NPGA
National PROPANE GAS Association
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Part 106, 49CFR, § 106.31
Petition For Rulemaking

16/251

January 4, 2001

RSPA-2002-11967-1

Mr. Robert A. McGuire
Associate Administrator for **Hazardous** Materials Safety
Research and Special Programs Administration
U.S. Department of Transportation
400 Seventh Street, S.W.
Washington, D.C. 20590

Subject: Petition P-1039, Volumetric Filling of Cylinders

Dear Mr. McGuire:

This letter supplements the National Propane Gas Association's ("NPGA's") May 12, 1988 rulemaking petition wherein NPGA recommended that the DOT **hazardous** materials ("hazmat") regulations be amended to permit volumetric filling of all liquefied petroleum gas cylinders, not just those over 200 pounds. Specifically, this letter transmits a risk assessment comparing the relative risks of overfill for transportable propane gas cylinders when filling by volume in contrast to filling by weight.

NPGA is the national trade association of the LP-gas (principally propane) industry with a membership of about 3,800 companies, including 39 affiliated state and regional associations representing members in all 50 states. Although the single largest group of NPGA members are retail marketers of propane gas, the membership includes propane producers, transporters and wholesalers, as well as manufacturers and distributors of associated equipment, containers and appliances. Propane **gas** is used in over 18 million installations nationwide for home and commercial heating and cooking, in agriculture, in industrial processing, and as a clean air alternative engine fuel for both over-the-road vehicles and industrial lift trucks.

NPGA's original petition noted in detail the significant conflict between DOT's regulations and those regulations based upon National Fire Protection Association safety standard 58, which have been adopted in virtually every state.[1] This conflict has become even more significant since DOT completed its HM-200 rulemaking extending jurisdiction to intrastate transportation of hazardous materials (See 62 Fed. Reg. 1208 (Jan. 8, 1997)). Such a regulatory gap only serves to foster confusion in the marketplace and hampers propane marketers from serving their customers in the safest and most efficient manner.

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[1] Most recently, the Texas Railroad Commission approved **a** rulemaking to adopt, for the first time, this standard by reference. Once completed, only Arkansas will not have adopted **NFPA** 58 as the basis of state propane regulation.

The risk assessment that NPGA presents today, entitled "Risk Assessment of Propane Gas Cylinder Filling", lays to rest the notion that filling by weight is inherently safer than filling by volume. The report's conclusion states, among other things,

> The results of this analysis suggest that the probability of overfilling of propane cylinders is likely to be higher when filling by weight compared with filling by volume. The analysis comparing the two filling methods under different filling temperature conditions indicates that filling by volume appears to be safer than filling by weight, for the respective standard filling procedures, when the cylinder is exposed to elevated temperatures after filling.

NPGA strongly believes that this risk assessment justifies a revision to the hazmat regulations to allow the option of volumetric filling of cylinders less than 200 pounds, and petitions for the following amendment to the first sentence of Section 173.304(d)(4):

> (4) Verification of content. Containers ~~**with a water capacity of 200 pounds or more and**~~ **for** use with a liquefied petroleum gas with a specific gravity at 60°F. of 0.504 or greater may have their contents determined by using a fixed length dip tube gauging device.

In light of the attached risk assessment, we urge RSPA to promptly publish a notice of proposed rulemaking regarding **NPGA's** request. Should you have questions or require further information, please do not hesitate to contact me.

Sincerely,

Philip A. Squair
Director of Regulatory Affairs

Attachment

US Department of Transportation

Research and Special Programs Administration

RECEIVED MAY 16 1988

Tufc-642

May 12, 1988

W. H. Butterbaugh
Assfstant Vice President
Technical Services
National LP-Gas Assoc.
1301 West 22nd Street
Oak Brook, Ill. 60521

Dear Mr. Butterbaugh:

Thank you for your petition for rule change of the Hazardous Materials Regulations dated Feb. 25, 1988 re: volumetric filling of LPG cylinders.
The petition has been assigned P-1039 . If your should write to us regarding this petition, please make reference to the petition number.

Sincerely,

Sandra D. Cureton

Sandra D. Cureton
Chief, Dockets Unit
Exemptions & Approvals Division

UHB

NLPGA

National LP-Gas Association • 1301 West 22nd Street • Oak Brook, Illinois 60521 • 312-573-4800

February 25, 1988
Filer Tdc-692

Mr. Alan I. Roberts, Director
Office of Hazardous Materials Regulation
Research & Special Projects Administration
U.S. Department of Transportation
400 Seventh Street SW
Washington, DC 20590

Subject: Volumetric Filling of Propane Cylinders

Dear Mr. Roberts:

The National LP-Gas Association (NLPGA) recommends that the DOT Hazardous Materials Regulations be amended to permit volumetric filling of all liquefied petroleum gas (LP-gas) cylinders. At present, these Regulations permit volumetric filling only for LP-gas cylinders 200 pounds water capacity and larger.

NLPGA is the national trade association of the LP-gas industry with a membership over 4,100, including 47 affiliated state and regional associations representing all 50 states. Considerably more than half our members market LP-gas at retail through bulk plants; some of these sales are into cylinders brought in by the customer for re-filling or exchange for a "full" LP-gas cylinder. Many of these members also distribute LP-gas through campgrounds, hardware stores and rural outlets, which likewise refill cylinders. Thus, NLPGA and its members have a very direct interest in efficient refilling and safe use of cylinders.

At present, there is a significant conflict between the DOT Hazardous Materials Regulations (specifically 173.304 (c) and (d)(4)) and NFPA 58 (paragraph 4-5.3). NFPA 58 - "Storage and Handling of Liquefied Petroleum Gases" is published by the National Fire Protection Association; as an American National Standard, it is used as the basis of regulation by virtually evefy state. While NFPA 58 rightly tequires containers shipped under DOT jurisdiction to be charged in accordance with DOT Regulations, it also permits volumetric filling of small portable containers not subject to DOT jurisdiction. These small portable containers are DOT specification cylinders used for industrial truck (such as fork lifts) engine fuel, vacation camper fuel, backyard barbeque grill fuel, and other similar applications.

In addition to this conflict between the DOT Regulations and the state LP-gas safety regulations, there is another growing conflict caused by the states adopting the DOT Hazardous Materials Regulations for the regulation of purely intrastate commerce. Thus, the LP-gas industry is faced not only with a conflict between state safety regulations and Federal transportation regulations but also a conflict between state safety regulations and state transportation regulations.

We believe that there is a simple and expedient way to resolve these conflicts, and to that goal and purpose present this petition for rule making. There has been a long history of petitions both from NLPGA and from others to DOT, and earlier to the Interstate Commerce Commission, seeking resolution of this conflict. At various times, additional information has been requested or the petition has been denied or rejected. NLPGA firmly believes that a significant and substantial history of in-service experience under state regulations has been developed despite this conflict. This record amply demonstrates that volumetric filling of cylinders provides a level of safety at least equal to that obtainable by filling cylinders by weight. Since the discussion of technical issues, the presentation of this service experience and the recommended revision to the Regulations are rather lengthy, this information is enclosed as Appendix A to this letter.

NLPGA has submitted a separate petition for rule making regarding filling densities for LP-gas cylinders. It is our intent that the change recommended there with respect to the 42 percent filling density would apply to the affected portion of this petition.

NLPGA shares DOT's goal of safe transportation of LP-gas. We believe that approval of this recommendation is entirely in the direction of greater safety and a step which should prevent misunderstanding and confusion in the enforcement of DOT Regulations and state LP-gas safety regulations.

We would be glad to discuss this petition for rule making and the supporting information further at your convenience.

Sincerely,

W H Butterbaugh

W. H. Butterbaugh, CAE
Assistant Vice President
Technical Services

WHB/cl

Enclosures

APPENDIX A

RATIONALE FOR THE VOLUMETRIC FILLING OF LP-GAS CYLINDERS

Transportation and distribution of LP-gas in cylinders is the largest single use of DOT cylinders in this country. Information on the annual production of DOT cylinders for use by the LP-gas industry is presented in the enclosed copy of NLPGA LP-Gas Market Facts 1986.

NLPGA has always striven to develop and support recommended revisions to NFPA 58 "Storage and Handling of Liquefied Petroleum Gases" to make it as consistent with the DOT Hazardous Materials Regulations as possible. NFPA 58 is published by the National Fire Protection Association, Quincy, Massachusetts, and in its capacity as an American National Standard, is used as the basis of regulation by virtually every state.

Likewise, we believe that wherever possible, Federal and state regulations should at least be consistent, if not identical. There is, however, a point of difference between NFPA 58 and the DOT requirements for filling LP-gas cylinders, which in some cases causes hardship on the LP-gas industry and its customers, due to misunderstandings or misinterpretations on the part of state or local enforcement agencies. This difference lies in the requirements for filling portable containers of less than 200 pounds water capacity. Paragraphs 173.304 (c) and (d) (4) of these Regulations stipulate that only containers of more than 200 pounds water capacity may be filled volumetrically (i.e., filling by fixed length dip tube gauge); smaller containers must be filled by weight. NFPA 58 requires containers shipped under DOT jurisdiction to be filled in accordance with DOT requirements but permits volumetric filling on small portable containers not subject to DOT jurisdiction (see paragraphs 4-5.3.2 in the enclosed copy of the 1986 edition of NFPA 58). These small portable containers include industrial and fork lift truck engine fuel cylinders, recreational vehicle and backyard barbeque grill fuel containers, and other similar applications.

It is noteworthy that subparagraph 1910.110(b)(12)(iii) of the OSHA Regulations carries substantially the same wording as NFPA 58.

This conflict has been in existence since the publication of the 1957 edition of NFPA 58. The first effort to correct the situation occurred on February 1, 1960 when the Los Angeles Fire Department wrote to the AAR Bureau of Explosives (with a copy to Mr. Ernest Cox, ICC Bureau of Motor Carrier Safety) requesting that they consider an amendment to the regulations which would recognize what was in fact a common and, they felt, safe practice. Since that time there have been at least three petitions from the National LP-Gas Association with respect to this problem.

In the intervening years, the acceptance and use of consumer handled small cylinders has vastly increased, These applications include cargo heating, recreational vehicle non-engine fuel, fuel for gas grills and many thousands of industrial trucks. The container filler may be a bulk plant operator, a service station or campground attendant or some other seller of LP-gas. In many cases, there is no way he/she can determine whether a given container is destined for use in intrastate commerce or, in accordance with some of today's definitions, in an activity that affects interstate commerce. Therein lies the problem -- the container filler is doing what they, and we believe, is a safe job, but at the same time, he/she may inadvertantly violate a Federal regulation that appears to be unnecessarily restrictive.

NLPGA believes volumetric filling to be equally as safe as filling by weight, regardless of the size of the LP-gas container. This entire matter of conflict between NFPA 58 (and the state LP-gas safety regulations) and the DOT Regulations has assumed an entirely new dimension since it is now causing a direct conflict between state LP-gas safety regulations and state transportation regulations. Many states have adopted the DOT Hazardous Materials Regulations as state regulations and are beginning more and more vigorous enforcement of these requirements.

This difference on the matter of volumetric filling has caused canfusion in industry thinking and the local regulatory view as well. Same individuals have tended to support the interpretation which agrees with their own view on the matter based upon their operating practice. The gathering of data to substantiate the safety of volumetric filling has not been simple since from both a practical and regulatory standpoint, volumetric filling of small cylinders is limited to a relatively narrow even though important field.

Filling small cylinders volumetrically has been limited mainly to industrial plants (in the filling of industrial truck engine fuel cylinders used within industrial plants and commercial facilities) and to the filling of 20-pound cylinders for vacation trailers and backyard grills. Volumetric filling of small cylinders seldom is done in bulk filling plants, not because it isn't safe, but rather for two other very important reasons:

(1) - State weights and measures laws and regulations generally require accuracy within one percent or less for sale of gas by the cylinder or "package", Since cylinders typically have their water capacity in pounds stamped on them, this pretty much dictates filling by weight. Charging could be safely done volumetrically but the cylinder would be underfilled by weight at any temperature above 40 F. This would require topping out by weight - an impractical approach. The weight differences resulting from volumetric charging (rather than weight charging) at some of the normally encountered liquid temperatures are as follows:

Temperature	% Error	Pounds Underfill 33.5 lb. LP-Gas Cylinder
50	1.5%	0.5 lb.
60	3.0%	1.0 lb.
70	4.6%	1.5 lb.
80	6.3%	2.1 lb.

(2) Bulk plants generally use automatic cylinder filling equipment for efficient filling of cylinders on a production-style basis. Such equipment operates by the weight method, making any other method impractical to use.

For most cylinder filling outside bulk plants, such as for industrial truck containers, safety and convenience in filling are of far greater importance than exactitude in weight, making volumetric filling attractive since scales and their related protection and maintenance are not necessary, In the case of vacation trailer and backyard grill cylinders, while it might be desireable to fill by weight (in order to put charge as much fuel into the cylinder as possible under the DOT Regulations), the convenience of getting service locally and quickly is of more importance to the customer, thus increasing the desirability of volumetric filling, It *is* important to note that the interests of the consumer here in receiving accurate measurement of the fuel purchased is served by the requirements in these same weights and measures regulations for accuracy of volumetric measurement by liquid meter. Neither fair measurement to the consumer nor safety are compromised by volumetric filling of LP-gas cylinders.

Thus, the principle fields in which volumetric filling is widely used have been (1) the industrial plant filling its own cylinders and (2) the individual, small LP-gas operator filling vacation trailer cylinders at campgrounds and retail establishments filling cylinders for backyard grills and other such small volume applications. It is effectively impossible to obtain statistics on these two kinds of operations,

However, there have been thousands upon thousands, numbering in the many millions, of instances where these small cylinders have been filled volumetrically and used over the years, If there were indeed a safety problem resulting from filling these cylinders volumetrically, there would have been a significant number of incidents which could be traced undeniably to the method of filling the cylinder. While from time to time there have been occasional incidents in all these applications, there have not been any in which the method of filling the cylinder was determined to be the critical element resulting in the incident, Just because a cylinder is filled by weight is no guarantee that the cylinder will not be overfilled. With either method of filling cylinders, the only real protection against over-filling and the consequent unsafe conditions that may result is thorough and adequate training of the personnel performing the filling operation. In recognition of this basic (though often overlooked) fact, NLPGA has produced several training aids, listed in the enclosed copy of our publications list, "Bookshelf", for use in training personnel in the proper and recommended procedures for filling cylinders.

In response to earlier concerns for statistical information, the following information has been based on a survey conducted among our member companies and presented in a November 3, 1971 petition for rule making presented to DOT on this same subject. From our continual review of incidents involving LP-gas, we have no reason to believe that this information would be changed in substance were the survey to be conducted today.

Summary of 12 months filling experience 1965-66

Number of cylinders 20, 33.5 & 43.5 lb. LP-gas capacity filled volumetrically			50,171
Number of cylinder fillings during 12-month period			1,051,500
Cylinders overfilled	number		79
	% of total	*	0.008
Cylinders where relief valve opened	number		53
	% of total	*	0.005
Accidents caused by overfilling			None Known

*Less than one per 10,000 cylinder fillings.

Much of the discussions in the earlier petitions have centered on the respective accuracy of the two filling systems. There is no question as to the benefits of a weight type system, if we are dealing with a commodity and container where all factors are absolute. But with LP-gas cylinders, that is not necessarily the case, There is a permitted downward variation in container tare weights of 5%, as stated in 173.34(e)(2), in addition to permitted scale tolerances. National Bureau of Standards Handbook 44 permits a 1/2 percent plus tolerance on scales of the type that are used to fill cylinders, These tolerances could in effect change the filling density from 0.42 to 0.4387, Even with these possible variations, the net effect on weight filling has been good and no particular problems have resulted,

As to volumetric filling of small containers: The concern, as we understand the matter, is the possibility of overfilling such a device on account of high speed filling systems. There is this possibility, just as there is the possibility when filling by weight because of a defective automatic fill valve or because the operator of a manual scale becomes inattentive. It seems to us that this is principally a matter of trading problems. With volumetric filling, we do away with the possible problems with tare weights and scale tolerances,

As a practical matter, the cylinders of concern have water capacities greater than 25 pounds, Cylinders smaller than this size are either handled on an individual or specialized basis and need not be considered in the proposed amendments. There is also a valve orifice provision in NFPA Standard No. 58, wherein excess flaw valves are not required on cylinders for vapor service if the controlling orifice in the valve is less than 0,3125" Dia. That provision, although not so intended, serves to substantially restrict container filling rates,

The fact that no serious accidents resulting from this type of filling have been reported, in an unstatistical way, is an indication that volumetric filling has proven to be safe,

NLPGA believes that there is no doubt of the safety of properly performed volumetric filling. Regulations cannot be based upon improper charging procedures, regardless of the method used - to advocate anything less is simply unconscionable. Also, there is no doubt that from both weights and measures and sales standpoints, filling by weight can be more accurate with respect to charging the cylinder with the absolute maximum permitted by safety considerations - in that respect, volumetric filling in most seasons of the year will result in slightly less product being placed in the cylinder than would be permitted had the cylinder been filled by weight. This, however, is not a question which we believe should be rightly of concern to DOT - its concern should be solely for safety, leaving weights and measures issues to be settled in appropriate arenas as a subsidiary issue to safety.

NLPGA recommends favorable consideration of the following proposed revision to 173.304(d)(4). It will be noted, recognizing the possibility of greater temperature rise in the smaller containers (due to the increasingly high ratio of surface area to volume as the cylinder size decreases), that a lower (ultra-conservative) filling density is specified for volumetric filled cylinders of 25 lb. water capacity (10 lb. LP-gas) and less. The two filling densities contemplated for the two size ranges of cylinders, specified above, are illustrated as follows:

Cylinder Capacity lb. water	Cylinder Capacity lb. LP-gas	Filling Density	Percent Liquid Full at 60 F	119 F	130 F	140 F
25 to 1000	10.5 to 420	42	83.0	92.0	95.1	97.5
less than 25	less than 10	40	79.0	87.5	90.5	92.8

Further, it may be questioned whether a cylinder filled with LP-gas having a temperature of 20 F may become liquid full at 130 F. A cylinder filled to 42 percent filling density by weight at 60 F is 0.42 x .5008 or 82.6 percent full, However, to fill by fixed length dip tube gauge, it is necessary to place in the container liquid LP-gas which at 40 F would fill it correctly by weight, oK 82.6 percent divided by the temperature correction factor for 40 F, 1.032 which is 80.2 percent, The following tabulation will illustrate the effect of liquid expansion of LP-gas, The opportunity of a cylinder with its product attaining 130 F after being filled at 0 E are extremely remote except in the case of Eire exposure and these cylinders would be protected by safety relief devices,

Liquid Temperature F	Percent Liquid Full When Filled at Temperature Indicated Below 0 F	20 F	40 F	60 F
40	84.5	82.5	80.2	77.7
60	87.3	85.2	82.6	80.2
80	90.4	88.2	85.5	83.0
100	93.9	91.7	89.0	86.1
120	97.9	95.5	92.8	89.9
130	100.2	97-7	95.0	92.1
140	102.8	100.0	97.3	94.3

Also, we recommend that the fixed length dip tube gauge be checked as a part of the periodic requalificiation of a cylinder.

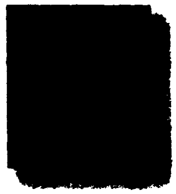
It is proposed that Section 173.304(d)(4) be revised to read as follows:

"(4) Verification of content. Containers for use with a liquefied petroleum gas with a specific gravity at 60 F or greater of 0.497 may have their contents determined for filling by using a fixed length dip tube gauging device- The length of the dip tube shall be such that when a liquefied petroleum gas with a specific volume of 0.03051 cu. ft./lb. at a temperature of 40 F is charged into the container, it just reaches the bottom of the tube, The weight of this liquid shall not exceed the appropriate percentage water capacity of the container as shown below- This water capacity must be stamped thereon-

Over 25 pounds water capacity	42 percent
Less than 25 pounds water capacity	40 percent

The length of the dip tube, expressed in inches carried out to one decimal place, i.e., where the computed length falls between even tenths of inches to the next greater length, and prefixed with the letters "DT" shall be stamped on the container and on the exterior of removable type dip tube; for the purpose of this requirement, the marked length shall be expressed as the distance measured along the axis of a straight tube from the top of the boss through which the tube is inserted to the proper level of the liquid in the container. The length of each dip tube shall be checked when installed by weighing each container after filling except when installed in groups of substantially identical containers in which case one of each 25 containers shall be weighed, The quantity of liquefied gas in each container must be checked by means of the dip tube after disconnecting from the charging line. The outlet from the dip tube shall be not larger than a No. 54 drill size orifice.

A container representative of each day's filling at each charging plant shall. have its contents checked by weighing after disconnecting from the charging line."



Risk Assessment of Propane Gas Cylinder Filling

Prepared for:

National Propane Gas Association (NPGA)
1101 17th St., NW, Suite 1004
Washington, DC 20036

RADIAN INTERNATIONAL
A DAMES & MOORE GROUP COMPANY

May 2000

Table of Contents

1.0 Introduction

The National Propane Gas Association (NPGA) commissioned a study to *compare* the relative risks of overfill for transportable propane gas cylinders when filling by volume in contrast to filling by weight. The study is concerned with small cylinders of less than 200 pounds water capacity designation. The study compared the risks in terms of overfill probability, estimated for each filling method, and the proximate consequences of overfill. Because the assessment is related specifically to U.S. Department of Transportation (DOT) cylinder filling requirements, the study is focused on the potential for overfill that would create a heightened threat of release during transportation of cylinders subject to DOT jurisdiction. The NPGA would like the DOT to allow volumetric filling of cylinders in the subject size range. Currently, DOT requirements only allow filling by weight for such cylinders. This is in contrast with National Fire Protection Association standard, NFPA *58* Liquefied Petroleum Gas *Code,* that allow filling by either weight or volume for such cylinders, with the exception of any cylinders that would fall under DOT jurisdiction, based on how and where the filled cylinders will be transported

For each filling method, the risk assessment identified potential causes of failure, such as equipment failures and human errors, which could lead to overfill. The assessment estimated probabilities of failure using a combination of generic, industry failure rate data; limited data from propane gas filling experience; and engineering judgment. A fault tree analysis was applied to estimate the probability of overfilling flkom the probabilities of individual events that could lead to overfilling. The scope of this analysis was limited to overfill, defined as exceeding 80 percent of the cylinder volume with liquid propane, based on the liquid density of liquid propane at 40 °F. Analysis of events resulting from an accidental release of propane from a cylinder were not included in this study, because the potential impacts would be the same whether the cylinder was filled by weight or by volume.

Filling by weight introduces a bias toward overfilling when compared with the 80 percent by volume standard. Operators calculate the allowable weight based on the specific gravity of propane at 40°F. The specific gravity of propane varies with temperature. At any fill temperature above 40°F, this results in the cylinder being more than 80 percent full by volume, even if the target weight is hit exactly. This bias toward an overfill reduces the margin of error allowable for filling by weight, compared with the margin for filling by volume.

These results suggest that filling by volume might pose less overall risk than filling by weight.

4. Adding together the weight of the hose end valve and hose with the weight of the maximum permitted amount of propane and the tare weight of the cylinder to arrive at the number used to set the scale balance beam.
5. Setting the scale to indicate the proper total filled weight of the container, propane, hose and hose end valve.
6. Connecting the fill hose end valve to the cylinder valve.
7. Opening the cylinder valve.
8. Starting the pump.
9. Opening the hose end valve.
10. Closing the hose end valve when the scale beam or indicator tips.
11. Closing the cylinder valve.
12. Shutting off the pump.
13. Disconnecting the hose from the cylinder valve.

atmosphere until the pressure drops below 375 psig and the relief valve closes again. For example, if a cylinder is filled to 90% liquid volume at 50 °F, it would approach liquid full at 115 °F (1). The temperature difference needed to achieve liquid full conditions decreases as the severity of overfilling increases.

The above information leads to one of the key arguments in favor of permitting volumetric filling of cylinders: The preponderance of portable cylinders (estimated to be over 60,000,000) are used for recreational purposes such as outdoor grilling, camping and other such activities. Assuming that most of these cylinders are filled during the warmer months of the year when the temperature exceeds 40°F, the use of the weight method to fill cylinders will result in cylinders which contain greater than 80% liquid propane by volume.

Calculations can show the extent to which a cylinder filled with propane at a given fill temperature will become overfilled when it is exposed to higher temperatures such as 130°F. When filling the cylinder by the two different procedures, the effect of temperature changes on the liquid expansion and vapor pressure is described in Section 5.3 of this report. But, first, we examine the failure modes leading to overfill for the two filling methods.

Figure 5-1 is the fault tree for filling by volume. Cylinder overfill might result from a faulty dip tube or operator error. Operator error might be failing to observe venting of the dip tube venting valve or failing to shut cylinder valve when the prescribed propane level has been reached. A faulty dip tube can be due one that is too short (e.g., bent), missing entirely or clogged from contamination present when it was installed.

Figure 5-2 is the fault tree for filling by weight. Cylinder overfill might result from faulty weighing equipment or operator error. Operator error includes failing to correctly note the tare weight, the weight of the hose and fill valve, calculate the fill weight, add the necessary weights or set the scale properly. Scale faults might be mechanical or electrical (in the case of electronic weighting devices).

Table 5-2 summarizes the probability calculations based on the fault tree figures.

Actual, detailed failure frequency or probability data for a cylinder overfill were not available nor could be located for this study, with the exception of some information from a letter on the overall rate of cylinder overfill reported from an industry survey (2).

Therefore, for the fault trees, values were assumed, based on experience with other equipment and process systems and engineering judgement. Industry persons familiar with filling operations were queried to obtain estimates of the frequency of observations of the failure modes reflected in the fault trees. However, few definitive numbers exist because the events are not common and records of such events are not kept. Nonetheless, the estimates provide useful insight into how the probabilities and hence risk of failure by the two filling methods might compare and what factors influence risk of overfill for both methods,

To provide some perspective on the individual probability values, one might consider a 1 chance in 100 event (1.00E-02) or a 1 percent chance as relatively common event for an industrial failure event, and a 1 chance in 1000 event (1.00E-03) as infrequent. A 1 chance in 10,000 event (1.00E-04) can be considered uncommon to relatively rare with smaller failure rates considered rare to remote.

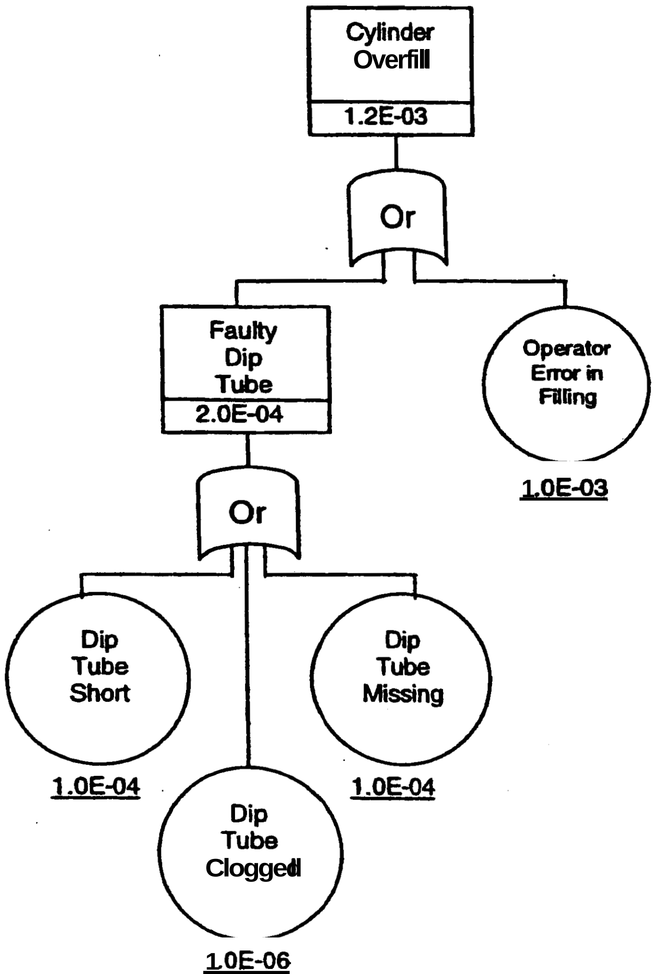


Figure 5-1. Fault Tree for Filling by Volume

Table 5-2. Process Failure Modes Comparison

	Volumetric Filling		Weight Filling	
Process Step	**Failure Mode**	**Probability**	**Failure Mode**	**Probability**
1. Open main supply valve				
2. Connect cylinder				
3. Open feed valve				
4. Open vent valve				
5. Fill	Dip tube too short	1.10E-04	Weigh scale fails	1.00E-04
	OR			
	Dip tube missing	1.00E-04		
	OR			
	Dip tube clogged	1.00E-06		
	OR		OR	
	Operator error	1.00E-03	Operator error	1.5E-03
6. Close feed valve				
7. Close vent valve				
8. Remove cylinder				
TOTAL PROBABILITY		**1.2E-03**		**1.6E-03**

NOTE: The relative operata error potential between filling by weight and fillingby volume was calculated as follows. Comparing the filling process steps given in Section 3.0, the following steps were deemed "critical" to overfill potential in each method:

<u>Volumetric Filling</u>

3. Opening the fixed liquid level gauge on the cylinder, using a screwdriver.

6. When a steady, white mist is emitted, turning off the hose end value.

Weight <u>Filling</u>

1. Reading the tare weight from the cylinder and noting it for further use.
2. Reading the water capacity in pounds from the cylinder.
3. Determining the maximum weight of propane permitted in the cylinder based on the water capacity of the cylinder, by referring to a chart,
4. Adding together the weight of the hose end valve and hose with the weight of the maxi" permitted amount of propane and the tare weight of the cylinder to arrive at the number used to set the scalance balance beam-
5. Setting the scale to indicate the proper total filled weight of the container, propane hose and hose end valve.

• • •

10. Closing the hose end valve when the scale beam or indicator tips.

If the probability of operator error for volumetric filling is assumed to be 1.0E-03 per fill event, given the increased number of operator steps required far filling by weight, *the* probability of operator error will be greater. Of the steps listed for filling by weight, at least three will be repeated for *each* individual cylinder filling; steps 1, 5, and 10.

Therefore,

probability for weight fill =

$$\left(\frac{\text{No. Critical Steps for Weight Fill}}{\text{No. Critical Steps for Volume Fill}}\right) \times \text{probability for volume fill} = \left(\frac{3}{2}\right)(1.0E-03) = 1.5E-03$$

For each filling method, the extent of overfill was examined for six cases:

Case	Fill Temperature (°F)	Exposure Temperature (°F)
1	40	40
2	70	70
3	100	100
4	40	130
5	70	130
6	100	130

Figure 5-3 shows the effects of filling errors on the extent of overfill for three filling temperatures: 40°F, 70°F, and 100°F, when the cylinder is maintained at the filling temperature. Propane property data used for the calculations were for pure propane, obtained from the technical literature (3). Figure 5-3 shows that filling by volume maintains the safety margin for each filling temperature and an error of 25 percent would have to occur before the potential for a liquid full container existed. When filling by weight, the 25 percent error margin is maintained only when fill temperature is 40°F. When filling by weight at 70°F and 100°F, filling errors of 19 percent and 12 percent, respectively, are the limits before the potential for a liquid full cylinder occurs.

Figure 5-4 shows the effect of exposure to a temperature of 130°F, after filling, for various extents of overfill. For example, Figure 5-4 shows that when filling by volume, even at a temperature of 100°F, the safety margin is maintained as long as the filling error is less than 17 percent. The safety margin is maintained with volume filling throughout the range of fill temperatures. When filling by weight, all filling temperature conditions will lead to a potentially liquid full cylinder if only a 5 percent filling error is committed.

These results show, that even with equivalent probabilities of overfill, the consequences of overfilling are potentially worse when filling by weight, because there is less margin for error before the potential for a liquid full cylinder occurs.

It is instructive also, to consider the average seasonal variations in temperature in the United States as part of the risk evaluation. The overall average winter and summer temperatures have been calculated to be, respectively 31°F and 74°F, from literature data (4).

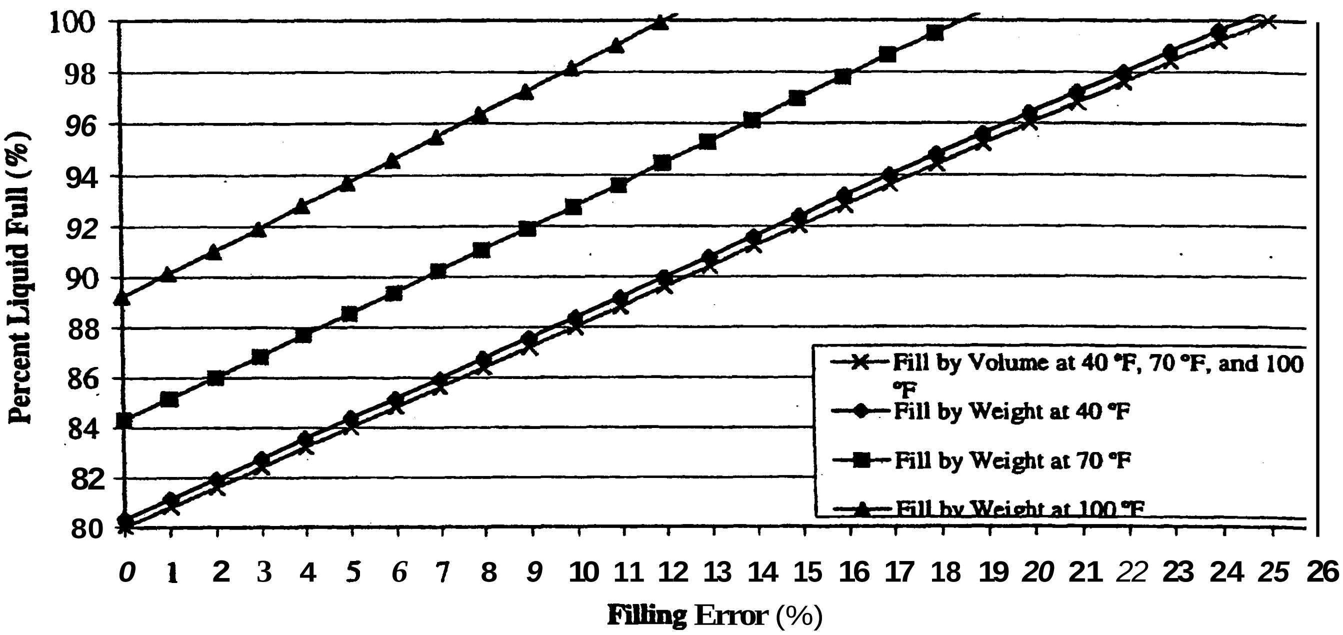


Figure 5-3. Effect of a Filling Error on the Overfilling **Magnitude,** Exposure Temperature = Filling Temperature

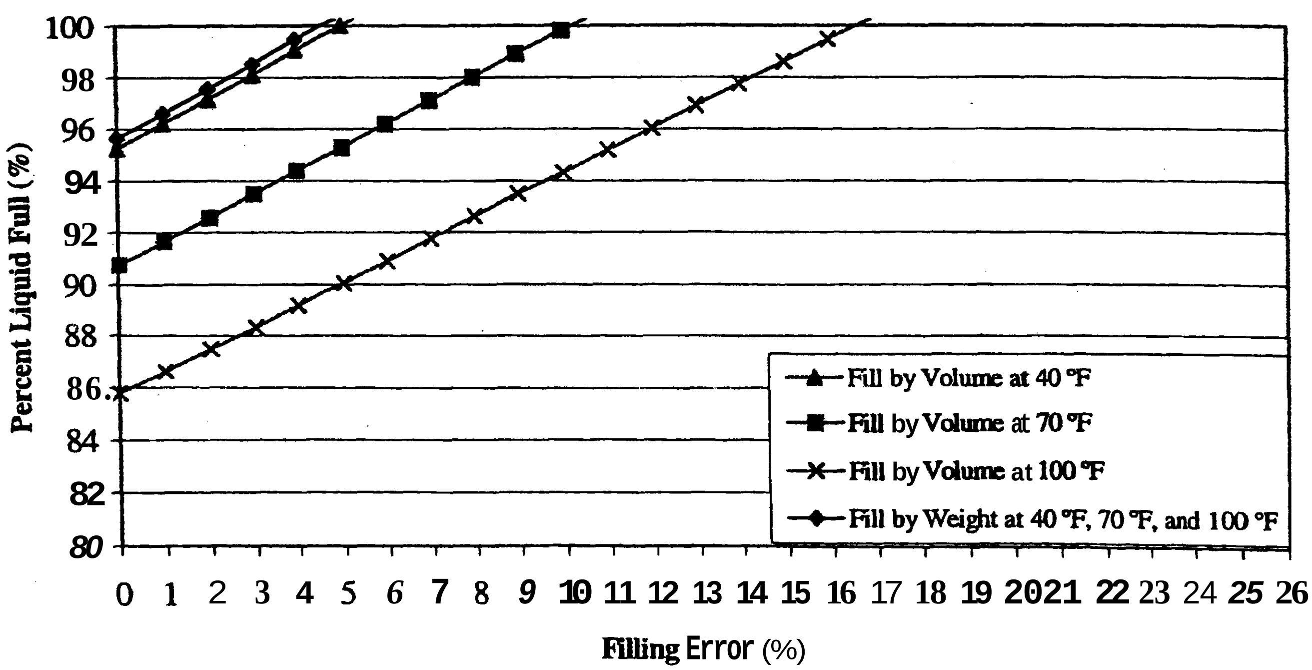


Figure 5-4. Effect of Filling Error on the Overfilling Magnitude, Exposure Temperature = 130ºF

7.0 References

1. Standard Procedure for Filling Propane Storage Containers, National Propane Gas Association, NPGA 3.4, Instruction Sheet III, 1999, p. *64 - 92.*

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3. DIPPR Pure Component Data Compilation, Numerica TM Version 10.2, Technical Database Services, Inc. (TDS), New York.

4. Famighetti, R. (ed.), The World Almanac and Book of Facts, 1995, p. 181.