NBSIR 77-1217

Safety Problems Associated with Pressure Containers

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Report to

Consumer Product Safety Commission
5401 Westbard Avenue
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U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, ***Secretary***

Dr. Betsy Ancker-Johnson, ***Assistant Secretary for Science and Technology***

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Acting Director***

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Safety Problems Associated with Pressure Containers

Introduction

The objective of this study was to develop preliminary engineering data needed to assess the adequacy of present standards for pressure containers. This study was limited to LP Gas containers and fire extinguishers since other pressurized containers such as aerosols and carbonated beverage bottles are addressed in other CPSC programs. This project addressed two tasks. The first task involved the review and analysis of the injury data related to pressure containers. The second task consisted of the review and critique of existing standards.

The injury data for this study was obtained from two sources, the National Electronic Injury Surveillance System (NEISS) and the CPSC in-depth epidemiological reports. The NEISS data was useful in obtaining a statistical sampling of the types of injuries related to pressure containers. The in-depth epidemiological reports enabled identification of accident patterns and hazards associated with the products.

Standards related to the design and maintenance of fire extinguishers and LP gas containers were analyzed. Relationships between the hazards identified in the injury data and the engineering issues from the standards are discussed in this report.

Fire Extinguishers

General Description

Fires involving different combustibles require different methods of extinguishment. Manufacturers have responded to this problem by producing extinguishers effective against the various types of fires. Advances in fire technology have resulted in improvement of old designs and introduction of new types of extinguishers, while many original designs have stayed in service. Thus, a wide variety of extinguishers are in use today.

The earliest type of commercial fire extinguisher still in use at present, is the soda acid extinguisher. This type of extinguisher is not pressurized until activated by inverting the container. An acid and base solution mix and react to form carbon dioxide which generates pressure forcing water out through a hose[1*]. For obvious reasons, this type of extinguisher is also referred to as "invert-to-operate". This type of extinguisher is effective against fires involving wood, paper, rubber and many plastics.

*References appear at the end of the report, following the appendix.

Another example of an early extinguisher is the type employing carbon tetrachloride as an extinguishing agent. Some carbon tetratrachloride extinguishers are still in service today; however, due to toxicity problems the vast majority of them have been replaced by the more compact and effective chemical extinguishers.

The foam extinguisher, another older type of extinguisher still used today, operates by mixing a base salt solution with an acid salt solution, producing a frothy agent which cools and smothers the flames. Such extinguishers are effective against liquid fires, and if non-conductive agents are used, against fires involving energized electrical equipment. Foam extinguishers, are becoming relatively uncommon due to the trend toward dry chemical extinguishers.

Most modern extinguishers contain agents such as carbon dioxide, dry chemicals and liquified gases. Agents used commonly in dry chemical extinguishers are sodium bicarbonate, potassium bicarbonate, ammonium phosphate and potassium chloride. Chlorobromomethane and bromotrifluoromethane are examples of liquified gas extinguishing agents.

NEISS Data

The NEISS data collected during the 4 year period beginning fiscal year 1973 and ending fiscal year 1976 show that 177 injuries involving fire extinguishers were treated at the 119 hospital emergency rooms on the NEISS system.

Review of the NEISS matrix report enabled identification of the number of each type of injury relative to the total number of injuries. Lacerations (36%) were the most commonly occurring injury followed by contusions (21%) and fractures (12%). Chemical burns, dermatitis, and poisoning were diagnosed in 7%, 5%, and 4% of the injuries, respectively.

The mean severity value* of these injuries was 40 indicating a moderate degree of injury. On a scale of 1 through 8 used by NEISS to categroize the severity of injuries, a severity value of 40 would fall between categories 4 and 5 as shown in Table 1. Examples of the type of injuries which would fall under each category is also included in this table. The mean severity value for fire extinguishers, when compared to the average of the mean severity for all products monitored by NEISS, is lower than average.

*In calculating mean severity, the number of cases in each severity category is first multiplied by the appropriate severity value for that category. The products of these multiplications are summed and then divided by the total number of reported cases for that product code.

Table 1

Mean Severity*

Severity Category	Examples of Injuries in Each Category	Severity Value *
1	Mild injuries to small areas, for example, sprained foot	10
2	Contusion to lower trunk; dislocated arm, hand puncture, non-hospitalized poisoning	12
3	Arm fracture, sprained neck	17
4	Finger crushing, head laceration, punctured eye	31
5	Concussion, fractured neck, ingested foreign object	81
6	Amputation, anoxia, arm crushing, hospitalized poisoning	340
7	All hospitalized category 6's	2,516
8	All deaths	2,516

*Incomplete or otherwise not acceptable data are assigned a severity value of 0 and are not included in calculations of mean severity.

*This table was reproduced from NEISS News, Volume 4, No. 1, Consumer Product Safety Commission, July 1975.

In-depth Investigations

The CPSC's Bureau of Epidemiology had on file 14 in-depth investigations related to fire extinguishers. These reports covered a four year period beginning fiscal year 1973 and ending fiscal year 1976. A tabulation of the description, reported cause, and number of the incidents appear in Table 2.

Table 2

Summary of Incidents

Description of incident	Reported Cause	# of cases
Explosion of container	Interior corrosion of extinguisher shell	8
Gage separation	Weak attachment of gage to extinguisher	1
Product failed to operate	Malfunction under normal use	1
Contact with toxic or caustic subtances	Misdirection of spray	2
Asphyxiation	Inhalation of toxic fumes	1
Consumer complaint	Dealer refused to service product	1

Explosions of fire extinguishers were cited in 8 of these in-depth reports. One particular model of foam extinguisher supplied by one manufacturer accounted for 7 of these 8 explosion incidents. In one of these cases the extinguisher exploded inside a kitchen closet, damaging the interior of the cabinet. In another case involving the same model extinguisher, the explosion of the extinguisher occurred on top of a kitchen counter, where it had been stored for 3 years, and injured the occupant who happened to be in the area at the time of the explosion. The victim suffered a laceration requiring two stitches behind her left ear. Another investigation reported an explosion of the same model extinguisher in the rear passenger compartment of a station wagon. None of these three cases apparently involved misuse of the product.

In another explosion incident, a 25 year old male was killed instantaneously when the soda acid extinguisher he was holding exploded. The explosion occurred several seconds after the activation of the extinguisher, propelling a section of the container upwards and striking the victim in the jaw.

There were two incidents associated with plastic pressure gage assemblies on dry chemical extinguishers. In one case the plastic pressure gage on a dry chemical extinguisher blew off discharging its contents. The extinguisher was mounted on the inside wall of a camper at the time of the incident. The other investigation regarding a pressure gage problem was the result of a consumer complaint filed with CPSC. The dealer reportedly refused to recharge a dry chemical fire extinguisher, claiming that the plastic gage "was hazardous".

Other Data

Some in-depth investigation reports were particularly useful in identifying sources of further information, such as persons to contact, and literature related to the product.

A telephone conversation with a representative of the manufacturer whose foam extinguishers accounted for 7 of the 8 explosion cases, identified the cause of these accidents as a materials problem. The contents of the extinguisher caused corrosion of the shell of the container, weakening the shell over a period of years, resulting in an explosion. The manufacturer had issued a voluntary recall on its 1970 model year extinguisher in August 1974.

Evidently, corrosion of the inside of the container is a problem which can occur in various types of extinguishers and is not limited to foam types. Literature published by the National Fire Equipment Distribution in 1970 cites examples of water, foam, dry chemical and carbon dioxide extinguishers which have exploded due to internal corrosion.[2]

The literature also pointed out the explosive hazards of the soda-acid extinguishers, especially those with stainless steel shells and urged a phase out of these extinguishers. According to NAFED, the hydrostatic failure rates are very high for soda acid extinguishers with stainless steel shells. The following statistics were published in the NAFED literature: 1) 22% of soda acid extinguishers failed the first 5 year hydrostatic test, 2) 8% failed the second 5 year retest, and 3) 15 to 40% failed the third 5 year retest.

In addition to the NAFED literature, three other sources caution against soda acid extinguishers.

1. A telephone conversation with the Fire Marshall's office in Salt Lake City, Utah revealed that 8 to 10% of the state owned soda-acid extinguishers failed the hyrostatic test in 1975. In comparison the hydrostatic failure rate of dry chemical extinguishers, according to the same source, was less than 1%.

2. A report[3] authored by NBS scientists provided one explanation for the high rate of failure of invert-to-operate extinguishers. According to that paper, the stainless steel alloys commonly used in the body of these extinguishers are particularly susceptible to intergranular corrosion. Such corrosion may be caused by corrosive fluids such as sulfuric acid used in invert-to-operate extinguishers.

3. The NFPA Handbook of 1976 points out the dangers associated with the use of invert-to-operate extinguishers[1]. The handbook states that the failure rates of these extinguishers are alarmingly high. Furthermore, the potential failures are not usually evident until the time of operation or hydrostatic test, because the extinguisher is not pressurized during storage. The normal pressure in these extinguishers, when activated, is about 687 kPa (100 psi) but when a blockage of the hose occurs, such as by kinking, the pressure may reach 2060 kPa (300 psi).

Invert-to-operate extinguishers have many important operational disadvantages when compared to modern extinguishers[1]. Some of these are 1) high electrical conductivity of the contents 2) high inspection, maintenance and recharging cost and 3) potentially dangerous to use.

Additional information regarding the plastic gages on chemical extinguishers was obtained from the telephone conversation with a representative of the Fire Marshall's office in Salt Lake City, Utah. The office has on file two reports of incidents of plastic gages separating from the extinguishers; one of these was also the subject of a CPSC in-depth report. Additionally, the office reportedly has received 30 complaints from consumers concerning these extinguishers. Fire extinguisher servicing companies in the Salt Lake City area have received about 100 complaints involving plastic gages, according to the Fire Marshall's office. The majority of the complaints reportedly involved extinguishers made by two companies. The complaints usually stemmed from premature loss of pressure in the extinguisher.

A conversation with the Chief of the NBS Fire Service provided an explanation for the problems associated with the plastic gages on some dry chemical extinguishers. These extinguishers reportedly will normally hold charging pressure when new, but after servicing, they have a marked tendency to develop a leak from the gage. Evidently there is great difficulty in applying the proper amount of torque when reinstalling the plastic gages after servicing the extinguisher. If too much torque is used when tightening the gage, subsurface cracks may occur at the neck of the gage; too little torque will result in a loose attachment of the gage. Either of these conditions could result in pressure leakage or separation of the gage from the extinguisher body.

Safety Standards

The standards relevant to the safety of fire extinguishers are listed in Table 3 with descriptions of the contents of each standard. Review of these standards indicated that in general they appear to be adequate.

The Code of Federal Regulations, and UL Standards 154, 299, and 626 provide specifications to prevent rupture of extinguisher shells during normal use and under some misuse conditions. The UL 154 refers to the Code of Regulations section 178 for cylinder strength specifications. According to these specifications, the cylinder should not rupture at pressures up to about 3 times its normal charging pressure at 21°C (70°F). UL 299 and UL 626 specify that rupture pressure shall be no less than (1) four times the charging pressure at 21°C for a metallic container or (2) six times for a non-metallic container.

Maintenance requirements to detect deterioration of the extinguishers which have been in service are covered by NFPA 10A and CGA-6. The maintenance requirements in the NFPA standard consist of the hydrostatic test which is summarized in Tables 4 and 5. The CGA-6 covers visual inspection methods of extinguisher shells to detect corrosion which may make continued use of the extinguisher unsafe.

The safety factors for rupture stress and maintenance requirements should be sufficient to prevent rupture of an extinguisher even if subjected to some degree of overpressurizing, provided that it has been designed to resist corrosion and has been maintained properly.

The only apparent weakness in these standards stems from the lack of tests to insure the compatibility of the extinguishing agent and propellant with the extinguisher shell to prevent corrosion of the shell. UL 299 and 626 require that the shell be resistant to corrosion, but no tests are specified. It is apparently assumed that a manufacturer knows which alloys used for extinguisher shells are susceptible to corrosion by certain extinguishing agents. However, incidents reported in the in-depth investigations seem to indicate that such an assumption cannot be made.

The review of UL 299 revealed some rigorous tests to insure that the pressure gage is attached securely to the extinguisher container assembly. One of the tests is a One Year Time Leakage Test in which extinguishers are charged with expellant gas at normal room temperature and checked for leakage during a 1 year period. The pressure leak is not to exceed the rate which would cause the pressure to drop below the lower limit of the operable range in 1 year. Other tests for checking attachment of pressure gages to the extinguisher shell are drop tests and accelerated aging tests for plastic parts. In the drop tests two samples of extinguishers are dropped from a height of 91.4 cm (3 feet) in the horizontal, upright and upside down positions for a total of three drops for each extinguisher. Generally, each extinguisher is positioned so that when dropped, its weakest point will be contacted upon impact. After these tests, each extinguisher is hydrostatically tested.

Table 3

Standards for Fire Extinguishers

Standard	Contents
Code of Federal Regulations Title 49, Transportion, Part 178	Construction specifications, compliance tests and requirements for cylinders shipped interstate
Compressed Gas Association CGA Pamphlet C-6, Standards for Visual Inspection	Visual inspection method for detecting corrosion in cylinder for compressed
Underwriters Laboratories UL 154, Safety Standards for Carbon Dioxide Fire Extinguishers	Requirements for construction operation, and tests for CO_2 extinguishers, exclusive of fire performance tests.
UL 299 Safety Standards for Dry Chemical Fire Extinguishers	Same coverage as above except applies to dry chemical extinguishers
UL 626 Safety Standards for 2 1/2 Gallon Stored Pressure Water-Type Fire Extinguishers	Same coverage except applies to Water-type stored pressure extinguishers
UL 711 Safety Standards for Rating and Fire Testing of Extinguishers	Rating and classification of fire extinguishers and related test procedures.
National Fire Protection Association NFPA 10, Standard for Installation of Portable Fire Extinguishers	Installation requirements for extinguishers.
NFPA 10A, Recommended Practice for Maintenance and Use of Portable Fire Extinguishers	Maintenance and use of extinguishers, including hydro-testing requirements and test procedures.

Table 4

Hydrostatic Test Pressure
Requirements (Note 1)

Soda-acid Foam Cartridge operated water	Original factory test pressure* as shown on nameplate
Carbon dioxide extinguishers Carbon dioxide and nitrogen cylinders (used with wheeled extinguishers)	5/3 service pressure† stamped on cylinder
Carbon dioxide extinguishers with cylinder specification ICC3	3,000 psi
All stored pressure and Bromochlorodifluoromethane (1211)	Factory test pressure not to exceed 2 times the service pressure
Carbon dioxide hose assemblies	1,250 psi
Dry chemical and dry powder hose assemblies	300 psi

* The factory test pressure is the pressure at which the shell was tested at time of manufacture. This pressure is shown on the nameplate.

† The service pressure is the normal operating pressure as indicated on the gage and nameplate.

(Note 1) Table reproduced from the NFPA Handbook 1976.

Table 5

Hydrostatic Test Interval
for Extinguishers (Note 1)

Extinguisher Type	Test Interval (years)
Soda acid	5
Cartridge operated water and/or antifreeze	5
Stored pressure water and/or antifreeze	5
Wetting agent	5
Foam	5
Loaded stream	5
Dry chemical with stainless steel shells or soldered brass shells	5
Carbon dioxide	5
Dry chemical, stored pressure, with mild steel shells, brazed brass shells, or aluminum shells	12
Dry chemical, cartridge operated, with mild steel shells	12
Bromotrifluoromethane—Halon 1301	12
Bromochlorodifluoromethane—Halon 1211	12
Dry powder, cartridge operated, with mild steel shells*	12

* Except for stainless steel and steel used for compressed gas cylinders, all other steel shells are defined as "mild steel" shells.

(Note 1) Table reporduced from the NFPA Handbook 1976.

Discussion

NEISS data provides a statistical data bank on types of injuries associated with fire extinguishers and other consumer products. Lacerations, contusions and fractures accounted for 69% of all fire extinguisher injuries treated at hospital emergency rooms, while chemical burns, poisoning and dermatitis were associated with only 16% of the cases. This suggests that most injuries were probably caused by either 1) fire extinguisher or a component part striking the victim, 2) victim struck by some object while holding a fire extinguisher. Thus, it appears that the major injury mechanism associated with fire extinguishers is mechanical in nature rather than chemical. While the NEISS data does not allow determination as to whether or not the preponderance of mechanical injuries was a result of faulty extinguishers, it does reveal that toxicity of the extinguishing agent is not a commonplace hazard of extinguishers.

The review of in-depth reports and other data revealed accident patterns associated with fire extinguishers. Incidents apparently were caused by the fault of the product in 10 of the 14 cases. This study revealed three problems needing attention associated with safety of fire extinguishers. These were internal corrosion, plastic pressure gages and use of obsolete extinguishers.

Fire extinguishers safety standards appear to address most safety problems adequately. However, none of the standards reviewed included a test to insure the compatibility of the contents with the extinguisher shell. Although the hydrostatic tests specified by NPFA 10A and the visual inspection test for corrosion outlined in CGA C-6 may detect internal corrosion and possible loss of structural integrity of the container after the extinguisher has been in service, a severe deterioration of the extinguisher shell could occur before the product is due for such tests. The 7 incidents cited in the in-depth reports involving explosions of one particular make of extinguisher exemplify such a situation. All of the explosions in those incidents occurred between two and three years after purchase of the extinguishers and at least 2 years before any in service tests were due.

Although the attachment of the plastic pressure gage on some dry chemical extinguishers seemed to be a problem as evidenced by data collected during this study, the review of the Dry Chemical Standard UL 299 revealed some tests to insure that the method of attachment of the gage results in a good seating and strong connection between the gage and the container body. After these tests each extinguisher is hydrostatically tested. An aging test which involves the exposure of the plastic parts to temperature of 100°C (212°F) for 180 days is also conducted to check possible degradation of plastic parts. These tests should preclude the certification of new extinguishers with inferior plastic pressure gage attachments. However, as indicated on page 6 of this report, these plastic gages are apparently very difficult to reinstall properly after servicing the extinguisher.

Although only one case involving a soda acid extinguisher was reported in the in-depth investigations, other sources (i.e., NAFED literature and the NFPA Handbook) indicate high failure rates and hazards associated with use of these extinguishers. The NFPA Handbook of 1976 states that "several million" invert-to-operate type extinguishers are still in service, with soda-acid types accounting for 85%.

LP Gas Containers

General Description

Liquefied Petroleum (LP) is a major source of heating and cooking energy in rural areas unserviced by gas mains. Additionally, LP gas is used as a fuel source by numerous campers and trailers because of the portability of LP gas powered ovens and ranges. According to Peet[4], nine million consumers relied on LP gas as a fuel source for heating and cooking in 1970.

Although there are several types of LP gases (such as isobutane, propylene, butylenes and mixtures of these hydrocarbons), propane and butane are the most extensively used LP gases[5]. Propane and butane are mixed in various ratios, depending on the climate, to take advantage of the desirable qualities of both gases[6]. LP gases are normally odorless; therefore, mercaptan, a compound having a disagreeable odor, is often added to these gases to facilitate detection in the event of a leak.

In operation the LP gas cylinder is partially filled with liquefied gas in equilibrium with a vapor occupying the space above the liquid. When the valve on the cylinder is opened, some of the pressurized vapor leaves the tank. Some of the gas in the liquid state immediately evaporates to maintain equilibrium, thus always keeping the pressure inside the cylinder constant with constant temperature regardless of the fluid level. The pressure in the LP gas tank is equal to the vapor pressure of that gas or mixture of gases stored in the tank at that temperature[6]. Thus, since propane and butane have vapor pressures at 21 $^{\circ}$C (70 $^{\circ}$F) of 906 kPa (132 psig) and 117 kPa (17 psig)[7], respectively, the pressure in the tank containing these gases will be between these two extremes, depending on the mixture of these two gases. At a temperature of 54 $^{\circ}$C (130 $^{\circ}$F) the same tank would have a pressure somewhere between 474 kPa (69 psig) and 2060 kPa (300 psig)[7].

LP gas tanks, usually cylindrical in shape, are produced in various sizes ranging from 17.8 cm (7 in) in diameter by 48.2 cm (19 in) in length to 47.0 cm (18.5 in) in diameter by 137 cm (54 in) in length.[6] These tanks normally contain 9.1 kg (20 lbs) to 45.5 kg (100 lbs) of gas.

NEISS Data

According to the NEISS data, 154 injuries associated with LP gas tanks and fittings were treated at NEISS hospital emergency rooms from fical year 1973 to fiscal year 1976. The most commonly occurring injury was thermal burns, averaging 38% of all injuries over the four year period. Lacerations (12%), and contusions and abrasions (10%) were other frequently occurring injuries.

For fiscal year 1976 the mean severity index of injuries associated with LP gas containers was 263* as compared to the average mean severity of 101 for the product group "General Household Appliances" consisting of 23 products.

Death Certificates

CPSC had on file 105 death certificates related to LP gas tanks and fittings as of June 1976. By comparison the total number of death certificates for all products monitored by CPSC was 128,744.

Explosions involving LP gas containers accounted for 64 deaths of which 12 were attributed to tank explosions. There were 30 deaths due to inhalation of gas fumes. The death certificates did not state whether or not the involved products were defective. The other 11 deaths occurred in incidents which could not be categorized under specific accident patterns.

In-depth Investigations

Review of the 31 in-depth investigations covering the period March 1967 through October 1975 identified leakage of gas from the LP gas tanks and fittings as the primary hazard. Explosions of the gas fumes occurred in 23 incidents.

The appendix of this report contains summaries of the 31 investigations.** Table 6 lists the nature of the incident, its reported cause, and the number of such incidents.

*See Table 1 for examples of injuries which would have a severity index of 263.

**Summaries of the in-depth reports for incidents occurring between March 1967 and June 1973 were reproduced from the CPSC Hazard Analysis on LP Gas, 1974[8].

Table 6

Summary of LP Gas Container Incidents

Type of incident	Reported Cause	Number of cases
Explosion	Gas leak from tank; ignition by spark or flame	7
Explosion	Gas leak from fuel line; ignition by spark or flame	7
Explosion	Gas leak from unknown source; ignition by spark or flame	6
Explosion	Overpressurization; rusted container; no safety relief valve	1
Explosion	Undetermined	1
Inhalation of gas fumes	Leak; no explosion	1
Other incidents not involving defective containers or fittings		8
	Total	31

Gas leaks occurred in 20 of the 31 investigated incidents. In all but one of those cases, the gas fumes from the leak were ignited by a source of a flame or spark such as a water heater or a match. The LP gas container was cited as the source of the leak in 7 investigations. The location of the leak on the container was identified in only 2 instances. In both of these incidents the valve was apparently the source of the leak. Review of the other 5 reports did not indicate whether the gas leak was from the container body or from the valve.

In one of the incidents caused by leakage of gas, a LP gas container stored in the back of a van developed a leak from its valve. The victim opened the vents and doors of the van for ventilation and repaired the leak. He waited 3 to 5 minutes to let the fumes escape. An explosion occurred when he pushed the ignition button on the van's heating unit.

In another case the victim heard a hissing noise coming from the garage where a butane tank was stored. As he was removing the leaking tank from the garage, an explosion occurred. The force of the explosion propelled the victim through the side door of his garage and through the side of the neighbor's garage. Evidently, the water heater flame ignited the gas fumes causing an explosion according to the investigation report. The leak was apparently caused by the safety relief which may have opened, since the outside temperature was close to 38°C (100°F) at the time of the accident.

There were three incidents where poor installation or maintenance were apparently involved. A non-leaking LP gas container exploded in one of these incidents. High temperature during a warm day evidently overpressurized the container. Lacking a safety relief valve, the container exploded. Inspection of the tank after the accident revealed that its interior was corroded. According to the investigative report the tank had been refilled only three or four days before the accident.

Poor installation was the probable cause for a leak in one incident. A gas leak developed in a 0.953 cm (3/8 inch) copper fuel hose where it rubbed against the side of a camper. Vibrations apparently wore a hole through the line.

In another case where poor installation or maintenance was suspected, a man was seriously injured in a explosion, which occurred in a trailer when he struck a match to light a cigarette. The force of the explosion blew apart the top and sides of the trailer. A new tank of propane had been installed a few days before the accident.

Safety Standards

The standards relevant to the safety of LP gas containers, listed in Table 7, were reviewed.

According to NFPA 58, LP gases are to be stored in containers built under either the Department of Transportation (DOT) specification, which are contained in the Code of Federal Regulations title 49, or manufactured in conformance to the ASME Pressure Vessel Code. The Code of Federal Regulations state that LP gas containers shipped interstate must meet DOT specifications.

Table 7

Standards for LP Gas Containers

Compressed Gas Association Standards:

CGA Pamphlet S-1.1
Safety Relief Device Standards
Part 1 - Cylinders for Compressed Gases

CGA Pamphlet C-6
Standard for Visual Inspection
of Compressed Gas Cylinders

National Fire Protection Association Standard

NFPA 58, (ANSI Z106.1)
Standard for Storage and Handling
of Liquified Petroleum Gases

Code of Federal Regulations

Title 49, Transportation
Parts 171 to 190 DOT Cylinder Specifications

American Society of Mechanical Engineers

ASME Pressure Vessel Code Section VIII
Division 1

Underwriters Laboratories:

UL 125, Valves for
Anhydrous Ammonia and
LP-Gas (other than safety relief)

UL 132, Safety Relief
Valves for Anhydrous
Ammonia and LP-Gas

UL 144, Pressure Regulating
Valves for LP-Gas

UL 644 Container Assemblies
for LP-Gas

Strength of LP Gas Containers

The DOT Cylinder Specifications prescribe the service pressure or range of service pressures for which a cylinder built under a particular specification may be used. The service pressure represents the highest pressure to which the tank will normally be subjected during transportation, storage or use. The service pressure for LP gas containers is based on the higher of the two vapor pressures of the gas in the container at two temperatures as follows:

a) The pressure in the container at 21°C (70°F) must be less than the service pressure.

b) The pressure in the container at 54°C (130°F) shall not exceed 5/4 times the service pressure.*

DOT containers for LP gases are hydrostatically tested at a pressure at least 5/3 times the service pressure and must exhibit permanent volumetric expansion less than 10% of the total volumetric expansion at test pressure. Used tanks are hydrostatically tested at 2 times the service pressure for requalification.

The LP gas containers built under the ASME code have a 4:1 safety factor.** The design pressure of the container is determined by the vapor pressure at 38°C (100°F) of the gas to be stored in the tank as shown in Table 8. Since commercial propane has a vapor pressure of 1410 kPa (205 psi) at 38°C a tank containing this gas must have a design pressure of at least 1720 kPa (250 psig). Thus, considering the 4:1 safety factor, the rupture pressure of a tank containing commercial propane will theoretically be at least 6870 kPa (1000 psig).

*For example, the minimum required service pressure for a tank containing commercial propane is 1648 kPa (240 psig), since the vapor pressure of commercial propane at 21°C (70°F) and 54°C (130°F) are 906 kPa (132 psig) and 2060 kPa (300 psig), respectively. (5/4 x 1648 kPa = 2060 kPa)

**Safety factor is the ratio of the ultimate strength of the metal to the design stress.

Table 8

Minimum Design Pressure for ASME Containers (Note 1)

For Gases with Vapor Pressure in psig at 38°C (100°F) not to exceed	Minimum Design Pressure in psig ASME Code, Section VIII Division 1, 1974 Edition
80	100 (Note 2)
100	125
125	156
150	187
175	219
215	250
215	312 (Note 3)

(Note 1) This table reproduced from NFPA 58

(Note 2) New containers for 100 psig design pressure are not authorized after Dec. 1947.

(Note 3) Tanks installed on vehicles require higher relief valve settings.

It is apparent from the preceding discussion concerning the strength of LP gas containers, that both the DOT and ASME containers should withstand the vapor pressure of the stored gas even at high temperatures (up to at least 38°C) if the container is not corroded or in some other way structurally weakened.

Examination and Requalification

All LP gas tanks must be periodically tested and requalified by methods prescribed in the Code of Federal Regulations part 173.34 e(10). The purpose of such tests is to detect and dispose of containers which have been structurally weakened due to corrosion, dents, gouges, or exposure to fire, or normal deterioration with age.

A new container must be requalified within 12 years after the date of manufacture. Subsequent reclassifications are required after 5, 7 or 12 years depending upon the requalification method used. Containers may be reclassified using one of three methods prescribed by the Code of Federal Regulations:

1) Water jacket type hydrostatic test. A pressure of two times the service pressure is applied and the volumetric expansion of the cylinder is recorded. If the container leaks or if permanent volumetric expansion exceeds 10% of the total expansion, the container is rejected. Containers rejected because of leaks may be repaired by a facility approved by DOT and the Bureau of Explosives. Containers requalified by this method must be retested in 12 years.

2) A hydrostatic test.

A pressure of two times the service pressure is applied, but volumetric expansion of the tank need not be measured. The container is carefully observed while pressurized for sign of leak, bulging or swelling. This test qualifies the cylinder for 7 years.

3) Recorded Visual examination.

A visual examination of the cylinder by a competent person, using CGA C-6 as a guide, may be conducted to requalify a container for 5 years. Containers which exhibit leaks, excessive dents, gouging or corrosion must be scrapped or repaired as in item 1) above.

Container Appurtenances

Container appurtenances, as defined by NFPA 58, are safety relief valves, regulator devices, container shutoff valves, plugs, liquid level gages and pressure gages. The design, fabrication and operation of these appurtenances are covered by CGA S-1.1, NFPA 58, ASME Code, UL 125, UL 132, and UL 144.

In general requirements for these appurtenances appear to be satisfactory. Tests are outlined in these standards to check gasket materials for compatibility with the LP gas. Corrosion resistant coatings are specified for ferrous parts which, when corroded, will interfere with the operation of valves. Tests for leakage from these appurtenances are also specified.

Safety Relief Valve Settings

Although the requirements for the design, fabrication and operation of safety relief valves appear to be adequate, the pressure at which the safety relief is set to operate on ASME containers causes some concern. As shown in Table 9 the safety relief valves on ASME tanks may be set to open at the lower limit of 88% of the design pressure of the container. Thus, the safety reliefs on propane tanks may open when tank pressure (which is equal to the vapor pressure of the stored gas) reaches 220 psig. Based on information from NFPA 58, the vapor pressure of propane would be 220 psig at temperatures between 41°C (105°F) and 43°C (110°F). This means that venting of the gas can occur at temperatures which are not uncommon in many parts of the U.S.

Since the LP gases are highly flammable, it seems undesirable to vent the gas at a pressure so close to the design pressure of the tank in view of the fact that the ASME tanks have a safety factor of 4:1.

The problem just mentioned does not exist for LP gases with very low vapor pressures such as butane. This is because ASME containers must not have a minimum design pressures less than 860 kPa (125 psig), as shown in Table 9. Thus, as shown, the pressure relief setting for butane tanks is much higher than the vapor pressure of the gas even at temperature as high as 54°C (130°F).

The containers built under DOT specifications use much higher pressure relief settings than the ASME containers. Table 10 indicates that the low limit specified by NFPA 58 for opening of the safety relief valve is 2470 kPa (360 psig) for tanks containing commercial propane. Thus even at 54°C (130°F) no venting of the gas will occur. Although the tank pressure at this temperature would be 2060 kPa (300 psig), the tank should withstand that pressure since these tanks are hydrostatically tested at 3300 kPa (480 psig).

It appears that the pressure relief settings prescribed for DOT containers would be more effective in preventing unwanted gas leaks due to venting in comparison to the valve settings recommended for ASME containers.

Discussion

The injury data and death certificates reviewed during this study indicate that there may be a significant risk of serious accidents associated with the use of LP gas containers. During the last four years NEISS hospital emergency rooms treated 154 injuries related to this product, with a mean severity index of 263. (See Table 1 for the relationship between seriousness of injuries and its severity index.) CPSC

Table 9

Design Pressures and Safety Relief
Operating Pressures for ASME Specification
Tanks Containing Commercial Propane and Butane[1]

Gas	Vapor Pressure[2] of Gas kPa (psig) 41 C	Vapor Pressure[2] of Gas kPa (psig) 54 C	Minimum Design Pressure of Tank kPa (psig)	Safety Relief Activation Pressure kPa (psig) Low Limit (88% of design pressure)	Safety Relief Activation Pressure kPa (psig) High Limit (100% of design pressure)
Propane	1484 (216)	2060 (300)	1720 (250)	1510 (220)	1720 (250)
Butane	282 (41)	474 (69)	860 (125)	755 (110)	860 (125)

[1] From NFPA 58

[2] LP gas tank pressure at a given temperature is equal to the vapor pressure of the contained gas at that temperature.

Table 10

Service Pressure, Minimum Test Pressure and Safety Relief Activation Pressure for DOT Specification Tanks Containing Propane[1]

Vapor Pressure of Commercial Propane kPa (psig)		Required Service Pressure of Tank	Minimum Test Pressure for Tank (2X Service Pressure)	Safety Relief Activation Pressure kPa (psig)	
21 C (70 F)	54 C (130 F)	kPa (psig)	kPa (psig)	Low Limit (75% of test pressure)	High Limit (100% of test pressure)
906 (132)	2060 (300)	1650 (240)	3300 (480)	2470 (360)	3300 (480)

[1] From NFPA 58

had on file 105 death certificates related to LP gas containers. By comparison the total number of death certificates on file for all products monitored by CPSC was 128,744.

The analysis of the in-depth investigation reports and the death certificates revealed that explosions were responsible for most of the injuries and deaths. The fact that thermal burns, lacerations, contusions and abrasions accounted for 60% of all LP gas container injuries cited by NEISS supports the argument that explosion is the major problem with these products.

Gas leakage was reported to be the primary cause of these explosions. In 20 of the 31 investigated incidents explosions occurred when leaking gas was ignited by a flame or a spark. The source of the leak was identified as the tank in only 7 instances.

Standards related to the design and maintenance of LP gas containers were reviewed. The analyses of the standards in general indicated adequacy of the requirements: There is no obvious explanation for the large number of leaks cited in the in-depth reports and numerous explosions described in the death certificates. However, two requirements in the reviewed standards raises some questions.

One of the questionable provisions in the standards deals with the requalification of used LP gas cylinders. As noted on page 19 of this report, DOT allows the use of three methods for requalifying cylinders for continued service. One of these methods, the visual inspection method appears to be much less rigorous than the other two. Although this inspection is to be performed according to Compressed Gas Association Standard CGA-6, a standard widely accepted by industry, visual inspections tend to be rather subjective.

An apparent deficiency in the standards concerns the low setting of the start-to-discharge pressure of the safety relief valves used on ASME containers as described on page 21. This could cause an unnecessary release of the flammable LP gas at elevated atmospheric temperatures. Thus, it is possible that some gas leaks described in the in-depth reports where high atmospheric temperatures were involved may have been due to containers having pressure reliefs with a low setting.

Other causes of the LP gas accidents appear to involve poor maintenance and installation as evidenced by 3 in-depth reports. In one of these incidents where rupture of a container occurred, inspection of the container after the incident revealed that its interior was rusted. (See case 750325 BEP 7010 in the Appendix.) Furthermore, the safety relief valve, required by Federal Regulations, was missing from the container at the time of the accident. Since the container was filled only 3 or 4 days before the accident and since NFPA 58 requires that the container be inspected before it is filled, it appears that this incident may have been prevented if requirements of the Federal Regulations and NFPA 58 were followed.

Many LP gas accidents could apparently be prevented if gas leaks, the major cause of these accidents, could be detected and reported immediately to a gas company or to qualified service personnel. Only 3 of the investigated cases stated that the victims smelled gas fumes prior to the explosions. In 9 cases the victims denied smelling the odor of gas. Apparently the addition of mercaptan to LP gas to facilitate detection of leak is ineffective in many instances.

Some accidents occurred even when the gas leaks were detected by the victims. In these cases the victims allegedly repaired the leaks, and allowed the fumes to escape. Explosions occurred when victims struck matches to relight pilot lights or to light cigarettes.

The number of LP gas accidents probably would be reduced by the introduction of a more positive method of detecting leaks and by education of consumers as to the proper action to take when a leak is suspected. One possibility may be to install gas detectors in areas where gas is likely to accumulate in the event of a leak.

Conclusions

Fire Extinguishers

Data collected during this study suggests that modern fire extinguishers appear to be relatively safe if used and maintained properly. However, the following problem areas were noted:

1) Internal corrosion of the container due to incompatibility between the container and its contents. UL 299 and UL 626 have no tests to check for such incompatibilities. Adoption of standard compatibility tests should reduce the possibility of occurrence of corrosion related incidents.

2) Method of attachment of pressure gages on dry chemical fire extinguishers. The data gathered during this study does not clearly indicate whether this problem is related to design or quality control. UL Standard 299 covering the dry chemical extinguishers appears to have requirements and tests to insure proper attachment of the gage to the extinguisher. A study other than a literature search is necessary to identify the cause of this problem.

3) Invert-to-operate extinguishers. Since the production of this type of extinguisher was discontinued in the late 1960's, there are no current standards covering the design of these products. However, the

continued widespread use of this obsolete extinguisher despite its poor safety record poses a safety problem. Although the exact mechanism of failure of these extinguishers has not been proven, many sources attest to the high failure rates and potential safety hazards of these extinguishers. It appears that some efforts at curbing or eliminating the use of invert-to-operate extinguishers would be desirable.

In general, (except as noted in item, 1) this study indicates that the present standards related to the safety of fire extinguishers appear to be adequate.

LP Gas Containers

The injury data and death certificates studied in this report indicates that a substantial number of serious accidents involving LP gas containers have occurred. The NEISS data indicates that injuries associated with LP gas containers tend to be much more severe in comparison with injuries associated with general household appliances.

The following conclusions were made from this study:

1) The low discharge pressure setting of safety reliefs used on ASME containers, as discussed on p. 21 of this report, may be a safety hazard if used in climates or in enclosed locations where ambient temperatures above 41°C are likely.

2) Based on this study, standards concerning the design, testing and maintenance of LP gas containers appear to be adequate (except as noted in item 1).

3) The primary hazard associated with the use of LP gas appears to be leakage from various parts of the system, including fuel lines, fittings, and tanks. The in-depth reports in most cases did not reveal the cause of development of a leak; however, there were instances where poor maintenance and installation were suspected.

4) The number of LP gas accidents could probably be reduced by use of a more positive means of detecting leaking gas and by consumer education on the proper course of action to take when a gas leak is suspected.

APPENDIX

Case # Date of Accident	Summary of Accident
A02561 4-8-73	The complainant and his family were traveling on a highway in a van. He noticed that the heat output from the propane heating unit was low, heard a hissing sound coming from it and smelled gas fumes. He stopped the van and went to the rear of the van where the heat unit and one 20 lb bottle and one 4 lb bottle of propane were stored. At this time the 20 lb bottle had been connected to the heater. He noticed that the heater flame had gone out. He disconnected the 20 lb bottle from the heating unit and connected the 4 lb unit to the heater. After opening the doors of the van and letting it air out for 3 to 5 minutes, he lit a match to relight the heater, when explosion of the fumes occurred. The tanks had been refilled two or three months before the accident.
A14548 11-18-73	The victim was driving a propane powered car home from work. After driving for about ten minutes with all the windows rolled up, he attempted to light a cigarette, when the explosion occurred. The force of the explosion tore away the rear section of the car. Strangely, the propane tank located in the trunk was undamaged.
A18503 6-73	The victim heard a hissing sound coming from the garage where two 5 gallon cylinders of butane gas were stored. After locating the cylinder which was the source of the noise, he attempted to carry it out of the garage, when an explosion occurred. The flame from the water heater inside the garge ignited the fumes from the gas cylinder. The investigator attributed the accident to a sticky safety relief. Since the outside temperature was 98°F, this may have increased the pressure inside the tank enough to activate pressure relief. Normally, the pressure relief should close automatically after pressure has been relieved, but probably stuck on open position.
A21740 7-7-73	LP gas powered oven exploded, causing a fire and damaging the oven. The cause of the explosion was not stated nor apparent from the report.

A29522 3-25-73	Two persons riding in a vehicle noticed a leaking propane gas tank. As they approached the tank, an explosion occurred. The leakage was apparently from a hole in the tank. The gas fumes may have been ignited by an ignition spark from the vehicle, cigarette smoke, or a fire arm (a 22 rifle and a shotgun were found in the vehicle).
A44688 3-31-73	A water heater flame ignited fumes from a leaking propane gas tank in the basement of a house.
A30079 4-11-73	Two children were playing with a small butane tank, which the mother thought was empty. When the butane tank was taken next to the water heater, an explosion occurred, resulting in a fire.
1974	Victim struck a match to light a propane gas range. Explosion occurred immediately. Cause of this accident was leakage due to poor installation. A 3/8 inch copper hose was used as a fuel line which goes through the wall of a camper. Vibrations caused the line to rub against the side of the camper wearing a hole in the fuel line.
750325 BEP7010 1-2-75	Propane gas tank exploded. "Atmospheric heat apparently caused swelling of contents" according to the in-depth report. The tank had been filled only 3 to 4 days before the accident. The interior of the tank was rusted. Follow up with the manufacturer indicated that the company has extensive quality control procedures, including radiographic tests, hydrostatic tests, and sampling methods. Manufacturer claims many consumers fail to maintain cylinders properly. This cylinder was built in 1964 and had no safety relief valve. Manufacturer stated that all cylinders shipped from his factory have pressure relief, but some people replace them with valves with no relief valve for economy.
750106 2-13-75	When the victim lit a match while standing near a propane gas stove, inside a trailer, an explosion occurred, blowing away the walls and top of the trailer. A new tank of propane gas had been installed outside the trailer a few days before the accident. Source of leak unknown.

750214 ISU 5019 2-14-75	A propane gas stove caught fire. The gas flow regulator in the stove stuck in the open position allowing gas to flow to the pilot light at full tank pressure. This apparently generated enough heat to melt other components of the stove releasing more gas.
750816 BEP 0021 8-10-75	A 14 year old male suffered a chemical burn to the eye. While sniffing gas from a 10 lb propane tank, his hand slipped releasing a blast of gas into his eye.
751025 BEP 0015 10-19-75	A spherical LP gas camping tank fell from a storage shell and rolled over victim's foot.

CASE NO.	DATE	AGE	SEX	PRECIPITATING EVENT/ACTIVITY	DESCRIPTION	RESULT (DIAGNOSIS)	DISPOSITION	PRODUCT MAKE COMPOSITION
GAS TANKS AND FITTINGS (0131) AND DISTRIBUTION SYSTEMS (0607)								
PATTERN: Liquified Petroleum Gas System Failure or Defect								
A18503*	6/6/73	50	M	Gas Accumulation (safety valve leak)	Safety valve on propane tank opened under pressure causing gas to leak. Nearby water heater ignited the fumes which resulted in an explosion and critically burned the victim. Victim expired after an undetermined stay in the hospital.	3^{o} burns/all parts of body	Expired	LP gas tank- ICC 4S240 E U3 2629 TS MWF C. TW 22-WC-48 3-60
A02561	4/8/73	31	M	Gas Accumulation (unknown leak-ignition by heater)	Victim and his family with another family were driving in a camper van when gas fumes were detected from LP gas tank located in the rear of the van. Victim opened vents in camper to allow the fumes to escape and then proceeded to fix LP tank. LP fumes did not completely escape and exploded when victim pushed ignition button on van's heater unit. All occupants of van were burned.	2^{o} and 3^{o} burns/ head, hands & wrist	Admitted (5 D)	LP gas tank- 20 lb. capacity (P)
A40354	4/8/73	30	M	Gas Accumulation (unknown leak-ignition by heater)	See Case #A02561	Burn-not stated	Treated & Released	
A40361	4/8/73	4	M	Gas Accumulation (unknown leak-ignition by heater)	See Case #A02561	1^{o} and 2^{o} burns/head	Not Specified	
A40355	4/8/73	19 mo.	M	Gas Accumulation (unknown leak-ignition by heater)	See Case #A02561	2^{o} and 3^{o} burns/head & hands	NS	
A40356	4/8/73	2	M	Gas Accumulation (unknown leak-ignition by heater)	See Case #A02561	2^{o} burn/head & hands	NS	

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CASE NO.	DATE	AGE	SEX	PRECIPITATING EVENT/ACTIVITY	DESCRIPTION	RESULT (DIAGNOSIS)	DISPOSITION	PRODUCT MAKE COMPOSITION
GAS TANKS AND FITTINGS (0131) AND DISTRIBUTION SYSTEMS (0607)								
PATTERN: Liquified Petroleum Gas System Failure or Defect								
A40357	4/8/73	28	M	Gas Accumulation (unknown leak-ignition by heater)	See Case #A02561	2° burn/head & hands	NS	
A40358	4/8/73	25	F	Gas Accumulation (unknown leak-ignition by heater)	See Case #A02561	3° burns/ face & hands	NS	
A40359	4/8/73	3	M	Gas Accumulation (unknown leak-ignition by heater)	See Case #A02561	1° & 2° burns/ head & hands	NS	
A40360	4/8/73	6	M	Gas Accumulation (unknown leak-ignition by heater)	See Case #A02561	1° & 2° burns/ head & hands	NS	
A17084	12/11/72	38	M	Ruptured tank	Accident happened at victim's auto repair shop. Valve of an LP gas tank ruptured when tank fell from a fork lift causing liquid fuel to escape. Heater flames ignited the fuel resulting in injury to victim and 7 employees.	2° burn/waist	Admitted (14 D)	LP gas tank-90 lb. capacity
A02496	12/26/72	62	M	Gas Accumulation (unknown leak-ignited by pilot light)	LP gas apparently was leaking from outside tank into basement and ignited by a pilot light causing an explosion. Victim was outside at the time of the explosion. He ran into the house to rescue 3 relatives who were trapped and was burned in the act. The 3 relatives expired after being admitted to the hospital.	2° & 3° burns/ face & hands	Admitted (17 D)	LP gas tank-500 gallon

CASE NO.	DATE	AGE	SEX	PRECIPITATING EVENT/ACTIVITY	DESCRIPTION	RESULT (DIAGNOSIS)	DISPOSITION	PRODUCT MAKE COMPOSITION

GAS TANKS AND FITTINGS (0131) AND DISTRIBUTION SYSTEMS (0607)

PATTERN: Liquified Petroleum Gas System Failure or Defect

CASE NO.	DATE	AGE	SEX	PRECIPITATING EVENT/ACTIVITY	DESCRIPTION	RESULT (DIAGNOSIS)	DISPOSITION	PRODUCT MAKE COMPOSITION
A16247	12/26/72	18 mo.	F	Gas Accumulation (unknown leak-ignition by pilot light)	See Case #A02496	3° burns/all parts of body	Expired	
A16248	12/26/72	25	M	Gas Accumulation (unknown leak-ignition by pilot light)	See Case #A02496	3° burns/all parts of body	Expired (2 D)	
A16249	12/26/72	61	F	Gas Accumulation (unknown leak-ignition by pilot light)	See Case #A02496	2° & 3° burns/all parts of body	Expired (5 D)	
A17029	7/30/72	24	F	Gas Accumulation	Blow torch cylinder was leaking in the basement and as victim opened basement door, air apparently carried fumes to a nearby furnace and was ignited by the pilot light causing burns to victim's feet.	2° burns/feet	Admitted (3 D)	Portable LP blowtorch cylinder with corroded top
A14326	6/29/72	40	M	Gas Accumulation (leaking hose)	Victim was looking in his camper for an object and struck a match to create some light. When he lit the match leaking LP gas fumes exploded. The leak occurred in the hose about 4 inches from where it was connected to the cooking stove.	Burn/face, arm, hand	Admitted (3 D)	LP gas tank 20 lb.
A42826*	11/10/71		M	Gas Accumulation (cracked feed line)	The feed line from an outside LP gas tank leading to the consuming unit in the house was cracked under the sink. Victim unaware of gas fumes proceeded to light a gas heater with a match and an explosion occurred.	1° & 2° burns/arms, hands	Admitted (11 D)	LP gas tank

CASE NO.	DATE	AGE	SEX	PRECIPITATING EVENT/ACTIVITY	DESCRIPTION	RESULT (DIAGNOSIS)	DISPOSITION	PRODUCT MAKE COMPOSITION
GAS TANKS AND FITTINGS (0131) AND DISTRIBUTION SYSTEMS (0607)								
PATTERN: Liquified Petroleum Gas System Failure or Defect								
A42767	3/1/71	56	M	Gas Accumulation (unknown leak-ignition by electric drill)	Two brothers were building a house and as one of the brothers was using an electric drill a spark emitted and ignited butane gas fumes. Neither of the brothers detected gas fumes prior to the accident. Butane tank was stored outside. Cause and location of leak could not be determined. Both men were burned, one seriously.	Burns/80% of body	Admitted	Butane tank-500 gallon
A40032	10/16/70	34	M	Gas Accumulation (escaping gas-human carlessness)	Two men were working in basement with a portable butane tank. Fumes escaped from the tank due to victim's carelessness and were ignited by the pilot light of a water heater. One victim sustained serious burns and required hospitalization.	1° & 2° burns/face, arms, hands, chest	T & R	Butane tank-Lennox
A42423	11/13/69	28	m	Gas Accumulation (leaking valve)	Victim just had the butane tank filled and stored it in basement. Apparently the valve was leaking gas and was ignited by the pilot light of a water heater. Victim carried the tank outside and on the way his wife and child were burned on the legs by flaming vapors dropping around them.	1° & 2° burns/arms, hands, thighs		
A28118	9/27/70	19	M	Gas Accumulation (unknown leak)	Exact circumstances involving this accident are not known, but it is evident that LP gas fumes accumulated in a camper during the night and when the victim awoke he lit the heater with a match and suddenly an explosion resulted. The LP gas had an odor but the victim did not smell it. LP tank was located outside the trailer.	2° burn/face, trunk, arms, legs	Admitted	LP gas tank

CASE NO.	DATE	AGE	SEX	PRECIPITATING EVENT/ACTIVITY	DESCRIPTION	RESULT (DIAGNOSIS)	DISPOSITION	PRODUCT MAKE COMPOSITION
GAS TANKS AND FITTINGS (0131) AND DISTRIBUTION SYSTEMS (0607)								
PATTERN: Liquified Petroleum Gas System Failure or Defect								
A27930	3/31/70	57	M	Gas Accumulation (unknown leak)	LP gas fumes accumulated in a trailer but could not be determined whether it came from the tank or feed lines. Victim entered trailer to light a fuel oil furnace and when he struck a match the trailer exploded.	3° burns/all parts of body	Dead on arrival	LP gas tank
A44234	3/23/67	46	M	Gas Accumulation (unknown leak)	Victim awoke from a night in a camper and lit a cigarette. When he struck the match the camper exploded. Victim did not smell gas when he awoke. It is not known how the fumes accumulated.	2° burns/all parts of body	Expired	LP gas
A43927	10/6/69	40	M	Gas Accumulation (unknown leak)	Victim and another person were found dead in a school bus converted to camper. LP gas had leaked into the camper while the victims were sleeping. Police investigation could not find source or cause of the leak.	Asphyxiation	DOA	LP gas tank-100 gallon
A42429	12/4/68	26	M	Gas Accumulation (insufficient ventilation)	Victim and his brother were using a propane wall steamer to remove wallpaper. After 10 minutes the brothers became ill due to the lack of oxygen and inhalation of the gas fumes. The brothers did not detect the oder of gas and there was insufficient ventilation in the house.	Asphyxiation	T & R	LP gas-portable propane wall steamer
A40238	10/2/67	19	M	Gas Accumulation (insufficient ventilation)	Victim was refueling a trailer which runs on LP gas. It is necessary to refuel from inside the cab and apparently the victim was overcome by the fumes.	Inhalation	DOA	

CASE NO.	DATE	AGE	SEX	PRECIPITATING EVENT/ACTIVITY	DESCRIPTION	RESULT (DIAGNOSIS)	DISPOSITION	PRODUCT MAKE COMPOSITION
GAS TANKS AND FITTINGS (0131) AND DISTRIBUTION SYSTEMS (0607)								
PATTERN: Miscellaneous								
A14944	7/1/72	44	M	Gas Accumulation (unknown-gas explosion)	Victim's employer was uncooperative and would not permit investigator to interview the victim. Employer stated that victim was entering a cellar when LP gas exploded. Cause of explosion could not be determined.	2° burns/face, trunk, arm, hands & legs	Admitted (85 D)	LP gas
A44298	6/13/71	47	M	Gas Accumulation (loose coupling)	Victim awoke in the morning and proceeded to light the stove in the camper. As he struck a match the camper exploded burning the victim, his wife and daughter. The LP gas tank was located outside the camper and the investigator could not determine the exact cause of the leak but a police officer said a coupling was loose in the gas line. Visitor did not smell any fumes when he awoke.	3° burn/all parts of body	Admitted	LP gas tank
A27821	6/16/69	43	M	Gas Accumulation (unknown leak)	Victim and 4 other members of his family were staying in a motel for the night. When victim awoke in the morning he lit a cigarette and suddenly the room exploded. An LP gas tank located outside the motel developed a leak in the lines and the fumes seeped into the victim's room even though there were no LP gas lines leading into the motel room. None of the victims detected any odor when they awoke. All other members of the family required hospitalization.	Burns/all parts of body	Expired (13 D)	LP gas

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CASE NO.	DATE	AGE	SEX	PRECIPITATING EVENT/ACTIVITY	DESCRIPTION	RESULT (DIAGNOSIS)	DISPOSITION	PRODUCT MAKE COMPOSITION
GAS TANKS AND FITTINGS (0131) AND DISTRIBUTION SYSTEMS (0607)								
PATTERN: Miscellaneous								
A17066	2/10/73	24	F	Frozen regulator	Victim awoke and found the gas stove smoking and the pilot light flickering violently. Her husband ran outside and turned off the main control valve on the bottled gas. Gas company said that freezing temperatures had affected the regulator on the gas filled cylinders causing air and moisture to mix with the gas. Victim burned thumb as she checked the control knobs.	1^{o} burn/ thumb	T & R	Stove- bottled gas
A17381	9/7/72	21	M	Gas Accumulation (open gas line)	Victim and his friend smelled gas leaking and went to the basement to find the leak. The friend thought the pilot light on a gas water heater had gone out and struck a match to relight it, when suddenly an explosion occurred. A fire department investigation determined that a gas line extending from the water heater to a gas dryer was not disconnected when the dryer was removed by the previous tenant causing propane gas to leak.	3^{o} burns/ head, trunk, arms, legs	Admitted (180 D)	Propane gas water heater
GAS RANGES WITH OVENS—EXCEPT SELF CLEANING OVENS (0203)								
PATTERN: Explosion								
A06679*	5/19/73	26	F	Gas Accumulation (relighting pilot)	Victim entered her mobile home and smelled gas. Before she left the home she turned on the oven to warm it up. The pilot light had gone out and gas accumulated in the oven. She turned off the oven and waited outside. She then lit a match to relight the pilot light and an explosion occurred.	1^{o} & 2^{o} burns/face, arms, legs	T & R (daily treatment)	LP gas oven- Tappan Co.

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Acknowledgments

The authors wish to thank Mr. Leonard Schachter of the Bureau of Epidemiology at the Consumer Product Safety Commission for his great assistance in obtaining injury data for this report. Also, Dr. B. W. Christ of the Metallurgy Section at the National Bureau of Standards was most helpful in suggesting sources of information related to the safety of fire extinguishers. Finally, we wish to thank Mrs. Rosemary Massengill for her diligent typing efforts.

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NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 77-1217	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE SAFETY PROBLEMS ASSOCIATED WITH PRESSURE CONTAINERS	5. Publication Date February 1977 6. Performing Organization Code 446.03
7. AUTHOR(S) S.K. Wakamiya and N.J. Calvano	8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234	10. Project/Task/Work Unit No. 4461430 11. Contract/Grant No.
12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)* Consumer Product Safety Commission 5401 Westbard Avenue Bethesda, MD 20016	13. Type of Report & Period Covered Final 14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Accident reports from hospital emergency rooms and reports of interviews with accident victims were reviewed to determine the probable causes of accidents involving two types of pressure containers: fire extinguishers and liquefied petroleum (LP) gas tanks. The data collected and reviewed during the study suggests that some of the safety problems associated with fire extinguishers involve: 1) incompatibility of the contents of an extinguisher with its shell; 2) faulty method attachment of plastic pressure gages on some dry chemical extinguishers; and 3) widespread use of obsolete extinguishers.

The primary hazard associated with LP gas containers appear to be leakage from various parts of the LP system. In many instances leaking gas accumulated in a closed area and was accidentally ignited, resulting in an explosion.

Engineering standards relevant to the safety of fire extinguishers and LP gas tanks were reviewed. Although the present standards governing these pressure containers address most safety problems adequately, a few of the requirements in some of these standards appear to be of questionable value in preventing certain types of accidents.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*
Container; corrosion; explosion; extinguisher; fire; gas; injury; liquefied; petroleum; standards.

18. AVAILABILITY	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
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USCOMM-DC 29042-P74