

Weights and Measures in the United States

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Abstract

What does the weights and measures system in the United States look like, and what impact does it have on commerce? Every state in the United States has its own weights and measures program, and many states have county and city run programs within their own jurisdiction. More importantly, each of these programs has sovereignty within its jurisdiction. There are over 650 independent regulatory jurisdictions in the United States. How then, can laws and regulations be applied uniformly? How can U.S. commerce be assured of accurate measurement and consistent application?

The National Conference on Weights and Measures (NCWM) was created by the National Bureau of Standards (NBS) in 1905 to bring together stakeholders in the weights and measures system in areas such as enforcement, manufacturing, and industry, in order to establish and modify laws governing weights and measures. Once adopted through the NCWM standards development process, the model laws and regulations are published and disseminated by the National Institute of Standards and Technology (NIST), but adopted and enforced by the representative jurisdictions.

The basis for any weights and measures program must start with accurate measurements. In addition to publishing and disseminating model laws and procedures, the Weights and Measures Division (WMD) at NIST provides training and support to state, county and industry metrology laboratories and weights and measures field officials to ensure traceability of measurements in commerce.

This paper discusses the makeup of the weights and measures system in the United States, how numerous separate weights and measures programs are able to provide uniformity, and the impact these entities have on our commerce.

Introduction

Historically, the development of weights and measures in the United States began with the writing of the Constitution. A fundamental role of the Federal Government was “to fix the standards of weights and measures”¹. The Office of Weights and Measures was created in 1836

and was a main component of the original National Bureau of Standards (NBS), formed in 1901 and now called the National Institute of Standards and Technology (NIST). In creating the National Conference on Weights and Measures (NCWM) four years later, NBS began the process of striving for uniformity in weights and measures across the nation that continues today. Through the NCWM, state and local weights and measures officials meet with manufacturers and industry representatives, federal agency representatives, and other stakeholders to set the standards for weights and measures. These standards are adopted into law and enforced by the states, or by regions within the states. The intent of a weights and measures system is to ensure a fair and equitable marketplace for both the consumer and for competing industries. When operating properly, a weights and measures system is invisible to the average person, yet affects almost every aspect of their lives.

The legal metrology system, of which the weights and measures system is a part, encompasses a broad range of measuring devices used in law enforcement, the medical industry and other applications, and is beyond the scope of this discussion. The current paper lays out the various functions of the U.S. weights and measures system and defines the roles and responsibilities of the key players. These include NIST, NCWM, state and local officials, other federal agencies and industry.

NIST

The technical basis for a weights and measures system begins with the national measurement institute, which in the United States is NIST. NIST contributes to the weights and measures system by providing access to traceability, training, education, and accreditation services, by participating in the development of national and international documentary standards and by publishing the model laws and regulations that are adopted into state law.

Traceability is a fundamental part of all legal metrology systems, and is achieved through a combination of steps. NIST laboratories provide calibration services to state laboratories and to industry, who continue the unbroken chain of calibration that is part of the traceability requirement. The state laboratory program at NIST Weights and Measures Division (WMD) publishes calibration procedures (NIST Handbook 145/NIST IR 6969)[15] and management system requirements (NIST Handbook 143)[14] for state laboratories. WMD also provides training to state metrologists on these procedures and assesses state laboratories to the published quality system requirements. Finally, WMD oversees a proficiency testing program to assure the quality of the results of calibrations performed by the state laboratories. State laboratories are encouraged to seek accreditation to ISO/IEC 17025[1], and are subsidized by NIST/WMD if they are accredited through the National Voluntary Laboratory Accreditation Program (NVLAP), which is part of the Standards Services Division of NIST. Currently, there are 16 NVLAP accredited state laboratories, and 45 state labs that have been assessed according to Handbook 143[14] and found to be compliant.

Defining the requirements used in laws and regulations in each jurisdiction is another essential component in any weights and measures system. In the United States, the model laws and regulations are developed through a partnership between NIST and NCWM. NIST participates in the development of, publishes, and disseminates a number of model laws and regulations

agreed to by the NCWM and used in weights and measures programs across the country. Staff of WMD provide technical expertise on a range of subjects from load cells to grain moisture meters. NIST Handbook 44[2] is adopted by all 50 states and is the standard for specifications and tolerances of commercial weighing and measuring devices. Some states incorporate exceptions to Handbook 44 into their law, or they use a previous version of the Handbook. It is important to the states that they retain sovereignty over weights and measures law. NIST Handbook 130[12] is the model for uniform laws and regulations for legal metrology and engine fuel quality. NIST Handbook 133[13] is the guideline that describes the methods for checking the net contents of packaged goods. A series of NIST Handbooks (105-1 through 105-8)[3-10] provide standard requirements for the design of commercial test equipment, from mass standards and volume measures to thermometers. NIST Handbook 112[11] documents the procedures used in testing commercial devices in the field. Together, these documents provide the framework for weights and measures laws used throughout the United States.

Once the proper tools are in place, officials must be trained to use them in order to be effective. In addition to the metrology laboratory training mentioned previously, NIST provides training at all levels in the weights and measures system. WMD conducts training of field staff both on-site and around the country. Input is sought before the training schedule for the coming year is developed. One way NIST/WMD collects input is by conducting periodic Administrators Workshops, where the chief Weights and Measures Administrator from every state is invited to participate, with typical participation of 15 to 20 Administrators. These workshops are useful in determining what training is needed at the state level. Training may include all types of device testing, package inspection methods, and contents of published Handbooks, as well as unique topics such as understanding audit trails. Because it was identified as a need in the national weights and measures system, WMD recently developed and conducted training on balance and scale uncertainties. NIST also conducts weights and measures tutorials at various conferences throughout the year. WMD responds to hundreds of questions directed at NIST about weights and measures each year. The metric program, which is a part of WMD, conducts outreach to educate the public about the metric system and legal metrology issues in general. In addition to World Metrology Day, the weights and measures community in the United States celebrates Weights and Measures Week every March.

In order to meet the needs of U.S. industry and commerce in the global marketplace, it is especially important that the United States interact with the international legal metrology community and contribute to the development of international legal metrology standards. NIST/WMD represents the U.S., on behalf of the U.S. Department of State, in an international treaty organization known as the International Organization of Legal Metrology (OIML). OIML's primary function is to harmonize legal metrology standards and practices worldwide in order to foster confidence in global trade and commerce. OIML covers areas of legal metrology that include weights and measures, but also areas of human health and safety, and environmental protection and monitoring. WMD staff assemble National Working Groups (NWGs) of U.S. stakeholders to provide consensus U.S. positions on the development, review and revision of these international standards. WMD staff also coordinate U.S. representation in OIML, including serving as Secretariat of several OIML Technical Committees and Subcommittees, and work closely with the NCWM in this regard.

A number of other federal agencies play a significant role in the legal metrology system for the United States. These include the Food and Drug Administration, the Federal Trade Commission, the Environmental Protection Agency, the Treasury Department and the Department of Agriculture. Many of these agencies participate in the standards development process and work closely with WMD and other stakeholders. There are specific cases of federal pre-eminence over state law, where states must conform and enforce the same laws as enacted at the federal level. For the most part, these are packaging and labeling laws designed to facilitate trade across state borders.

NCWM

The National Conference on Weights and Measures was created in 1905 to bring together stakeholders in the weights and measures system in areas such as enforcement, manufacturing and industry, in order to establish and modify laws governing weights and measures. Changes to the weights and measures handbooks are proposed, debated and adopted within the NCWM. NCWM also manages the National Type Evaluation Program (NTEP), ensuring that the design of commercial devices is appropriate for their intended use. By providing a forum for numerous stakeholders to communicate and interact, NCWM contributes to the overall uniformity of both law and enforcement in the United States weights and measures system.

Four independent regional weights and measures associations, the Northeast, Central, Western and Southern Weights and Measures Associations, exist in addition to NCWM. Members from these regions meet, conduct business and vote on proposals that are forwarded on to the NCWM for consideration. As in the case of the NCWM, both weights and measures officials and industry take part in the regional associations.

NCWM membership consists of state and local weights and measures officials, industry representatives and representatives from various federal agencies. This unique combination of stakeholders provides a balanced forum for discussion and debate of weights and measures issues.

Handbooks 44, 130 and 133 form the backbone by which weights and measures law is promulgated across the United States. Changes to these standards are made through a process that begins with a written proposal, usually submitted to a regional association. Each association and the NCWM have committees whose responsibility is to review proposals and make recommendations to the association or to NCWM. In some cases, a proposal may be referred to a technical working group for further development. Both the working groups and the committees are made up of members representing industry and government. The NCWM holds an Interim Meeting where items are classified as informational, under development, withdrawn or ready for voting. At its annual conference, the NCWM conducts a voting process and formally adopts changes to the Handbooks. The changes are incorporated and new editions are published by NIST and then adopted by states and localities.

The voting process consists of a series of open hearings, where all proposals are discussed and debated by all NCWM members, followed by a voting session. During the voting session, the membership is divided into three bodies. One individual from each state or territory makes up

the House of State Representatives, additional weights and measures officials make up the House of Delegates, and other industry members and federal officials form the House of General Membership. During a vote to make technical changes to a Handbook, members from the House of General Membership are not allowed to vote. It is also important to note that only NCWM members are allowed to vote; thus a state representative in attendance may not vote if not registered as a member of NCWM. While industry is welcome to attend NCWM meetings and to voice their opinions during open hearings, industry members are considered associate members and are not allowed a vote on technical issues during the voting session.

The NCWM also manages the National Type Evaluation Program (NTEP), which evaluates weighing and measuring devices intended for commercial use, issuing certificates of conformance to those meeting NTEP requirements. Many states require commercial devices to have an NTEP certificate as part of overall compliance with their weights and measures law. Manufacturers of commercial devices submit new products to NTEP laboratories in the United States for testing where they are more stringently evaluated for full compliance to NIST HB 44 than is possible in field testing conditions.

The NCWM, along with the regional weights and measures associations, facilitates communication between local jurisdictions, industry, other federal agencies and NIST. With the number and variety of legal metrology programs in existence around the United States, it is important for there to be close interaction and continuous communication between all parties. The result of communication among the states and regions is increased uniformity in weights and measures across the country. This interaction also provides opportunities for joint investigations and surveys. A survey may be conducted periodically to determine the rate of compliance in a specific area or with a specific commodity. A joint investigation may be initiated when there is an indication of widespread non-compliance with a specific device or product.

State and Local Jurisdictions

States are responsible for adopting and enforcing weights and measures laws and maintaining a weights and measures program for their jurisdiction. The size and scope of each state's weights and measures program varies widely for a variety of reasons. A number of states have additional weights and measures jurisdictions in the cities and/or counties within them. States with larger populations, unique products or whose commerce is largely agricultural all have different needs and have designed programs to fit those needs. A significant portion of a state or local weights and measures official's time is spent testing and inspecting commercial devices that are used in determining cost per unit of measure, such as scales or meters. Most states require that a device be tested prior to its use in commercial transactions, and then periodically retested to assure continued proper function. Devices that fail inspection are normally removed from service until repair or replacement is completed, but officials may take additional enforcement action as necessary and as allowed by law.

In order for an enforcement action to be upheld in a court of law, proof of measurement traceability is required. The state weights and measures official assures traceability by first using traceable field standards when testing devices. In addition to using proper equipment, the official must follow documented procedures for testing devices, and must be able to provide

evidence that he has been properly trained both on the use of the equipment and the procedure. States maintain metrology laboratories for, at a minimum, calibrating field equipment used in legal metrology. This equipment may be owned by the state or by a private company that installs, repairs or owns commercial devices.

States are ultimately responsible for the training of the weights and measures officials within their state. This includes state field staff, local (city or county) officials, and may include privately employed agents that may be licensed to test, inspect, install or repair commercial devices. Additionally, some states may provide training to device owners in order to help them understand and comply with the law. Training may be done in a number of ways. For state employees, initial training is conducted upon hire, followed by periodic supplemental training at group meetings. The initial training period may range from three to six months. States conduct training courses for city and county officials and may bring in a NIST/WMD trainer for some types of instruction. Some jurisdictions require officials to pass a test or a series of tests before being allowed to inspect and test commercial devices. Similarly, registered agents may also be required to pass a test before being granted authority to install or repair a device and then place it into service.

In most states, state law provides for some type of enforcement of weights and measures law; however, authority varies by state so that there is not a single procedure for how weights and measures law is enforced. Some states have authority to write warnings, citations, or issue fines. Others may prosecute violations in court. In states where private individuals or companies are licensed to act on behalf of the government, the state may be responsible for the oversight of the licensees' actions. State and local jurisdictions also respond to consumer complaints, and take action as warranted.

In addition to enforcement, state and local officials participate in NCWM through membership, by serving on committees or the board, and by attending the interim and annual meetings. Because state and local weights and measures officials can identify needs that may be unique to their region or an industry within their region, they often provide valuable input to the NCWM standards development process. For this reason, the majority of the members of NCWM and regional association working groups and technical committees are state and local officials. Some states have their own weights and measures associations where training is conducted and potential changes to weights and measures law is discussed. State and local weights and measures officials also participate in other standards development forums, such as the American Society for Testing and Materials (ASTM) and OIML.

Licensed Agents

In order to assure fair competition, many states allow private agents to place a commercial device into service after installing or repairing it. Most private agents work for scale or meter repair companies, but some operate independently or work for manufacturers and others in industry. These agents are normally registered or licensed with the state and must uphold the same laws that the state or county officials follow. Because there are many more private agents operating within a state than there are state or county weights and measures officials, they can be more responsive than a government official. Thus, a business requiring a new commercial

device will be able to use the device to conduct business much more quickly if a private agent is allowed to place the device in service as opposed to waiting for the state official to test and inspect it. States that license private agents will normally conduct a follow-up inspection within 30 days to make sure that the device was installed properly and is operating correctly.

Agents who are licensed to place commercial devices in service must use calibrated test equipment, similar to the equipment used by the legal metrology officials in order to assure traceability of measurement in commerce. This equipment must meet specifications contained in the NIST Handbook 105 series. It is important that the agent using the test equipment be knowledgeable regarding its proper design, care and use. The agent must also know and understand Handbook 44 and the laws specific to the state where doing business. This is especially important for agents working in multiple states. Knowledgeable and well-trained agents contribute to the legal metrology system by educating device owners in addition to assuring that accurate measurements are made. These agents are an important link between commerce and government because they interact with both. Agents may introduce new technology to the state legal metrology official or ask for advice on interpreting the law.

Industry

Manufacturers of commercial devices and industries that package goods sold by measure or count are both links in the traceability chain that begins with the International System of Units (SI) and ends with the consumer. Industry is dependent on a robust and well-functioning legal metrology system and, as a result, is often involved in the standards development process. It is critical to have adequate industry representation during the standards adoption process. Industry depends on the creation and implementation of weights and measures laws to assure a level playing field for fair competition. Harmonization of standards facilitates commerce and international trade, thereby benefiting industry and consumers.

Consumers

The ultimate goal of a legal metrology program is to assure accurate measurements between buyer and seller, and to facilitate transactions between parties. The consumer can be many things, from the purchaser of retail products, to the patient at the hospital, to the company buying electricity. Consumers expect protection from unfair practices in commerce. This means assured accuracy of measurements in commercial transactions, but it also means the ability to make value comparisons. For example, if someone tried to sell gasoline by the kilogram, customers would not be able to compare the value of their purchase to that of the competitor selling by the gallon or liter. It is the role of a legal metrology system to define how a commodity may be sold, so that value comparisons may be made on the basis of common units.

Enforcement and Compliance

Because enforcement of weights and measures law takes place at the state and local level, there is not a consistent method of enforcement. Compliance with weights and measures law is also highly variable. It stands to reason that a state that has an effective legal metrology system in

place will have greater compliance with weights and measures law. So what are the components of an effective weights and measures system? First, the system must provide traceability of measurement from SI to consumer to assure consistent application. Second, proper documentary standards, laws and regulations must be in place for the official to use. Third, there must be adequate training of legal metrology officials, and proper equipment must be available. Perhaps the most difficult step in implementing an effective program is careful planning to identify potential problems and then allocating resources to address them. Finally, there must be a thoughtful approach to interaction with the regulated customer. A combination of education and public outreach with enforcement and consequence of violation is necessary. The legal metrology official must develop a relationship with the regulated customer in order to achieve the optimal program.

Compliance rates with weights and measures laws are not available for all states and all types of regulated transactions, but an example of successful compliance is in retail motor fuel dispensers (gas pumps). In 2002, the overall U.S. compliance rate for gas pumps was greater than 93 %, where the required accuracy was less than a 0.5 % error². This equates to an error of no more than one cup or 250 ml for a typical purchase of 12 gallons or 45 liters of gasoline. The failures may have been the result of an inaccurate meter, or from a number of other causes for rejection, such as improper labeling, a leaking hose, or a malfunctioning price display. The table below (Table 1) provides typical compliance data from a state program for a variety of device types. Keep in mind that a device may be rejected for reasons other than accuracy. In the case of gas pumps, approximately half of the rejections are due to tolerance failure.

Table 1. Compliance data from one state (2002).

Inspection Class	Rejection Rate
Retail Scales	8 %
Industrial Scales	16 %
Large Scales	24 %
Gas Pumps	9 %
High Volume Pumps	23 %
Terminal Meters	2 %
LP Meters	19 %
Package Inspection	14 %

Impact on Commerce

It is estimated that legal metrology affects over \$6 trillion in commerce. This is not surprising when you look at the scope of impact. From transportation and the petroleum industry, to agriculture, to manufacturing and retail sales, legal metrology touches every facet of the commercial marketplace.

As an example, let's examine the petroleum industry. The chain of custody goes something like this: Crude oil is processed by the refiner, transported by the pipeline, distributed by the terminal, stored and further distributed by the bulk plant and sold at the retail station. The retail sale may also occur at the terminal, the bulk plant or even at an airport or marina. Digging deeper, there are variable octane and cetane ratings for gasoline and fuel oils on which price may

be based. Petroleum products must also comply with specifications published in ASTM standards. To further complicate the issue, alternative fuels may be blended with petroleum products, changing the specifications. The legal metrology system must address each component and enforce laws relevant to each level of this sub-system. In 2002, retail petroleum sales at gas stations only were \$250 billion in the United States.³ Table 2 below provides a breakdown of petroleum sales in 2002.

Table 2. U.S. petroleum product sales 2002⁴.

Commodity	Barrels sold (millions)	Sales (millions)
Gasoline	3 230	\$188 025
Distillate Fuel (Diesel)	1 378	\$76 338
Aviation Fuel	596	\$33 900

A similar breakdown could be done for other sub-systems within the commercial marketplace. In agriculture, from grain and produce to livestock and aquaculture, there are numerous scenarios for weights and measures to affect commerce. The transportation industry frequently charges by weight for a load, whether shipping by truck, barge, air or railway. Some of the other industries that are notably impacted by the effectiveness of the legal metrology system are the mining industry and forestry. Look at Table 3⁵ to see some commodity sales data that demonstrates the impact weights and measures law can conceivably have on commerce.

Table 3. Retail and wholesale sales data 2002.

Commodity	Sales (millions)
Grain	\$85 593
Livestock	\$7 095
Sand, Gravel, Stone	\$3 146
Trucking	\$164 219
Building Materials	\$215 641
Garden Supplies/Nursery	\$26 402
LP Gas	\$9 286

A specific example of the impact that weights and measures has on the marketplace is the results of the market studies of packaged milk in 1997 and 1998⁶. In 1997, over \$8 billion of milk was sold in the United States. The results in the first study found a 46 % failure rate due to shortage of product. The average shortage was 0.76 %, which amounted to a \$28 million shortage. Once the problem was identified and effort was made to correct it, a follow-up study was conducted. In 1998, the data showed a decline to a 19 % failure rate due to shortage of product, with an average shortage of 0.71 %. This amounted to a savings of \$17 million to consumers and competitors. This is only one of thousands of packaged products that are sold by measure, but it demonstrates in tangible dollars the amount of money directly affected by accuracy of measure.

Summary

In the United States, only \$0.25 per person is spent on weights and measures annually, and yet it has been estimated that over 50 % of the Gross Domestic Product (GDP is \$12.7 trillion in 2006⁷) is impacted by weights and measures regulations on transactions. To industry, a robust weights and measures system means a fair market and reduced production costs. To the average consumer, it means getting what he paid for in a transaction. NIST and NCWM work hard to ensure that the laws, regulations, procedures and knowledge are in place to provide equity in commerce for both buyer and seller.

Footnotes

1. United States Constitution, Article I, Section 8.
2. RTI Survey Data, 2004.
3. United States Census Bureau – 2002 Economic Census, Retail Trade by sub-sector.
4. United States Department of Energy, Energy Information Administration, Annual Energy Review, Table 5.11.
5. U.S. Census Bureau, 2002 Economic Census, Retail Trade by sub-sector, Wholesale Trade by sub-sector, Transportation and Warehousing by sub-sector data.
6. Report by the Staff of the Federal Trade Commission, Food and Nutrition Service of the U.S. Department of Agriculture, and Office of Weights and Measures of the National Institute of Standards and Technology, in Coordination with the Office of Food Labeling of the U.S. Food and Drug Administration, July 17, 1997 and August 13, 1998.
7. Bureau of Economic Analysis, News Release: Gross Domestic Product and Corporate Profits, March 30, 2006.

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8. *NIST Handbook 105-7: Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures, 7. Specifications and Tolerances for Dynamic Small Volume Provers*, United States Department of Commerce, Technology Administration, National Institute of Standards and Technology, 1997.

9. *NIST Handbook 105-8: Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures, 8. Specifications and Tolerances for Field Standard Weight Carts*, United States Department of Commerce, Technology Administration, National Institute of Standards and Technology, 2003.
10. *NIST Handbook 112 – 2002 Edition: Examination Procedure Outlines for Commercial Weighing and Measuring Devices – A Manual for Weights and Measures Officials*, United States Department of Commerce, Technology Administration, National Institute of Standards and Technology, 2002.
11. *NIST Handbook 130 – 2006 Edition: Uniform Laws and Regulations in the Areas of Legal Metrology and Engine Fuel Quality*, United States Department of Commerce, Technology Administration, National Institute of Standards and Technology, 2006.
12. *NIST Handbook 133 – Fourth Edition: Checking the Net Contents of Packaged Goods*, United States Department of Commerce, Technology Administration, National Institute of Standards and Technology, 2005.
13. *NIST Handbook 143: State Weights and Measures Laboratories Program Handbook*, United States Department of Commerce, Technology Administration, National Institute of Standards and Technology, 2003.
14. *NIST Handbook 145/NISTIR 6969: Selected Laboratory and Measurement Practices, and Procedures to Support Basic Mass Calibrations*, United States Department of Commerce, Technology Administration, National Institute of Standards and Technology, 2003.