)(1)(v) (see table 29), it must close the internal self-closing stop valve and shut off all motive and auxiliary power equipment unless the qualified person attending the unloading operation prevents it from doing so at least once every 5 minutes.[105] Testing and certification must be as specified in paragraph (n)(3).

[104] §173.315(n)(3) Cargo Tank Motor Vehicles in Metered Delivery Service
[105] §173.315(n)(4) Query Systems

6.2 DEFINITIONS

Appurtenance: any attachment to a CT that has no lading retention or containment function and provides no structural support to the CT.

Authorized Inspection Agency:

1. A jurisdiction which has adopted and administers one or more sections of the ASME Boiler and Pressure Vessel Code as a legal requirement and has a representative serving as a member of the ASME Conference Committee.
2. An insurance company that has been licensed or registered by the appropriate authority of a State of the United States or a Province of Canada to underwrite boiler and pressure vessel insurance in such State or Province.

Authorized Inspector: an inspector who is currently commissioned by the National Board of Boiler and Pressure Vessel Inspectors and employed as an Inspector by an Authorized Inspection Agency.

Baffle: a non-liquid-tight transverse partition device that deflects, checks, or regulates fluid motion in a tank.

Bulk: refers to a packaging, other than a vessel or barge, including a transport vehicle or freight container, in which hazardous materials are loaded with no intermediate form of containment and which has one of the following:

1. A maximum capacity greater than 450 liters (119 gallons) as a receptacle for a liquid.
2. A maximum net mass greater than 400 kg (882 lbs) and a maximum capacity greater than 450 liters (119 gallons) as a receptacle for a solid.
3. A water capacity greater than 454 kg (1,000 lbs) as a receptacle for gases defined in §173.115.

Bulkhead: a liquid-tight transverse closure at the ends of or between CTs.

Cargo tank: bulk packaging which:

1. Is intended primarily for the carriage of liquids or gases and includes appurtenances, reinforcements, fittings, and closures (for tank, see 49 CFR 178.345, 178.337, or 178.338, as applicable).
2. Is permanently attached to or forms a part of a motor vehicle, or is not permanently attached to a motor vehicle but which, by reason of its size, construction or attachment to a motor vehicle is loaded or unloaded without being removed from the motor vehicle.
3. Is not fabricated under a specification for cylinders, portable tanks, tank cars, or multi-unit tank car tanks.

CTMV: a motor vehicle with one or more CTs permanently attached to or forming an integral part of the motor vehicle.

CT wall: those parts of the CT that make up the primary lading retention structure, including shell, bulkheads, and fittings and, when closed, yield the minimum volume of the CT assembly.

Charging line: means a hose, tube, pipe, or similar device used to pressurize a tank with material other than the lading.

Companion flange: one of two mating flanges where the flange faces are in contact or separated only by a thin leak-sealing gasket and are secured to one another by bolts or clamps.

Connecting structure: the structure joining two CTs.

Constructed and certified in accordance with the ASME Code: a cargo tank is constructed and stamped in accordance with Section VIII of the ASME Code, and is inspected and certified by an Authorized Inspector.

Constructed in accordance with the ASME Code: a CT is constructed in accordance with Section VIII of the ASME Code with authorized exceptions (see 178.346 through 178.348) and is inspected and certified by an RI.

Corroded or abraded: any visible reduction in the material thickness of the CT wall or valve due to pitting, flaking, gouging, or chemical reaction to the material surface that affects the safety or serviceability of the CT. The term does not include cosmetic or minor surface degradation that does not affect the safety or serviceability of the CT.

Corrosive to the tank or valve: a lading that has been shown through experience or test data to reduce the thickness of the material of construction of the tank wall or valve.

Defect: an imperfection requiring the removal of a cylinder from service.

Delivery hose assembly: a liquid delivery hose and its attached couplings.

Design Certifying Engineer: a person registered with the USDOT in accordance with 49 CFR 107 subpart F who has the knowledge and ability to perform stress analysis of pressure vessels and otherwise determine whether a CT design and construction meets the applicable DOT specification. DCEs meet the knowledge and ability requirement by meeting any one of the following requirements:

1. Has an engineering degree and 1 year of work experience in CT structural or mechanical design.
2. Is currently registered as a professional engineer by appropriate authority of the United States or a province of Canada.
3. Has at least 3 years' experience in performing the duties of a DCE prior to September 1, 1991.

Design type: one or more CTs that are made:

1. To the same specification.
2. By the same manufacturer.
3. To the same engineering drawings and calculations, except for minor variations in piping that do not affect the lading retention capability of the CT.

4. Of the same materials of construction.
5. To the same cross sectional dimensions.
6. To a length varying by no more than 5 percent.
7. With the volume varying by no more than 5 percent (due to a change in length only).
8. For purposes of §178.338 only, with the same insulation system.

External self-closing stop valve: a self-closing stop valve designed so that the self-stored energy source is located outside the CT and the welded flange.

Extreme dynamic loading: the maximum loading a CTMV may experience during its expected life, excluding accident loadings resulting from an accident, such as overturn or collision.

Flange: the structural ring for guidance or attachment of a pipe or fitting with another flange (companion flange), pipe, fitting or other attachment.

Inspection pressure: the pressure used to determine leak tightness of the CT when testing with pneumatic pressure.

Internal self-closing stop valve: a self-closing stop valve designed so that the self-stored energy source is located inside the CT or CT sump or within the welded flange. The valve seat is located within the CT or within one inch of the external face of the welded flange or sump of the CT.

Lading: the HM contained in a CT.

Loading/unloading outlet: a CT outlet used for normal loading/unloading operations.

Loading/unloading stop valve: the stop valve farthest from the CT loading/unloading outlet to which the loading/unloading connection is attached.

Manufacturer: any person engaged in the manufacture of a DOT specification CT, CTMV, or CT equipment that forms part of the CT wall. This term includes attaching a CT to a motor vehicle or to a motor vehicle suspension component that involves welding on the CT wall. A manufacturer must register with the USDOT in accordance with 49 CFR 107 subpart F.

Maximum allowable working pressure (MAWP): the maximum pressure allowed at the top of the tank in its normal operating position. The MAWP must be calculated as prescribed in Section VIII of the ASME Code. In use, the MAWP must be greater or equal to the maximum lading pressure conditions for each material transported.

Maximum lading pressure: As defined in 49 CFR 173.33(c)(1). Prior to loading and offering a CTMV for transportation with material that requires the use of a specification CT, the person must confirm that the CTMV conforms to the specification required for the lading and that the MAWP of the CT is greater than or equal to the largest pressure obtained under the following conditions:

(i) For compressed gases and certain refrigerated liquids that are not cryogenic liquids, the pressure prescribed in § 173.315 of this subchapter.

(ii) For cryogenic liquids, the pressure prescribed in §173.318 of this subchapter.
(iii) For liquid hazardous materials loaded in DOT-specification CTs equipped with a 1 psig normal vent, the sum of the tank static head plus 1 psig. In addition, for HM loaded in these CTs, the vapor pressure of the lading at 115°F must be not greater than 1 psig, except for gasoline transported in accordance with Special Provision B33 in §172.102(c)(3) of this subchapter.
(iv) For liquid HM not covered in paragraph (c)(1)(i), (ii), or (iii), the sum of the vapor pressure of the lading at 115°F, plus the tank static head exerted by the lading, plus any pressure exerted by the gas padding, including air in the ullage space or dome.
(v) The pressure prescribed in subpart B, D, E, F, G, or H of this part, as applicable.
(vi) The maximum pressure in the tank during loading or unloading.
(2) Any specification MC 300, MC 301, MC 302, MC 303, MC 305, MC 306, or MC 312 CTMV with no marked design pressure or marked with a design pressure of 3 psig or less may be used for an authorized lading where the pressure derived from §173.33(c)(1) is less than or equal to 3 psig. After December 31, 1990, a CT may not be loaded and offered for transportation unless marked or remarked with an MAWP or design pressure in accordance with 49 CFR 180.405(k).
(3) Any specification MC 310 or MC 311 CTMV may be used for an authorized lading where the pressure derived from §173.33(c)(1) is less than or equal to the MAWP or MWP, respectively, as marked on the specification plate.
(4) Any CT marked or certified before August 31, 1995, marked with a design pressure rather than an MAWP may be used for an authorized lading where the largest pressure derived from §173.33(c)(1) is less than or equal to the design pressure marked on the CT.
(5) Any material that meets the definition of a Division 6.1, Packing Group I or II (poisonous liquid) material must be loaded in a CTMV having a MAWP of 25 psig or greater.
(6) Substitute packagings. Unless otherwise specified, where MC 307, MC 312, DOT 407, or DOT 412 CTs are authorized, minimum tank design pressure is 172.4 kPa (25 psig) for any Packing Group I or Packing Group II liquid lading that meets more than one hazard class definition.

Minimum thickness: the minimum required shell and head (and baffle and bulkhead when used as tank reinforcement) thickness needed to meet the specification. The minimum thickness is the *greatest* of the following values:

- **(1)(i) For MC 330, MC 331, and MC 338 CTs, the specified minimum thickness found the applicable specification(s).**
- **(ii) For DOT 406, DOT 407, and DOT 412 CTs, the specified minimum thickness found in Tables I and II of the applicable specification(s).**
- **(iii) For MC 300, MC 301, MC 302, MC 303, MC 304, MC 305, MC 306, MC 307, MC 310, MC 311, and MC 312 CTs, the in-service minimum thickness prescribed in Tables I and II of 180.407(i)(5) of this subchapter, for the minimum thickness specified by Tables I and II of the applicable specification(s).**
- **(2) The thickness necessary to meet with the structural integrity and accident damage requirements of the applicable specification(s).**
- **(3) The thickness as computed per the ASME Code requirements (if applicable).**

Modification: any change to the original design and construction of a CT or a CTMV that affects its structural integrity or lading retention capability, including changes to equipment certified as part of an emergency discharge control system required by §173.315(n)(2). Any modification that involves welding on the CT wall must also meet all requirements for "Repair" as defined. Any modification that involves welding on the CT wall must also meet all requirements for "Repair." Excluded from this category are the following:

1. A change to motor vehicle equipment such as lights, truck or tractor power train components, steering and brake systems, and suspension parts and changes to appurtenances, such as fender attachments, lighting brackets, and ladder brackets.
2. Replacement of components such as valves, vents, and fittings with components of similar design and of the same size.

Multi-specification cargo tank motor vehicle: a CTMV equipped with two or more CTs fabricated to more than one CT specification.

Non-corrosive service: a hazardous material that in the presence of moisture is not corrosive to the materials of construction of a cylinder (including valve, pressure relief device, etc.).

Normal operating loading: the loading a CTMV may be expected to experience routinely in operation.

Nozzle: a subassembly consisting of a pipe or tubular section with or without a welded or forged flange on one end.

Outlet: any opening in the shell or head of a CT, (including the means for attaching a closure), except for the following: a threaded opening securely closed during transportation with a threaded plug or a threaded cap, a flanged opening securely closed during transportation with a bolted or welded blank flange, a manhole, a gauging device, a thermometer well, or a pressure relief device.

Outlet stop valve: the stop valve at a CT loading or unloading outlet.

Owner: the person who owns a CTMV used for the transportation of hazardous materials, or that person's authorized agent.

Pipe coupling: a fitting with internal threads on both ends.

Piping system: any component of a CT delivery system, other than a delivery hose assembly, that contains product during loading or unloading.

Proof pressure test: a pressure test by interior pressurization without the determination of a cylinder's expansion.

Rear bumper: the structure designed to prevent a vehicle or object from underriding the rear of another motor vehicle. Additional information regarding bumper requirements may be found in 49 CFR 393.86.

Rear-end tank protection device: the structure designed to protect a CT and any lading retention piping or devices in case of a rear-end collision.

Rebarrelling: replacing more than 50 percent of the combined shell and head material of a CT.

Rebuild: the replacement of a pressure part (e.g., a wall, head, or pressure fitting) by welding.

Repair: any welding on a CT wall done to return a CT or a CTMV to its original design and construction specification, or to a condition prescribed for a later equivalent specification in effect at the time of the repair. Excluded from this category are the following:

- A change to motor vehicle equipment such as lights, truck or tractor power train components, steering and brake systems, and suspension parts and changes to appurtenances, such as fender attachments, lighting brackets.
- Replacement of components such as valves, vents, and fittings with a component of a similar design and of the same size.
- Replacement of an appurtenance by welding to a mounting pad.

Replacement of a barrel: to replace the existing tank on a motor vehicle chassis with an unused (new) tank.

Self-closing stop valve: a stop valve held in the closed position by means of self-stored energy that opens only by application of an external force and that closes when the external force is removed.

Shell: the circumferential portion of a CT defined by the basic design radius or radii excluding the bulkheads.

Stop valve: a valve that stops the flow of lading.

Sump: a protrusion from the bottom of a CT shell designed to facilitate complete loading and unloading of lading.

Tank: a container, consisting of a shell and heads, that forms a pressure-tight vessel having openings designed to accept pressure tight fittings or closures but excludes any appurtenances, reinforcements, fittings, or closures.

Test pressure: the pressure to which a tank is subjected to determine structural integrity.

Toughness of material: the capability of a material to absorb energy represented by the area under a stress strain curve (indicating the energy absorbed per unit volume of the material) up to the point of rupture.

Vacuum cargo tank: a CT that is loaded by reducing the pressure in the CT to below atmospheric pressure.

Variable specification cargo tank: a CT that is constructed in accordance with one specification but that may be altered to meet another specification by changing relief device, closures, lading discharge devices, and other lading retention devices.

Void: the space between tank heads or bulkheads and a connecting structure.

Welded flange: a flange attached to the tank by a weld joining the tank shell to the cylindrical outer surface of the flange, or by a fillet weld joining the tank shell to a flange shaped to fit the shell contour.