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2022 NCWM-NIST National Survey on 20 lb LPG (Propane) Cylinders

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Abstract

The National Conference on Weights and Measures (NCWM) in partnership and cooperation with the NIST Office of Weights and Measures (OWM) and the Weights and Measures Divisions of select U.S. states initiated the 2022 National Survey on 20 lb LPG (Propane) Cylinders that represents the current marketplace practice of manufacturing, filling, selling, and exchanging 20 lb LPG cylinders. The survey determined the accuracy of the stamped tare weight (TW) to the actual tare weight by collecting contemporary data; evaluated the methods of sale, fill procedures, and price posting practices used at direct sale refilling locations; and determined the net weight compliance when performing a cylinder exchange and how much product remains after consumers perform an exchange. This study was designed to examine, validate, and ultimately ensure "Equity in the Marketplace," by confirming accuracy and fair competition in commercial transactions of LPG products based on product weight or other measures (e.g., flat fees).

For all the evaluated cylinders (9,482 new and 822 used cylinders), nearly half (44.3 %) of new cylinders and significantly less (32.0 %) of used cylinders were in compliance with existing tare weight requirements. With a shift to more lenient Department of Transportation (DOT) regulations to be effective for cylinders manufactured after December 28, 2022, nearly all of these new cylinders (98.4 %) and a significant majority of the used cylinders (65.7 %) would be in compliance. A total of 1,559 direct sale refilling locations across 18 states were evaluated to determine how 20 lb propane cylinders were being sold, posted or advertised, and if the safe fill level was being verified through proper procedures. A range of selling approaches (by weight, volume, flat fees) were observed, and nearly 10 % of locations are improperly verifying the safe fill level of cylinders. Of the cylinder exchange locations that were surveyed, only 74.2 % passed the overall individual package requirements for accurate net contents and 1.1 % of cylinders were found to exceed the safe fill level of 20 lbs. An average of 25.4 % of consumers return more than 1 lb of propane when they return a cylinder. Of these, approximately 9.1 % returned cylinders with over 5 lbs of propane.

The results provided in this report are to assist and inform the states, propane industry, consumer and workplace protection organizations, and Federal agency stakeholders of the present needs and opportunities to establish improved procedures and oversight of the manufacturing, refilling, reselling and consumer-based transactions for LPG cylinders. States should consider performing more routine inspections and enforcement beyond the 20 lb cylinders, as similar issues and concerns may exist for different sized cylinders and other types of compressed gasses. States should review and develop programs to ensure the accuracy of scales being used at the plant and at direct sale refilling locations. Industry and their trade associations should also consider conducting a "root cause analysis" to determine any underlying processes or procedures that may be contributing to non-compliance. Improving the manufacturing process and safety considerations while also informing and educating consumers on potentially wasted product will ensure improved safety and marketplace equity for businesses and consumers alike.

Keywords

cylinders; compressed gas; DOT; liquefied petroleum gas; manufacturers; method of sale; net content compliance; packaging requirements; propane; quantity control practices; safety; state inspections.

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Foreword

This report is the culmination of the 2022 National Survey on 20 lb LPG (Propane) Cylinders undertaken as a cooperation between the National Conference on Weights and Measures (NCWM), the Weights and Measures Divisions of select U.S. States, and the NIST Office of Weights and Measures (OWM). These organizations have distinct yet complimentary roles in promoting uniformity in weights and measures across the U.S. Thus, this National survey is an exemplar of Federal and state governmental agencies and national organizations working in partnership to ensure equity in the marketplace for both businesses and consumers and with the ultimate goal of serving the weights and measures community at large.

As a non-regulatory agency within the Department of Commerce, NIST has statutory responsibility to promote cooperation with the States in securing uniformity in weights and measures laws and methods of inspection. NIST OWM cooperates with NCWM and other Federal agencies, states, other countries, standards development organizations, business, and industry to develop uniform laws and regulations related to legal metrology. NIST also has a statutory duty under the Fair Packaging and Labeling Act (FPLA): Sec. 1458. Cooperation with State Authorities; Transmittal of Regulations to States.

The NCWM is a professional not-for-profit association of state and local weights and measures officials, Federal agencies, manufacturers, retailers, and consumers. NCWM develops uniform and equitable weights and measures standards to promote commerce and fair competition by ensuring marketplace equity for consumers, fostering confidence in commercial transactions, and advancing economic growth. NCWM works with NIST to publish model laws, regulations and standards adopted by NCWM in NIST Handbooks which are then used and adopted by the states.

Each U.S. state and select territories, and the District of Columbia maintains its own weights and measures program which are responsible to enforcing legal requirements in such areas as packaging and labeling laws and regulations, net content compliance of packaged goods, and the accuracy of weighing and measuring devices. Weights and measures programs inspect products at retail, wholesale, and manufacturer plant locations, and anywhere commerce takes place within the state jurisdiction.

Both consumers and businesses may not always be able to protect themselves from potential fraudulent practices that may occur in routine commercial transactions. The oversight provided by weights and measures authorities in any business sector helps to protect against unfair practices and minimize the proliferation of “fraud” and harm to the local, state, and national economies. Thus, the presence of official weights and measures authorities and through nationwide surveys of commercial products directly promote equity in the marketplace.

We welcome comments and feedback regarding the 2022 National Survey on 20 lb LPG (Propane) Cylinders and any suggestions for future engagements with our weights and measures and industry stakeholders. Please feel free to send an email to owm@nist.gov.

Acknowledgments

The authors wish to thank all the weights and measures personnel of the following U.S. states that participated in, contributed data to, and provided invaluable feedback regarding the 2022 National Survey on 20 lb LPG (Propane) Cylinders:

Arizona,

Arkansas,

California, including the individual counties of Almeda, El Dorado, Lassen, Lake, Mendocino, Napa, Orange, Sacramento, San Luis Obispo, San Bernadino, San Mateo, San Diego, Santa Barbara, Santa Cruz, Sonoma, Tulare, Ventura, and Yolo,

Florida,

Iowa,

Kansas,

Maryland,

Minnesota,

Missouri,

Montana,

Nevada,

New Hampshire,

New Mexico,

New York, including the individual counties of Otsego, Westchester, and Putnam,

North Carolina,

Ohio, including the individual counties (and city) of Fayette, Lucas, Huron, Licking, Franklin, Columbus (City), Cuyahoga, Wayne, Homes, and Mahoning,

Utah,

Vermont, and

Wisconsin.

Without their diligence to the details and dedication to their professions, this survey would not be possible.

We also wish to thank the National Propane Gas Association (NPGA) and their members for their support in working with NIST OWM and the states that participated in the survey.

Introduction

In 2020, nearly 9.5 billion gallons of liquefied petroleum gas (LPG, or commonly referred to as propane) were sold in the U.S. [1] including over 40 million individual cylinders of propane. The 20 lb propane cylinder is one of the more frequently used "convenience" products in U.S. households. Many of the U.S. state's weights and measures authorities have found systematic and potentially significant problems with short weight (underfilled) 20 lb propane cylinders, but also with cylinders being filled beyond the safe capacity.

To ensure "*Equity in the Marketplace*," the National Conference on Weights and Measures (NCWM) in partnership with the NIST Office of Weights and Measures (OWM) initiated the 2022 National Survey on 20 lb LPG (Propane) Cylinders that represents the current practice of manufacturing, filling, selling and exchanging 20 lb LPG cylinders in the current marketplace. The purpose of this survey was three-fold:

1) to determine the accuracy of the stamped tare weight (TW) to the actual tare weight by collecting contemporary data;
2) to evaluate the methods of sale, fill procedures, and price posting practices used at direct sale refilling locations; and
3) to determine the net weight compliance when performing a cylinder exchange, and to determine how much product remains after consumers perform an exchange.

This national survey on LPG cylinders not only represents a collaboration between NIST and NCWM, but also represents a highly coordinated effort involving over 19 U.S. states and 31 local (e.g., county and city) jurisdictions (see Fig. 1).

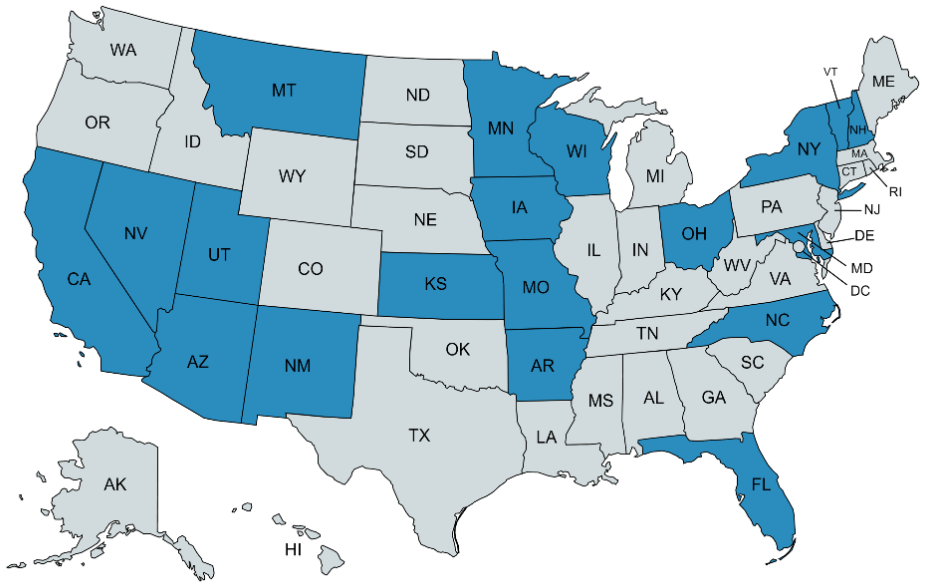

Fig. 1. Map of U.S. States that participated (shown in blue) in the LPG (Propane) cylinder survey. (Credit: www.mapchart.net)

The results of the 2022 survey are intended to provide an initial assessment of the marketplace compliance with NIST Handbook 130 (2022) [2] "Uniform Regulation for the Method of Sale of Commodities, Section 2.16. Compressed or Liquified Gases in Refillable Cylinders. The results obtained from this survey will provide data to inform NCWM as whether to petition U.S. Department of Transportation (DOT) on their recent release of 49 CFR § 178.35 "General Requirements for Specification Cylinders" [3] that apply to cylinders manufactured after December 28, 2022.

This survey was designed to examine, validate, and ultimately ensure the accuracy and fair competition in commercial transactions of LPG products that are based on product weight or measure. The accurate quantity declarations on LPG products (and other commercial products and packaged goods) enable consumers to make value comparisons and informed purchasing decisions.

Uniform Weights and Measures Law and Regulations

The adoption of uniform weights and measures laws and regulations, requirements for weighing and measuring devices and prepackaged products, and inspection and test procedures helps ensure equity and fair competition in the marketplace. NIST publishes the uniform model laws, regulations and standards adopted by NCWM in NIST Handbook 130 Uniform Laws and Regulations in the Areas of Legal Metrology and Fuel [2] and NIST Handbook 44 Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices [4]. All states adopt and implement NIST Handbook 44 which applies to a wide range of commercial weighing and measuring devices including LPG liquid-measuring systems. Thousands of inspections of weighing and measuring devices are carried out across the country to ensure they are suitable for the purpose in which they are used; they are accurate; and they are used properly.

States inspect prepackaged commodities to ensure they contain the net quantity of contents expressed on their labels. To carry out these inspections, states adopt and use NIST Handbook 133 Checking the Net Quantity of Contents of Packaged Goods [5].

Establishment of Requirements for Accuracy of Tare Weights on Cylinders

Beginning in the late 1980s, in response to requests from several states, the NCWM Laws and Regulations Committee began developing proposals for establishing requirements for the accuracy of tare weights on cylinders to improve the accuracy of the net quantity of contents delivered to consumers to both ensure equity and fair competition in the marketplace. In 1990, and after several years of work (which included representatives from the propane industry and Compressed Gas Association), the NCWM adopted Section 2.16. Compressed or Liquefied Gases in Refillable Cylinders within the Method of Sale of NIST Handbook 130.

Within the 75th (1990) Report of the NCWM [6] the following statement noted NCWM recognized the DOT regulations required a 1 % tolerance between the actual tare weight and the stamped tare weight, but the DOT regulations were intended solely for safety purposes and did not relate to net quantity of content verification:

> *"These Federal regulations permit a 1 percent tolerance between the actual tare weight and the stamped tare weight. This tolerance, although acceptable for safety purposes (for example, to avoid overfilling a cylinder and for determining if the cylinder is empty prior to refilling), is not precise enough for use in determining the net contents to arrive at a final charge for the cylinder of compressed gas."*

States previously understood that, for the purposes of net quantity of contents verification and commercial transactions, a tolerance less than the 1 % specified in the DOT regulation was essential to avoid economic harm to both buyers and sellers. This is summarized in Table 1. Summary of NIST Handbook 130, Section 2.16 Compressed or Liquefied Gases in Refillable Cylinder, Uniform Regulation for the Method of Sale of Commodities.

DOT Final Rule (49 CFR § 178.35)

The U.S. Department of Transportation (DOT) issued 49 CFR § 178.35 "General Requirements for Specification Cylinders" on December 28, 2020, that applies to cylinders manufactured after December 28, 2022. The new DOT requirements regarding the accuracy of the tare weight stamped on a cylinder will preempt and significantly relax the requirements found in NIST Handbook 130.

Cylinders that weigh 25 lb or less will be permitted a minus tare weight tolerance of − 3 %, which is more than six times the tolerance allowance (for cylinders that weigh 20 lb or less) in NIST Handbook 130. The plus tare weight tolerance under the DOT regulation will change to + 1 %, which is double the tolerance in NIST Handbook 130 and represents a significant increase. The DOT tolerances are based on safety, and the economic impact on consumers and businesses was not considered.

For cylinders that weigh more than 25 lb, the requirements are less stringent. The DOT has determined that the minus tare weight tolerance is 2 % (eight times the NIST Handbook 130 tolerance for cylinders that weigh more than 20 lb) and the plus tare weight can be + 1 % (four times the NIST Handbook 130 tolerance for cylinders that weigh more than 20 lb).

The purpose of a tolerance is to provide a limit of allowable error between the actual (known) tare weight and the tare weight stamped on the cylinder. Under the new DOT allowable differences, nearly all cylinders would pass. The tolerance should establish "reasonable allowances" and consider factors such as limitations of available equipment used to determine the quantity; weighing and distribution practices; the nature of the commodity being packaged; and economic impact to the buyer and seller. Furthermore, the value of the tolerances needs to be based on substantive data that is accessible for peer review.

Upon further examination of the allowable differences, for a − 3 % tolerance this equates to approximately 0.5 lb for cylinders with average stamped/stenciled tare weights between 16.6 lb and 18 lb. Likewise, a + 1 % tolerance equates to an allowable difference or error of approximately 0.17 lb for cylinders with average stamped or stenciled tare weights between 16.6 lb and 18 lb.

Table 1. Summary of NIST Handbook 130, Method of Sale of Commodities, Section 2.16. Compressed or Liquefied Gases in Refillable Cylinder

Section	Description
2.16.1. Application	This section does not apply to disposable cylinders of compressed or liquefied gases.
2.16.2. Net Contents	The net contents shall be expressed in terms of cubic meters or cubic feet, kilograms, or pounds and ounces. See Section 2.21. Liquefied Petroleum Gas for permitted expressions of net contents for liquefied petroleum gas. A standard cubic foot of gas is defined as a cubic foot at a temperature of 21 °C (70 °F) and a pressure of 101.35 kilopascals (14.696 psia), except for liquefied petroleum gas as stated in Section 2.21. Liquified Petroleum Gas.
2.16.3. Cylinder Labeling	Whenever cylinders are used for the sale of compressed or liquefied gases by weight, or are filled by weight and converted to volume, the following [subcodes] shall apply.
2.162.16.3.1. Tare weights. (a) Stamped or Stenciled Tare Weight	For safety purposes, the tare weight shall be legibly and permanently stamped or stenciled on the cylinder. All tare weight values shall be preceded by the letters "TW" or the words "tare weight." The tare weight shall include the weight of the cylinder (including paint), valve, and other permanent attachments. The weight of a protective cap shall not be included in tare or gross weights. The 49 CFR 178.35 "General Requirements for Specification Cylinders" requires the maker of cylinders to retain test reports verifying the cylinder tare weight accuracy to a tolerance of 1 %.
2.16.3.1. Tare weights. (b) Tare Weight for Purposes of Determining the Net Contents	The tare weight used in the determination of the final net contents may be either: (1) the stamped or stenciled tare weight; or (2) the actual tare determined at the time of filling the cylinder. If the actual tare is determined at the time of filling the cylinder, it must be legibly marked on the cylinder or on a tag attached to the cylinder at the time of filling.
2.16.3.1. Tare weights. (c) Allowable difference	If the stamped or stenciled tare is used to determine the net contents of the cylinder, the allowable difference between the actual tare weight and the stamped (or stenciled) tare weight, or the tare weight on a tag attached to the cylinder for a new or used cylinder, shall be: (1) $^1/_2$ % for tare weights of 9 kg (20 lb) or less; or (2) $^1/_4$ % for tare weights of more than 9 kg (20 lb).
2.16.3.1. Tare weights. (d) Average requirement	When used to determine the net contents of cylinders, the stamped or stenciled tare weights of cylinders at a single place of business found to be in error predominantly in a direction favorable to the seller and near the allowable difference limit shall be considered to be not in conformance with these requirements.

Design of the National Cylinder Survey

The 2022 National 20 lb LPG (Propane) Cylinder Survey was designed to occur in three phases to be conducted over several months (February to April 2022). These included Phase I: Point of Pack, Phase II: Direct Sale Refilling Stations, and Phase III: Exchange Locations. NIST OWM had designed the data collection and inspection coordination to occur separately for each phase of the survey (see Appendix B. Templates and Reporting Sheets). An overview and training for officials participating in the LPG survey was provided by NIST OWM on January 26, 2022. The NCWM in conjunction with NIST OWM and the North Carolina Department of Agriculture and Consumer Services, prepared a series of training videos to assist surveyors with the data collection for each of the three phases of the survey.

Phase I: Point of Pack

The purpose of Phase I was to determine the accuracy of the stamped tare weight (TW) (see Fig. 2) compared to the actual TW of new and used cylinders by a determination of data collected primarily at the plant location. A "plant," is defined as a location where exchange cylinders are filled for shipment and sale to retail exchange locations. To ensure a survey-wide accurate assessment of tare weights, all new and used cylinders tested at the various locations were verified to be completely empty.

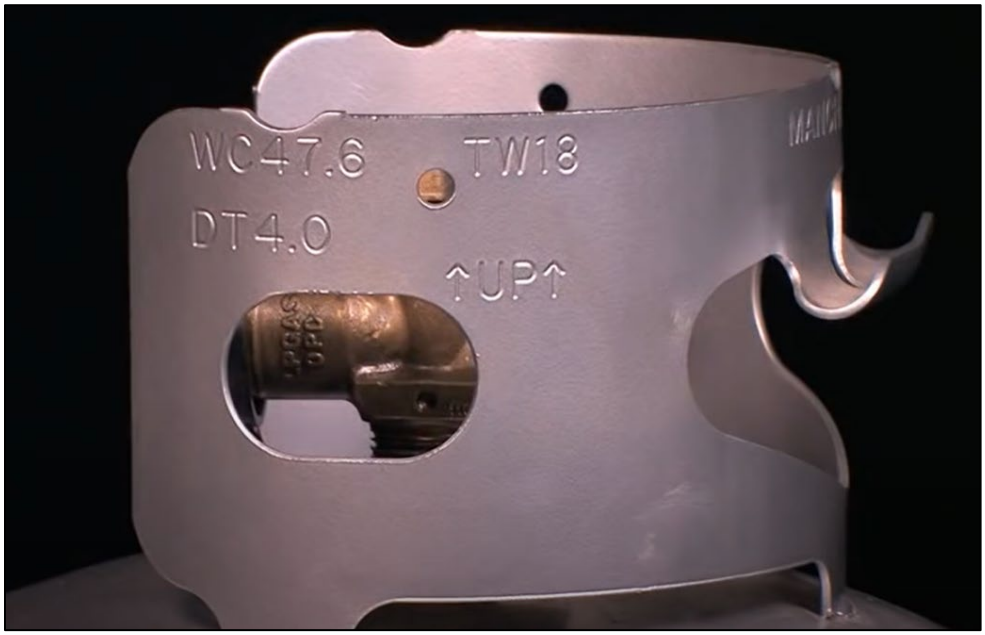

Fig. 2. An example of LPG (propane) cylinder steel collar ring with a stamped tare weight (TW) of 18 lbs.

Phase II: Direct Sale Refilling Stations

The purpose of Phase II: Direct Sale Refilling Stations was to collect data at direct sale propane refilling stations (see Fig. 3) and document the method of sale, price posting practices and the filling procedures. This information will be used to evaluate the impact that various marketing practices have on consumers and help determine whether the NIST Handbook 130, Method of Sale

of Commodities Regulation should be revised to add new requirements related to advertising and price posting. This may include unit pricing and clarifying labeling requirements associated with commercial cylinder exchange cages and LPG cylinder vending machines.

Fig. 3. An example of a direct sale refilling station.

Phase III: Exchange Locations

The purpose of Phase III: Exchange Locations was to determine net weight compliance of 20 lb propane cylinders and assess how much product is left behind by customers when performing a cylinder exchange or return (see Fig. 4). The results are anticipated to demonstrate the impact of both underfill and overfill on both consumers and industry which reflects the need for the development "good quantity control practices" for the LPG industry.

An appropriate determination of net weight compliance of 20 lb cylinders must meet two requirements: 1) the "Average Requirement" and 2) the "Individual Package Requirement" (see NIST Handbook 130 [2]). A detailed explanation of the process and test procedure can be found in Appendix A. "Determination of Package Requirements".

The results obtained from Phase III may be used to determine if current industry filling procedures are followed. The results are anticipated to assist and inform the states of any present need to better cooperate with their stakeholders (e.g., Propane Education and Research Council (PERC), National Propane Gas Association (NPGA), National Fire Protection Association (NFPA), OSHA, DOT) to establish improved procedures and oversight.

Fig. 4. An example of a weights and measures net weight compliance inspection at an exchange location. (Credit: Lucas County, OH and used with permission)

Inspector Training to Conduct Survey

A virtual training session for over 150 participating officials was provided in preparation of the launch of Phase I of the National Survey on 20 lb LPG (Propane) Cylinders. A survey "kick off" meeting was conducted on January 12, 2022, to review expectations and requirements for data collection and documentation, including the use of the data collection templates (see Appendix B) during each phase of the survey. A series of training videos to assist surveyors with the data collection for each of the three phases of the survey and to provide guidance on how to communicate the inspection activities to the commercial propane suppliers and retail locations included:

- NCWM National LPG Survey: Phase I - Point of Pack (https://www.youtube.com/watch?v=PiokcvkjBzY)
- NCWM National LPG Study: Phase II - Direct Sale Refilling Locations (https://www.youtube.com/watch?v=nkLYVbBxVjE)
- NCWM National LPG Survey: Phase III - Exchange Locations (https://www.youtube.com/watch?v=WHFoR3QApi0&t=337s)

Weights and measures inspectors also had the opportunity to attend the NIST OWM webinar "LPG (Propane) - Verifying the Net Contents of 20 lb Cylinders (Part 1)" [7] that provided instructions on how to verify the net contents, determine tare weights, and labeling requirements of 20 lb cylinders, with additional background on how cylinders are filled, offered or exposed for sale (method of sale), and safe working requirements and procedures during inspections.

Survey Data Collection and Results

Upon completion of each phase of the survey, all data was submitted to NIST. The data was then anonymized, analyzed, and summarized by NIST and the results are described in this report. Example data collection worksheets and templates for the various survey phases are provided in Appendix B. Templates and Reporting Sheets.

Phase I: Point of Pack (conducted during February 2022)

To obtain an accurate tare weight, it is critical that all used cylinders are first verified to be completely empty. Thus, all cylinders evaluated for Phase I: Point of Pack were verified to be evacuated prior to evaluation (see Fig. 5). LPG plant personnel were asked to confirm that all cylinders had been evacuated (termed "EVAC"), for which the LPG has been drained out by a passive release via vapor pressure drop. It is rare that used cylinders are both evacuated and purged in which the remaining contents are actively pulled out by a vacuum source.

A total of 9,482 new cylinders from 702 lots across 19 states were evaluated (see Appendix C Fig. C-1) and recorded according to their manufacture DOT identification codes (see Appendix D Table D-1). For the new cylinders, 92 lots (13.1 % of total) were determined to have a positive average percentage (%) error with a median % error of 0.23 % (see Fig. 6). A large majority of the lots (607 lots; 86.5 %) exhibited a negative average percentage error with a median % error of − 0.54 %. A small number of lots (three lots; 0.4 %) were observed to have effectively a zero average % error.

A "lot", for purposes of Phase 1, is defined as a group of cylinders tested and submitted on a given report form (see Appendix B Fig. B-1. and Fig B-2**.** Phase I: Point of Pack – Actual vs. Stamped Tare Weight data reporting template for new and used cylinders). This is not to be confused with an "inspection lot" as discussed in Phase 3 (see Appendix A).

A total of 822 used cylinders from 71 lots across eight states were also evaluated (see Appendix C Fig. C-2) and recorded according to their manufacture DOT identification codes (see Appendix D Table D-2). For the used cylinders, 69 of the 71 lots (97 % of total) were determined to have a positive average percentage (%) error with a median % error of 0.82 % (see Fig. 7). In contrast to the new cylinders, only a very small percentage (2 lots; 2.8 %) exhibited a negative average percentage error with a median % error of − 0.03 %.

For completeness of the report, the individual data collected for each cylinder within each of the lots (and sorted independently from the lots) for both new and used cylinders is illustrated in Fig. 8. Where Fig. 6 and Fig. 7 shows the performance of lots (as measured by the average percentage error), Fig. 8 shows the performance of individual cylinders (as measured by percentage error).

An examination of the overall performance of lots (Figs. 6 and 7) as the average percentage error versus the individual cylinders (Fig. 8) as the percentage error can illustrate some of the more extreme data that was collected during the survey. Considering the data for the new cylinders as an example, no lots were observed to be below the new (effective December 28, 2022) DOT lower limit and only one lot is determined to be above the new (effective December 28, 2022) DOT upper limit (Fig. 6). However, an examination of the *individual cylinder data* in Fig. 8a reveals that the percentage error values for 21 cylinders are below the new DOT lower limit and 222 cylinders are above the new DOT upper limit. This is not surprising as averaging the individual cylinder data

over the respective lot will hide the more extreme individual high and low measurements within that particular lot. A similar effect is observed for the used cylinder data, for which 21 individual cylinders had percentage errors below the new DOT lower limit (Fig. 8b), but the averaged percentage error used to define the lot performance was not below the DOT lower limit (Fig. 7).

Data to illustrate the effect of the new DOT tolerance limits on the percentage of cylinders that are accepted by lot are provided in Appendix E.

Additional "strip" plots are also provided in Appendix F that illustrate the percentage of new and used cylinders that are within the tolerance across the various lot sizes. These plots also illustrate the distribution of lot sizes that were determined during the survey and are used to evaluate if any significant patterns or trends for the percentage of acceptance were observed relative to lot size. Accordingly, no significant patterns or trends related to the sample size of the lots was determined for the data obtained in Phase I.

Fig. 5. (a) Used nominal 20 lb cylinders to be evacuated ("EVAC") and (b) cylinders following EVAC in preparation for a point of pack tare weight (TW) assessment.

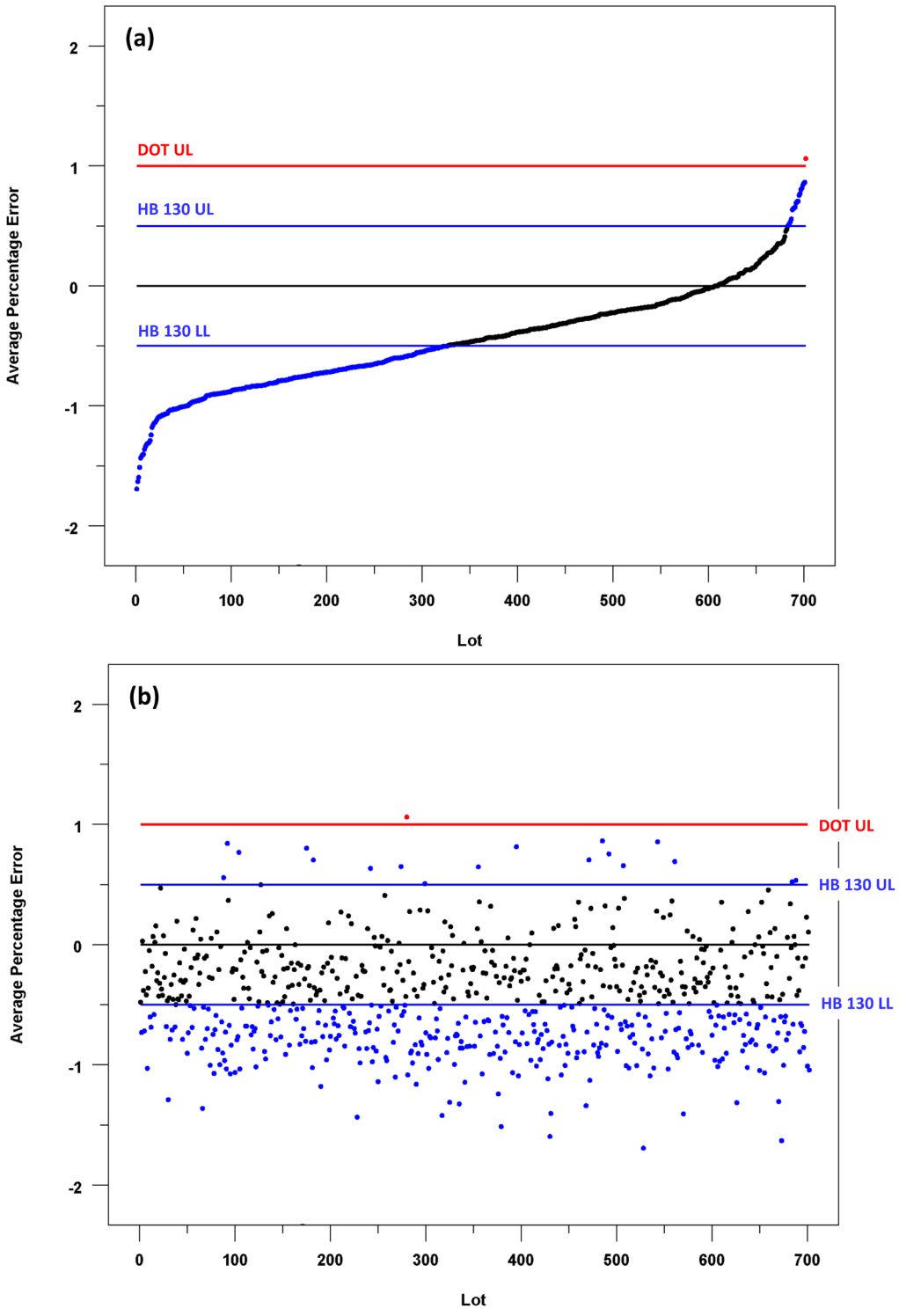

Fig. 6. Average percentage error by lot for new cylinders with a nominal weight ≤ 20 lbs sorted by (a) the value of the average percentage error and (b) the individual lots assigned (randomly) tested during the survey. The red symbol (●) denotes the value that exceeds the new (effective December 28, 2022) DOT upper limit (UL) whereas the blue symbols (●) and black symbols (●) denote values that either exceed or are within the current NIST HB 130 upper limit (UL) and lower limit (LL), respectively. The new (effective December 28, 2022) DOT lower limit (LL) (− 3) is not illustrated on this scale.

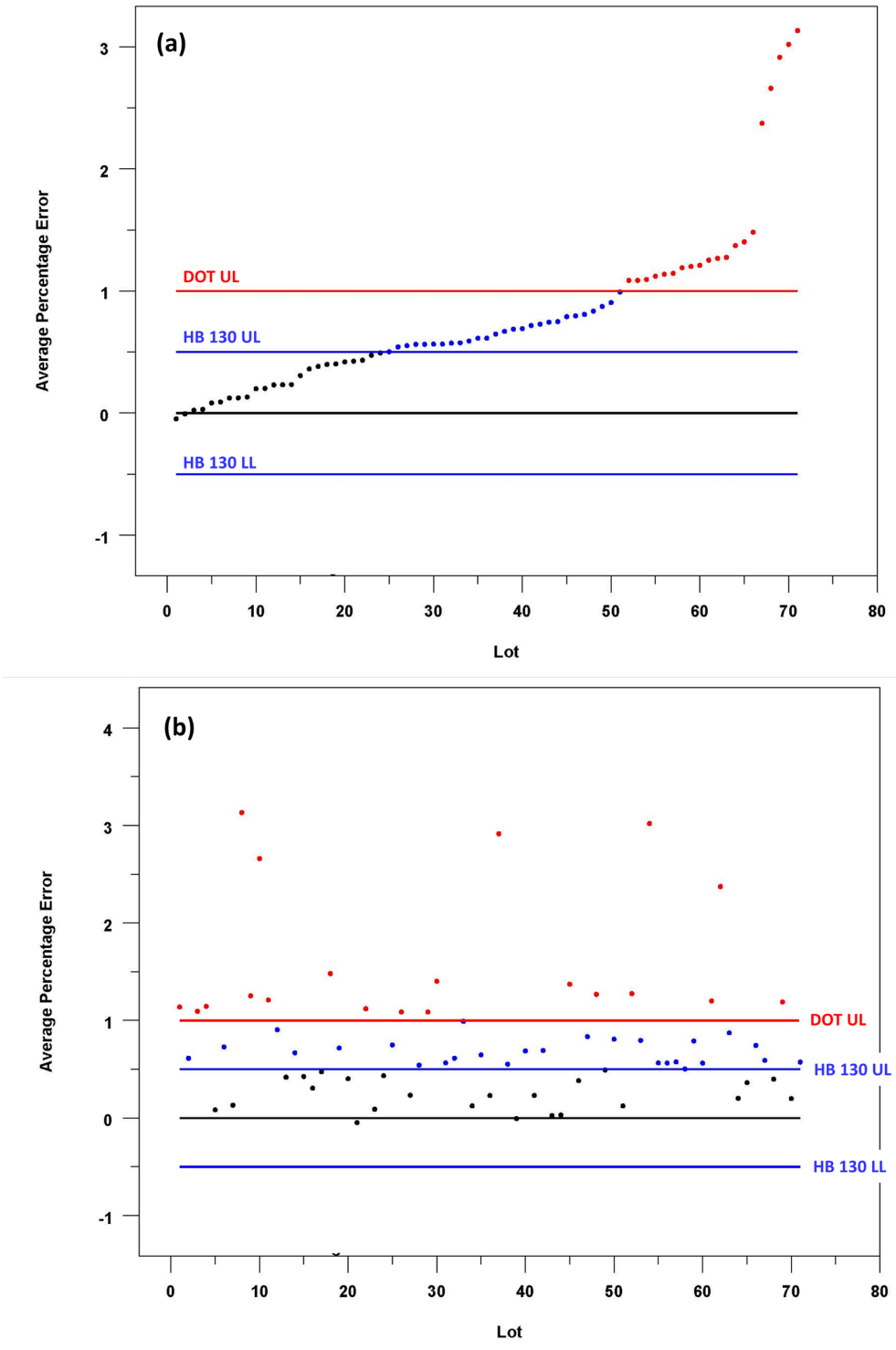

Fig. 7. Average percentage error by lot for used cylinders with a nominal weight ≤ 20 lbs sorted by (a) the value of the average percentage error and (b) the individual lots assigned (randomly) tested during the survey. The red symbol (●) denotes the value that exceeds the new (effective December 28, 2022) DOT upper limit (UL) whereas the blue symbols (●) and black symbols (●) denote values that either exceed or are within the current NIST HB 130 upper limit (UL) and lower limit (LL), respectively. The new (effective December 28, 2022) DOT lower limit (LL) (− 3) is not illustrated on this scale.

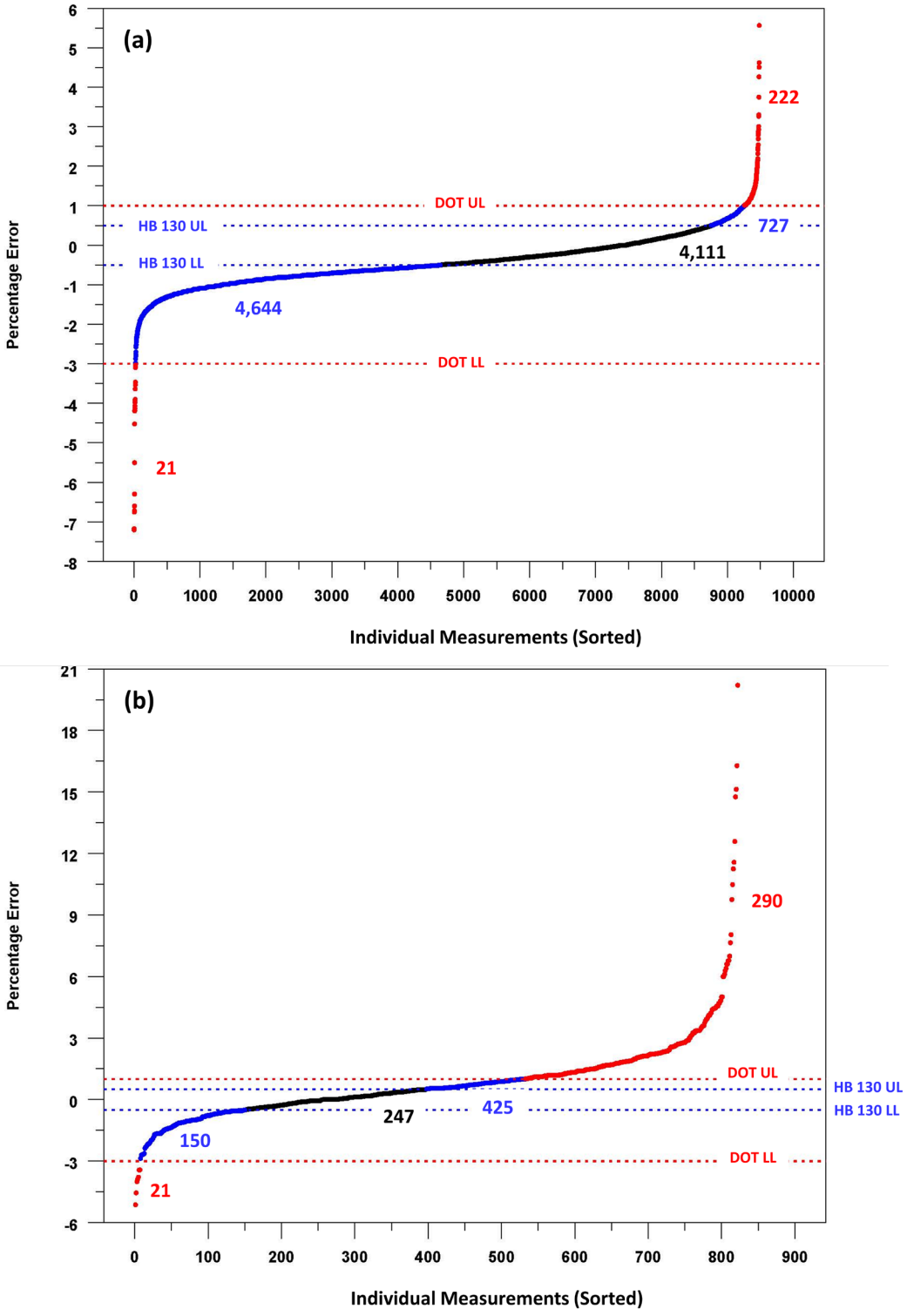

Fig. 8. Percentage error for each individual cylinder within all lots (and sorted independently from the lots) with a nominal weight ≤ 20 lbs for (a) new cylinders (9,482 in total) and (b) used cylinders (822 in total). The red symbol (●) denotes the value that exceeds the new (effective December 28, 2022) DOT upper limit (UL) and lower limit (LL), whereas the blue symbols (●) denote values that exceed the current NIST HB 130 UL and LL. Black symbols (●) denote values that are within the current NIST HB 130 UL and LL. Numbers indicate the specific count of individual cylinders exceeding each limit or within the bounds.

For all the evaluated cylinders (see Table 2. Summary of Percentage of New and Used Cylinders within Specified Tolerances), nearly half (44.3 %) of the new cylinders and significantly less (32.0 %) of used cylinders were in compliance with NIST HB 130 (within ± 0.5 %).

Of these compliant with NIST HB130:

- 29.7 % of new cylinders were within (− 0.5 to 0) %
- 14.6 % of new cylinders were within (0 to + 0.5) %
- 16.1 % of used cylinders were within (− 0.5 to 0) %
- 15.9 % of used cylinders were within (0 to + 0.5) %

In contrast, nearly all (98.4 %) of these new cylinders and a significant majority (65.7 %) of the used cylinders would be in compliance with the new DOT regulations (+ 1 % and − 3 %). Of these compliant with the new DOT regulations:

- 78.5 % of new cylinders were within (− 3 to 0) %
- 19.9 % of new cylinders were within (0 to + 1) %
- 33.7 % of used cylinders were within (− 3 to 0) %
- 32.0 % of used cylinders were within (0 to + 1) %

However, a consideration of current industry practice and the packaging tolerances for cylinder manufactures is necessary. Initial assessments suggest that cylinder manufactures use a tolerance of 1 %, which is primarily based on Measurement Canada's requirement of 1 % [8]. Therefore, when cylinders are manufactured to 1%, nearly half (44.3 %) are still in compliance and further demonstrates that ± 0.5 % as an allowable difference is achievable.

Table 2 also provides a summary of the percentage of new and used cylinders in compliance with the tare weight tolerance as defined in NIST Handbook 130, Method of Sale, and the DOT regulation effective December 28, 2022. Each cylinder tested compared the actual tare weight to the stamped tare weight. To ensure an accurate assessment of tare weight survey-wide, all new and used cylinders tested at the various locations were verified to be completely empty.

Table 2. Summary of Percentage of New and Used Cylinders within Specified Tolerances

	New Cylinders (n = 9,482)[a]		Used Cylinders (n = 1,535)[a]	
Range of Tolerance (%)	**NIST HB 130[b]**	**DOT[c]**	**NIST HB 130[b]**	**DOT[c]**
(− 0.5 to 0) %	29.7 %	----	16.1 %	----
(0 to + 0.5) %	14.6 %	----	15.9 %	----
(− 3 to 0) %	----	78.5 %	----	33.7 %
(0 to + 1) %	----	19.9 %	----	32.0 %
TOTAL	44.3 %	98.4 %	32.0 %	65.7 %

[a]number of cylinders tested
[b]NIST HB 130, Uniform Laws and Regulations. Section 2.16. Method of Sale Regulation [2]
[c]DOT Final Rule 49 CFR § 178.35 "General Requirements for Specification Cylinders" [3]

Phase II: Direct Sale Refilling Stations (conducted during March 2022)

In Phase II, a total of 1,559 direct sale refilling locations across 18 states were evaluated to determine how 20 lb propane cylinders were being sold, whether the safe fill level was being verified through proper procedures, and whether a price of propane was posted or advertised. An illustrative summary of the number of direct sale refilling stations tested per state are provided in Appendix G. During the data collection of Phase II, the inspectors posed three primary questions and/or made direct observations while on-site at the commercial propane suppliers:

1. How is propane sold at this location? And is a service fee also applied?
2. How is the fill level of the 20 lb cylinder verified?
3. Is the price of propane posted or advertised?

How is propane sold at this location? The unit of measure in which propane is sold is referred to as the Method of Sale. Propane is sold by weight (e.g., $1.05 lb), volume (e.g., $3.75 gal) or a flat fee (e.g., $19.99 a fill) and a large majority (89 %) of direct sale refilling locations employ a singular type of method of sale: 11 % by weight, 53.6 % by volume and 24.7 % by flat fee (see Table 3).

For some locations, propane is sold by a combination of measures, such as weight and volume, weight and flat fee, volume and flat fee, or a combination of all three methods. In addition, some locations (3.3 % of locations visited) charge a service fee in addition to the price charged for the propane sold, which is based on either weight, volume, or flat fee methods of sale (see Table 3 Summary of the Percentage of Method of Sale Approaches).

While most locations sell by weight or volume, 33.2 % of all locations include a method of sale by a flat fee. When selling by flat fee, consumers typically are not credited for product remaining in the tank. It is often unclear to the consumer how much product they receive with the flat fee service. During the survey, it was not apparent if the consumer would receive a credit for any product remaining behind in the tank or if the "fill" is based on the labeled net contents (usually 15 lbs) or the fill capacity (20 lbs).

Table 3. Summary of the Percentage of Method of Sale Approaches (singular or combination) for 1,559 Direct Sale Refilling Locations across 18 States.

Method Of Sale	Percentage
Weight Only	11.0 %
Volume Only	53.6 %
Weight and Volume	2.2 %
Flat Fee Only	24.7 %
Combination of Weight and/or Volume, with a Flat Fee	8.5 %

How is the fill level of the 20 lb cylinder verified? A nominal "20 lb cylinder" is designed to safely hold 20 lbs of propane. Overfilling beyond the safe capacity of 20 lbs is illegal and poses significant safety risks. Therefore, it is critical that 20 lb propane cylinder refillers at direct sale refilling locations use the proper method to validate that the safe fill level was not exceeded.

Based on National Fire Protection Association (NFPA), only one of two verification methods can be used; this includes 1) verification by weight or 2) verification by using the "bleeder valve". A summary of the fill level verification methods observed for the 1,559 direct sale refilling locations is provided in Table 4. Approximately (90 %) of the locations employ a NFPA recommended fill level verification method (weight, and/or bleeder valve).

Table 4. Summary of the Percentage of Fill Level Verification Methods (singular or combination) for 1,559 Direct Sale Refilling Locations across 18 States

Fill Level Verification Method	Percentage
Weight Only	26.2 %
Bleeder Valve Only	33.0 %
OPD Only	10.0 %
Combination of Weight, Bleeder Valve, and or OPD	30.8 %

Verification of the safe fill level solely based on the overflow protection device (OPD) is strictly prohibited. The OPD appears as part of the cylinder valve and is a cylinder safety device that is designed to provide an automatic means to prevent the filling of cylinder in excess of the maximum permitted filling limit. Nearly 10 % of locations are improperly verifying the safe fill level of cylinders by solely relying on the OPD, and thus raises significant safety concerns. However, the use of the OPD in conjunction with verification by weight or use with the "bleeder valve" is acceptable.

Is the price of propane posted or advertised? Only six of the 18 states participating in Phase II required price posting at the direct sale refilling locations. Of the 1,559 direct sale refilling locations inspected, 49 % of the overall locations had a price posted whereas the remaining 51 % of locations did not. In the six states that require price posting, 68 % of the locations posted a price and in the 12 states that do not require price posting, only 30 % posted a price.

Phase III: Exchange Locations (conducted during April 2022)

In Phase III, a total of 959 exchange locations across 17 states were visited, which comprised a total of 10,456 cylinders that were inspected. The net weight compliance of 20 lb propane cylinders at these locations comprised the testing of 959 lots. Illustrative summaries of the number of individual cylinders and lots tested per state are provided in Appendix H. Testing was conducted based on NIST Handbook 133 [2].

For cylinder exchanges the amount of product left behind by consumers on return cylinders was determined for 6,896 cylinders, separate from the net content compliance determinations. Illustrative summaries of the number of individual cylinders tested per state are provided in Appendix I. Exchanged cylinders were gross weighed and subtracted with the stamped tare weight, to determine the amount of propane product (in lbs) that remained in the cylinder.

Net Content Compliance. Of the 959 lots tested, only 74.2 % passed overall. The results for the number of lots that passed and failed are based on meeting the average error and the individual package requirement (cannot exceed the MAV) (see Fig. 9 Net content compliance results for the number of exchange locations (i.e., lots) that passed and failed based on (a) average error and (b) MAV). Of the significant portion of lots that failed (25.8 %), the majority (over two-thirds) of the cylinders (17.1 %) failed on the Individual Package Requirement (MAV) (Fig. 9b) alone, with only 1.2 % failing on the Average Requirement (Fig. 9a) alone. Of the lots that failed, 7.5 % failed on both the Average Requirement and MAV.

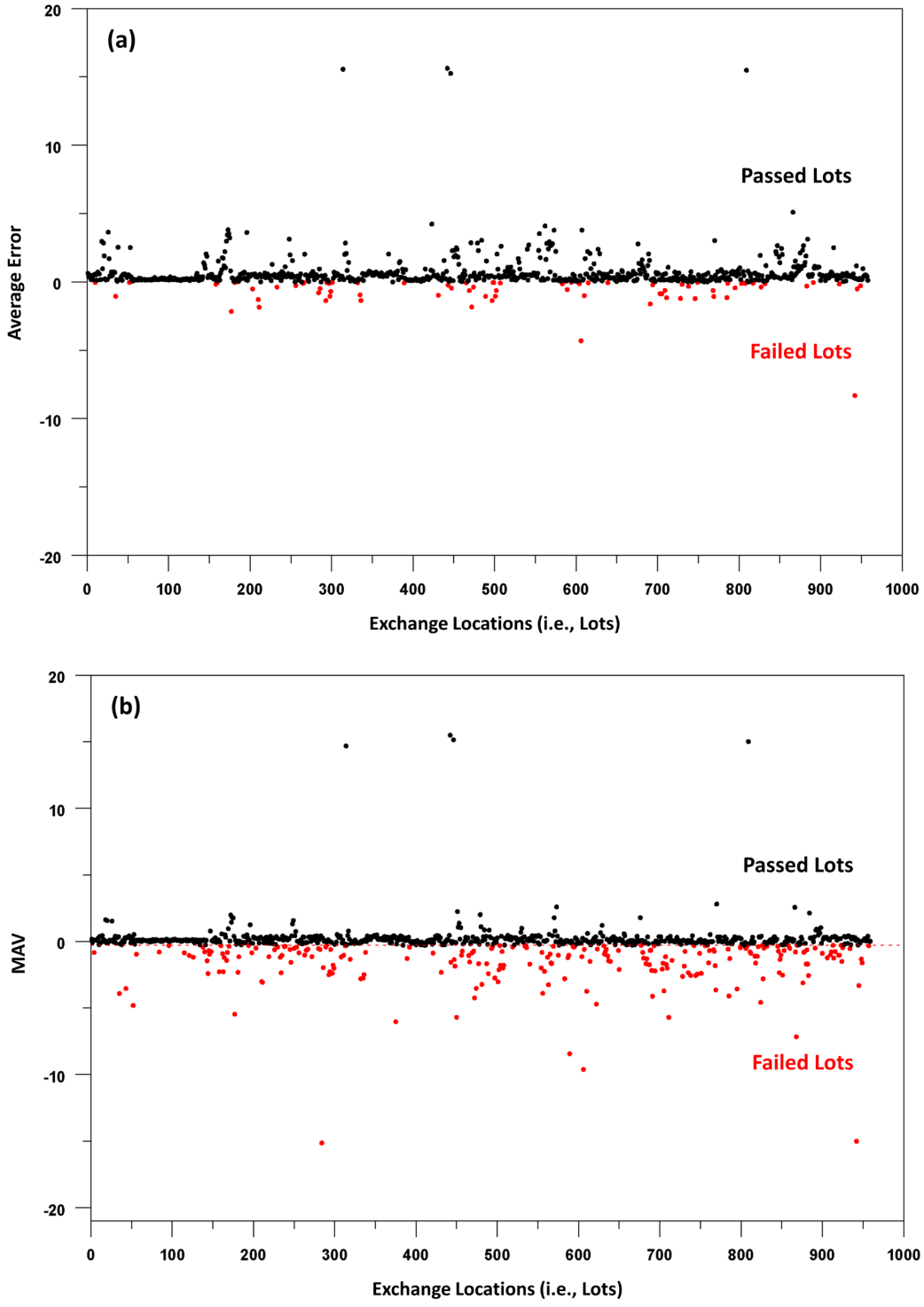

Fig. 9. Net content compliance results for the number of exchange locations (i.e., lots) that passed (black symbols; ●) and failed (red symbols; ●) based on (a) average error and (b) MAV.

Cylinders Exceeding the Safe Fill Level. While determining the error of each cylinder, the number of cylinders exceeding the safe fill level was also examined. Filling a 20 lb cylinders beyond the safe fill level is not allowed and poses a significant safety risk. Of the 10,456 cylinders tested, 118 cylinders in total (1.1 % of those tested) were found to exceed the safe fill level of 20 lbs (see Fig. 10) and distributed accordingly to the severity of overfilling as follows:

- 91 (0.87 % of total tested) cylinders contained > 20 lb and up to 21 lb
- 10 (0.1 % of total tested) cylinders contained > 21 lb and up to 22 lb
- 7 (0.07 % of total tested) cylinders contained > 22 lb and up to 23 lb
- 5 (0.05 % of total tested) cylinders contained > 23 lb and up to 24 lb
- 5 (0.05 % of total tested) cylinders contained > 24 lb

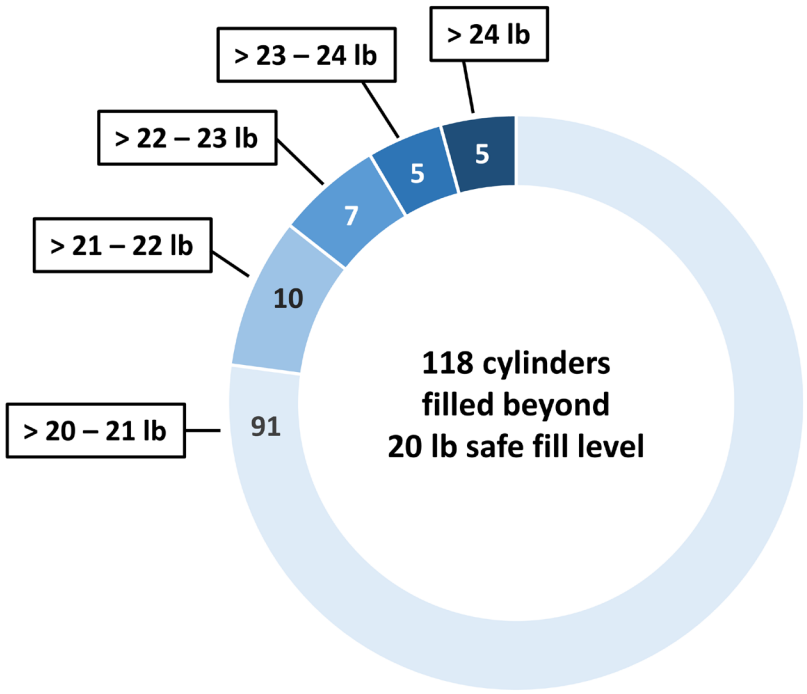

Fig. 10. Number of cylinders inspected during Phase III that were filled beyond the 20 lb safe fill level and according to a range of overfill severity.

Product Remaining in the Cylinder. Based on 6,896 cylinders tested, an average of 25.4 % of consumers return more than 1 lb of propane when they return a cylinder. In summary, customers returned cylinders with the following amount of LPG (propane) product remaining:

- 15.9 % of cylinders were either empty (0 lb) or had negative values (< 0 lb)
- 58.8 % of cylinders contained up to 1 lb
- 10.6 % of cylinders contained between 1 lb to 3 lbs
- 5.6 % of cylinders contained between 3 lbs to 5 lbs
- 9.1 % of cylinders contained over 5 lbs

These data are also illustrated in Fig. 11. As shown, 15.9 % of cylinders (1,094) were evaluated and reported with zero or negative values for product remaining behind in the cylinders. A likely explanation is that the tare weight is not accurate for these cylinders. The possibly does exist that erroneous values were recorded but given the number (1,094) of cylinders tested that fall into this category, it is unlikely. These negative values more likely indicate that a significant percentage of these cylinders may have an inaccurate tare weight.

With the preponderance of cylinders containing a measurable, and in some cases, significant amount of propane remaining, this may be worthy of a notice to consumers and consumer advocacy groups. With the current price of LPG products and the millions of cylinder exchanges that occur over a year, this may represent a significant loss for consumers overall.

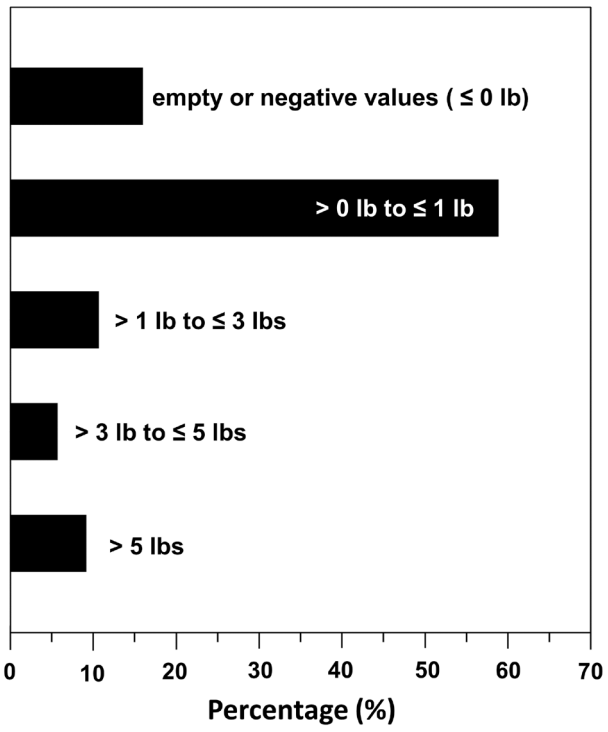

Fig. 11. Percentage of customer-returned cylinders (Phase III) that contained a measurable amount of propane (in lbs) remaining in the cylinders.

Discussion

The LPG industry is encouraged to review their established quality assurance and quality control (QA/QC) processes in place to audit and ensure the accuracy of stamped tare weights both at the manufacturing facilities (Fig. 12) and refill plant locations. The stamped tare weight must remain accurate for the life of the cylinder and throughout the supply chain, especially given that this value is used as a key reference point to assist in accurately filling the net contents. The actual weight of cylinders may change over time, as cylinders are often repainted, valves replaced (which are often different than the original equipment manufacturer valve), collars or foot rings rewelded, and are subject to both collection of petroleum residual inside the cylinders and to external weathering due to the accumulation of dirt, oil, and rust.

An illustration of the impact of the difference in stamped and actual TW is provided in Fig. 13. Depiction of a nominal 20 lb cylinder filled with 15 lbs of propane that a) over-weight (overfilled) cylinder due to the actual TW being less than the stamped TW, b) has a properly stamped TW comparable to the actual TW (both 18 lbs), and c) short weight (underfilled) where the actual TW is more than the stamped TW. A discrepancy where the actual TW is less than the stamped TW (as illustrated in Fig. 13(a)) will result in an overfilled cylinder and could create both a safety issue and result in a potential loss to the propane supplier. For cylinders in which the actual TW is greater than the stamped TW (Fig. 13(c)), the potential loss will primarily be to the consumer.

The causes for the difference between stamped TW and actual TW can be due to many factors. This includes, but is not limited to, poor quantity control practices, replacement of valves that are of greater or less weight than the original valves, rewelding of collars or foot rings that could affect the overall weight of the cylinder, and the presence of residual petroleum distillates inside cylinder, or any significant accumulation of dirt, oil, and rust on the outside of the cylinder.

It was observed that the accuracy of the TW does change as the cylinder is utilized in service over time. This data suggests that a determination of the accuracy of the TW for used cylinders may need to be considered as part of regulation, similar to or as part of requalification. To the best of our knowledge, it is not common practice, and unlikely that used cylinders have been restamped with an adjusted TWs upon excessive wear and/or modifications.

Based on the results obtained from the accuracy determination stamped tare weights for new and used cylinders in Phase I, it is apparent that good quantity control practices are a key consideration. The frequent use of checks and balances, audits, statistical analysis, and other methods must be employed to monitor tare weight compliance to meet both NIST Handbook 130 Method of Sale and the DOT requirements for tare weight. Although 98.4 % of new cylinders would be in compliance under the DOT regulations, it must be noted that these tolerances are based on safety and does not include the potential for economic harm. It is highly unusual and irregular to see a tolerance where a very significant majority of the packages are in compliance (in this case, 98.4 %). This would apply not only to TWs, but to any measure of stated tolerance. It is also important to note that under the DOT tolerances, 34.3 % of used cylinders would fail to be in compliance. From a weights and measures community perspective, enacting a wider tolerance makes it difficult to provide economic protections to consumer and businesses.

Fig. 12. A typical manufacturing facility automatic filling process of nominal 20 lb cylinders with propane by weight.

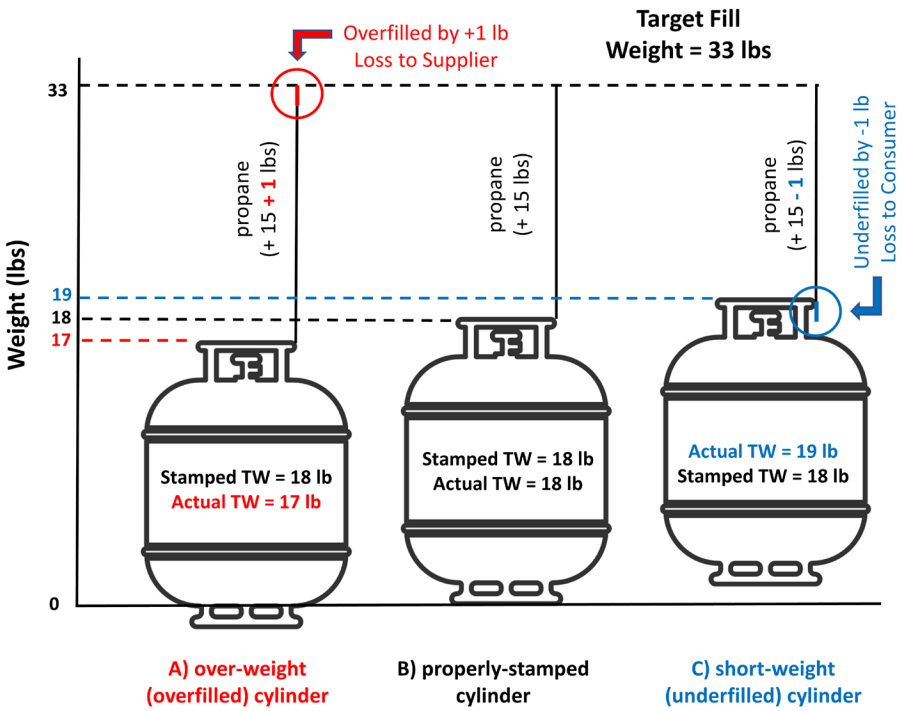

Fig. 13. Depiction of a nominal 20 lb cylinder filled with 15 lbs of propane that a) over-weight (overfilled) cylinder due to the actual TW being less than the stamped TW, b) has a properly stamped TW comparable to the actual TW (both 18 lbs), and b) short weight (underfilled) where the actual TW is more than the stamped TW.

During Phase II, a summary of the various methods of sale, fill procedures at direct sale refilling locations, and price posting practices will allow an opportunity for states and industry to provide greater protections to consumers and businesses in which LPG is being sold. States should consider discussing the results of this survey to determine if the Method of Sale in NIST Handbook 130 could be improved. This should include, but not limited to, content to address flat fee sales to ensure consumers know what they are getting, proving guidance on price posting, and language to provide clarity on proper fill methods and requirements. For example, adding a price posting requirement, including requiring the unit price is a valuable consumer tool to make value comparisons and an informed purchase decision.

As demonstrated in the net content accuracy results in Phase III, 25.8 % of all lots were determined to fail based on the particularly high rate (17.1 %) due to unreasonable minus errors. Thus, it is imperative that industry reexamine and consider its current practices to ensure future compliance. There is an additional concern that 1.1 % of all the cylinders tested were determined to exceed the safe fill level of 20 lb capacity. The frequent use of checks and balances, audits, statistical analysis, and other methods must be employed to monitor net weight compliance.

Many services typically do not provide credit for product remaining in the tank therefore consumers are likely losing credit for product left in the cylinder when exchanging and having cylinders refilled. Over one quarter (25.4 %) of consumers returned more than 1 lb of propane when they performed a cylinder exchange. Whether intentional or not, outreach and education should be provided to the consumer on how to best use their propane cylinder and its contents.

Economic Impact of the New DOT Regulations

As an illustrative example, if manufacturers used a stamped or stenciled tare weight (TW) of 18 lb with an average variance of − 2.5 % of the − 3 % allowable difference, then each cylinder stamped TW on average could weigh 0.45 lb less than actual. At current prices of around $1.30 per pound for propane, this would equate to a $0.59 loss to industry per cylinder from having to “overpack” to meet the labeled net weight. With over 50 million cylinders sold last year, this could be a potential loss of nearly $30 million to industry.

Subpar quantity control could create an unfair competition between businesses within the commercial sector. Sellers and packers using cylinders with stamped or stenciled TWs that are in error in the minus direction could benefit financially from the wide tolerance and have an unfair advantage. In contrast, sellers and packers who maintain tighter controls would be at a competitive disadvantage. Increasing the allowable difference for overages could result in problems with overfilling beyond the safe capacity level for a cylinder.

Using the example of an 18 lb TW cylinder and assuming an average + 0.75 % variance rather than the + 1 %, then each cylinder could weigh on average 0.14 lb more based on the inaccurate stamped tare weight. At current prices of approximately $1.30 per pound for propane, this would equate to $0.19 loss or overcharge to consumers for every cylinder purchased. With over 50 million cylinders used by consumers per year, there is a potential of nearly $10 million loss to consumers.

Impact on the Unreasonable Minus Error (UME)

The principles of weights and measures exist for businesses and consumers for ensuring equity and preventing economic harm. One of primary requirements for weights and measures enforcement is to address marketplace situations where an error or shortage is unreasonably large. This unreasonable error is defined in NIST Handbook 133 and is based on the labeled quantity and established values for "maximum allowable variations" (MAV) are provided in Appendix A, Table 2-5. Maximum Allowable Variations (MAVs). The MAV varies based on the labeled net quantity. Exceeding the MAV creates "unreasonable minus error" (UME).

The UME stipulates that "reasonable variations" (+ and −) are permitted and that a UME should not occur in a good quantity control system; however, if a negative error or shortage exceeds a certain value, it is considered a "red flag" that suggests that a manufacturer may have poor quantity controls in place. As a result, and in accordance with NIST Handbook 133 test procedures, if a UME is found, the entire lot is pulled from sale.

The DOT allowable difference of + 1 % increases the chance that a package may exceed the "Maximum Allowable Variation" based on weights and measures testing requirements. For example, the MAV (or shortage) for a labeled net weight of 14.3 lbs to 17.7 lbs is − 0.28 lb. That means if there is a shortage in net weight of more than 0.28 lb in any cylinder, then the lot fails. Under 49 CFR 178.35, a tolerance of + 1 % is allowed, which would allow a maximum variation of TW tolerance to range from − 0.14 lb to − 0.18 lb. Therefore, a cylinder manufacturer may be in compliance with DOT TW tolerances but must consider the risk of having their product being pulled off sale due to short net weight. These gross errors, if left undetected, may only benefit the packer. Thus, the established UME requirement exists to protect consumers who may ultimately lose otherwise.

The accuracy of the TW directly affects the accuracy of the net weight. Because the plus tolerance will be more relaxed now with the DOT regulations, it will increase the likelihood that cylinders will fail based on net weight compliance and that consumers will ultimately be shorted. The stamped TW also plays a very important role for cylinder fillers both at the plant and direct sale refill locations to ensure that the correct quantity is filled. When cylinder filling occurs, the TW is used as a reference point to determine the proper fill level.

The increase from the current NIST Handbook 130 requirement of − 0.5 % to the new DOT − 3 % tolerance can potentially result in a significant loss to industry. If over 50 million exchange cylinders are sold per year, and if a − 2.75 % average allowable difference was maximized during that time frame, then potentially over $30 million may be lost. This can create an unfair competitive disadvantage for certain companies depending on which manufacturer they obtain their cylinders from and the specific pack tolerances that are applied.

The increase from the current NIST Handbook 130 requirement of + 0.5 % to the new DOT + 1 % tolerance may have a potentially significant loss to U.S. consumers as well. If over 50 million exchange cylinders are returned per year and if, on average + 0.75 % average allowable difference was maximized, then potentially over a $10 million could be lost due to short net weight.

Tighter tolerances will minimize the discrepancies in the delivery of product quality and will ultimately provide improved marketplace equity for both consumers and industry. Irrespective of the TW tolerances, cylinder packers still must meet or exceed the labeled net weight. Thus, TW

tolerances and/or the determination of accuracy will have a direct correlation on whether a packer will meet the labeled net weight.

Scale Accuracy

Although scale accuracy was not in the scope of the survey, it is worth noting its importance because it is a critical factor in ensuring the accuracy of the net weight. Scales are used throughout industry to verify the tare weight and net weight of a cylinder.

Scale accuracy directly impacts the accuracy of the net contents. Inaccurate scales can cause weighing shortages which economically harm consumers or cause weighing overages which could economically harm a business.

To ensure accurate weighing, scales must be suitable for the purpose in which they are to be used and then be accurate and properly used. State inspections demonstrate a long history of problems with scale maintenance and filling practice issues involving LPG cylinders, including direct sale refilling locations.

Industry shall ensure that any weighing and measuring devices meet the requirement of NIST Handbook 44. This will not only ensure economic integrity, but safety practices could also be enhanced.

Recommendations

Good Quantity Control Practices

It is clear from the results from each phase, opportunities exist to improve accuracy and business practices. These opportunities include improving current practices to ensure accurate tare weights was demonstrated in Phase I, in which 55.7 % of new cylinders and 68 % of used cylinders were determined not to be in compliance with NIST Handbook 130 Method of Sale requirements. A need to increase the rate of proper filling practices was also demonstrated in Phase II, for which 10 % of the location tested are improperly verifying the safe fill level of cylinders by solely relying on the OPD. Furthermore, additional opportunities to ensure the accurate net contents were demonstrated in Phase III in which 25.8 % of all cylinders tested failed, with 17.1 % exceeding the maximum allowable variation. In addition, 1.1 % of all cylinders tested were filled beyond the safe fill capacity.

Considering these results, industry should work to evaluate their internal procedures, and their trade associations (CGA, NPGA, NFPA, PERC) should assist their membership through the development of best practice guides and requirements including “good quantity control”.

Good quantity control practices and industry best practices are not explicitly regulated but should be considered when determining an “allowable difference” or tolerance. It applies equally to ensuring accurate net contents as well as accurate stamped tare weights. Examples of “good quantity control practices” can be found in NIST Handbook 130, NCWM Policy, Interpretations and Guidelines, 2.6.11. “Good Quantity Control Practices.” Good manufacture (best) practices for propane cylinders might include:

- Proper sampling (frequency determined by the manufacturer) at manufacturing plants to ensure the actual tare weight as compared to the stamped tare weight is within the allowable difference for both new and used cylinders.
- Requirements or a best practice at plants on when the tare weight should be revalidated and re-stamped, if necessary (out of tolerance), for example, when it is refurbished, repainted, or the valve replaced.
- Standards and specifications on the type and weight of the valve to minimize variations.
- Audits for verifying the actual tare weight used at the time of filling as compared to the stamped tare weight.
- Field audits to determine proper filling at direct sale refilling locations.

Scale Accuracy

In addition to the laws and regulations and net content of packaged goods uniform code in NIST Handbook 130 and 133, respectively, all 50 states (along with USDA) adopt NIST Handbook 44. NIST Handbook 44 establishes the requirements and test procedures used to verify the accuracy of all weighing and measuring devices used in commercial and law enforcement applications.

Scales must first be suitable for the purpose in which they are to be used and then be accurate and properly used to ensure accurate weighing. State inspections demonstrate a long history of problems with scale maintenance and filling practice issues involving LPG cylinders, including direct sale refilling locations.

Industry must ensure that any weighing and measuring devices meet the requirement of Handbook 44. We recommend that future Federal regulations include a requirement that scales used to refill compressed gases and LPG must conform to the suitability, installation requirements and tolerances in NIST Handbook 44. This will not only ensure economic integrity, but safety practices could also be enhanced. As a point of reference, the USDA Food Safety and Inspection Service adopted NIST Handbook 44 in the 1990s for all meat and poultry plants. The result has been greatly improved weighing accuracy and a dramatic reduction in the number of complaints from consumers and competitors over short weight packages as received by weights and measures officials.

The presence of weights and measures officials at points of filling ensure scales in operation are suitable for the purpose they are intended and that they meet legal requirements for suitability and accuracy. Officials also ensure the scales are used properly and maintained in good operation condition throughout their service life.

Average Requirement

An “Average Requirement” is essential to ensuring the net quantity of contents in packaged goods and is designed to avoid complaints from consumers and competitors who believe the seller misrepresented the net quantity of the product. The average requirement will help ensure cylinder manufacturers do not stamp a TW that is within allowable difference but is also favorable to their business. Commercial transactions in the absence of an average requirement thus could create an unfair competition and may be potentially abused, either intentional or unintentionally.

We would recommend the inclusion of an "Average Requirement" to tare regulations in future DOT regulations, as this is anticipated to improve measurement accuracy and production controls when large plus and minus tolerances in specifications are allowed. This would be consistent with what is detailed in NIST Handbook 130 Method of Sale Regulation of Commodities, Section 2.16 (see Table 1). This also ensures the businesses are not using the allowable differences to gain a competitive advantage by imposing an "average requirement" on the variations. Below is the language in NIST Handbook 130 that is recommended to be adopted by the DOT:

> ***Average requirement.*** *– When used to determine the net contents of cylinders, the stamped or stenciled tare weights of cylinders at a single place of business found to be in error predominantly in a direction favorable to the seller and near the allowable difference limit shall be considered to be not in conformance with these requirements.*

Conclusions and Future Considerations

The results provided in this report are to assist and inform the States, propane industry (PERC, NPGA, CGA), consumer and workplace protection organizations (NFPA, OSHA), and Federal agency stakeholders (DOT) of the present needs and opportunities to establish improved procedures and oversight of the manufacturing, refilling, reselling and consumer-based transactions for 20 lb LPG cylinders. In addition, NCWM and NIST OWM will work together to develop a strategy on how to best engage and collaborate with the commercial propane industry and stakeholders to update the Method of Sale for LPG in NIST Handbook 130. The information provided in this report will also be available to DOT PHMSA to inform and assist in their evaluation on whether to revise its regulations based on the survey findings.

Though the focus of this survey was on 20 lb LPG cylinders, it is recognized that many other size cylinders and compressed gases exist in the marketplace. Although the conclusions, recommendations and considerations may not apply to other size cylinders and compressed gases, these products should not be overlooked. Some of the general trends observed during this survey may help guide future surveys and in helping industry determine good quantity control and other best practices for these other commercial compressed gas products.

Based on the preliminary efforts associated with this survey, the enforcement by individual state weights and measures authorities of the 20 lb propane cylinders is already occurring in the marketplace. Beyond the 19 states that participated in this survey, this is an opportunity for all states, industry, and other stakeholders to glean some of the main takeaways from this report and improve cooperation towards a common goal of improved safety and marketplace equity for businesses and consumers alike.

Some future considerations that are relevant to manufacturing, safety, consumer protection and education, and underpinning marketplace equity may include:

Improving Manufacturing Processes:

- CGA and NPGA to establish new practices to ensure tare weight for new and used cylinders are within established tolerances throughout the cylinder's life in the supply chain.
- PERC to develop Good Quantity Control Practices for the industry and provide training to members.
- CGA and NPGA add requirements for meeting the "Average Requirement" and "Maximum Allowable Variation" as part of their best practices for Good Quantity Control.

Improving Safety:

- NPGA working with their members to eliminate overfilling beyond the safe fill level.
- NPGA working with Direct Sale Refilling Locations to ensure proper training takes place to ensure the correct procedure is used to determine the safe fill level.

Informing and Educating Consumers:

- PERC to educate consumers on product remaining in cylinders when performing an exchange or returns.
- NCWM to engage states that allow 20 lb cylinders of LPG to be sold by flat fee sales. Develop protections for consumers to receive credit for product returned in tank, which may require pricing and unit pricing.
- NCWM consider developing price posting requirements at the Direct Sale Refilling Location.

Ensuring Marketplace Equity:

- The focus of this survey was on 20 lb cylinders but there may be similar issues and concerns for other types of compressed gasses (acetylene, oxygen, argon, nitrogen, helium and hydrogen). In addition, states should consider and determine if they can expand their scope of inspections to continue enforcement efforts in protecting consumers and business.
- All States to perform more routines inspections and enforcement beyond the 20 lb cylinders. Typical sizes of portable LPG cylinders in the marketplace can range from 1 lb to 100 lb.
- States should develop a program to ensure the accuracy of scales being used at the plant and at direct sale refilling locations.
- Industry and their trade associations should consider conducting a "root cause analysis" to determine any underlying processes or procedures that may be contributing to non-compliance.
- DOT to review and reconsider its tolerances which are based on safety, to recognize and include economic protection.

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[2] 2022 Version of NIST Handbook 130, Uniform Laws and Regulations in the Areas of Legal Metrology and Fuel Quality (https://www.nist.gov/pml/weights-and-measures/publications/nist-handbooks/handbook-130-current-edition)

[3] U.S. Department of Transportation (DOT) Final Rule 49 CFR § 178.35 "General Requirements for Specification Cylinders" https://www.ecfr.gov/current/title-49/subtitle-B/chapter-I/subchapter-C/part-178/subpart-C/section-178.35 (last accessed 2022-09-16)

[4] 2022 Version of NIST Handbook 44, Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices Current Version (https://www.nist.gov/pml/weights-and-measures/publications/nist-handbooks/handbook-44-current-edition)

[5] 2020 Version of NIST Handbook 133, Checking the Net Contents of Packaged Goods (https://www.nist.gov/pml/weights-and-measures/publications/nist-handbooks/handbook-133-current-edition)

[6] NIST Special Publication 979 Reports of the National Conference on Weights and Measures (1905-2019), including the Report for the 75th Annual Meeting (1990). https://www.nist.gov/pml/owm/publications/ncwm-annual-reports (last accessed 2022-09-16)

[7] LPG (Propane) -Verifying the Net Contents of 20 lb Cylinders (Part 1). Weights and Measures Calendar of Events. https://www.nist.gov/pml/owm/training (last accessed 2022-09-16)

[8] 2022 Canadian Standards Association CSA B339 "Cylinders, spheres, and tubes for the transportation of dangerous good". B339 TC-4BM, TC-4BAM, and TC-4BWM CSA B339 (canada.ca)

Appendix A. Determination of the Package Requirements

NIST Handbook 133 Checking the Net Contents of Packaged Goods [2] was prepared as a procedural guide for the compliance testing of net content statements on packaged goods. Compliance testing of packaged goods is the determination of the conformance of the results of the packaging, distribution, and retailing process (the packages) to specific legal requirements for net content declarations. NIST Handbook 133 was developed primarily for the use of government officials. However, commercial and industrial establishments that package, distribute, and sell commodities will find this handbook useful as well.

The net quantity of content statement must be "accurate," but reasonable variations are permitted. Variations in package contents may be a result of deviations in filling. The limits for acceptable variations are based on current good manufacturing practices in the weighing, measuring, and packaging process. The first requirement is that accuracy is applied to the average net contents of the packages in the lot. The second requirement is applied to negative errors in individual packages. These requirements apply simultaneously to the inspection of all lots of packages except as specified in Section 1.2.5. "Exceptions to the Average and Individual Package Requirements."

For determining net weight compliance of 20 lb cylinders for this survey, officials used the "Test Procedure for Packages Labeled by Weight – Gravimetric Testing", as found in Chapter 2 of the NIST Handbook 133 [2]. The test procedure covers areas such as inspector scale requirements and accuracy, defining the inspection lot, random sample selection, tare determination, recording of inspection data, determining the package error, and evaluating the results for compliance.

An "inspection lot" is defined as a collection of identically labeled packages available for inspection at one time. The inspection lot will pass or fail as a whole based on the results of tests on a sample drawn from the lot. A package (cylinder) must meet two requirements: 1) the average requirement and 2) the individual package requirement. In general, the average net quantity of contents of packages in a lot must be (at a minimum) equal to the net quantity of contents declared on the label. Any plus or minus variations from the declared net weight are permitted when they are determined to be caused by unavoidable variations in weighing, measuring, or counting the contents of individual packages that occur in current good manufacturing practice.

The variation of individual package contents from the labeled quantity must not be "unreasonably large." Packages that are under filled by more than the Maximum Allowable Variation (see NIST Handbook 133, Appendix A – Table 2-5. Maximum Allowable Variation (MAVs) for Packages labeled by Weight) specified for the package are considered unreasonable errors. Unreasonable shortages are not generally permitted, even when overages in other packages in the same lot, shipment, or delivery compensate for such shortage.

The limit of the "reasonable minus variation" for an under filled package is called a "Maximum Allowable Variation" (MAV). An MAV is a deviation from the labeled weight, measure, or count of an individual package beyond which the deficiency is considered an unreasonable minus error. Each sampling plan limits the number of negative package errors permitted to be greater than the MAV.

The MAV is based on the labeled net weight. The MAV for a cylinder with a labeled net weight of 15 lbs is 0.28 lb. This only applies to a negative or "short net weight" error. This means that if a cylinder exceeds the MAV (e.g., 0.28 lb) based on the labeled quantity (e.g., 15 lb) the lot fails.

No unreasonable minus errors (UME) (exceeding the MAV) are allowed when testing a lot. If any UME are found, the lot automatically fails.

For a complete and detailed explanation of how an inspection is conducted, please see NIST Handbook 133, Chapter 2, "Test Procedure for Packages Labeled by Weight – Gravimetric Testing" [2].

Appendix B. Templates and Reporting Sheets

The following are copies of the data reporting templates in the form of Excel spreadsheets for each of the three Phases of the LPG (Propane) survey (Phase I: Point of Pack, Phase II: Direct Sale Refilling Locations, and Phase III: Exchange Locations).

LPG Survey – Phase I: Point of Pack
"Actual vs. Stamped Tare Weight Worksheet"
NEW CYLINDERS

Instructions:	· Please enter in the survey information and data in Columns 1 - 5 for all cells highlighted with italicized blue text. After all data is entered for each Package (e.g. 1-12), then delete the remaining data in the rows that were not used (e.g., 13-24). · The data for all cells highlighted with normal red text are automatically calculated (please do not modify). This includes Columns 6 - 9, the Adjusted Empty Weight, Total Error, Sample Standard Deviation (Std Dev), Average Error, Sample Error Limits (SEL), and the Number of Failed Cylinders. · The determination of compliance according to the Average Requirement (Sample Passes/Fails) is automatically determined and noted with normal red text. · Add in any additional comments, and provide the Official's Name and/or Business Representative information. [space] If you have any questions or need assistance completing this form, please contact David Sefcik (david.sefcik@nist.gov).
Packer:	*Example: LPG R US - Point of Pack*
Location:	*Example: 1111 Main St, Capital City, State 20102*
Date:	*1/1/2022*

New Cylinders?	*Select from list*			**Nominal Cylinder Size (lb):**	*20*		**Inspection Lot Size:**	*n/a*	
				Unit of Measure (lb):	*0.000*		**Sample Size (n):**	*24*	
Column	**1**		**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Package (Cylinder)	**Stamped Markings on Collar Ring**		**Is the Label/Cap ON/OFF?***	**Label/Cap (if ON) Weight (lb)**	**Stamped Tare Weight (TW) (lb)**	**Actual Empty Weight (EW) (lb)**	**Adjusted Empty Weight (EW - Label/Cap) (lb)**	**± Error (Adj EW - TW) (lb)**	**Allowable Difference (0.005 × TW) (lb)****	**Is Cylinder within Allowable Difference?**
	Manufacturer Code	**Manufacturer Date (month-year)**								
1	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
2	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
3	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
4	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
5	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
6	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
7	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
8	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
9	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
10	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
11	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
12	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
13	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
14	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
15	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
16	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
17	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
18	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
19	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
20	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
21	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
22	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
23	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
24	*MXXXX*	*01-21*	*OFF*	*0.000*	*0.0*	*0.000*	0.000	0.000	0.000	N/A
							Total Error (lb):	0.000		
							Sample Std Dev (lb):	0.000		
							Average Error (lb):	0.000		

* Tare Weight of Label and Cap is not included in manufacturer Stamped Tare Weight (TW)
** Allowable Difference applies to only TWs of 20 lb or less

Allowable Difference. If the error determined for an individual cylinder (Column 7) exceeds the Allowable Difference (Column 8), then the Cylinder is marked as "NO" (Column 9) and counted as Failed.	**Number of Failed Cylinders:**	0
Average Requirement. The Average Error determines if the seller meets the Average Requirement for cylinders for the allowable difference between the actual tare weight/Empty Weight (EW) and the Stamped Tare Weight (TW). If the Average Error is zero or positive (+), the Sample Passes. If the Average Error is negative (-), then the Sample Error Limit (SEL) is calculated as Sample Standard Deviation (Std Dev) × Sample Correction Factor (SCF) (automatic calculation below) and will determine compliance (Sample Passes/Fails).	**Sample Passes/Fails?**	**Passes**

Sample Correction Factor (SCF):	Not determined	Category A Sampling Plan: · if Sample Size (n) = 12, then maintain SCF = 0.635 · if Sample Size (n) ≠ 12, then manually enter the correct SCF value	**Sample Error Limit (SEL):**	Not determined

Comments:	*Please add in any additional information here*				
Official's Name:	*J.Q. Public*			Business Representative:	*J.Q. Public*

Fig. B-1. Phase I: Point of Pack – Actual vs. Stamped Tare Weight data reporting template for used cylinders.

LPG Survey – Phase I: Point of Pack
"Actual vs. Stamped Tare Weight Worksheet"
USED CYLINDERS

Instructions:

- Please enter in the survey information and data in Columns 1 - 4 for all cells highlighted with *italicized blue text* . After all data is entered for each Package (e.g. 1-12), then delete the remaining data in the rows that were not used (e.g., 13-24).
- The data for all cells highlighted with normal red text are automatically calculated (please do not modify). This includes Columns 5 - 7, the Total Error, Sample Standard Deviation (Std Dev), Average Error, Sample Error Limits (SEL), and the Number of Failed Cylinders.
- The determination of compliance according to the Average Requirement (Sample Passes/Fails) is automatically determined and noted with normal red text.
- Add in any additional comments, and provide the Official's Name and/or Business Representative information.

If you have any questions or need assistance completing this form, please contact David Sefcik (david.sefcik@nist.gov).

Packer:	*Example: LPG R US - Point of Pack*						
Location:	*Example: 1111 Main St, Capital City, State 20102*						
Date:	*1/1/2022*						
Used Cylinders?	*Select from list*		**Nominal Cylinder Size (lb):**	*20*		**Inspection Lot Size:**	*n/a*
			Unit of Measure (lb):	*0.000*		**Sample Size (n):**	*24*

Column	**1**		**2**	**3**	**4**	**5**	**6**	**7**
Package (Cylinder)	**Stamped Markings on Collar Ring**		**Is the Label/Cap ON/OFF?***	**Stamped Tare Weight (TW) (lb)**	**Actual Empty Weight (EW) (lb)**	**± Error (EW - TW) (lb)**	**Allowable Difference (0.005 × TW) (lb)****	**Is Cylinder within Allowable Difference?**
	Manufacturer Code	**Manufacturer Date (month-year)**						
1	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
2	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
3	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
4	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
5	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
6	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
7	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
8	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
9	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
10	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
11	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
12	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
13	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
14	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
15	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
16	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
17	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
18	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
19	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
20	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
21	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
22	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
23	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
24	*MXXXX*	*01-21*	*OFF*	*0.0*	*0.000*	0.000	0.000	N/A
					Total Error (lb):	0.000		
					Sample Std Dev (lb):	0.000		
					Average Error (lb):	0.000		

* Tare Weight of Label and Cap is not included in manufacturer Stamped Tare Weight (TW)
** Allowable Difference applies to only TWs of 20 lb or less

Allowable Difference. If the error determined for an individual cylinder (Column 5) exceeds the Allowable Difference (Column 6), then the Cylinder is marked as "NO" (Column 7) and counted as Failed.

Number of Failed Cylinders: 0

Average Requirement. The Average Error determines if the seller meets the Average Requirement for cylinders for the allowable difference between the actual tare weight/Empty Weight (EW) and the Stamped Tare Weight (TW). If the Average Error is zero or positive (+), the Sample Passes. If the Average Error is negative (-), then the Sample Error Limit (SEL) is calculated as Sample Standard Deviation (Std Dev) × Sample Correction Factor (SCF) (automatic calculation below) and will determine compliance (Sample Passes/Fails).

Sample Passes/Fails? Passes

Sample Correction Factor (SCF):	Not determined	Category A Sampling Plan: · if Sample Size (n) = 12, then maintain SCF = 0.635 · if Sample Size (n) ≠ 12, then manually enter the correct SCF value	**Sample Error Limit (SEL):**	Not determined

Comments:	*Please add in any additional information here*		
Official's Name:	*J.Q. Public*	Business Representative:	*J.Q. Public*

Fig. B-2. Phase I: Point of Pack – Actual vs. Stamped Tare Weight data reporting template for used cylinders.

LPG Survey – Phase II: Direct Sale Refilling Locations Determination of the Method of Sale and Filling Procedure Worksheet				
Instructions:	• Please enter in the survey information for all cells highlighted with *italicized blue text* . • Please check 'Confirmed' for all that apply and/or Yes/No for all questions listed in Sections 1, 2, and 3. • Add in any additional comments and provide the Official's Name. If you have any questions or need assistance completing this form, please contact David Sefcik (david.sefcik@nist.gov).			
Location (Name):	*Example: LPG R US - Direct Sale*			
Location (Address):	*Example: 1111 Main St, Capital City, State 20102*			
Date:	*1/1/2022*			
Nominal Cylinder Size (lb):	*20*			
Section 1	**How is Propane sold at this location? Check all that apply.**			
	By WEIGHT (e.g., $1.05 lb)	☐ Confirmed	If WEIGHT confirmed, is a service fee also applied?	Yes/No? (select)
	By VOLUME (e.g., $3.75 gal)	☐ Confirmed	If VOLUME confirmed, is a service fee also applied?	Yes/No? (select)
	By FLAT FEE/FIXED PRICE per fill (e.g., $19.99)?	☐ Confirmed		
Section 2	**How is the fill level of the 20 lb cylinder verified (through your observation and asking attendant)? Check all that apply.**			
	Fill level is verified by WEIGHT			☐ Confirmed
	Fill level is verified by use of "BLEEDER VALVE"			☐ Confirmed
	Fill level is verified by use of the OVERFLOW PROTECTION DEVICE (OPD)			☐ Confirmed
	Other vertification process	*Please provide details of other observations here (if applicable)*		
Section 3	**Is the PRICE of Propane posted or advertised?**			Yes/No? (select)
Comments/Notes:	*Please provide additional information here*			
Official's Name:	*J.Q. Public*			

Fig. B-3. Phase II: Direct Sale Refilling Locations – Determination of the Method of Sale and Filling Procedure data reporting template.

LPG Survey – Phase III: Exchange Locations "Product Left Behind Worksheet"				
Instructions:	• Please enter in the survey information and data in Columns 1 - 2 for all cells highlighted with *italicized blue text* . Add in any cylinder-specific comments in Column 4. • The data for all cells highlighted with normal red text are automatically calculated (please do not modify). This includes the Remaining Product amount in Column 3, the Total Error, Average Error, and the Sample Size (n). • Add in any additional comments, and provide the Official's Name. If you have any questions or need assistance completing this form, please contact David Sefcik (david.sefcik@nist.gov).			
Packer:	*Example: LPG R US - Exchange Location*			
Location:	*Example: 1111 Main St, Capital City, State 20102*			
Date:	*1/1/2022*			
Nominal Cylinder Size (lb):	*20*	**Sample Size (n):**	*20*	
Column	**1**	**2**	**3**	**4**
Package (Cylinder)	**Gross Weight (GW) (lb)**	**Stamped Tare Weight (TW) (lb)**	**Remaining Product (GW - TW) (lb)**	**Comments**
1	*0.000*	*0.0*	0.000	
2	*0.000*	*0.0*	0.000	
3	*0.000*	*0.0*	0.000	
4	*0.000*	*0.0*	0.000	
5	*0.000*	*0.0*	0.000	
6	*0.000*	*0.0*	0.000	
7	*0.000*	*0.0*	0.000	
8	*0.000*	*0.0*	0.000	
9	*0.000*	*0.0*	0.000	
10	*0.000*	*0.0*	0.000	
11	*0.000*	*0.0*	0.000	
12	*0.000*	*0.0*	0.000	
13	*0.000*	*0.0*	0.000	
14	*0.000*	*0.0*	0.000	
15	*0.000*	*0.0*	0.000	
16	*0.000*	*0.0*	0.000	
17	*0.000*	*0.0*	0.000	
18	*0.000*	*0.0*	0.000	
19	*0.000*	*0.0*	0.000	
20	*0.000*	*0.0*	0.000	
		Total Error (lb):	0.000	
		Average Error (lb):	0.000	
Comments:	*Please add in any additional information here*			
Official's Name:	*J.Q. Public*			

Fig. B-4. Phase III: Exchange Locations – Product Left Behind data reporting template.

LPG Survey – Phase III: Exchange Locations
"Net Weight Worksheet"

Instructions:	• Please enter in the survey information and data in Columns 1 - 4 for all cells highlighted with *italicized blue text* . The data for all cells highlighted with normal red text are automatically calculated (please do not modify). This includes Columns 5 - 8, Number of Failed Cylinders, the Total and Average Packaging Error, Sample Standard Deviation, Sample Error Limits (SEL). • The determination of compliance according to the Average Requirement (Sample Passes/Fails) is automatically determined and noted with normal red text. • Add in any additional comments, and provide the Official's Name and/or Business Representative information. If you have any questions or need assistance completing this form, please contact David Sefcik (david.sefcik@nist.gov).
Packer:	*Example: LPG R US - Exchange Location*
Location:	*Example: 1111 Main St, Capital City, State 20102*
Date:	*1/1/2022*

Nominal Cylinder Size (lb):	*20*		**Inspection Lot Size:**	*enter number here*		**Average Tare Weight of Cap/Label (lb)***	*0.000*
Unit of Measure (lb):	*0.001*		**Sample Size (n):**	*12*		**Total Number of Tare Samples:**	*enter number here*
Column	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Package (Cylinder)	**Labeled Net Weight (lb)**	**Gross Weight (lb) (GW)**	**Stamped Tare Weight (lb) (TW)**	**Adjusted Gross Weight (lb) (GW - Avg TW Cap/Label)**	**Calculated Net Weight (lb) (Adj GW - TW)**	**Package Error (lb) (Calculated Net Weight - Labeled Net Weight)**	**Does the Package Error Exceed the MAV?****
1	*0*	*0.000*	*0.0*	0.000	0.000	0.000	N/A
2	*0*	*0.000*	*0.0*	0.000	0.000	0.000	N/A
3	*0*	*0.000*	*0.0*	0.000	0.000	0.000	N/A
4	*0*	*0.000*	*0.0*	0.000	0.000	0.000	N/A
5	*0*	*0.000*	*0.0*	0.000	0.000	0.000	N/A
6	*0*	*0.000*	*0.0*	0.000	0.000	0.000	N/A
7	*0*	*0.000*	*0.0*	0.000	0.000	0.000	N/A
8	*0*	*0.000*	*0.0*	0.000	0.000	0.000	N/A
9	*0*	*0.000*	*0.0*	0.000	0.000	0.000	N/A
10	*0*	*0.000*	*0.0*	0.000	0.000	0.000	N/A
11	*0*	*0.000*	*0.0*	0.000	0.000	0.000	N/A
12	*0*	*0.000*	*0.0*	0.000	0.000	0.000	N/A
Maximum Allowable Variation (MAV) for Labeled Net Weight (lb)	**0.28**				**Total Package Error (lb):**	0.000	
					Sample Standard Deviation (lb):	0.000	
					Average Package Error (lb):	0.000	

* Follow the procedures in NIST HB 133 Section 2.3.5.1. "Determination of the Tare Sample and Average Tare Weight if the individual tare weight vary."
**Packages that are underfilled by more than the MAV (negative (-) package errors) are considered "unreasonable errors". NIST HB133 does not specific limits of overfilling (positive (+) package errors).

Unreasonable Minus Package Errors. If the Package Error determined for an individual cylinder (Column 7) exceeds the MAV for Labeled Net Weight, then the Cylinder is marked as "YES" (Column 8) and counted as Failed.				**Number of Failed Packages (Cylinders) (based on MAV):**	0
Average Requirement. If any of the Package Errors (7) exceed the MAV, the Sample Fails. If not, and if the Average Package Error is zero or positive (+), the Sample Passes. If there are no Package Errors that exceed the MAV and the Average Package Error is negative (-), then the Sample Error Limit (SEL) is calculated as Sample Standard Deviation (Std Dev) × Sample Correction Factor (SCF) (automatic calculation below) and will determine compliance (Sample Passes/Fails).				**Sample Passes/Fails?**	**PASSES (based on SEL)**
Sample Correction Factor (SCF):	N/A	Category A Sampling Plan (see Table 2-1 in NIST HB133 Appendix A): · if Sample Size (n) = 12, then maintain SCF = 0.635 · if Sample Size (n) ≠ 12, then manually enter the correct SCF value	**Sample Error Limit (SEL):**	N/A	
Comments:	*Please add in any additional information here*				
Official's Name:	*J.Q. Public*				

Fig. B-5. Phase III: Exchange Locations – Net Weight data reporting template.

Appendix C. Cylinders and Lots Inspected per State for Phase I: Point of Pack

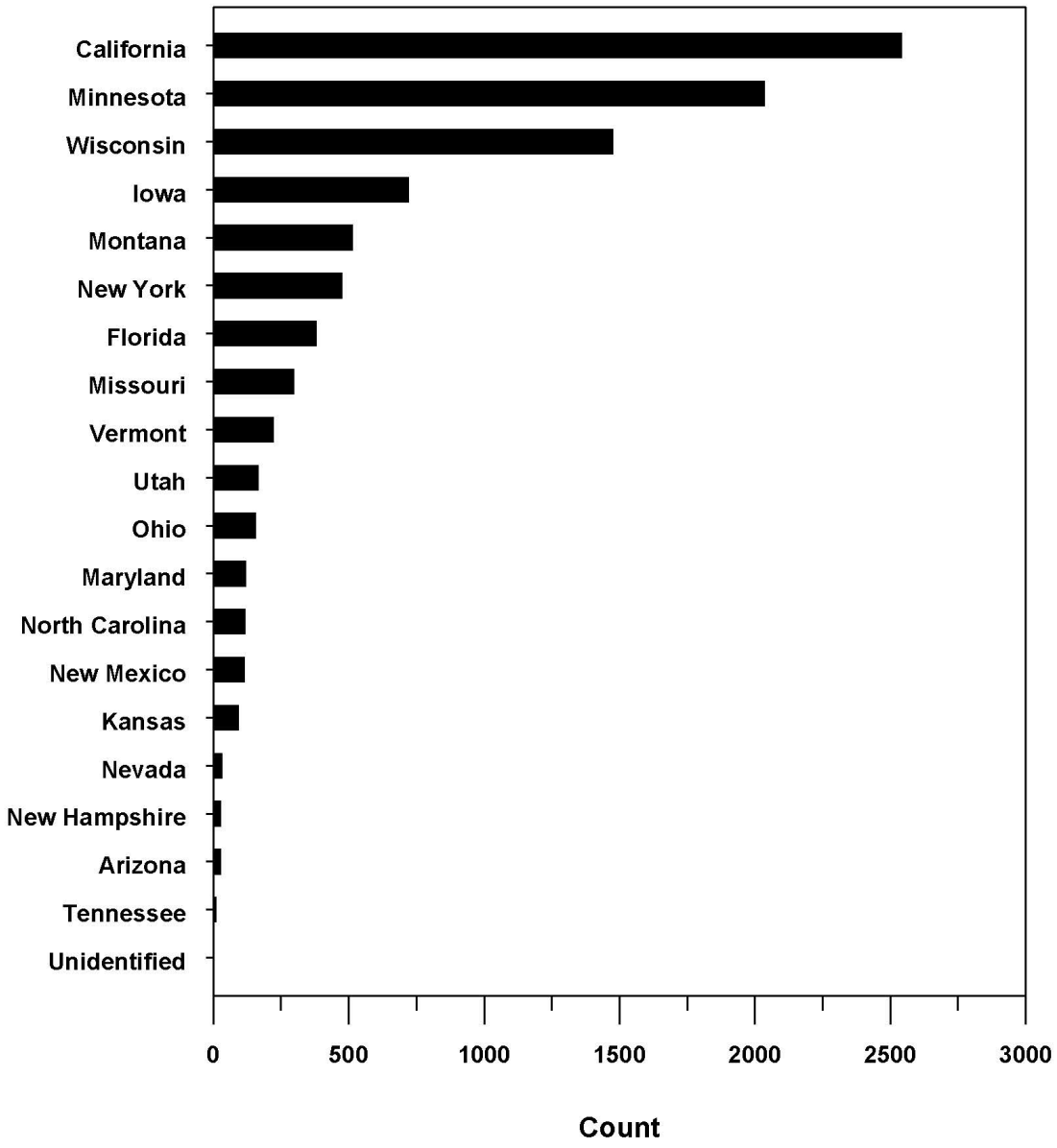

Fig. C-1. Number of new cylinders inspected per state (9,482 in total).

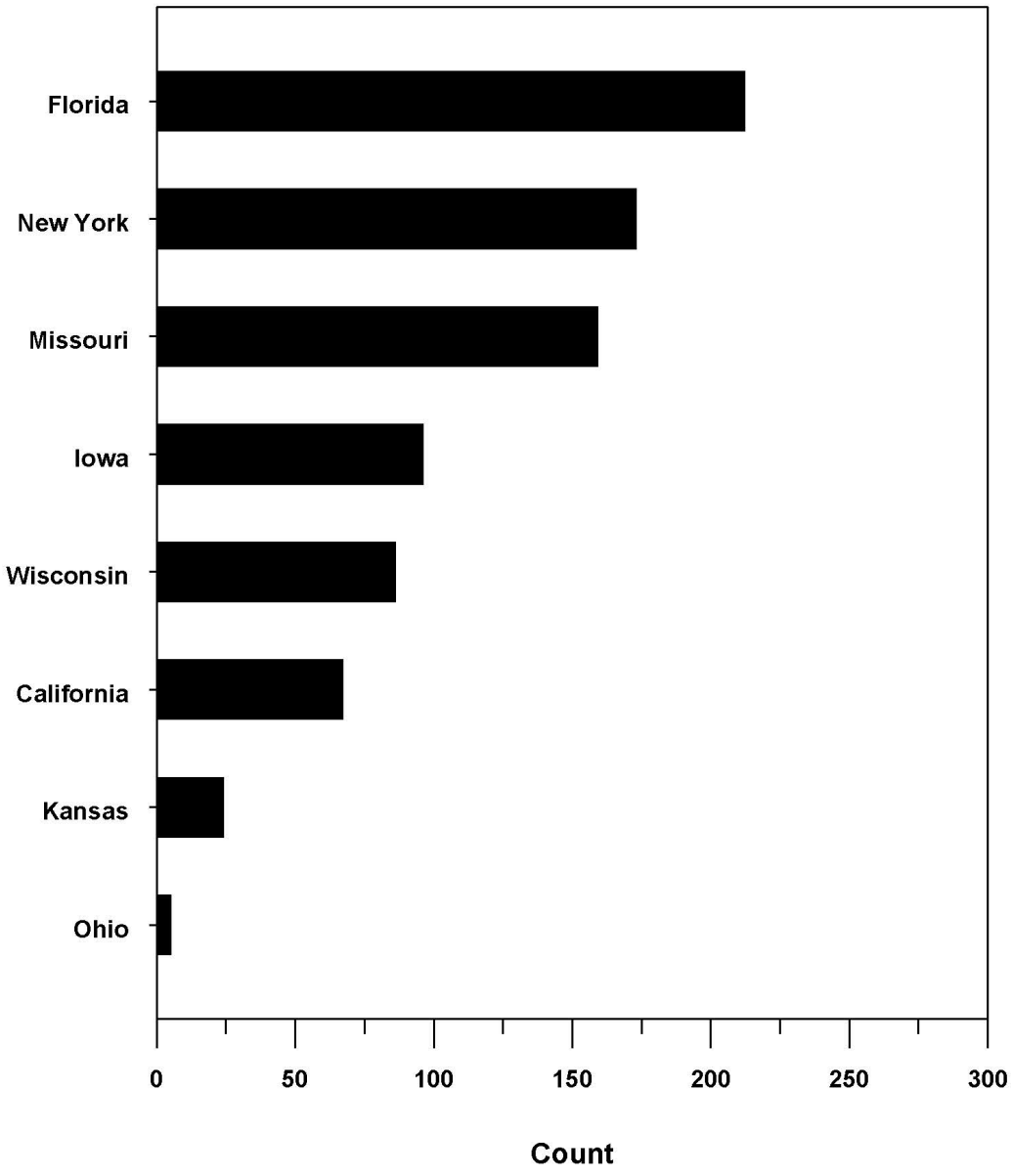

Fig. C-2. Number of used cylinders inspected per state (822 in total).

Appendix D. Manufacturer Codes of Evaluated Cylinders for Phase I: Point of Pack

Table D1. Different manufacturer codes[a] for new cylinders as best determined and reported by officials with the corresponding counts of the number of times within the survey.

Manufacturer Code	No. of counts
M4875	4282
M0102	2256
M0850	1379
M4014	1070
M0712	131
M4875_WCW	128
M102	46
SMPC	38
M4013	24
WCW	24
M8475	23
MO102	13
M9701	10
MANCHESTER	9
MUL	9
MAN	8
M0201	5
M4499	5
M4001	2
M4104	2
M4876	2
M4975	2
MXXXX	2

Manufacturer Code	No. of counts
159458	1
1888	1
5908121X	1
M0103	1
M04014	1
M0405	1
M10	1
M1404	1
M4016	1
M4020	1
M4044	1
M4074	1
M41014	1
M41075	1
M41175	1
M4629	1
M4675	1
M4775	1
M4877	1
M491	1
MO850	1
T0713104	1

[a]Codes were best determined, transcribed and reported by inspectors during the cylinder inspection. Some errors may be inherent in these data, as some of the stamped cylinder information may be occluded and difficult to read.

Table D2. Different manufacturer codes[a] for used cylinders as best determined and reported by officials with the corresponding counts of the number of times within the survey.

Manufacturer Code	No. of counts	Manufacturer Code	No. of counts
M4875	305	COLAY	1
M4014	182	ICC	1
MANCHESTER	119	INGUSA	1
WORTHINGTON	50	M0303	1
M0102	37	M1001	1
M4001	23	M4054	1
GENERAL	18	M48975	1
M8903	11	M8205	1
N/A	11	M8404	1
M0850	8	M8901	1
M4543	7	M9603	1
4875	5	M9701	1
M0804	5	MXXXX	1
LEE	4	PHILLIPS	1
M0301	4	TAISHAN	1
M0405	4	THE	1
805	2	UNK0WN	1
M4801	2	UNKNOWN	1
SMPC	2	UNREADABLE	1
804	1	VOYAGEUR	1
BLUE	1	WOLFDALE	1

[a]Codes were best determined, transcribed and reported by inspectors during the cylinder inspection. Some errors may be inherent in these data, as some of the stamped cylinder information may be occluded and difficult to read.

Appendix E. Effect of Tolerance Limits on Accepted Cylinders for Phase I: Point of Pack

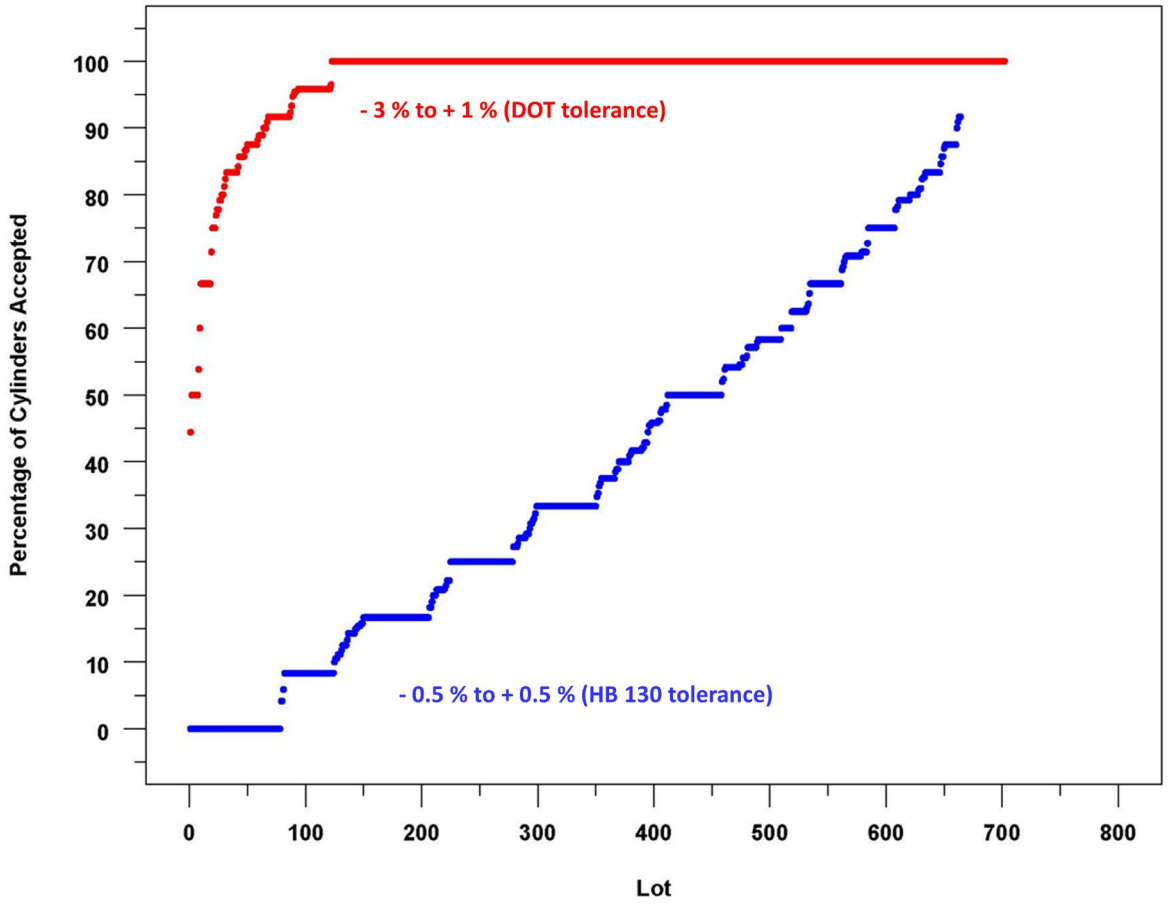

Fig. E-1. Percentage of new cylinders that are accepted by lot (702 in total) with respect to the new (effective December 28, 2022) DOT tolerance (red symbols; ●) compared to the current HB 130 tolerance (blue symbols; ●) evaluated in Phase I: Point of Pack.

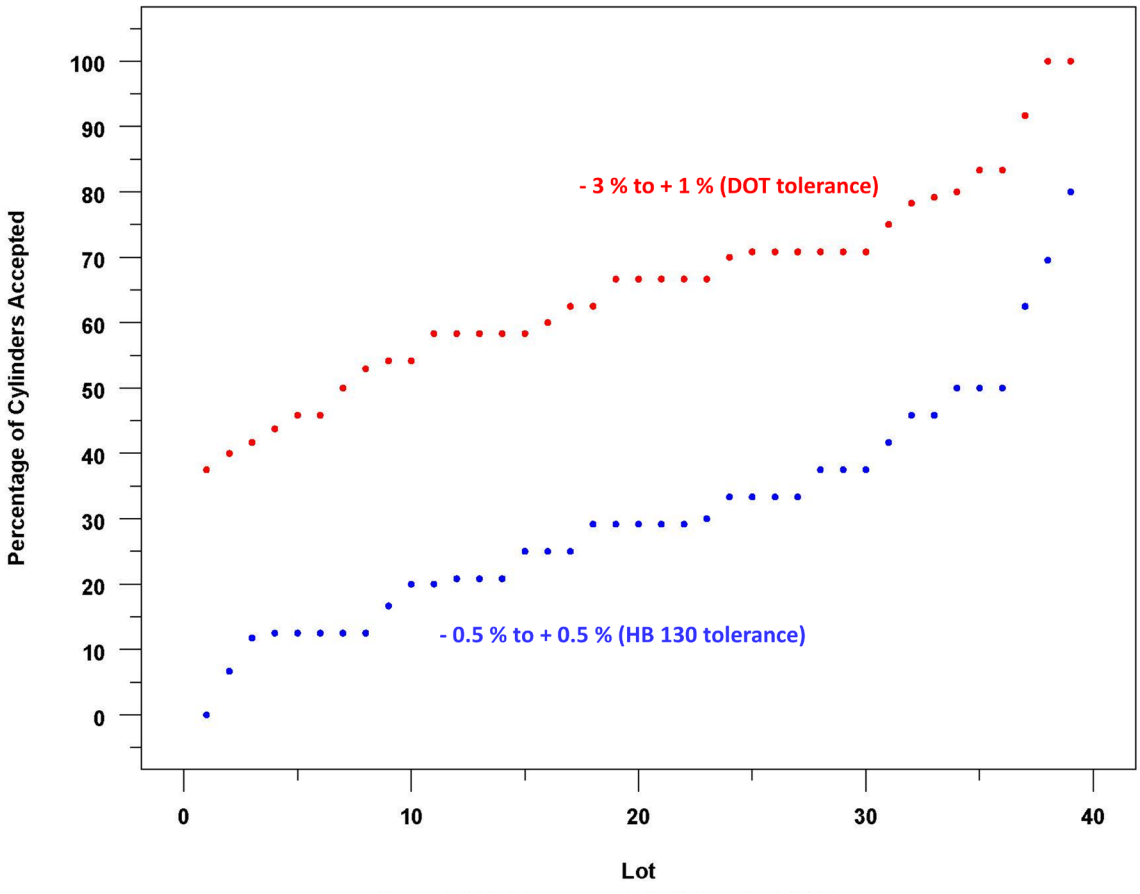

Fig. E-2. Percentage of used cylinders that are accepted by lot (39 in total) with respect to the new (effective December 28, 2022) DOT tolerance (red symbols; ●) compared to the current HB 130 tolerance (blue symbols; ●) evaluated in Phase I: Point of Pack.

Appendix F. Percentage of Cylinders within Tolerances for Different Lot Sizes for Phase I: Point of Pack

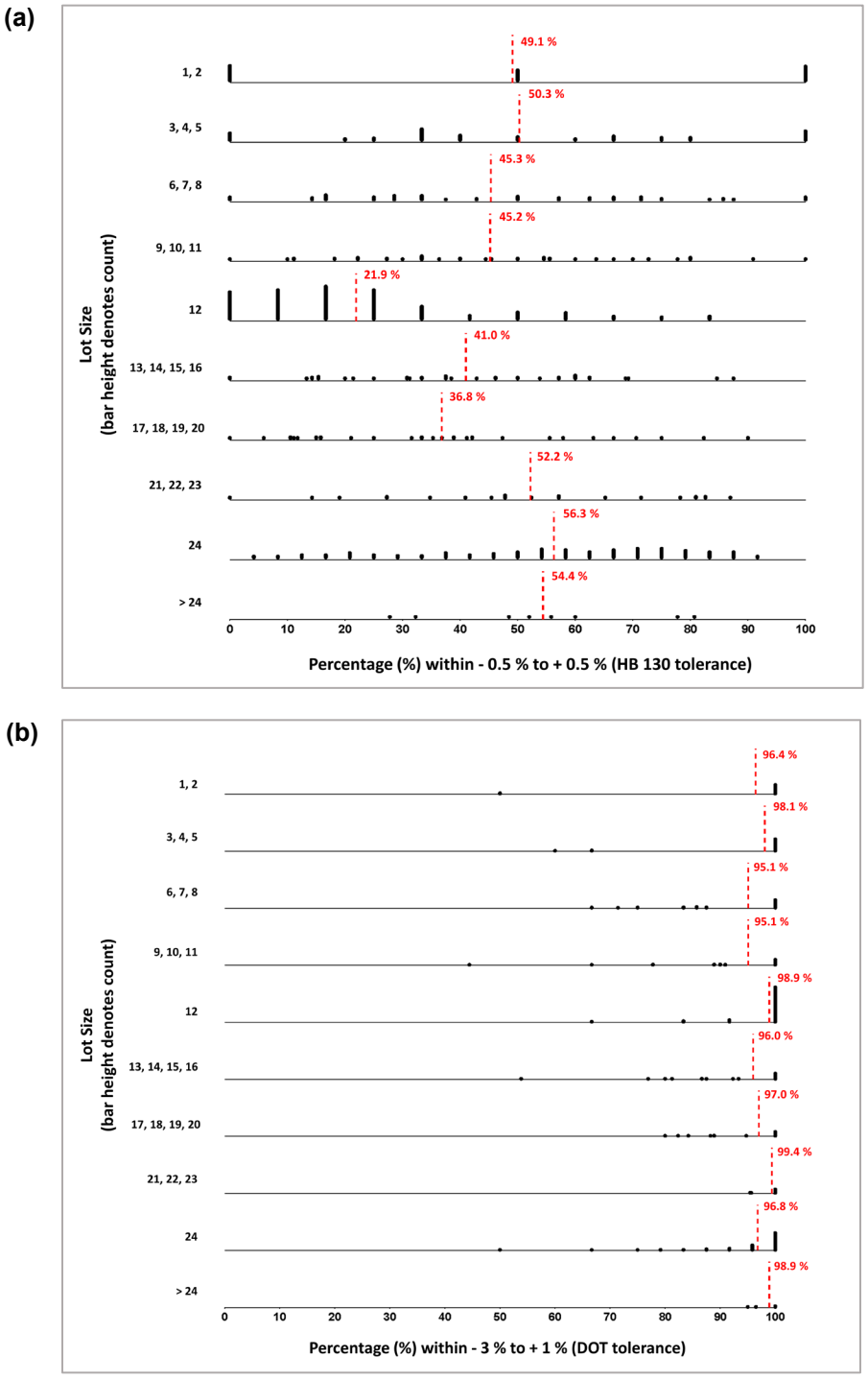

Fig F-1. Percentage (%) of new cylinders that are within the (a) current HB 130 and (b) new (effective December 28, 2022) DOT tolerances as grouped according to various lot sizes (where lot size is defined as the number of cylinders inspected per lot). The average percentage (%) for each lot size is represented by a vertical dashed red line.

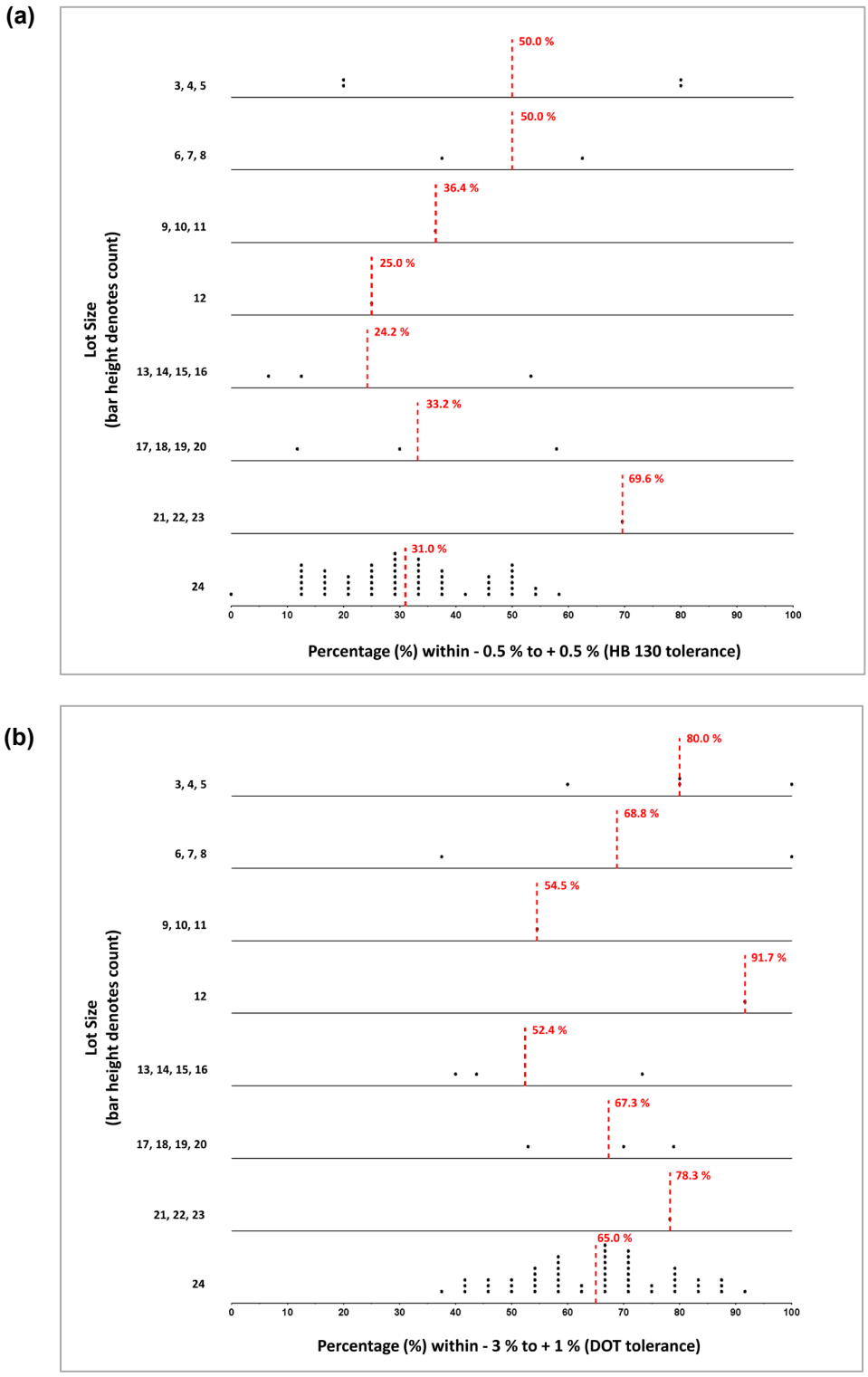

Fig F-2. Percentage (%) of used cylinders that are within the (a) current HB 130 and (b) new (effective December 28, 2022) DOT tolerances as grouped according to various lot sizes (where lot size is defined as the number of cylinders inspected per lot). The average percentage (%) for each lot size is represented by a vertical dashed red line.

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Appendix G. Cylinders and Lots Inspected per State for Phase II: Direct Sale Refilling Locations

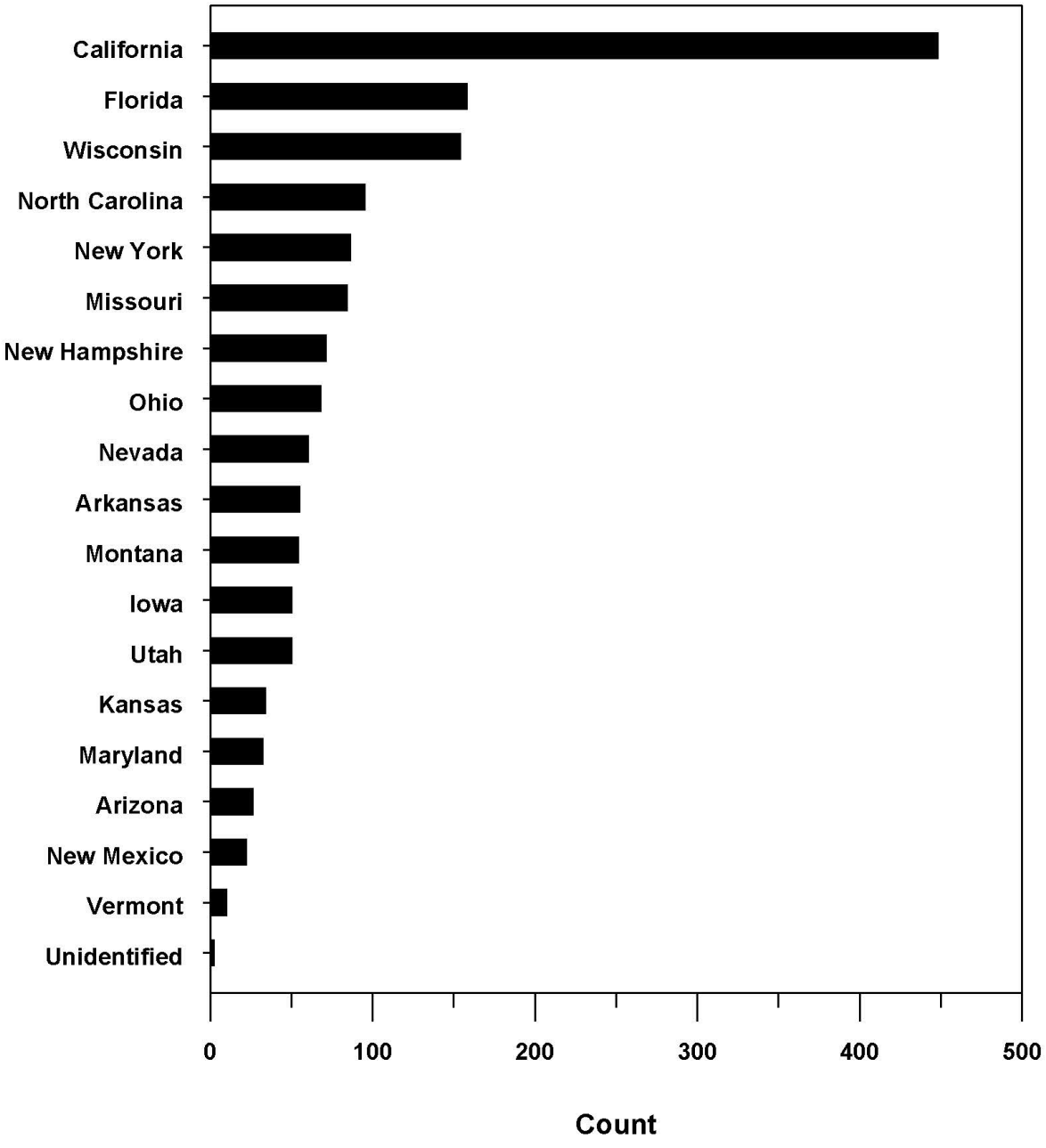

Fig. G-1. Number of direct sale refilling locations inspected per state (1,559 in total).

Appendix H. Cylinders and Lots Inspected per State for Phase III: Exchange Locations

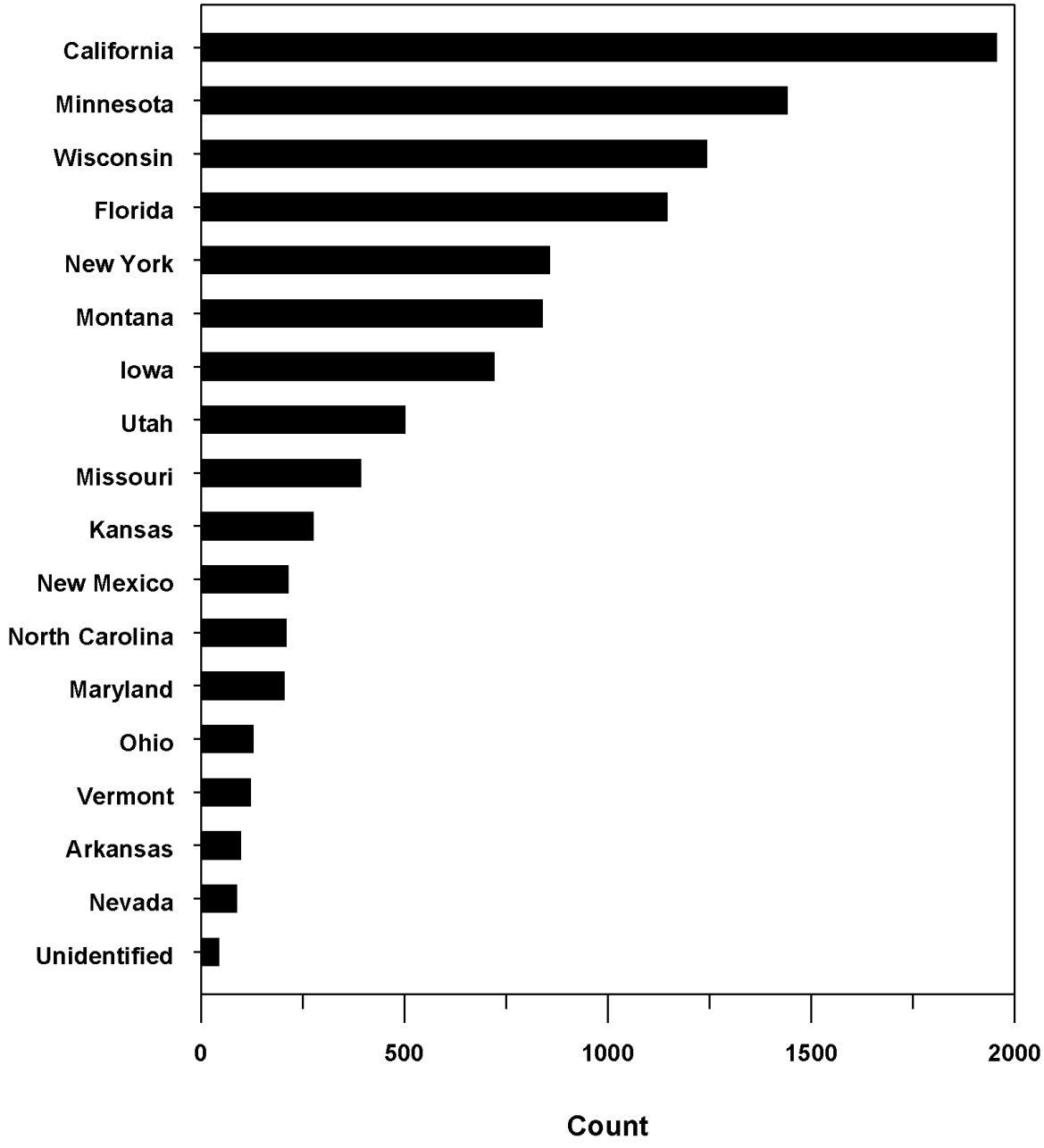

Fig. H-1. Number of cylinders inspected per state (10,456 in total).

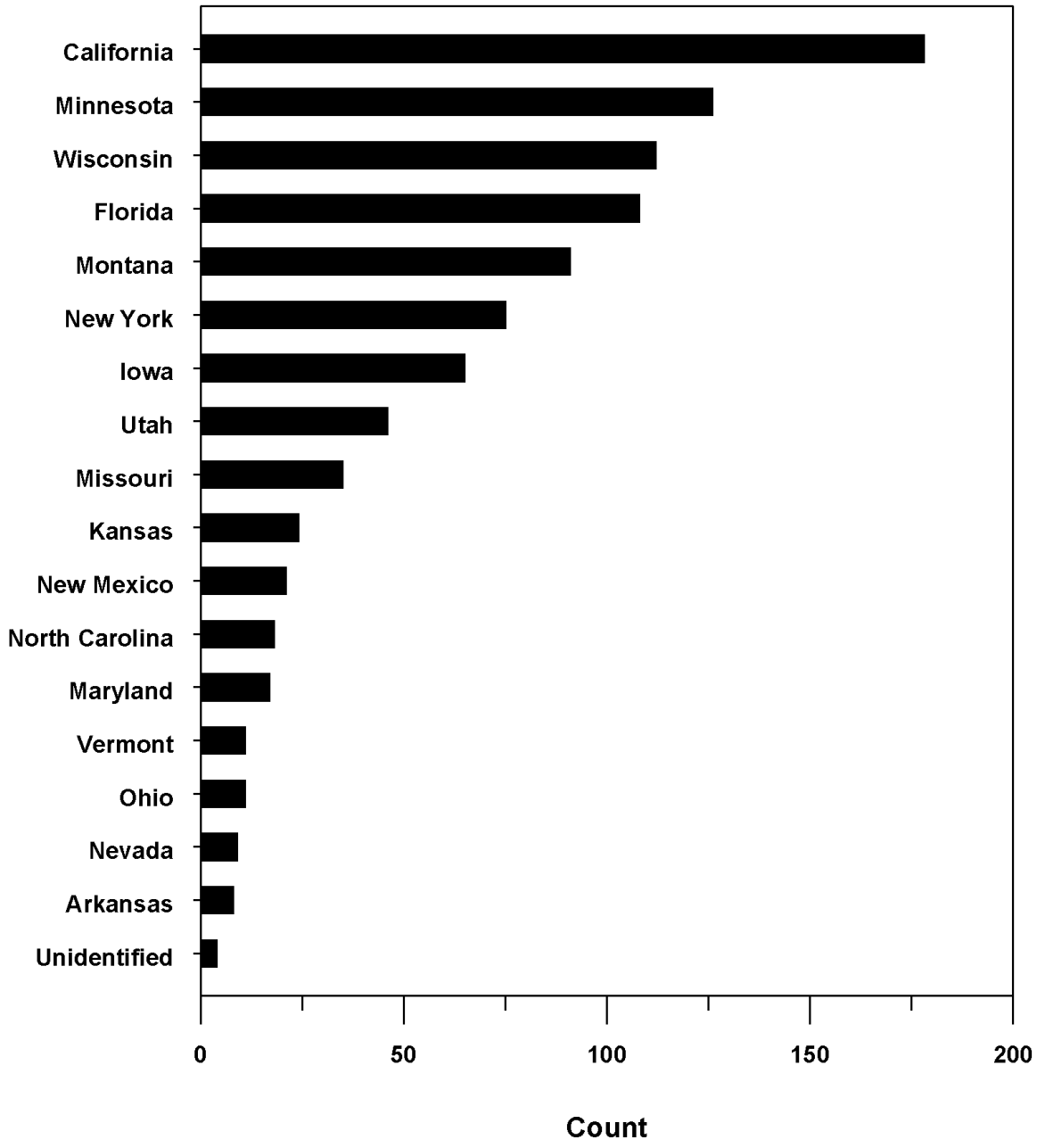

Fig. H-2. Number of exchange locations (i.e. lots) inspected per state (959 in total).

Appendix I. Cylinders Tested per State for Determining the Amount of Product Left Behind on Returned Cylinders for Phase III: Exchange Locations

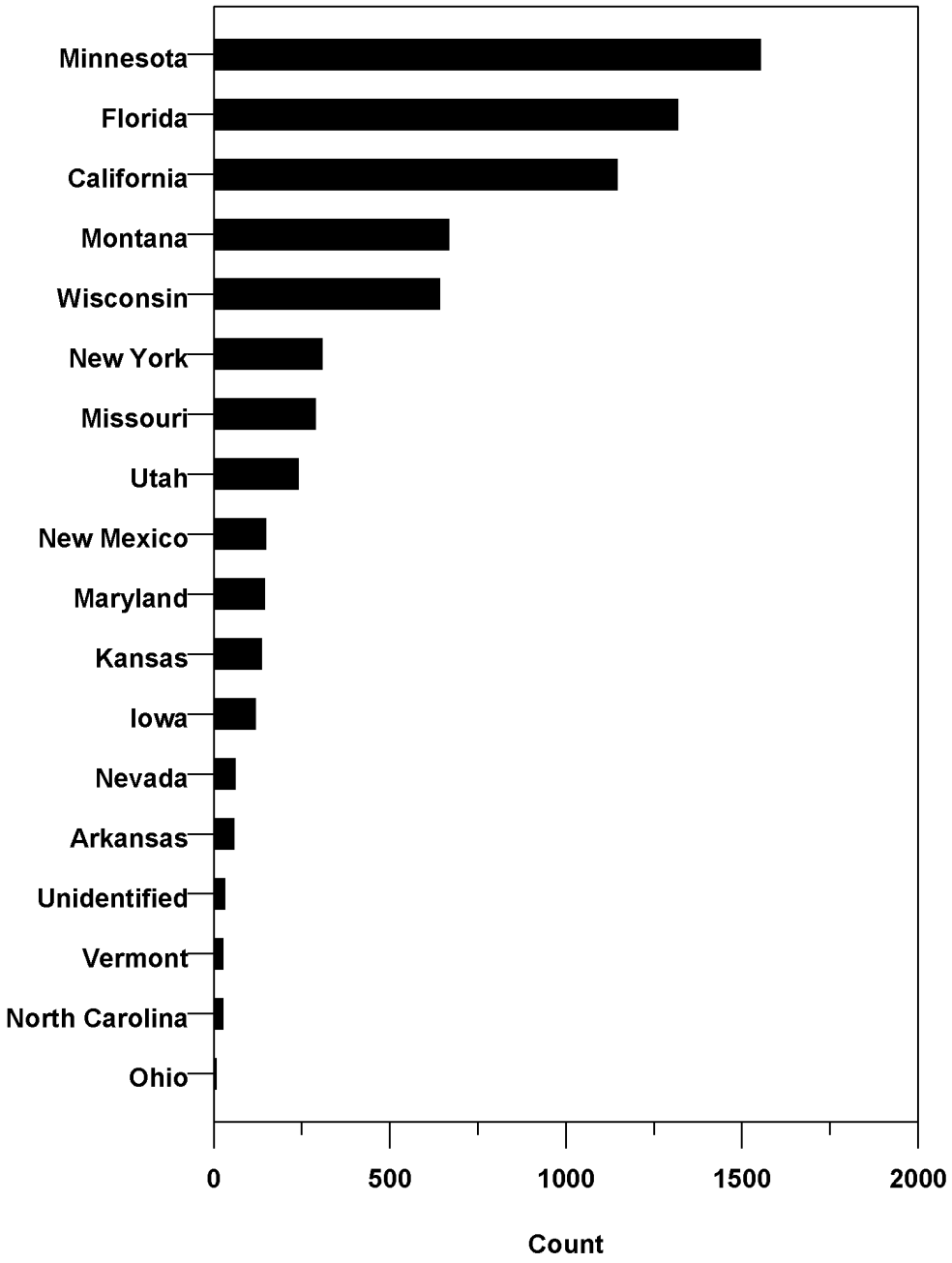

Fig. I-1. Number of cylinders inspected per state (6,896 in total).

Appendix J. Glossary of Acronyms

CFR
Code of Federal Regulations

CGA
Compressed Gas Association

DOT
U.S. Department of Transportation

EVAC
Evacuated cylinder

EW
Empty Weight

GW
Gross Weight

HB
Handbook (NIST)

LPG
Liquefied Petroleum Gas

MAV
Maximum Allowable Variation

NC
North Carolina

NCWM
National Conference on Weights and Measures

NFPA
National Fire Protection Association

NPGA
National Propane Gas Association

OH
Ohio

OPD
Overflow Protection Device

OSHA
Occupational Safety and Health Administration

OWM
Office of Weights and Measures (NIST)

PERC
Propane Education and Research Council

QA/QC
Quality Assurance and Quality Control

SCF
Sample Correction Factor

SEL
Sample Error Limit

TW
Tare Weight

UME
Unreasonable Minus Error