P-1605

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October 31, 2012

Charles Betts, Director
U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
Office of Standards and Rulemaking
Attn: PHH–10
East Building 2nd Floor
1200 New Jersey Avenue, SE
Washington, DC 20590–0001.

Subject: Petition to Incorporate by Reference CGA G-1.6, 2011, Seventh Edition

Mr. Betts:

The Compressed Gas Association (CGA), founded in 1913, is dedicated to the development and promotion of safety standards and safe practices in the industrial, medical, and food gases industry. CGA represents over 115 member companies in all facets of the industry – manufacturers, distributors, suppliers, and transporters of gases, cryogenic liquids, and related products and services. Through a committee system, CGA develops technical specifications, safety standards, training and educational materials, and works with government agencies to formulate responsible regulations and standards and to promote compliance with these regulations and standards.

In accordance with 49 CFR §106.100 (a), CGA is requesting a rulemaking change to 49 CFR §171.7 to incorporate by reference CGA G-1.6, 2011, *Standard for Mobile Acetylene Trailer Systems, Seventh Edition* (G-1.6, 2011). This standard provides the minimum requirements necessary for the design, construction, and operation of mobile acetylene trailer systems (MATS) consisting of trailers having acetylene cylinders mounted and manifolded for the purposes of charging, transporting, and discharging acetylene. It also covers ground-mounted auxiliary equipment used with the MATS such as piping, meters, regulators, flash arrestors, and fire protection equipment. For your reference copies of G-1.6, 2011 are enclosed with this petition.

As an overview, CGA G-1.6 is divided into 9 sections. A synopsis of each is provided as follows:

**Section 1** is the Introduction to the standard.

**Section 2** is the Scope of the standard.

**Section 3** provides the definitions that are used in the standard.

**Section 4** provides details of the piping specifications, piping design standard, cylinder securement, pressure testing and leak-testing requirements. This is to ensure the piping on the MAT is properly designed and to ensure that the cylinders and the piping system are protected during transit and use. This section also provides details on the types of cylinders to be used and piping system design so as to withstand pressures developed should acetylene gas decomposition and detonation occur inside the piping system. These specifications are already in use by major suppliers of MATS. This publication identifies the requirements and facilitates the fabrication of safe MATS and the safe use of MATS by non-gas producing companies.

**Section 5** provides details on the allowable quantity of acetylene to be filled into each cylinder, control of cylinder temperatures during filling, and an acetylene liquefaction temperature chart to aid the operator in avoiding the possibility of undissolved acetylene condensing into an unstable liquid and decomposing explosively. Included is the requirement of securing cylinders in vertical position on the MAT as per 49 CFR §393.102. A requirement for closing all cylinder valves and reducing the pressure in the manifold to less than 15 psig is specifically included to address the NTSB concern of a MAT fire in the event of a rollover. NTSB/SIR-09/01 PB2009-917002 is included in this petition as Attachment A. The amount of gas contained in the manifold is very minimal and at low pressure which will not auto-ignite in the event of a pipe system rupture. This section also details the requirement of trained personnel to handle the discharge operations at customer locations, as acetylene system operations are unique in nature.

**Section 6** details the siting requirements for MAT filling and discharging operations. These include required separation distances for protection of other MATS and other property. Requirements for safety equipment and components are also addressed. This section provides details on the type of weather protection and buildings that are acceptable for housing MATS being filled or discharged.

**Section 7** addresses the fire protection requirements necessary for MAT discharge locations. The fill locations are already covered by NFPA-51A/NFPA55, the discharge locations which fall under DOT jurisdiction are addressed in this section. This is in response to NTSB recommendation to provide deluge fire protection systems at MAT discharge locations. This section provides for the Authority Having Jurisdiction (AHJ) to verify and approve other equivalent protection systems for existing or new facilities to meet the intent of the fire protection requirements specified in this standard. This section includes details on essential training required for operating personnel to meet 49 CFR §§390-397 as mandated by DOT.

**Sections 8** provides a listing of references.

**Sections 9** provides a listing of additional references.

Where applicable, this Publication aligns itself with the definitions that are used by the Department of Transportation and Transport Canada.

CGA has identified the sections of 49 CFR in which to incorporate CGA Standard G-1.6, 2011, in the following table and in Attachment B of this petition.

| Source and name of material | 49 CFR reference |
|---|---|
| CGA Publication G-1.6, Standard for Mobile Acetylene Trailer Systems, 2011, 7th edition | 171.7; 173.301 (g) |

The changes made to this edition are in response to the recommendations from the US Department of Transportation (DOT), and National Transportation Safety Board (NTSB) (reference DOT Docket No.PHMSA-2007-29133; Notice No. 07-08.). In addition, comments and suggestions from National Fire Protection Association (NFPA), Transport Canada (TC), industry experts, and the general public were also incorporated.

CGA has addressed each of the changes suggested in the NTSB report by the revisions made to G-1.6, 2011, Seventh Edition.

In addition to the requirements of 49 CFR §106.100 (a), the CGA offers the following responses to the requirements of 49 CFR §106.100 (b).

The impact of this proposal will create standard minimum requirements necessary for the design, construction, and operation of mobile acetylene trailer systems MATS consisting of trailers having acetylene cylinders mounted and manifolded for the purposes of charging, transporting, and discharging acetylene. It also covers ground-mounted auxiliary equipment used with the MATS such as piping, regulators, flash arrestors, and meters.

The US Department of Transportation, industry experts, and others were involved in the revision of G-1.6, 2011. By this involvement, all aspects of equipment, test methods, personnel, and certifications were openly reviewed resulting in a publication that establishes requirements that will enhance the safety of MATS in the transportation and usage modes.

The incorporation of G-1.6, 2011will not preempt any state or federal regulations. These specifications are already in use by major suppliers of acetylene.

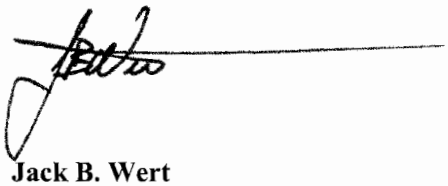
There will be no additional regulatory burden on small businesses, small organizations, small governmental jurisdictions, or Indian tribes.

The recordkeeping requirements will be no greater than those required today by the US Department of Transportation and Transport Canada.

The incorporation of G-1.6, 2011will not affect the quality of the natural and social environments other than minimizing the risk of future incidents involving MATS.

Please contact me with any questions you may have or for any assistance CGA can provide to achieve the approval of our request. Please give notice, by return e-mail, when this request has been assigned a docket number.

Respectfully Submitted,



**Jack B. Wert**

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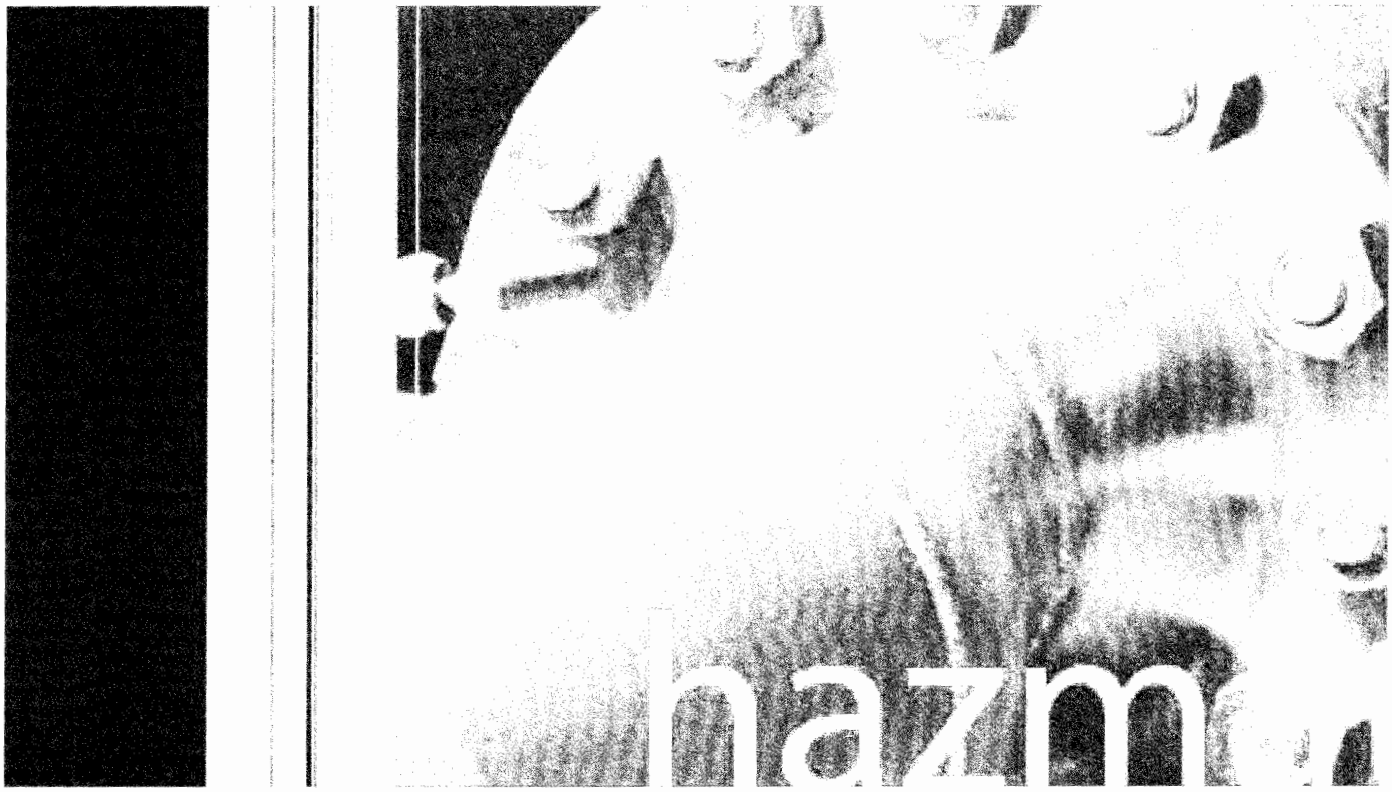
Enclosures: G-1.6, 2011

Attachment A

# Mobile Acetylene Trailer Accidents: Fire During Unloading in Dallas, Texas, July 25, 2007; Fire During Unloading in The Woodlands, Texas August 7, 2007; and Overturn and Fire in East New Orleans, Louisiana, October 20, 2007




**Special Investigation Report**

NTSB/SIR-09/01
PB2009-917002

**National Transportation Safety Board**

Attachment A

Attachment A

NTSB/SIR-09/01
PB2009-917002
Notation 8071
Adopted January 13, 2009

# Special Investigation Report

## Mobile Acetylene Trailer Accidents: Fire During Unloading in Dallas, Texas, July 25, 2007; Fire During Unloading in The Woodlands, Texas, August 7, 2007; and Overturn and Fire in East New Orleans, Louisiana, October 20, 2007

**National Transportation Safety Board**

490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

# Attachment A

**National Transportation Safety Board. 2009.** ***Mobile Acetylene Trailer Accidents: Fire During Unloading in Dallas, Texas, July 25, 2007; Fire During Unloading in The Woodlands, Texas, August 7, 2007; and Overturn and Fire in East New Orleans, Louisiana, October 20, 2007.*** **Special Investigation Report NTSB/SIR-09/01. Washington, DC.**

**Abstract:** The National Transportation Safety Board investigated three accidents that involved highway vehicles transporting bulk quantities of acetylene gas that occurred in 2007 and reviewed reports of a 2008 overturn accident of another vehicle. The vehicles, called mobile acetylene trailers, carried up to 225 cylinders that were connected by a manifold system and filled with acetylene. Two of the accidents occurred as the vehicles overturned on public highways, and two of the accidents occurred while the vehicles were being prepared for unloading. In the two overturn accidents, cylinders were ejected from the trailers and damaged, releasing acetylene, which ignited. In one unloading accident, the fire on the initial trailer spread to cylinders on an adjacent trailer; in the other, the fire also spread to nearby buildings and vehicles. The failures of the cylinders on these trailers and the resultant damage raised concerns about the accident protection provided by these vehicles, the adequacy of the minimum safety standards and procedures applicable to unloading these vehicles, and the adequacy of fire suppression systems at loading and unloading facilities.

The safety issues discussed in this report are adequacy of mobile acetylene trailer design for protecting cylinders during transport, effectiveness and safety of unloading procedures for mobile acetylene trailers, and adequacy of fire suppression systems at mobile acetylene trailer loading and unloading facilities.

As a result of this special investigation, the Safety Board makes safety recommendations to the Pipeline and Hazardous Materials Safety Administration and the Compressed Gas Association.

# Contents

# Figures

# Acronyms and Abbreviations

| | |
|---|---|
| CFR | *Code of Federal Regulations* |
| CGA | Compressed Gas Association |
| DOT | U.S. Department of Transportation |
| F | Fahrenheit |
| NFPA | National Fire Prevention Association |
| PHMSA | Pipeline and Hazardous Materials Safety Administration |
| psig | pounds per square inch, gauge |
| Southwest | Southwest Industrial Gases |
| Western | Western International Gas & Cylinders, Inc. |

# Executive Summary

The National Transportation Safety Board investigated three accidents that involved highway vehicles transporting bulk quantities of acetylene gas that occurred between July 25 and October 20, 2007, and reviewed reports of a 2008 overturn accident of another vehicle. The vehicles, called mobile acetylene trailers, carried up to 225 cylinders that were connected by a manifold system[1] and filled with acetylene. Two of the accidents occurred as the vehicles overturned on public highways, in East New Orleans, Louisiana, on October 20, 2007, and in Lamar, Colorado, on June 9, 2008. Two of the accidents occurred while the vehicles were being prepared for unloading, in Dallas, Texas, on July 25, 2007, and in The Woodlands, Texas, on August 7, 2007. In the two overturn accidents, cylinders were ejected from the trailers and damaged, releasing acetylene, which ignited. In one unloading accident, the fire on the initial trailer spread to cylinders on an adjacent trailer; in the other, the fire spread to cylinders on adjacent trailers and to nearby buildings and vehicles. The failures of the cylinders on these mobile acetylene trailers and the resultant damage raised concerns about the accident protection provided by these vehicles, the adequacy of the minimum safety standards and procedures applicable to unloading these vehicles, and the adequacy of fire suppression systems at loading and unloading facilities. To address these concerns, the Safety Board conducted a special investigation of mobile acetylene trailers.

These trailers, with multiple cylinders and a manifold system for loading and unloading the cylinders, are the only vehicles authorized to transport and deliver bulk quantities of acetylene. Currently, two companies in the United States operate mobile acetylene trailers. Each company has about 200 trailers, thus the total number of these trailers is about 400.

The trailers in the four accidents that the Safety Board investigated and reviewed were operated by Western International Gas & Cylinders, Inc. (Western). In the 10 years before these four accidents, Western mobile acetylene trailers had been involved in additional accidents; the company investigated four of them. The Safety Board reviewed reports of three of these accidents that had some relevance to the accidents in this investigation.

In its investigation, the Safety Board attempted to determine the hazards of the transportation and delivery of acetylene gas in bulk. The investigation looked at the protection of the cylinders during a vehicle overturn and the standards and procedures for handling acetylene during loading and unloading. The following safety issues were identified in this special investigation:

- Adequacy of mobile acetylene trailer design for protecting cylinders during transport
- Effectiveness and safety of unloading procedures for mobile acetylene trailers
- Adequacy of fire suppression systems at mobile acetylene trailer loading and unloading facilities.

[1] A *manifold system* collects the acetylene gas from multiple cylinders into one pipe or chamber; when the cylinders are filled, the acetylene gas is dispersed from one pipe to multiple cylinders.

As a result of this special investigation, the Safety Board makes recommendations to the Pipeline and Hazardous Materials Safety Administration and the Compressed Gas Association.

# Acetylene Gas

Acetylene is a colorless flammable gas that has historically been handled relatively safely at pressures below atmospheric pressure (about 15 pounds per square inch, gauge[2] [psig]). However, at elevated pressures acetylene becomes extremely unstable.[3] With the addition of energy, acetylene undergoes a decomposition reaction in which it breaks down to flammable hydrogen gas and elemental carbon. Carbon generated during this reaction is deposited on piping and other components. The decomposition reaction releases tremendous amounts of energy and may generate temperatures between 5072° and 5252° Fahrenheit (F). A black plume forms when the carbon and hydrogen are expelled from the cylinder. External heating, compression heating, an electrostatic spark, or a shockwave can also cause an acetylene decomposition reaction. With substantial energy input, a decomposition reaction can occur within a cylinder or pressurized system in the absence of air. When combined with air, pressurized acetylene will readily ignite with very little energy input and a lower temperature. Such a reaction can result in deflagration or detonation.[4]

Western has a material safety data sheet for acetylene that states that the flash point[5] for acetylene is 32° F, acetylene has flammable limits[6] between 2.5 percent and 82 percent in air, and it is lighter than air. Acetylene also may decompose explosively at elevated temperatures and pressures. The potential for a decomposition reaction to occur is proportional to the pressure; the higher the pressure, the more likely it is for a reaction to occur.

According to a paper by S. A. Miller and E. Penny,[7] the progression from deflagration to detonation is dependent on the original pressure and the diameter and length of the pipe. Testing showed that an acetylene deflagration in a 1-inch-diameter pipe originally pressurized to 73.5 psig takes 12 feet to reach detonation. However, when the original acetylene pressure is 294 psig, detonation occurs between 2.8 and 3.2 feet. Once detonation occurs, the reaction front travels through open piping at a speed greater than the speed of sound. The acetylene in the cylinders on the vehicles involved in the accidents in East New Orleans, The Woodlands, and Dallas was

[2] The term psig is a unit of pressure relative to the surrounding atmosphere (as in a container).

[3] Acetylene ($C_2H_2$) has a triple bond between the two carbon atoms in its molecular structure. The triple bond is highly unstable. *Ullmann's Encyclopedia of Industrial Chemistry*, Electronic Release, 7th ed., Wiley-VCH, Weinheim, Germany, 2001.

[4] *Deflagration* is a very rapid exothermic chemical reaction that is propagated through the unreacted material at a velocity less than the speed of sound. The propagation is achieved by the spread of flame and hot gases into the unreacted material. *Detonation* is an explosive process in which the extremely rapid chemical reaction is propagated through the unreacted material at supersonic velocity by means of a shockwave. The shockwave is associated with a compressive zone of very high temperature passing through the unreacted material.

[5] The *flash point* of a chemical is the lowest temperature at which a liquid can form an ignitable mixture in air near the surface of the liquid. The lower the flash point, the easier it is to ignite the material.

[6] The *flammable limits* of a chemical define the concentration range in which a flammable substance can produce a fire or explosion when an ignition source (such as a spark or open flame) is present. The concentration is generally expressed as percent fuel by volume.

[7] S. A. Miller and E. Penny, "Hazards in Handling Acetylene in Chemical Processes Particularly Under Pressure." Symposium on Chemical Process Hazards, INSTN Chemical Engineers, 1960.

pressurized to about 250 psig. Residue pressure in the cylinders involved in the Lamar, Colorado, accident was less than 15 psig.

According to Samuel A. Miller's book, *Acetylene: Its Properties, Manufacture and Uses,*[8] testing of acetylene explosions caused by shockwaves in piping showed that for certain pipe lengths, pipe diameters, and acetylene pressures, ignition occurred after the shock wave was reflected from the closed end of a tube. In postaccident discussions, a representative of Praxair, Inc.,[9] stated that testing performed by Union Carbide had revealed that a decomposition reaction could occur with the rapid introduction of high-pressure acetylene into a blocked 1-inch-diameter pipe as the shockwave was reflected. Union Carbide found that this pipe must be at least 1 1/4 inch long for the reaction to occur.

## Transporting Acetylene

Given the extreme reactivity of pressurized acetylene, no bulk or large pressure vessel has been developed that is considered safe for its transportation. Therefore, bulk acetylene is transported on mobile acetylene trailers, of which one often contains more than 200 U.S. Department of Transportation (DOT) specification 8AL cylinders that are manifolded, that is, linked together by a manifold system used for loading and unloading. (These cylinders are approximately 4 feet tall and 1 foot in diameter.) The trailers were designed so that the cylinders are mounted upright, set close together, and braced in groups to control their movement during transportation and to prevent them from falling over. (See figure 1.) The cylinders on these vehicles are not secured to the trailer to prevent their ejection during overturn, nor are they required to be.

Title 49 *Code of Federal Regulations* (CFR) 178.60 contains the DOT specifications for the 8AL cylinders that are designed specifically to contain acetylene gas during transportation. The 8AL cylinders are filled with a porous mass and a liquid solvent. Although acetone typically is the solvent used in individual acetylene cylinders, dimethylformamide is the liquid solvent used in bulk transportation cylinders because it is less volatile and requires less maintenance. These features are designed, in part, to reduce the likelihood that the acetylene will undergo a decomposition reaction within the cylinder. Each cylinder has two fusible plugs in the top that are designed to melt in the event of an internal decomposition reaction or when exposed to external heat and thus relieve pressure in the container. Venting pressure through the fusible plug openings reduces the likelihood of a cylinder overpressure failure. However, exposing an acetylene cylinder to excessive heat or energy can overwhelm the ability of the fusible plugs to vent sufficient gas, and a cylinder failure can occur.

[8] Samuel A. Miller, *Acetylene: Its Properties, Manufacture and Uses*. Vol. 1. (New York: Academic Press, 1965).

[9] According to the Compressed Gas Association, Union Carbide Corporation originally designed and tested mobile acetylene trailers. In 1992, Union Carbide Corporation's Industrial Gas Division formed an independent company that is now called Praxair, Inc.


**Figure 1.** The Woodlands trailer (a small mobile acetylene trailer).

Figure 2 shows cylinders on a mobile acetylene trailer. The valve opening on each cylinder is connected by spiral tubing, called a pigtail, to the manifold that delivers or receives the acetylene gas to or from the cylinder. Attached to the manifold, on the back of the trailer, is a cargo transfer fitting, which is not visible in this photograph. This fitting is the connection between the trailer and the piping from the plant. The tubing and manifold piping are designed to contain the energy of an accidental decomposition reaction. A manual block valve (block valve) controls the flow of acetylene to and from the cargo transfer fitting. The piping includes an air-actuated valve that shuts off the flow if a trailer pulls away accidentally before it is disconnected. A needle valve on the manifold is used to reduce pressure on the manifold after cargo transfer and leak testing. Pressure gauges are mounted on the trailer: one on the manifold and one on the trailer piping between the block valve and the connection to the plant piping. According to Western, filling the cylinders through the manifold connection takes about 12 hours.

During transportation of the cylinders, each cylinder valve must be closed and the pressure in the manifold and pigtails is reduced. Because pressurized acetylene's potential for ignition increases dramatically when it is combined with air, some positive acetylene pressure must be maintained in the manifold and pigtails at all times to prevent the introduction of air.

Although the trailer has strong outer railings and the manifold is mounted above the top of the cylinders, neither the railings nor the manifold protects the cylinder valves in case of a trailer overturn. The four accident mobile acetylene trailers had no rollover protection for the valves, nor were they required to.

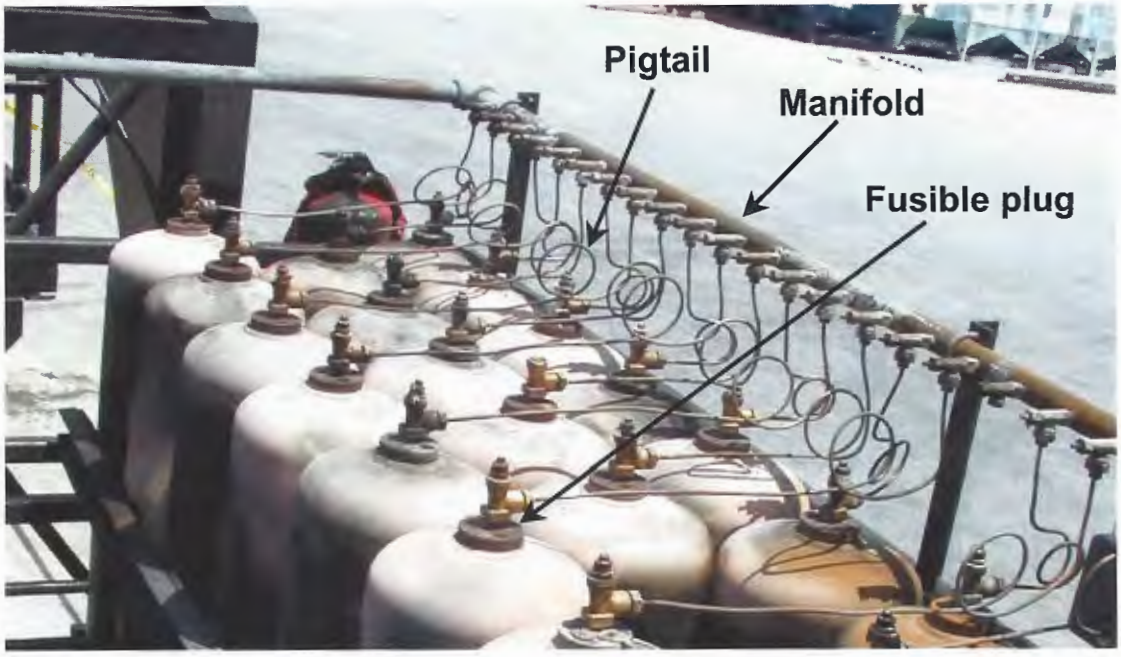



**Figure 2.** The Woodlands cylinders on front right of accident trailer.

## Western's Acetylene Unloading Procedures

Western had standard operating procedures for connecting mobile acetylene trailers to piping at customer sites. The procedures that were used at the sites of the two unloading accidents—the Hughes Christensen (The Woodlands) and Southwest (Dallas) unloading sites—are shown in figure 3.

Operating a mobile acetylene trailer encompasses two jobs: driving the trailer and performing the tasks involved in loading and unloading the acetylene cylinders carried on the trailer. Although one person can both drive the trailer and load/unload the trailer, mobile acetylene trailers are often operated by a team of two people, called "driver/operators," with one driving the trailer and one or both performing the tasks of loading/unloading. In this report, the driver/operators will be identified as "operators." Each operator is required to carry a copy of the standard operating procedures and to follow the procedures step by step when preparing a trailer for unloading.

Western's standard operating procedures require that after connecting the trailer to the plant piping (step 9), the manual block valve on the trailer be opened (step 10) before the trailer manifold is fully pressurized (step 12). Performing these operations out of sequence—opening the block valve after pressurizing the manifold allows highly pressurized acetylene to enter a blocked section of piping that contains residual air, which is dangerous because (1) a blocked pipe potentially can cause a reflected shockwave that can initiate a decomposition reaction and (2) pressurized acetylene that mixes with air inside piping can ignite easily with little energy input. Western's procedure of slowly opening the block valve when the pressure in the manifold is at 50 psig (step 10) allows lower pressure acetylene to mix safely with air in that portion of the

piping. This minimizes the potential for an accidental decomposition reaction to occur within the piping by reducing the pressure shockwave and by slowly mixing the acetylene and residual air.

**Western International Gas & Cylinders Unloading Procedures**

1. Stop at least 50 feet from any on-site trailer.
2. Open two cylinders on the trailer and pressurize the manifold to 150 psi. Upon reaching 150 psi, close the cylinders.
3. Perform a leak check by soaping the entire trailer manifold, B-valves, and cylinders. Do not try to fix any cylinder or B-valve neck leaks. Identify the leaks using the Trailer Leak Report. Leaks will be repaired by certified personnel when the trailer is returned to a Western repair facility.
4. Open the needle valve on the manifold and vent to atmosphere until the pressure reaches approximately 50 psi. Then, close the needle valve. Do not close or tighten the needle valve excessively. Do not use a dummy B valve to vent manifold.
5. Back the trailer into the empty bay.
6. Attach the ground wire to the trailer.
7. Unhook the tractor from the trailer.
8. When parking a chemical trailer at any location, a glad hand lock must be attached to the red airbrake glad hand.
9. Ensure that the O-ring is in place and attach the discharge arm to the trailer and tighten using a union wrench. DO NOT OPEN THE DISCHARGE ARM VALVE.
10. Open the trailer manual block valve AND verify that the half union pressure gauge reading matches the header pressure gauge reading.
11. Slowly open the discharge arm valve, pause 5 seconds, and close the valve. Repeat this cycle 3 times. Verify that the pressure gauge at the half union rises and falls. This allows the gas to slowly pressurize the discharge arm and purge any air from the line. Leave the valve in the closed position.
12. Open all cylinder valves four wrist turns. Go over the trailer again and turn one more wrist turn to verify that all cylinder valves are open.
13. Verify that the trailer manual block valve AND the half union pressure gauge readings match the header pressure gauge reading. Attach the airline to the trailer.
14. Slowly open the discharge arm valve and leave it open at these sites:
    Airgas Baker-Hughes (Hughes Christensen)
15. Leave the discharge arm valve closed at these sites:
    Southwest Industrial Gas

**Figure 3.** Western unloading procedures. (Pressurizing manifold in step 2 is for leak test. Opening cylinder valves in step 12 is pressurizing manifold for unloading.)

# Accident Narratives

The accidents included in this special investigation are two trailer overturns that occurred in East New Orleans, Louisiana, on October 20, 2007, and in Lamar, Colorado, on June 9, 2008, and two accidents that occurred before the acetylene was unloaded, in Dallas, Texas, on July 25, 2007, and in The Woodlands, Texas, on August 7, 2007. Also included in this report are three previous accidents (in 2001 and 2005) involving Western mobile acetylene trailers at loading/unloading sites in which cylinders were damaged, releasing acetylene, which ignited, or the acetylene decomposed, resulting in fire.

## Overturn Accidents

### *East New Orleans, Louisiana*

About 5:00 a.m. central daylight time[10] on October 20, 2007, an eastbound Western tractor and mobile acetylene trailer carrying 220 manifolded DOT 8AL specification cylinders (450 standard cubic feet[11] capacity each) filled with acetylene gas overturned on Interstate Highway 10 in East New Orleans, Louisiana. As a result of the overturn, the cylinders were thrown from the trailer, and acetylene gas from 145 of the 220 cylinders was released and ignited. The overturn and resulting fire destroyed the tractor, the mobile acetylene trailer, and many of the cylinders. (See figure 4.) Six other vehicles were damaged when they struck or were struck by the accident debris. There were no fatalities; the operator sustained minor injuries from the accident. Property damage to the vehicle totaled $200,000.

Just after midnight on October 20, the operator had picked up a load of acetylene from the BASF Corporation plant in Geismar, Louisiana, and was to take the load to the Western facility in Slidell, Louisiana. He had been off duty since 3:00 p.m. October 17. The capacity of all the cylinders was about 100,000 standard cubic feet of acetylene. The operator told the police that he had fallen asleep while driving and hit a bridge rail.

Of the 145 cylinders that released acetylene, 88 were so severely damaged that they were discarded. Of the remaining 57 cylinders that released acetylene, 32 had their valves broken off, and all 57 had evidence of heat exposure and melted fusible plugs. Significant damage to these cylinders included burst heads, a bulging and burst sidewall near the top head weld, extreme localized bulging of the heads and sidewalls, and denting. (See figure 5.)

[10] Except where otherwise noted, all times in this report are central daylight time.

[11] A standard cubic foot is the volume of a gas at a pressure of 14.7 psi (atmospheric pressure) and 60° F.

**Figure 4.** East New Orleans accident vehicle and cylinders.

**Figure 5.** East New Orleans cylinder showing burst near head.

### *Lamar, Colorado*

About 12:15 p.m. mountain daylight time on June 9, 2008, a southbound Western tractor and mobile acetylene trailer carrying 225 DOT 8AL specification cylinders (450 standard cubic feet capacity each) containing acetylene gas residue overturned on Highway 287 about 6.5 miles south of Lamar, Colorado.[12] As a result of the overturn, about half of the cylinders were thrown from the trailer, and acetylene gas from 86 of the 225 cylinders was released and ignited. (See figure 6.) The overturn damaged the tractor and the trailer. There was some fire damage on the trailer. There were no injuries from the accident. Property damage to the tractor and trailer totaled about $200,000.

**Figure 6.** Lamar accident vehicle.

The trailer had been unloaded at a Western facility in Pueblo, Colorado, and was en route to Louisiana to be refilled. There was still a residue of acetylene in each cylinder. The valves of all the cylinders were closed during transportation. Before this trip, the operator had been off duty since June 6, 2008. The Colorado accident report indicated that the vehicle skidded for 106 feet, went off the right side of the roadway, and traveled an additional 250 feet before striking a delineator pole. The vehicle was then steered to the left onto the roadway, where it rolled over completely. The vehicle came to rest perpendicular to and completely across the two-lane road. At least half of the cylinders were thrown from the vehicle, and the remainder fell over. The valves were broken off of 52 cylinders, and acetylene was released and ignited. The fire caused

[12] The Safety Board did not investigate this accident.

fusible plugs on other cylinders to melt, which released acetylene that also ignited. About 86 cylinders were damaged by the fire. The tractor and trailer had extensive collision damage; the trailer had some fire damage.

## Unloading Preparation Accidents

### *The Woodlands, Texas*

About 2:55 p.m. on August 7, 2007, acetylene gas ignited on a Western mobile acetylene trailer containing 62 manifolded DOT 8AL specification cylinders (420 standard cubic feet capacity each) resulting in a fire on that trailer and an adjacent trailer at the Hughes Christensen plant in The Woodlands, Texas. (See figure 7.) The fire occurred as the operators were preparing the trailer to be unloaded. There were no injuries or fatalities. Property damage to the two trailers totaled $40,200.

**Figure 7.** Security camera photograph of acetylene gas fire in The Woodlands, Texas.

The trailer had been filled and shipped from the Western plant in Bellville, Texas. The total capacity of the cylinders on the trailer was about 26,040 standard cubic feet of acetylene. A trainee operator was to make his first delivery of a mobile acetylene trailer. An operator trainer accompanied the trainee. The operator trainer had made a few trips in which connections were made to facility piping; however, he usually delivered truckloads of filled and palletized cylinders to customer sites. He had made two earlier trips to The Woodlands, the latest in June 2007. The team said that they had followed the written standard operating procedures when they prepared the trailer and connected it at the Hughes Christensen site. Tape from a security camera showed a person on the trailer moving back and forth along the length; the person appeared to be opening the cylinder valves and pressurizing the manifold. When the accident occurred, the two operators

were standing on the ground at the back of the trailer near the trailer's block valve and attachment to the plant's discharge arm, but the focus of the camera was not adequate to show what they were doing. During postaccident interviews, both operators said that they had believed that they had completed the connection procedures and had pressurized the manifold. They told interviewers that after they had reviewed Western's standard operating procedures manual, however, they realized that they had not opened the block valve before pressurizing the manifold as Western's procedures required. Just after the accident, the trainee operator told a Hughes Christensen employee that the trailer had jumped as they opened the block valve. Shortly after that, the security camera recorded a black plume coming from one of the cylinders on the trailer. (See figure 8.) A similar reaction occurred on other cylinders on the trailer until the released gases ignited. Heat from the fire on the accident trailer caused the release of unreacted acetylene gas on an adjacent trailer.

**Figure 8.** Security camera photograph of black plume coming from a cylinder on trailer in The Woodlands, Texas.

The postaccident examination of the trailer being prepared for unloading revealed that the trailer and manifold piping had some fire damage at and above the level of the top of the acetylene cylinders. There was little damage to the trailer below that level. The cylinders' fusible plugs were all melted, with some evidence of fusible material remaining on the top of some of the cylinders. At least three cylinders in one cluster had visible bulging on their sidewalls just below the circumferential head weld. The cylinder valves appeared to be intact; however, the hand wheels had been consumed in the fire. The pigtails also had evidence of heat exposure but appeared to be intact. The connection fitting from the trailer to the plant piping had a large deposit of black powderlike material inside. A large deposit of the same black material was also in the plant discharge arm at the Hughes Christensen plant. There was no deposit of a similar material in the discharge arm for the second trailer.

The only emergency response fire fighting equipment available at the Hughes Christensen acetylene unloading location was fire extinguishers. There was no automated water deluge system to suppress a fire.

### *Dallas, Texas*

About 9:50 a.m. on July 25, 2007, acetylene gas ignited on a Western mobile acetylene trailer containing 225 manifolded DOT 8AL specification cylinders (450 standard cubic feet capacity each) on the docks at the Southwest Industrial Gases (Southwest) facility in Dallas, Texas. (See figure 9.) The fire occurred as the operator was preparing the trailer to be unloaded. A video recording made by a Dallas television network did not record the initiation of this accident; however, it showed a gradual progression of the fire and explosions from the trailer on which the operator was working to adjacent trailers, to Southwest's building, and to vehicles parked in front, one of which contained acetylene-filled cylinders for delivery. The fire and explosions destroyed the Southwest facility and many vehicles, damaged several nearby buildings, and caused the failure of hundreds of acetylene-filled cylinders from three other Western acetylene trailers,[13] the delivery truck, and the facility's docks and storage. (See figure 10.) The operator sustained back injuries, and the plant manager and general manager were severely burned during the accident. There were no fatalities. Property damages have not been fully assessed, but Southwest estimated losses of more than $5 million.

**Figure 9.** Acetylene gas fire at Southwest facility in Dallas.

[13] The three other trailers were attached to the plant piping and in use at the time of the accident.

**Figure 10.** Dallas accident damage to Southwest facility and vehicles. (Accident trailer and cylinders in foreground.)

The accident trailer was filled and shipped from the BASF Corporation plant in Geismar, Louisiana. The capacity of the cylinders was approximately 100,000 standard cubic feet of acetylene. The operator typically worked in a two-person team that drove, loaded, and unloaded mobile acetylene trailers. The accident occurred during the operator's third delivery to Southwest, which was his first solo delivery to that location. He had made five solo deliveries to other facilities. The operator said that he had followed Western's standard operating procedures when he prepared the trailer for unloading at the Southwest facility. He said that after cycling the facility's discharge arm valve, leaving it closed (step 11 of Western's unloading procedures), he checked the pressure gauges on the manifold and both read 0 psig, which he did not identify as a problem. Step 4 of Western's unloading procedures requires that 50 psig of acetylene pressure remain in the manifold, and discussions with Western management revealed that at the completion of step 11 there should still have been slightly less than 50 psig pressure in the manifold.

The operator said that he had climbed on the bed of the trailer and had begun opening the cylinder valves, beginning with the cylinders at the rear of the trailer on the right side of the vehicle, when he heard a "boom" and felt a pressure surge that threw him back against the support rail for the cylinders on the side of the trailer. He said that he saw black smoke and

flames coming from the top of a cylinder toward the front of the trailer. He then ran from the trailer down the dock and around the building.

A Southwest employee on the facility dock about 8 or 9 feet away from the back of the accident trailer said that about 5 minutes after he saw the operator climb on the trailer he saw black smoke over a 5-foot-high partial wall. He stated that he saw fire coming from one of the two rear cylinders on the right side of the trailer. He said he then heard a loud noise, not an explosion, which he described as pressure being released through an open valve. Then he grabbed a fire extinguisher, ran into the break room, and shouted, "Fire!" He ran out the door toward the trailer as the operator passed him going in the opposite direction. He was not able to use the fire extinguisher because, when he ran onto the dock, a cylinder exploded. He said that before he evacuated he saw the plant manager and general manager using a fire hose on the fire.

The plant manager and the plant general manager heard a loud pressure release noise and ran to the dock. The plant manager said that he saw a gray haze over the trailer, indicating a gas leak. He could not tell where the leak was coming from. The general manager said he saw "a mirage of gas, like you see on a hot day on the highway mixed with black eyelashes" over the accident trailer. He noted that the gas was coming from the back of that trailer.

Both managers then helped operate the fire hose, and both saw cylinder explosions, were knocked down, and received second and/or third degree burns while they were operating the hose. Another employee turned on a permanently mounted water monitor and began spraying water onto the trailer. However, because supplying water to the monitor reduced the water pressure in the fire hose, the water monitor was shut off. The hose was not effective in suppressing the fire, which was extinguished about 9 hours later by the Dallas Fire Department. (See figure 11.) The only fire-fighting equipment available at the Dallas plant included fire extinguishers, one fire hose, and the manually operated water monitor on the roof. There was no automated water deluge system.

Postaccident examination of the accident site revealed that the discharge arm to the accident trailer had broken from the plant's piping and the trailer connection. The discharge arm valve was found in the closed position. No acetylene cylinders were found on the accident trailer. The three other Western mobile acetylene trailers that were attached to Southwest's unloading apparatus were destroyed, although some cylinders remained on two of these trailers. More than 1,000 cylinders from the trailers and from plant inventory were recovered from an area with a radius of about 1/4 mile. (See figure 12.) Although the cylinders from the Western trailers could be differentiated from Southwest's cylinders, Western's records did not identify the cylinders that were mounted on each trailer, so no detailed examinations were performed on the cylinders. A sampling of cylinders of the same size and construction as those from the trailers were visually examined. Damage ranged from a melted fusible plug to a longitudinal tear running the length of the cylinder. In some cases, the top or bottom cylinder head had torn off.

**Figure 11.** Final phase of fire suppression at Southwest facility in Dallas.

**Figure 12.** Dallas cylinder damage.

An examination of postaccident photographs of Southwest's equipment revealed significant problems with Southwest's acetylene compressors. These problems included plugged or missing pressure safety relief devices, pressure safety relief devices with vent piping that did not exit the building, crankcase oil level devices that did not have sight glasses, and an automated emergency shutdown device with a shutdown indicator set to about 420 psig, or 20 psig higher than allowed by the National Fire Prevention Association (NFPA) standards. Also, the flash arrestor tower[14] between the trailer and the plant lacked about 3 feet of its maximum capacity of 13 feet of pall rings or Raschig rings,[15] thus about 10 feet of the rings remained in the flash arrestor. The Western representatives were concerned that a flame front from a failure within the plant may have passed through the flash arrestor and involved the trailers.

## Earlier Western Accidents

Western investigated four earlier accidents that involved its mobile acetylene trailers in the last 10 years; three had some relevance to the four accidents discussed above.

On April 10, 2001, a mobile acetylene trailer containing 227 manifolded cylinders caught fire at Western's plant in Bellville, Texas. The fire destroyed a tractor and two other bulk acetylene trailers. A fourth trailer had minor damage resulting from a tire fire. There were no serious injuries. Western's investigation determined that the fire initiated on the ball of a ball valve on the trailer's manifold system. Western determined that stainless steel shavings had been left inside the manifold piping during the construction of the trailer. When high-pressure acetylene was introduced into the piping, these shavings were entrained in the flow and ignited the acetylene as they struck the ball of the valve.

The damage resulting from this accident was increased by the force of the reaction, causing the failure of several of the pigtails on the manifold, which allowed the fire to escape the system. Flames from the broken pigtails touched the sides of adjacent cylinders, causing one or more of them to rupture. This was followed by the rupture and ejection of most of the remaining cylinders on the trailer. The investigation also determined that at least one cylinder valve was open and that the acetylene from this cylinder provided additional fuel to the reaction. The fire on the initial trailer caused the melting of fusible plugs on cylinders on two adjacent acetylene trailers. This released additional acetylene that also ignited. None of the cylinders on the other trailers failed catastrophically.

As a result of this fire, plantwide water deluge systems were installed in many of Western's facilities. Also, concrete block firewalls were constructed in the trailer gas area at Bellville. Valves were removed from the manifolds on all of Western's trailers, and the system was flushed with high-pressure nitrogen to remove any shavings or other material. The ball

[14] A *flash arrestor tower* is located on a mobile acetylene trailer between the manifold and the plant piping and is designed to stop a decomposition reaction both from occurring and from continuing through the piping if such a reaction was not stopped.

[15] *Pall rings,* or *Raschig rings,* are types of packing in the shape of a short piece of pipe. These are placed into a flash arrestor tower, and because they have a lot of surface area they absorb and dissipate heat from an acetylene reaction.

valves were retrofitted with flash arrestors to slow the actuation of the valve, and "Y" strainers were installed in the manifolds to prevent material in a manifold from reaching the valve.

On June 21, 2001, at Dow Olefin's Seadrift, Texas, plant, a detonation occurred in facility piping at a control valve while a mobile acetylene trailer was being prepared for loading. Both the trailer piping beyond the block valve on the trailer and the plant discharge arm beyond the discharge arm valve were open to the atmosphere before the trailer was connected. Therefore, after the trailer was attached to the plant piping, the piping contained residual air. The explosion self-extinguished, and the operator was not seriously injured. Western's investigation of this accident determined that air had been trapped between two valves as the fill arm was connected to the trailer. Then, as high-pressure acetylene was introduced into the section of piping containing air, the heat of compression caused the acetylene to ignite. Contributing to the accident was a leakage in a facility control valve on the fill line that raised the internal pressure on that line.

As a result of this accident, Western's procedures were changed to require the pressure in the facility fill line to be reduced after disconnecting a trailer and to require the fill arm to be purged with nitrogen after it is connected to a trailer. Also, alarms were installed to detect leaking facility control valves.

On June 8, 2005, a decomposition reaction occurred in the manifold system on a mobile acetylene trailer at Western's Bellville plant that caused the fusible plugs of five cylinders to melt, releasing the products of decomposition. The materials released did not ignite before the deluge system was manually activated, controlling the incident. The incident started when a mobile acetylene trailer, with the cylinder valves open and the manifold fully pressurized, was moved into another bay and the block valve was opened, which initiated an acetylene decomposition reaction.

Western's investigation determined that the accident was caused by a failure to follow Western's procedures that require that all cylinder valves be closed and the manifold pressure be reduced. The quick activation of the water deluge system and workers closing other cylinder valves on the trailer under the protection of the water deluge limited the consequences of the accident. After the accident, Western implemented measures to ensure that its standard operating procedures are followed for all trailers.

# Other Information

## Regulations and Standards

### *Federal Regulations*

Title 49 CFR Subchapter C, Hazardous Materials Regulations, regulates acetylene as a Division 2.1 flammable gas. "Acetylene, dissolved" is the proper shipping name for the material, and it is assigned United Nations identification number UN1001. Section 173.303 of the Hazardous Materials Regulations authorizes acetylene for transportation only in DOT specification 8 or 8AL cylinders or in United Nations cylinders conforming to ISO 3807-2. Transportation of acetylene in bulk packagings, such as cargo tanks, portable tanks, or rail tank cars, is prohibited.

Section 173.301(g) states that cylinders containing acetylene and other regulated gases can be manifolded during transportation. However, the manifolded cylinders must conform to the following conditions: (1) manifolded branch lines must be sufficiently flexible to prevent damage to the valves; (2) the cylinders must be supported and held together as a unit by structurally adequate means; (3) each cylinder must be equipped with an individual shutoff valve that is tightly closed in transit and an individual pressure relief device that discharges upward; and (4) the valves and pressure relief devices must be protected from damage by framing, a cabinet, or other method.

Section 177.834(h) states that except for cargo tanks and portable tanks, the discharge or emptying of a package's contents before the package is removed from the motor vehicle is prohibited. However, as a direct result of the Dallas and The Woodlands accidents, the Pipeline and Hazardous Materials Safety Administration (PHMSA) issued a safety advisory in September 2007 that stated that this prohibition does not apply in all circumstances. For example, PHMSA said that it has interpreted the prohibition in section 177.834(h) as not applying to tube trailers, which are DOT specification 3AX, 3AAX, and 3T cylinders securely mounted (horizontally) to a transport vehicle, because removing them from the motor vehicle before discharging their contents is not practicable. PHMSA added that it has long applied the same standard to discharge operations involving manifolded acetylene cylinders that are securely mounted to a motor vehicle.

In addition, PHMSA stated the following:

> ... because of acetylene's volatility and instability, we have determined that the safety risks associated with removing individual acetylene cylinders from a manifolded system that conforms to [the Hazardous Materials Regulations] requirements and industry standards are far greater than the safety risks associated with discharging cylinder contents while the manifolded cylinders are securely mounted on the vehicle.

### *Industry Standards*

The Compressed Gas Association's (CGA's) publication G-1.6, *Recommended Practices for Mobile Acetylene Trailer Systems,* provides safe practices for the design, construction, and operation of mobile acetylene trailer systems. The publication also provides recommended safe practices for auxiliary equipment used in conjunction with mobile acetylene trailers, including piping, regulators, flash arrestors, and meters. The relevant areas addressed by the publication are the following:

In section 4, "Design and construction"

- Piping must: … be braced and supported ….
- Leads between cylinders and manifolds must be sufficiently long and flexible to minimize strain on valves and leads.
- Manifolds must be equipped with a shut-off valve, pressure gauge, and vent.
- Vents and pressure relief devices must be directed upwards above the acetylene piping
- Cylinders must: conform to the Hazardous Materials Regulations; be vertical, supported, and secured; have valves that are capable of being closed in the event of an emergency; … and be arranged in aisles to allow access.

In section 5, "Operation"

- Valves must be closed during transportation.
- Acetylene pressure must be maintained in leads and manifolds during delivery and return shipments.
- During any manual valve operations, or when the trailer is being connected or disconnected, a trained person must be in attendance.

In section 7, "General provisions"

- Charging and discharging stations for mobile acetylene trailers must be provided with conspicuously located and easily accessible fire hoses or fixed spray systems and dry chemical fire extinguishers. Nozzles on fire hoses should be of the type that adjusts from full stream to a fog pattern.

The CGA publication G-1.2, *Acetylene Metering and Piping,* also provides recommended practices for use with acetylene trailers and in acetylene processing facilities. Section 14.2.1.3, "Design," specifically addresses the construction and maintenance of flash arrestors:

NFPA 70[16] recommends 6.5 feet (2 meters) packed height in a wetted tower in low pressure service, though successful tests were made with a packed height of 40 inches (102 centimeters). The code further recommends that the packed height be doubled for dry-packed arrestors. The packing should be examined at intervals no longer than 1 year for conditions of settling, corrosion, and plugging.

## Postaccident Activities

Since the accidents, Western has made a number of changes to its procedures and equipment to address problems identified during the investigations. The company has improved its procedures for preparing trailers for unloading at customer sites, provided additional equipment for trailer and cylinder safety, reviewed its customers' facilities to insure their safe operation, and installed water deluge systems at customer facilities. These measures are described below.

Western operators preparing their trailers for unloading at facilities without computer-generated instructions are now required to call the Western headquarters control room operator five times throughout the process to verify that critical steps are performed in the proper sequence. During each of the five calls, the control room operator verifies that the current step has been performed before allowing the operator to proceed to the next step in the sequence.

The additional safety equipment Western is installing includes flash arrestors on every mobile acetylene trailer line between the manifold and the trailer loading and unloading attachments to stop the propagation of an acetylene flame front and decomposition reaction between the trailer and the plant. Also, valve protection caps will be installed on all cylinders mounted on mobile acetylene trailers.

Regarding the safety of its customers' facilities, Western has performed enhanced surveys at all customer facilities to ensure they are compliant with all applicable codes, regulations, and industry practices. Western's management has stated that automated water deluge systems have prevented escaping acetylene from igniting and would have prevented the property damage and injuries that occurred in these accidents had such systems been in place. Since these accidents, Western has completed installation of water deluge systems at every customer's unloading site and will require them to be installed at future customer sites.

[16] NFPA 70 does not address packed height in flash arrestors, and the NFPA has found no reference for this section.

# Analysis

Transporting acetylene cylinders poses risks because of the inherent reactivity of the gas. Additional risk is incurred when the cylinders are moved at speed on roads because the risk of a motor vehicle accident is added. Although the causes of the highway accidents addressed in this report include a driver falling asleep, that cause and others such as driver error are not included in this analysis. Rather, we have documented and analyzed the results of mobile acetylene trailer accidents in an attempt to identify ways to reduce the risk of fire.

When a mobile acetylene trailer is not on the road but is loading or unloading, the reactivity of acetylene gas requires that specific procedures be followed to ensure safety. In these accidents, the operators carried standard procedures lists that they were supposed to follow; nevertheless, steps were performed out of order or incorrectly. Therefore, we looked at the loading/unloading processes in their entirety, focusing on ways to guide and assist operators as they perform their complex tasks.

## Overturn Accidents

In the East New Orleans, Louisiana, accident in which the tractor and mobile acetylene trailer overturned, the cylinders mounted on the trailer were thrown from the vehicle. The postaccident examination of the cylinders recovered from the scene revealed that 32 of the cylinders recovered had their valves broken off during the accident, releasing acetylene that ignited. Similarly, in the Lamar, Colorado, accident, about half of the 225 cylinders were thrown from the trailer. The postaccident examination of the cylinders recovered from the scene revealed that 86 of the cylinders had their valves broken off during the accident, resulting in the release and ignition of the residual acetylene. An examination of these cylinders showed that the fire from the cylinders with broken valves caused the fusible plugs of other cylinders to melt, releasing additional acetylene that ignited. Possible ignition sources include the generation of a static charge in the rapidly escaping acetylene and solvent and a spark caused by the steel cylinders striking concrete, rocks or stones, or the road surface.

The Safety Board concludes that the fires in the East New Orleans, Louisiana, and Lamar, Colorado, accidents occurred as a result of the ejection of unsecured cylinders during the rollovers of the mobile acetylene trailers, resulting in damage to many of the cylinder valves and the release of acetylene, which then ignited.

These two accidents demonstrate the high likelihood of an acetylene release and fire when cylinder valves are damaged in rollover accidents. With the extreme flammability of acetylene, undamaged cylinders in proximity to burning cylinders are likely to become involved in a fire. In overturn accidents in which a mobile acetylene trailer rolls onto its side, unprotected or unrestrained cylinders may be ejected from the trailer, as occurred in these two accidents. Ejection of cylinders from a trailer in an accident significantly increases the likelihood of damage to the cylinder valves. In the event that cylinders remain secured to the trailer in an

overturn, their valves can be damaged by guard rails and other roadside objects and even contact with the road surface. With the extreme flammability and reactivity of acetylene, undamaged cylinders close to burning acetylene cylinders are also very likely to become involved in a fire.

The cylinders in these two accidents were not adequately secured to the trailers to prevent their ejection during overturn. Current DOT regulations for manifolded cylinder systems on trailers, such as mobile acetylene trailers, require only that each cylinder be equipped with an individual shutoff valve that is tightly closed in transit and that the valves and pressure relief devices be protected from damage by framing, a cabinet, or other method. Current Federal regulations do not set sufficient standards for the level of protection that must be provided. To reduce the risks of transporting acetylene, cylinders must remain secured to the trailer during a rollover accident, and the cylinder valves must be protected from impact and damage.

Therefore, the Safety Board concludes that the requirements in the Hazardous Materials Regulations covering mobile acetylene trailers do not sufficiently address (1) the protection of the cylinders, valves, and fittings on the trailers from impact forces that occur during an overturn accident and (2) the secure mounting of the cylinders to the vehicles. The Safety Board believes that PHMSA should modify 49 *Code of Federal Regulations* 173.301 to clearly require (1) that cylinders be securely mounted on mobile acetylene trailers and other trailers with manifolded cylinders to reduce the likelihood of cylinders being ejected during an accident and (2) that the cylinder valves, piping, and fittings be protected from multidirectional impact forces that are likely to occur during highway accidents, including rollovers.

## Unloading Accidents

The two unloading accidents occurred when the mobile acetylene trailers were connected to piping at loading/unloading plants while the operators were preparing the trailers to be unloaded.

### *The Woodlands, Texas*

The accident in The Woodlands, Texas, was described in detail by witnesses and recorded by a security camera at the plant. According to the statements of the operators and the video recording, the team had completed connecting their trailer to the plant's discharge arm and had pressurized the trailer manifold by opening all of the cylinders on the trailer. At that point, the team realized that they had not opened the trailer's block valve. They then opened the valve. According to the team's initial statement to emergency responders, when they opened the block valve they heard a loud noise and felt the trailer shake. As noted previously, opening the block valve allows highly pressurized acetylene to enter a blocked section of piping that contains residual air, which is dangerous because (1) a blocked pipe potentially can cause a reflected shockwave that can initiate a decomposition reaction and (2) pressurized acetylene that mixes with air inside piping can ignite easily with little energy input. The black plume rising from the top of a cylinder seen in the security camera video is an indication that an acetylene decomposition reaction had occurred on the trailer. With this evidence of the decomposition

reaction, the black powder found in the fitting between the trailer and the plant piping and in the plant discharge arm was determined to be carbon, which is a byproduct of a decomposition reaction. The Safety Board concludes that the ignition of the acetylene in the accident in The Woodlands, Texas, likely occurred because of the operators' failure to follow Western's standard operating procedures, which resulted in the introduction of high-pressure acetylene into closed piping that contained air, which in turn initiated an acetylene decomposition reaction.

### *Dallas, Texas*

The video recording of the Dallas, Texas, accident did not record the initiation of the accident, and the operator and other witnesses made contradictory observations about the initiation of the accident. In addition, representatives of Western expressed concern that a flame front caused by a failure within the plant's compressor system may have passed through the poorly maintained flash arrestor and started the fire on the accident trailer. Several varying scenarios of the initiation of the accident were considered and discounted during the investigation.

The first scenario was the catastrophic failure of a cylinder. The operator said that he heard an explosion and was thrown back by it and then he saw a black plume coming from one of the closed cylinders; such a plume is an effect of the venting of carbon, which is a byproduct of an acetylene decomposition reaction. An explosion of sufficient force to throw an adult requires a large pressure surge, and an acetylene cylinder failing catastrophically was the only source on the trailer that was capable of such a surge. However, the operator was not burned, and neither he nor the nearby witness observed a fireball or explosive damage to the trailer during the initial stage of the accident, which could be expected in the event of catastrophic failure of an acetylene cylinder. Further, the witness did not hear an explosion despite being only about 9 feet from the trailer. In addition, there were no known conditions that could have caused a catastrophic cylinder failure; the cylinders on the trailer had been filled more than 10 hours before the accident, and the closed cylinders had not been handled since the trailer was backed into the unloading area. Therefore, it is unlikely that a catastrophic cylinder failure caused this accident.

The second scenario was a fire originating in the plant's compressor system that resulted in a flame front passing through the plant's piping, through the flash arrestor, and into the accident trailer. All the witnesses stated that the first events occurred on the accident trailer: the first black plume was observed coming from the trailer, the trailer was surrounded by vapor, and the video recordings showed the trailer fully engulfed in fire before the fire progressed to the three adjacent trailers. Given the extreme reactivity of acetylene and the explosive propagation of a decomposition reaction through open piping, the three other trailers that had valves open to the plant piping likely would have been affected immediately had the fire originated in the plant rather than at the accident trailer. More important, the plant's discharge arm valve, between the plant piping and the accident trailer, was closed, so there was no channel through which the flame front could enter the trailer. Therefore, it is unlikely that a fire that originated in the plant passed into the accident trailer and caused the accident.

The most likely scenario was the initiation of an acetylene decomposition reaction on the accident trailer. This is supported by witness observations of a black plume over the trailer and the operator's postaccident statement that the trailer's pressure gauges indicated that the pressure in the manifold was 0 psig after the operator had cycled the valve on the plant's discharge arm, leaving it closed. Because Western's standard operating procedures mandate that 50 psig of pressure be maintained in the manifold between the completion of the leak test and the opening of the discharge arm valve, a pressure reading of 0 psig indicate that the unloading procedures had not been performed correctly. The lack of positive pressure in the manifold likely allowed some air to enter the manifold. In addition, had there been 0 psig acetylene pressure in the manifold when the operator connected the trailer to the plant's discharge arm, the procedures used to mix acetylene and the air in the connection fittings at low pressure would have been ineffective and air could have remained in that area. As the operator began opening the cylinder valves and introduced pressurized acetylene into the manifold, the pressure surge likely hit the closed discharge arm valve and was reflected, generating heat that was sufficient to ignite the acetylene-air mixture in the manifold. The air was quickly consumed, and a decomposition reaction propagated through the manifold and into the trailer's cylinders through their open valves. The heat from the reaction inside the cylinders melted the cylinders' fusible plugs and released black plumes. Finally, when the released products of decomposition (hydrogen gas and carbon) ignited, the fire heated nearby cylinders, causing their fusible plugs to melt, releasing acetylene gas that then ignited, and fire engulfed the accident trailer. The fire then spread by radiant heat to the three adjacent trailers. Had the manifold pressure been maintained at 50 psig, as required by Western's standard operating procedures, air could not have entered the manifold piping to lower the ignition temperature of the acetylene, and the air between the block valve on the trailer and the plant discharge arm valve would have mixed safely with the acetylene entering from the manifold.

Therefore, the Safety Board concludes that the ignition of the acetylene in the Dallas, Texas, accident likely occurred as a result of the operator's failure to follow Western's standard operating procedures, which resulted in the reduction of the pressure in the manifold to 0 psig, allowing air to enter the manifold and initiating a decomposition reaction when pressurized acetylene was subsequently introduced into the manifold.

Because the Dallas and The Woodlands accidents likely were initiated by the failure of operators to correctly perform Western's detailed unloading procedures, the Safety Board evaluated Western's unloading requirements. Each trailer operator carried a detailed standard operating procedures manual for reference and guidance during loading and unloading. However, in both these accidents, the operators did not perform the unloading procedures correctly or in the proper sequence, which resulted in the acetylene decomposition reactions. In The Woodlands, when the operators realized that they had not performed a required step, they performed the skipped step after they realized their omission. In Dallas, the operator did not recognize that the lack of pressure in the trailer manifold, at a step in the process in which some pressure should be maintained in the manifold, indicated that the unloading procedures had not been performed correctly.

Federal regulations and CGA guidance concerning mobile acetylene trailers focus on design and are silent concerning trailer unloading procedures other than the recommendation that a trained person be in attendance during manual valve operations and when a trailer is being connected or disconnected.

The accidents in Dallas and The Woodlands demonstrate the catastrophic results that can occur when the unloading procedures are not followed exactly. Despite the detailed written unloading procedures Western developed and implemented, the procedures were not sufficient to safeguard against the initiation of a decomposition reaction within the manifold piping and cylinders when simple human errors occurred, as they will from time to time. The complexity of the unloading procedures and the extreme instability of acetylene together created situations having little or no room for human error. The Safety Board, therefore, concludes that because of the instability of acetylene, the current acetylene unloading procedures by themselves are not adequate to ensure safety. The Safety Board believes that PHMSA should require fail-safe equipment that ensures that operators of mobile acetylene trailers can perform unloading procedures only correctly and in sequence.

## Fire Suppression at Unloading Sites

There was no automated water deluge system at either The Woodlands or Dallas. Western installed automated water deluge systems at many of its facilities after the April 10, 2001, mobile acetylene trailer fire at its Bellville, Texas, facility. According to Western, the effectiveness of such systems at controlling the spread of fire to other cylinders on the same trailer and from one trailer to the next was proven at the June 8, 2005, decomposition reaction that also occurred at Bellville. The actuation of the water deluge system limited the spread of the fire to other cylinders on the same trailer. In the Dallas accident, attempts to extinguish the fire using a fire hose were ineffective. Had the unloading facilities at The Woodlands and Dallas had automated water deluge systems, the fires also may have been controlled and the spread of fire between the cylinders and to the nearby mobile acetylene trailers may have been reduced or eliminated. After these accidents, Western completed installation of water deluge systems at all Western-owned and customer unloading sites, including The Woodlands. However, the CGA standards require only conspicuously located and easily accessible fire hoses or fixed spray systems and dry chemical fire extinguishers. Automated water deluge systems, which appear to be effective on acetylene cylinder fires, are not required by the CGA standards. Therefore, the Safety Board believes that the CGA should revise the recommended practices in CGA standard G-1.6, section 7, *General Provisions,* to require automated water deluge systems at all mobile acetylene trailer loading and unloading locations to control the spread of fire to other cylinders on a trailer and to nearby mobile acetylene trailers.

# Conclusions

## Findings

1. The fires in the East New Orleans, Louisiana, and Lamar, Colorado, accidents occurred as a result of the ejection of unsecured cylinders during the rollovers of the mobile acetylene trailers, resulting in damage to many of the cylinder valves and the release of acetylene, which then ignited.

2. The requirements in the Hazardous Materials Regulations covering mobile acetylene trailers do not sufficiently address (1) the protection of the cylinders, valves, and fittings on the trailers from impact forces that occur during an overturn accident and (2) the secure mounting of the cylinders to the vehicles.

3. The ignition of the acetylene in the accident in The Woodlands, Texas, likely occurred because of the operators' failure to follow Western International Gas & Cylinders, Inc.'s, standard operating procedures, which resulted in the introduction of high-pressure acetylene into closed piping that contained air, which in turn initiated an acetylene decomposition reaction.

4. The ignition of the acetylene in the Dallas, Texas, accident likely occurred because of the operator's failure to follow Western's standard operating procedures, which resulted in the reduction of the pressure in the manifold to 0 psig, allowing air to enter the manifold and initiating a decomposition reaction when pressurized acetylene was subsequently introduced into the manifold.

5. Because of the instability of acetylene, the current acetylene unloading procedures by themselves are not adequate to ensure safety.

# Recommendations

As a result of its investigation of the mobile acetylene trailer accidents in East New Orleans, Louisiana, on October 20, 2007; in Dallas, Texas, on July 25, 2007; and in The Woodlands, Texas, on August 7, 2007, the National Transportation Safety Board makes the following safety recommendations:

**To the Pipeline and Hazardous Materials Safety Administration:**

Modify 49 *Code of Federal Regulations* 173.301 to clearly require (1) that cylinders be securely mounted on mobile acetylene trailers and other trailers with manifolded cylinders to reduce the likelihood of cylinders being ejected during an accident and (2) that the cylinder valves, piping, and fittings be protected from multidirectional impact forces that are likely to occur during highway accidents, including rollovers. (H-09-01)

Require fail-safe equipment that ensures that operators of mobile acetylene trailers can perform unloading procedures only correctly and in sequence. (H-09-02)

**To the Compressed Gas Association:**

Revise the recommended practices in Compressed Gas Association standard G-1.6, section 7, *General Provisions,* to require automated water deluge systems at all mobile acetylene trailer loading and unloading locations to control the spread of fire to other cylinders on a trailer and to nearby mobile acetylene trailers. (H-09-03)

## BY THE NATIONAL TRANSPORTATION SAFETY BOARD

**MARK V. ROSENKER**
Acting Chairman

**ROBERT L. SUMWALT**
Member

**DEBORAH A. P. HERSMAN**
Member

**STEVEN R. CHEALANDER**
Member

**KATHRYN O'LEARY HIGGINS**
Member

**Adopted: January 13, 2009**

Kathryn O'Leary Higgins, Member, filed the following concurring statement on January 9, 2009.

# Board Member Statement

**Member Kathryn O'Leary Higgins, concurring:**

I concur in this special investigation report on mobile acetylene trailer accidents and am pleased that our hazardous materials investigators looked at several accidents and proposed recommendations to the Pipeline and Hazardous Materials Safety Administration to improve the handling and securing of acetylene tanks. But I write this statement because I am concerned that we do not address the reasons that two of these accidents occurred.

Two of the four operators overturned their vehicles. I have reviewed the police reports for the two rollover accidents that are part of the docket for this special investigation report. The report of the rollover accident in East New Orleans, Louisiana indicates driver condition (falling asleep) as the cause of the accident. No drug or alcohol tests were administered. The report for the Lamar, Colorado accident is much less specific, and the driver's actions are not explained. It indicates that the truck left the road to the right, hit a post, was steered to the left back on to the road and rolled over. Nothing was said in the report about the driver's condition.

Based on the limited information in the police reports, it seems that these rollover accidents would not have occurred but for driver error. I believe we should have looked more closely at driver issues, including the experience and training of these drivers and their recent history, as part of our special investigation to try to determine what led to these accidents. Once we identified our interest in these accidents, I believe we should have asked our highway investigators to assist our hazardous materials team so we could answer questions about driver performance and company practice. But without such investigation, we do not know what really caused these accidents and how they might be prevented in the future. There are only two companies that transport acetylene. It should not have been too difficult to take a closer look at their operations as part of this investigation to better understand their practices and policies for their drivers.

The NTSB is a small agency and our resources are limited. We cannot do everything, but if we decide to look more closely at accidents because of the hazardous materials release and subsequent fires, I think we should take the steps necessary to understand what caused the accidents in the first place. I also understand that our limited approach is consistent with other special investigations. Our recommendations, if adopted, will improve how these canisters are mounted, secured and handled – and that will be a solid safety improvement. But our failure to look more closely at driver performance is a missed opportunity to understand what led to two of these accidents and to make recommendations to prevent such accidents in the future.

# Appendix A

## Investigation

The National Transportation Safety Board was notified of the Dallas, Texas, accident on July 27, 2007; however, the initial information did not indicate that it was a transportation incident. The Chemical Safety Board launched on the accident. When the National Transportation Safety Board received information that vehicle unloading was involved in the accident, a highway investigator from the Dallas regional office was dispatched to the site. On August 1, 2007, a hazardous materials investigator from the Washington, D.C., headquarters was assigned as investigator-in-charge of the National Transportation Safety Board's investigation and dispatched to the carrier's headquarters. On August 7, 2007, the Chemical Safety Board notified the National Transportation Safety Board of a second accident involving the unloading of a similar vehicle in The Woodlands, Texas. On August 9, 2007, the hazardous materials investigator from the Washington, D.C., office was dispatched to investigate this accident as well. On October 20, 2007, the National Transportation Safety Board was notified of the overturn of a similar vehicle in East New Orleans, Louisiana. On October 23, 2007, the hazardous materials investigator from Washington, D.C., traveled to New Orleans to begin the investigation of this accident also. One group was established to investigate all three hazardous materials accidents. On January 18, 2008, the Chemical Safety Board announced that it was discontinuing its investigations of the Dallas and The Woodlands, Texas, incidents to avoid duplication of effort.

Participating in the investigations were representatives of the Pipeline and Hazardous Materials Safety Administration and Western International Gas & Cylinders, Inc.

No depositions were taken, and there was no public hearing.

## ATTACHMENT B

## 49 CFR 171.7 (inclusion in the reference table)

## 49 CFR 173.301 (g)

(g) *Manifolding cylinders in transportation.* (1) Cylinder manifolding is authorized only under conditions prescribed in this paragraph (g). Manifolded cylinders must be supported and held together as a unit by structurally adequate means. Except for Division 2.2 materials, each cylinder must be equipped with an individual shutoff valve that must be tightly closed while in transit. Manifold branch lines must be sufficiently flexible to prevent damage to the valves that otherwise might result from the use of rigid branch lines. Each cylinder must be individually equipped with a pressure relief device as required in paragraph (f) of this section, except that pressure relief devices on manifolded horizontal cylinders that are mounted on a motor vehicle or framework may be selected as to type, location, and quantity according to the lowest marked pressure limit of an individual cylinder in the manifolded unit. The pressure relief devices selected for the manifolded unit must have been tested in accordance with CGA S–1.1 and CGA S–7. Pressure relief devices on manifolded horizontal cylinders filled with a compressed gas must be arranged to discharge unobstructed to the open air. In addition, for Division 2.1 (flammable gas) material, the pressure relief devices (PRDs) must be arranged to discharge upward to prevent any escaping gas from contacting personnel or any adjacent cylinders. Valves and pressure relief devices on manifolded cylinders filled with a compressed gas must be protected from damage by framing, a cabinet or other method. Manifolding is authorized for cylinders containing the following gases:

(i) Nonliquefied (permanent) compressed gases authorized by §173.302.

(ii) Liquefied compressed gases authorized by §173.304. Each manifolded cylinder containing a liquefied compressed gas must be separately filled and means must be provided to ensure no interchange of cylinder contents can occur during transportation.

(iii) Acetylene as authorized by §173.303 must be transported in accordance with CGA G-1.6.

(2) For the checking of tare weights or replacing solvent, the cylinder must be removed from the manifold. This requirement is not intended to prohibit filling acetylene cylinders while manifolded.

# CGA G-1.6—2011

# STANDARD FOR MOBILE ACETYLENE TRAILER SYSTEMS

SEVENTH EDITION

COMPRESSED GAS ASSOCIATION, INC.

**PLEASE NOTE:**

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Work Item 15-013
Acetylene Committee

NOTE—Due to extensive changes in this document, technical changes from the previous edition are not identified.

SEVENTH EDITION: 2011
SIXTH EDITION: 2008
FIFTH EDITION: 2007
FOURTH EDITION: 1996

**Contents** **Page**



**Figures**



**Tables**

# 1 Introduction

This standard is one of a series compiled to provide information relative to the production, transportation, handling and storage of compressed gases, cryogenic liquids, and related products.

# 2 Scope

This standard contains the minimum requirements necessary for the design, construction, and operation of mobile acetylene trailer systems (MATS) consisting of trailers having acetylene cylinders manifolded for the purposes of charging, transporting, and discharging acetylene. It also covers ground-mounted auxiliary equipment used with the MATS such as piping, regulators, flash arrestors, and meters.

# 3 Definitions

For the purpose of this standard, the following definitions apply.

### 3.1 Acetylene trailer
Open transport vehicle designed to be towed that consists of a group or groups of acetylene cylinders secured in accordance with Title 49 of the U.S. *Code of Federal Regulations* (49 CFR) 393.102 or Part 1 of the National Safety Code (NSC) Standard 10, *Cargo Securement,* as adopted by provincial and territorial regulations in Canada, and manifolded together as a single unit, for filling, transporting, and delivering acetylene [1, 2].[1]

### 3.2 Authority having jurisdiction (AHJ)
Organization, office, or individual responsible for enforcing the requirement of a code or standard or responsible for approving equipment, materials, installations, or procedures.

### 3.3 Charging
Process of filling containers to limits authorized by DOT/TC for a specific product including mixtures.

### 3.4 Deluge sprinkler system
Sprinkler system employing open sprinklers that are attached to a piping system that is connected to a water supply through a valve that is opened by the operation of a detection system installed in the same areas as the sprinklers. The sprinkler systems shall also be able to be activated manually. When this valve opens, water flows into the piping system and discharges from all sprinklers attached thereto [3].

### 3.5 Department of Transportation (DOT)
U.S. Department of Transportation is a federal body authorized to formulate, administer, and enforce regulations for the safe transportation of hazardous materials within the United States.

### 3.6 Detached building
Separate single-story building, without a basement or crawl space, used for the storage or use of hazardous materials and located an approved distance from all structures [4].

### 3.7 Discharging
Withdrawal of product from a container.

### 3.8 DOT *Hazardous Materials Regulations*
Federal regulations set forth by DOT for the preparation, acceptance, and transportation of hazardous materials within the United States.

### 3.9 Fast acting detection system
Detection system designed to detect a fire more rapidly than standard smoke or heat detectors. Examples for outdoor installations are optical (UV/IR) systems that detect visible flames and do not rely on products of combustion to be transported by the energy of the heat plume to the location of the detector. For indoor installations examples include high sensitivity smoke detection (HSSD), optical (UV/IR), or other early detection systems.

[1] References are shown by bracketed numbers and are listed in order of appearance in the reference section.

### 3.10 *Federal Motor Carrier Safety Regulations*
Safety regulations set forth by DOT for the construction, operation, inspection, maintenance, repair, and testing of commercial motor vehicles on federal highways in interstate commerce.

### 3.11 Fill valve
Shutoff valve on the charging system for filling MATS where the acetylene supply first enters the charging connection.

### 3.12 Fire barrier
Fire-resistant rated wall assembly of materials designed to restrict the spread of fire.

### 3.13 Fire wall
Fire-resistant rated wall that restricts the spread of fire and extends continuously from the foundation to or through the roof with sufficient structural stability under fire conditions to allow collapse of construction on either side without collapse of the wall.

### 3.14 Mobile acetylene trailer systems (MATS)
System that integrates an acetylene trailer with piping, controls, and protective equipment for delivering acetylene.

NOTE—The system includes the acetylene trailer, pressure control device(s), flash arrestors, protective devices, meter (optional), and interconnecting piping. The system terminates at the source valve.

### 3.15 Mobile acetylene trailer systems (MATS) building
Single-story detached building, without an attic, basement, crawl space, or false ceiling, used for acetylene trailer(s) or MATS operations located indoors and the balance of the building is used exclusively for acetylene operations including storage and use of hazardous materials.

### 3.16 Mobile acetylene trailer systems (MATS) fire area
Area or footprint occupied by the mobile acetylene trailer(s) to include the control system up to the point of the source valve for MATS being discharged or to the point of the fill valve for MATS being charged.

### 3.17 Outdoor installation
Uncovered area or weather protection used for parking one or more acetylene trailers that contains loading/unloading hoses, piping, and/or controls.

### 3.18 Source valve
Shutoff valve on the piping system serving MATS where the acetylene supply first enters the user's supply line.

### 3.19 Transport Canada (TC)
Transport Canada is the Canadian government body authorized to administer and enforce regulations for the safe transportation of all dangerous goods within Canada.

### 3.20 Weather protection
An outdoor structure constructed of noncombustible materials that is open without sidewalls on 75% or more of the perimeter and a roof.

## 4 Design and construction

MATS shall be designed and installed so a decomposition or flashback either cannot occur or is contained by the system.

### 4.1 Trailer

The trailer shall be designed, constructed, maintained, and operated in compliance with all applicable regulations and this standard. Figures 1 and 2 are views of typical acetylene trailers.

A connection shall be provided to ground and bond the trailer during loading and unloading operations in accordance with National Fire Protection Association (NFPA) 70, *National Electrical Code*® [5]. Cylinders, trailer structure, and the trailer piping manifold shall be electrically bonded.

**Figure 1—Typical acetylene trailer**


**Figure 2—Rear view of typical acetylene trailer**

## 4.2 Piping

Piping and tubing systems for MATS shall be designed, constructed, inspected, and tested in accordance with the applicable requirements of American Society of Mechanical Engineers (ASME) B31.3, *Process Piping* [6].

Acetylene piping installed at discharge stations, up to the point where the acetylene first enters the user's system, shall be identified in accordance with ASME A13.1, *Scheme for the Identification of Piping Systems* [7].

Piping on an acetylene trailer shall be braced and supported to resist strain and vibration normally incident to transportation.

Tubing and cylinder leads shall be flexible to prevent damage to valves, gauges, and fittings during transit.

Acetylene piping, tubing, fittings, gauges, and other associated equipment shall be carbon steel, stainless steel, wrought iron, malleable iron, or copper alloys meeting the following requirements:

- Unalloyed copper, silver, or mercury shall not be used where they can be exposed to acetylene or to liquids containing acetylene in solution; and
- Copper alloys containing more than 65% copper shall not be exposed to acetylene unless such alloys are compatible with the specific application by experience or by test (e.g., welding tips, Bourdon tubes, metal filters, etc.) For more information, see CGA G-1, *Acetylene* [8].

For pressures exceeding 15 psig (103 kPa)[2]:

- Pipe, tubing, and fittings shall be rated for a minimum working pressure of 3000 psig (20 680 kPa);
- Piping of nominal sizes 1 in (2.5 cm) and less shall be a minimum of Schedule 80;
- Piping of nominal sizes exceeding 1 in (2.5 cm) and less than or equal to 1-1/2 in (3.8 cm) shall be a minimum of Schedule 160;
- Piping and tubing shall be hydrostatically tested at a pressure not less than 4500 psig (31 030 kPa) at the time of fabrication or assembly and after cutting, welding, threading, or other similar repairs are performed on the piping system:
  - Hoses and cylinder leads hydrostatically tested at a pressure not less than 4500 psig (31 030 kPa) at the time of manufacture and not welded or brazed to the manifold do not require hydrostatic testing at the time of trailer fabrication
  - Pressure relief valves, pressure gauges, diaphragm valves, and regulators shall not be required to be hydrostatically tested
  - Flash arrestors shall not be included in hydrostatic testing because the water can cause them to plug;
- Following hydrostatic testing, piping and tubing shall be pneumatically leak tested using nonliquefied inert gas or air and the parameters below:
  - The system shall be pressurized to 600 psig (4140 kPa) and tested by measuring pressure degradation over a minimum 8-hour period with the component being tested isolated from the pressure source
  - The maximum temperature compensated pressure variation shall not exceed 15 psi (103 kPa, differential)
  - Pressure relief devices shall be exempt from pneumatic testing; and
- Upon completion of fabrication and testing, piping and tubing shall be cleaned of foreign material and, if required, dried. All water must be drained from the system and all traces must be thoroughly evaporated

[2] kPa shall indicate gauge pressure unless otherwise noted as (kPa, abs) for absolute pressure or (kPa, differential) for differential pressure. All kPa values are rounded off per CGA P-11, *Metric Practice Guide for the Compressed Gas Industry* [9].

before the introduction of acetylene. The evaporation is accomplished by purging with an inert gas, which may be heated to shorten drying time.

Cylinder leads connecting cylinders to manifolds shall be designed to resist strain and vibration encountered when the trailer is in transit.

All cylinder leads shall have a minimum working pressure of 3000 psig (20 680 kPa), a minimum burst rating of 10 000 psig (69 000 kPa), and be constructed of materials compatible for use with acetylene, and the solvent in the cylinders.

A manifold valve shall be provided at each point where a single cylinder or a group of cylinders connects into the manifold.

Each manifold or manifold section shall be equipped with a:

- shutoff valve;
- pressure gauge; and
- means for purging and/or venting. See Figure 3.

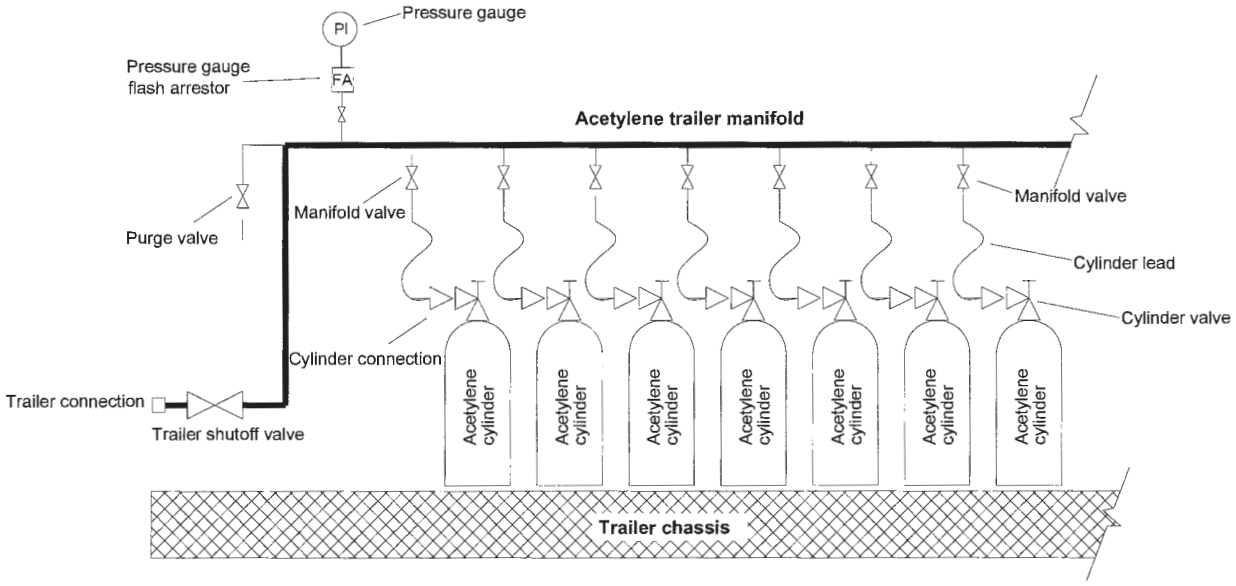


**Figure 3—Typical acetylene trailer manifold diagram**

## 4.3 Cylinders

In the United States, all cylinders used for acetylene service shall comply with DOT Specification DOT-8, DOT-8AL, ICC-8, ICC-8AL, DOT SP-6517, or DOT SP-10320 [1]. In Canada, all cylinders shall comply with Specifications TC-8WM or TC-8WAM or shall be grandfathered cylinders in use in Canada before January 1, 1993, that were manufactured in accordance with Specifications CTC-8, CTC-8AL, CTC-8WC, or one of the aforementioned DOT or ICC specifications [10, 11]. DOT approved UN cylinders conforming to ISO 3807-2, *Cylinders for acetylene—Basic requirements—Part 2: Cylinders with fusible plugs* and 49 CFR 178.71 are also authorized in the United States [12, 1].

NOTE—Requirements for UN cylinders in Canada are specified in CSA B341, *UN Pressure Receptacles and Multiple-Element Gas Containers For The Transport Of Dangerous Goods* and CSA B342, *Selection and Use of UN Pressure Receptacles and Multiple-element Gas Containers for the Transport of Dangerous Goods, Class 2*, which have not yet been adopted into the *Transportation of Dangerous Goods Regulations* [13, 14, 15]

Manifolded cylinders shall be transported vertically and secured together as a unit in accordance with 49 CFR 393.102 or Part 1 of NSC Standard 10, as adopted by provincial and territorial regulations in Canada [1, 2].

All manifolded cylinders shall be equipped with valves having a hand wheel, a wrench operated valve, or a quick shutoff mechanism to allow quick closure in the event of an emergency. If tools are required to close the valve, they shall be on the trailer.

Manifolded cylinders, on a single acetylene trailer, shall have equal marked gas capacities determined by dimensions, porous mass, and type of solvent.

Manifolded cylinder valves shall be provided with valve protection meeting the requirements of DOT *Hazardous Materials Regulations* (see 49 CFR Parts 100-185) [1]. Valve protection shall be retrofitted to existing trailers on or before April 1, 2012.

Cylinders shall be arranged in aisles to allow access to all valves for leak testing and quick closure in the event of an emergency.

The acetylene trailer shall be marked with UN 1001 for a bulk unit per 49 CFR 172.302 and 172.331 [1].

# 5 Operations

Standard operating procedures (SOP) shall be implemented to perform loading or unloading in the specified sequence to minimize the risk of decomposition or flashback.

To prevent contamination, positive pressure shall be maintained inside the manifold at all times. If positive pressure is lost, the manifold shall be purged before charging or discharging.

## 5.1 Charging

Only cylinders manufactured and maintained in compliance with DOT and TC as listed in Table 1 and whose solvent content is verified to be within the specified limits shall be charged [1, 10, 11].

**Table 1—DOT/TC cylinder requirements**

| Cylinder requirements | DOT | TC |
|---|---|---|
| Cylinder requalification | 49 CFR 180 Subpart C | CSA B339, Clause 24.2 |
| Pressure relief devices | 49 CFR 173.301(f) | CSA B340, Clause 4.3 |
| Cylinder usage | 49 CFR 173.301, 173.303 | CSA B340, Clauses 4.4.9, 5.4 |
| Cylinder specification | 49 CFR 178.59, 178.60, 178.71 | CSA B339, Clause 22 |

Acetylene trailers are composed of individually valved cylinders connected by flexible leads to a common manifold(s) to a single trailer connection point. Cylinders are typically charged with acetylene simultaneously without disconnecting the cylinders from the manifold(s).

Cylinders shall be filled in accordance with DOT or TC regulations, which provide that the settled pressure of a cylinder shall not exceed 250 psig (1720 kPa) at 70 °F (21.1 °C).

At low temperatures and high pressures acetylene can condense into an unstable liquid that can decompose explosively. To prevent liquefaction of acetylene during the filling of acetylene trailers, the ambient temperature and charging pressure shall be monitored so the maximum pressure at a given temperature as listed in Table 2 is not exceeded.

After charging, all the cylinder valves shall be left open to allow equalization of pressure among the manifolded cylinders. After pressure equalization, the cylinder valves shall be closed and the pressure in the manifold shall be reduced to 15 psig (103 kPa) or less.

**Table 2—Liquefaction temperatures and pressures**

| Ambient temperature | | Maximum charging pressure | |
|---|---|---|---|
| (°F) | (°C) | (psig) | (kPa) |
| –5 | –21 | 200 | 1380 |
| 0 | –18 | 220 | 1520 |
| 10 | –12 | 260 | 1790 |
| 20 | –6.7 | 305 | 2100 |
| 30 | –1.1 | 360 | 2480 |
| 37 | 2.8 | 400 | 2760 |

### 5.2 Transportation

Acetylene trailers shall be operated and maintained in accordance with the *Federal Motor Carrier Safety Regulations* of the Federal Motor Carrier Safety Administration and the following (see 49 CFR Parts 300-399) [1]:

- Cylinders shall be secured in a vertical position on the trailer in a manner that meets the cargo securement system requirements of 49 CFR 393.102;
- Cylinder valves shall be closed during transit; and
- Positive acetylene pressure not in excess of 15 psig (103 kPa) should be maintained in cylinder leads and manifolds during transit.
    - If trailer piping and fittings are pressurized to greater than 15 psig (103 kPa) during transit, they shall be protected from multi-directional forces that are likely to occur during highway accidents, including rollovers.

### 5.3 Discharging at user sites

For installations requiring operation of any equipment by the user, instructions shall be posted and maintained at the discharge location. Where drivers operate valves at discharging stations, the driver shall be in possession of the valve operating instructions.

The trailer shall be chocked or secured to prevent movement during discharging operations.

A person who is trained in valve operations, purging and connecting to the discharge station shall be in attendance while the acetylene trailer is being connected to or disconnected from the discharge station piping. Any person who is performing specific functions, such as manual valve operations on MATS, shall be trained on those specific functions.

MATS or portions of systems located in enclosures or buildings shall have piping vents connected full size to the termination point outside of the building and shall be directed to a location in compliance with NFPA 51A, *Standard for Acetylene Cylinder Charging Plants* [16]. This termination point shall be located at least 12 ft (3.7 m) above the ground, at least 10 ft (3 m) from combustible construction, 25 ft (7.6 m) from building openings, 25 ft (7.6 m) from sources of ignition, and 50 ft (15.2 m) from air intakes. The minimum required distances, except for air intake openings, shall not apply when fire barriers without openings or penetrations having a minimum fire-resistant rating of 2 hours interrupt the line of sight between the discharge and the exposure. This termination point shall be constructed so it is protected from rain and not obstructed by snow, ice, insects, or birds, etc.

## 6 Associated equipment

### 6.1 Trailer fill station

The trailer fill station shall conform to NFPA 51A [16]. The trailer, including fill connections shall be a minimum distance of 25 ft (7.6 m) from property lines, 50 ft (15.2 m) from buildings of combustible construction, and

15 ft (4.6 m) from buildings of noncombustible construction not associated with the filling or discharging of the trailer. The use of approved fire walls can lower the minimum distance requirements.

Acetylene trailer fill stations shall meet these requirements:

- The trailer site shall be located so it is accessible and provides space for trailer positioning;
- The connected trailer shall not be located within 15 ft (4.6 m) horizontal distance from the vertical plane of the nearest overhead electric power lines, or within 15 ft (4.6 m) of piping containing flammable liquid, flammable gas (other than acetylene), or oxidizing materials;
- The trailer site shall be posted as follows, or with equivalent wording: ACETYLENE—FLAMMABLE GAS—NO SMOKING—NO OPEN FLAMES;
- Provisions shall be made for a cylinder cooling water spray system and water run-off where needed for removing the heat of solution of acetylene, as determined by ambient temperature and cylinder charging rates during filling;
- Electrical equipment shall be in accordance with NFPA 70 [5];
- An electrical grounding system for the acetylene piping shall be provided in accordance with the NFPA 70 [5];
- The trailer shall be connected to the grounding system before being connected to system piping;
- Acetylene piping to the trailer fill stanchion and on the stanchion shall conform to NFPA 51A [16];
- Protection such as pipe stanchions, curbing, or guard rails shall be provided to prevent damage to the facilities and piping during movement of the trailer or the tractor around the trailer fill station facilities;
- If a flexible transfer hose is used for cylinder charging of acetylene, the hose shall have a minimum burst pressure of 10 000 psig (69 000 kPa); and
- Flammable gases and incompatible materials in containers other than MATS shall be located not less than 15 ft (4.6 m) from MATS being charged or discharged [17].
    - This distance may be reduced to 5 ft (1.5 m) if flammable gases and incompatible materials are isolated from the MATS by a barrier of noncombustible material at least 5 ft (1.5 m) high and with a minimum fire-resistant rating of 1/2 hour.

### 6.2 MATS discharge station

In addition to the following requirements for MATS discharge stations, the trailer discharge station shall conform to all requirements of 6.1 with the exception of cylinder cooling spray and water run-off provisions.

The trailer discharge station shall be designed to prevent:

- backflow of contaminants into the acetylene supply system (e.g., air, oxygen, solvents, etc.);
- passage of flashback into the acetylene supply system; and
- development of pressures in excess of the pressure rating of the system components designed in compliance with CGA G-1.2, *Acetylene Metering and Piping* [18].

All vents from pressure relief devices on piping shall exhaust at an elevation not less than the highest elevation of acetylene piping on the acetylene trailer and in compliance with the vent piping requirements of 5.3 [8]. The discharge of the relief valve vent shall not impinge upon the trailer cylinders.

MATS discharge stations shall meet the following requirements:

- The trailer discharge station shall be located in accordance with the separation distance requirements specified in NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* from exposures [14];

- Acetylene meters, where used, shall be of a type specified in CGA G-1.2 for acetylene service and shall operate at a pressure not to exceed 15 psig (103 kPa) [18]; and
- When a flexible transfer hose is used for withdrawal of acetylene at cylinder pressure, the hose shall have a minimum burst pressure of 10 000 psig (69 000 kPa).
  - A flexible transfer hose used for acetylene withdrawal at 15 psig (103 kPa) or less shall be rated for a minimum working pressure of 125 psig (860 kPa), and a minimum burst pressure of 500 psig (3450 kPa).

### 6.3 Weather protection and MATS buildings for trailer system discharge stations

Where weather protection is provided on outdoor installations, it shall be constructed of noncombustible materials, meet the building code requirements of the authority having jurisdiction (AHJ) and the following requirements:

- Electrical equipment shall be in accordance with NFPA 70 [5];
- MATS buildings shall be built of noncombustible construction. Windows and doors shall be located to be accessible in case of emergency. Windows shall be of reinforced glass or plastic in metal frames;
- Ventilation shall be in accordance with NFPA 51A [16];
- Explosion venting shall be in accordance with NFPA 55 [17];
- There shall be no sources of ignition from open flames or heating equipment;
- Heating, if provided, shall be by steam, hot water, or other indirect means. Electric heaters shall be allowed provided they meet the area classification requirements; and
- In addition to the requirements for egress established by the building code, two means of egress, located at opposite ends of the structure or building, shall be provided for all building or fenced enclosures of trailer discharge stations.

## 7 General provisions

### 7.1 Exterior markings and signs

Each trailer shall display the marking, labeling, and placarding as required by applicable DOT or TC regulations [1, 15].

### 7.2 Fire protection

A deluge sprinkler system shall be provided for MATS fire areas used as indoor and outdoor charging and discharging stations. The system shall be designed to provide water as a means of cooling the containers located on the trailer that are potentially exposed to fire. Deluge sprinkler systems shall provide a minimum design density of 0.3 gpm/ft$^2$ (0.2 lps/m$^2$) over the MATS fire area being protected. The deluge sprinkler system shall be able to be activated automatically by a fast acting detection system and also by a manual actuator.

MATS fire areas used for charging or discharging operations shall be separated from each other by not less than 30 ft (9 m) or by fire barriers or fire walls.

- When fire barriers are used to separate outdoor MATS fire areas without weather protection, the fire barriers shall be not less than 2-hour fire-resistant construction and shall separate individual fire areas by line of sight;
- When fire barriers are used to separate outdoor MATS fire areas covered by weather protection, the fire barriers shall be full height walls without openings extending from the foundation to the roof constructed of not less than 2-hour fire-resistant construction. The allowable area occupied by weather protection shall be in accordance with the requirements of the local building code; and

- When MATS are installed indoors in a MATS building, fire walls, fire barriers, or 2-hour fire-resistant rated exterior walls are allowed to be used to separate MATS fire areas. Walls shall be constructed in accordance with the requirements of the local building code.

Existing acetylene charging and discharging stations shall be protected by an automatic deluge sprinkler system meeting these requirements no later than January 1, 2015.

These requirements for deluge sprinkler systems shall not apply to existing indoor or outdoor facilities, equipment, structures, or other installations where MATS are charged or discharged that existed or were approved for construction or installation prior to the effective date of this standard providing the MATS are protected with an automatic sprinkler system with a minimum design density of not less than 0.25 gpm/ft$^2$ (0.17 lps/m$^2$).

In those cases where the AHJ determines that the existing situation presents an unacceptable degree of risk, the AHJ shall be permitted to apply these requirements for a deluge sprinkler system retroactively.

The retroactive requirements of this standard shall be permitted to be modified if their application would be impractical in the judgment of the AHJ if it is evident that an equivalent degree of safety is provided.

Manual activation controls shall be identified and marked with a sign and shall be positioned for use in an emergency.

Fire protection equipment and manual activation controls shall not be blocked or obstructed.

At least one Underwriters Laboratories (UL) listed fire extinguisher with a rating of not less than 20 B:C shall be mounted on the acetylene trailer [19].

### 7.3 Training requirements

Drivers transporting acetylene trailers, employees of carriers, or users connecting or disconnecting trailers, operating valves and associated equipment shall meet the training requirements specified in DOT and TC regulations [1, 15]. In addition, these personnel should meet the function specific training requirements of their employer.

Examples of function specific training include, but are not limited to:

- purging techniques for hoses, piping, and manifolds;
- emergency procedures;
- sequence of valve operation; and
- checking for leaks.

In addition to these training requirements, no carrier shall transport, or cause to be transported, a hazardous material (dangerous good) unless each employee who will operate a motor vehicle has been trained in the applicable requirements of 49 CFR Parts 390-397 or the applicable provincial regulations and the procedures necessary for the operation of that motor vehicle [1].

## 8 References

Unless otherwise specified, the latest edition shall apply.

[1] *Code of Federal Regulations,* Title 49 (Transportation), Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20401. www.gpo.gov

[2] National Safety Code Standard 10, *Cargo Securement,* Canadian Council of Motor Transport Administrators, 2323 St. Laurent Blvd, Ottawa, ON K1G 4J8. www.ccmta.ca

[3] NFPA 13, *Standard for the Installation of Sprinkler Systems,* National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269. www.nfpa.org

[4] *International Building Code*, 9th Edition, Section 415.2, International Code Council, Country Club Hills, IL 60478. www.iccsafe.org

[5] NFPA 70, *National Electrical Code®*, National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269. www.nfpa.org

[6] ASME B31.3, *Process Piping*, ASME International, Three Park Ave., New York, NY 10016. www.asme.org

[7] ASME A13.1, *Scheme for the Identification of Piping Systems*, ASME International, Three Park Ave., New York, NY 10016. www.asme.org

[8] CGA G-1, *Acetylene,* Compressed Gas Association, Inc., 14501 George Carter Way, Suite 103, Chantilly, VA 20151. www.cganet.com

[9] CGA P-11, *Metric Practice Guide for the Compressed Gas Industry,* Compressed Gas Association, Inc., 14501 George Carter Way, Suite 103, Chantilly, VA 20151. www.cganet.com

[10] CSA B340, *Selection and Use of Cylinders, Spheres, Tubes, and Other Containers for the Transportation of Dangerous Goods,* Class 2. Canadian Standards Association, 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada. www.csa.ca

[11] CSA B339, *Cylinders, Spheres and Tubes for the Transportation of Dangerous Goods,* Canadian Standards Association, 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada. www.csa.ca

[12] ISO 3807-2, *Cylinders for acetylene–Basic requirements–Part 2: Cylinders with fusible plugs,* Compressed Gas Association, Inc., 14501 George Carter Way, Suite 103, Chantilly, VA 20151. www.cganet.com

[13] CSA B341, *UN Pressure Receptacles and Multiple-Element Gas Containers For The Transport Of Dangerous Goods*, Canadian Standards Association, 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada. www.csa.ca

[14] CSA B342, *Selection and Use of UN Pressure Receptacles and Multiple-element Gas Containers for the Transport of Dangerous Goods, Class 2*, Canadian Standards Association, 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada. www.csa.ca

[15] *Transportation of Dangerous Goods Regulations*, Transport Canada, Canadian Government Publishing, Public Works and Government Services Canada, Ottawa, ON K1A 0S9, Canada. www.tc.gc.ca

[16] NFPA 51A, *Standard for Acetylene Cylinder Charging Plants,* National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269. www.nfpa.org

[17] NFPA 55, *Compressed Gases and Cryogenic Fluids Code,* National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269. www.nfpa.org

[18] CGA G-1.2, *Acetylene Metering and Piping,* Compressed Gas Association, Inc., 14501 George Carter Way, Suite 103, Chantilly, VA 20151. www.cganet.com

[19] UL 711, *Rating and Fire Testing of Fire Extinguishers,* Underwriters Laboratories Inc., 333 Pfingsten Rd., Northbrook, IL 60062. www.ul.com

## 9 Additional references

CGA G-1.1, *Commodity Specification for Acetylene,* Compressed Gas Association, Inc., 14501 George Carter Way, Suite 103, Chantilly, VA 20151. www.cganet.com

CGA SB-4, *Handling Acetylene Cylinders in Fires,* Compressed Gas Association, Inc., 14501 George Carter Way, Suite 103, Chantilly, VA 20151. www.cganet.com

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