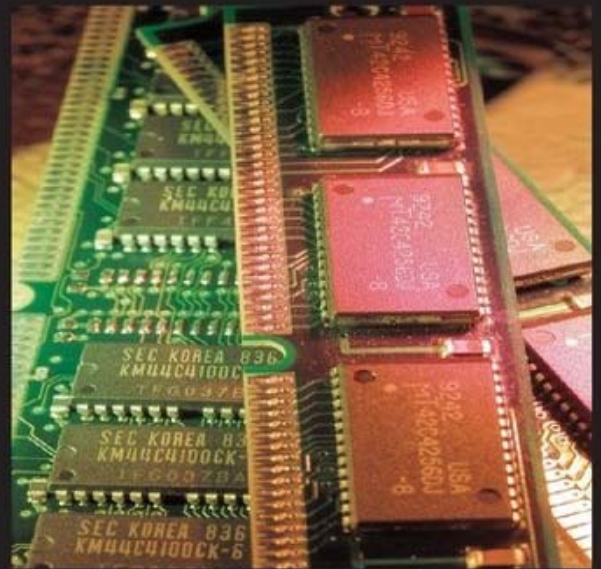


PRIMER on ENGINEERING STANDARDS



**Maan H. Jawad
Owen R. Greulich**

PRIMER
ON
*Engineering
Standards*

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To those who seek excellence through their knowledge of standards

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PREFACE

Standards play an important role in the engineering world. They supplement the design process by guiding the designer or user to ensure consistent products with safe and reliable operation. Understanding and complying with pertinent standards helps to ensure successful design, fabrication, and operation of a product.

This book introduces the concept of standards and their impact and value. Chapter 1 gives a brief introduction to the general concepts of procedures, rules, standards, regulations, codes, and jurisdictional requirements. While these entities often overlap in subject coverage, the engineer needs to be cognizant of their existence, intent, and how their interrelationships affect the engineering at hand.

Chapter 2 discusses Engineering Standards developed by the consensus process. Limited consensus standards are presented in Chapter 3, and jurisdictional standards are presented in Chapter 4.

Development of Standards is briefly discussed in Chapter 5, and Chapter 6 discusses types of standards. In Chapter 7 the need and processes for exemptions from existing standards are explained. Chapter 8 identifies characteristics of a good standard.

There are tens, perhaps hundreds of thousands of engineering standards worldwide, covering every imaginable subject related to engineering. Listing them all would be a monumental undertaking and this book, by necessity, covers only a small portion of them. The appendices at the end of this book provide assistance in identifying a few of these engineering standards, who developed and maintains them, and contact information to help the reader obtain further information.

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1. Introduction



(Courtesy of XKCD, www.xkcd.com)

Standards, including procedures, rules, codes, regulations, and jurisdictional requirements, play an important role in the engineering world. They furnish a means of ensuring consistent designs, quality, and operating characteristics with adequate safety factors, safe operation of components, and well-defined configurations. Their development, applications, limitations, and benefits are detailed in this book to give the user, specifier, and standard writer a proper perspective of their importance, usefulness, and limitations, to promote their effective use, and to improve the quality of future standards.

This book does not attempt to address legal, commercial, or other non-engineering aspects of standards.

Rules, procedures, and standards can be developed by a single individual with authority over an organization or operation, by a sub-group of an organization, by the organization as a whole, or by other groups with a common interest.

The reader will find that common usage of terminology related to standards is inconsistent in the literature. Accordingly, the following definitions are provided and will be used in this book:

Rule: A single specific requirement that must be met. Many types of requirements exist, such as requirements to perform actions, for how to perform actions, for results that must be achieved, for specific properties or characteristics that must be attained, and for dimensions that must be met.

Procedure: A set of rules regarding how a task or function is performed. Procedures are used to ensure consistency of results and to promote efficiency.

Standard: A set of rules and/or procedures recognized as authoritative in a particular area of interest. One definition of standards given by the American Society of Mechanical Engineers (ASME) is

“A set of technical definitions, instructions, rules, guidelines, or characteristics set forth to provide consistent and comparable results, including:

- Items manufactured uniformly, providing for interchangeability
- Tests and analyses conducted reliably, minimizing the uncertainty of the results
- Facilities designed and constructed for safe operation”

It is of interest to note that by custom, some standards are called codes.

The effectiveness of standards in conducting business is best explained by The American Society for Testing and Materials (ASTM) in a 1991 report

“Standards are the vehicle of communication for producers and users. They serve as a common language, defining quality and establishing safety criteria. Costs are lower if procedures are standardized; training is also simplified.”

1.1 Procedures and rules

Procedures and rules are usually developed within an organization to establish operating methods that will lead to consistent desired results. They include such items as drawing and calculation formats, dimensional standards, checking sequences, and hierarchical progression of a task within the organization. The applications of procedures and rules form the operating norm of an organization, and they differ from one organization to another. Hence, the procedures and rules used for the design and manufacturing of the same product at two companies may differ substantially even though the end product is the same. One company manufacturing a light switch, for example, might bring in large quantities of component parts from suppliers and depend on a high level of automation and process control to ensure a consistent product. A competitor may choose to manufacture all parts in-house, use hand assembly, and control product quality through a rigorous inspection process. The final products may be practically indistinguishable in spite of procedures that have little in common.

Procedures and rules, by their general nature, are limited in scope to an individual task or component within an organization such as a how to manufacture and assemble a gear box, or a methodology for project progression within the organization. A separate procedure then details the next step, whether packaging the gearbox for shipping or assembling it into an

automobile. Procedures can also be updated or revised frequently to fit the changing requirements of the organization.

1.2 Standards

1.2.1 History and purpose of standards

Any discussion of the purpose of standards is nearly impossible without a concurrent look at their history. The nature of society, the natural human resistance to accept constraints, the thought and effort needed to develop standards, and general inertia have dictated that they not be produced and imposed without a reason.

As society has become more complex, the need for standards has occurred more frequently, and the increasing sophistication of society has been mirrored by an increasing sophistication in the standards developed.

While there is sometimes resistance to their development and implementation, the term “Voluntary Consensus Standard” refers to the benefits that standards provide to business and to society in general, and it is applicable to a vast number of standards developed for a wide range of reasons and applications. People, companies, and other organizations now generally recognize that standards can have a favorable effect on their lives, the quality of their work, and their business opportunities. Companies and individuals are therefore willing to apply resources, to give up a certain amount of freedom, to admit that they may function better and be more successful operating as a part of a larger whole than with complete independence, and to share a certain amount of what may be proprietary knowledge. These things are given up in the interest of a safer home or society, efficiency in design, improved business opportunities, a certain amount legal protection in case of product failure, and other benefits.

While standards can be categorized in a number of ways, for purposes of this chapter the following categorization will be considered on the basis of benefits: Safety and reliability, cost reduction, increased flexibility, promotion of business, and generally helping society to function. Most standards provide more than one of these benefits.

1.2.2 A few examples of standards throughout the ages

One of the first known, and very rudimentary, standards, known as the Code of Hammurabi, was developed approximately 4000 years ago, apparently to ensure fairness in the kingdom of Babylonia. In this case, the standard was promulgated by the king and enshrined in laws. Many of the laws included in this document related to crimes, torts, marriage, and general legal obligations. The Code of Hammurabi may be most well known for its “an eye for an eye and a tooth for a tooth” approach to justice, but portions of this document also provide very basic performance standards for construction of buildings and boats. That is, the document specified what must be achieved. Walls must not fall down, and boats must be tight.

It appears that there was a problem with the quality of workmanship in the kingdom of Babylonia, but the solution had no specific criteria for how things were to be constructed. Rather, the standard that was put in place simply required that the construction be good, and if it failed, specified the penalty. This approach to standards provides no guidance as to how the requirements are to be accomplished, simply specifying the required result. A performance standard is in some cases the easiest to write, and it allows the maximum level of flexibility to the implementer, since any means of accomplishing the end is sufficient. This standard promoted a fair and just — if somewhat brutal — society. It should also be noted that this particular standard dealt with very limited aspects of the products, and including in a performance standard all the details that are needed to ensure a successful product can be challenging.

Another step on the way to modern standards came about as a result of a massive fire that burned most of the city of London in 1666. The Rebuilding London Acts, promulgated by the Parliament of England over the following several years, are precursors of current building and safety codes. The specific motivation of these acts was first to ensure safety and stability in society, and they did so by widening streets and by specifying brick construction, so as to prevent recurrence of the disastrous fire.

Compared to the Code of Hammurabi, these Acts are quite prescriptive, specifying street widths, brick construction, thickness of walls (in terms of bricks), story heights and maximum heights of houses, and requirements for roof drainage. The effect of these and other associated requirements was to improve access, provide fire breaks in case another fire got started, and reduce the probability of its spread by replacing what was previously almost entirely wooden construction largely with bricks. Safety was enhanced, and it is to be expected that quality of life may also have been improved.

With the advent of the industrial revolution, other benefits of standards became obvious. As society developed, the ability to produce products in quantity increased, and as machine tools were developed, interchangeability of components became desirable. In the mid 1800s, for example, the British Standard Whitworth thread system was developed to allow for interchangeability of threaded parts.

Throughout the 1800s, there were many boiler explosions [1]. While mourned, these seemed to have been somewhat accepted as a cost of having boilers, which were providing benefits to society in the forms of more efficient transportation, working efficiency, and heating. The explosion of the boiler in a shoe factory in Brockton, MA, in 1905, which resulted in close to 60 deaths, and another shoe factory boiler explosion in Lynn, MA, the following year helped lead to a greater concern with industrial safety. In 1907, the Massachusetts legislature passed the Massachusetts Boiler Law. This was followed by the first ASME Boiler and Pressure Vessel Code (BPVC) in 1914.

The years between then and now have seen a proliferation of standards. These include the further development of the ASME BPVC with sections on various types of pressure vessels, materials, welding, inspection, etc., and piping codes, lifting devices standards, electrical codes, and more. More recent work includes standards in the fields of energy efficiency, electronic components, software development, and assessment of risk, and every time a new technology arises, it seems that standards for its application are not far off.

1.2.3 Classification

Engineering standards are sets of rules and procedures developed, documented, approved, and configuration managed to assure the adequacy of a given product, methodology, or operation. Standards are normally developed in committees by people who have experience in a particular field of endeavor and who have an interest in the outcome that the standard is intended to ensure. Generally, standards fit into one of the following three categories:

1. Limited consensus
2. General consensus
3. Governmental action

1.2.4 Limited consensus standards

Limited consensus standards, by their nature, are developed by experts in a given organization and then made available to the organization for their guidance. Prime examples are some internal company standards for work hardened, heavy wall, stainless steel tubing for ultra-high pressure applications, and a number of company standards for compression fittings.

Trade groups such as the Expansion Joint Manufacturers' Association (EJMA) and the Tubular Exchanger Manufacturers' Association (TEMA) have developed standards specific to their lines of work. While keeping a greater level of control than would be allowed them if their standards were subject to the American National Standards Institute (ANSI) process and requirements, these organizations reap many of the same benefits that they would by following that more public process.

1.2.5 General consensus standards

There is a great difference between the procedures involved in writing limited consensus and general consensus standards. General consensus standards are developed by experts to serve the need of a given industry with substantial input from other interested parties, and potentially from the public. An example of such a standard is the ASME's BPVC. The BPVC contains numerous standards (referred to in the BPVC as sections, divisions, and parts) as will be explained later. The development of each of

these standards follows a unique process by which experts from differing interest groups (designers, fabricators, users, insurers of pressure vessels, and perhaps others) collaborate in writing the rules in order to arrive through a balanced consensus process at a product that is not dominated by any one particular interest group. The resulting standard becomes acceptable to a wide range of interested parties within the industry since all entities were involved in developing it. These standards have been so successful and have garnered such a high level of respect that they are often cited in laws and regulations (a part of governmental standards, discussed below).

Typically, in the United States, the organizations developing such standards follow a process certified by the American National Standards Institute and include a designation of such in their name, identifying number, or on their cover or title page. International standards typically follow a similar process. Because of the integrity of the process and the quality of the resulting product, the standards from many United States standards developers are commonly accepted, or even demanded, overseas, and many of the international standards are likewise accepted or required in the United States, both by industry and by jurisdictions.

1.2.6 Governmental standards

Both jurisdictional and non-jurisdictional standards are produced by a wide range of governmental organizations. Jurisdictional standards are those promulgated by governmental agencies to implement laws, ordinances, and other legal documents, and carrying with them legal enforceability by fines, injunctions, imprisonment, or other sanctions. Non-jurisdictional governmental standards are developed by governmental entities for their own use, whether for internal purposes or for contracted or other outside work.

1.2.6.1 *Jurisdictional standards*

Jurisdictional standards are normally produced by the enforcing jurisdiction, which has legal authority for their enforcement. Jurisdictions include the United States (Federal) Government, States, cities, and municipalities, and their defined sub-authorities such as federal agencies, building departments, and districts, with the authority to enforce the law, regulation or other standard. Standards such as those published by the United States Occupational Safety and Health Administration (OSHA) are intended to assure safety in the workplace by providing generally prescriptive requirements for the design and operation of various pieces of equipment and products within a wide range of occupations. Many standards published by local jurisdictions are intended to do the same.

1.2.6.2 *Non-jurisdictional governmental standards*

These standards are typically produced by governmental entities to promote safe, predictable, and efficient performance of their work. Some of these

will be implementing standards for jurisdictional standards. An example of this type of standard would be an internal standard of a large governmental agency providing requirements enforced internally and used to ensure compliance with a jurisdictional standard enforced by another agency such as the Department of Transportation. It might detail the design process or other specific requirements related to procurement of pressure vessels to be used by the National Science Foundation on research aircraft. Its application could be either internal or through their application on an external procurement.

Another category of non-jurisdictional governmental standards might be used within a National Aeronautics and Space Administration (NASA) Center to ensure reliable and consistent designs for instrumentation on spacecraft. Such a standard could define the design flow, component ranges, and reliability requirements needed for a successful mission. It helps with the implementation of the mission, but is not an implementation of any other governmental mandate such as a regulation from OSHA, the Department of Transportation (DOT), the Department of Energy (DOE), or the Environmental Protection Agency (EPA).

1.3 Applicability of standards

Standards form the backbone for many engineering processes by providing requirements and guidelines of:

1. Practical limits for operating conditions to improve safety and reliability
2. Permissible materials of construction, performance criteria, and pertinent data
3. Safe design rules
4. Construction details
5. Available methodologies for inspection and testing
6. Safe operating parameters
7. Process control
8. Practical limits for operating conditions to improve safety and reliability

Standards take theoretical material and make modifications to permit its application in a practical way. Theoretical equations for a variety of engineering applications are found in textbooks. An example is the equation for stress in a thin cylindrical shell ($R/T > 10$) given by

$$S = \frac{PR}{T} \quad (1)$$

where S is stress, P is internal pressure, R is inside radius, and T is thickness.

Another example is the elastic buckling of a column given by the equation

$$S_c = \frac{\pi^2 E}{\left(\frac{L}{r}\right)^2} \quad (2)$$

where S_c is critical compressive buckling stress, E is modulus of elasticity, L is the effective length, and r is the radius of gyration.

While representing a classical analysis and theoretically correct, both of these equations have limitations that could lead to unsafe designs if not used properly. Accordingly, standards have been written to promote the effective application of engineering principles to everyday life, establishing limits and modifying theoretical equations in order to aid engineers in developing safe designs.

Thus, the ASME Boiler and Pressure Vessel Code [2] modifies Eq. (1) to the following:

$$t = \frac{PR}{SE - 0.6P} \quad (3)$$

In this equation, t is the required minimum wall thickness, and P is pressure. R is the inside radius, and is adjusted by the second term in the denominator to approximate the thick walled cylinder equation. S includes a design factor (currently 3.5 in Section VIII, Division 1 of the BPVC) used to account for a reasonable design life, unknowns such as a certain amount of out-of-roundness (limited by the Code to 1%), residual stresses, possible local material variability below the specified material properties (from another part of the Code), allowance for reduced material properties at operating temperatures, and other aspects of final construction. Finally, the joint efficiency E provides an additional factor based on the level of nondestructive evaluation performed on welds, and allowing for a certain amount of weld defects.

Similarly, the structural handbook from the American Institute of Steel Construction (AISC) [3] reformats Eq. (2) in order to prevent S_c from getting higher than the yield stress of the material. This allows for a certain amount of material variation, lack of straightness of the column and other variation in form, and actual installation characteristics, with, again, a design factor to ensure that the column does not fail just as it reaches its design load. Equation (2) is thus modified to the following format

$$F_a = F_n / 1.8 \quad (4)$$

where

$$F_n = (0.658^{\lambda_c^2})(F_y) \quad \text{when } \lambda_c \leq 1.5$$

$$\begin{aligned}
 F_n &= 0.877 F_y / \lambda_c^2 & \text{when } \lambda_c > 1.5 \\
 \lambda_c^2 &= F_y / F_e \\
 F_e &= \pi^2 E / (L/r)^2
 \end{aligned}$$

and

F_y = yield stress
 E = elastic modulus
 F_a = allowable compressive stress
 L = effective length
 r = radius of gyration

Often one of the most important aspects of an engineering standard is its application of a design factor, variously referred to as “design factor,” “safety factor,” and “ignorance factor.”

1.3.1 Permissible materials of construction, performance criteria, and pertinent data

Engineers have access to thousands of materials of construction varying from metallic such as steel, aluminum, copper, and titanium, to nonmetallic such as concrete, wood, plastic, and composites. Numerous subcategories of these materials are available with their own properties, limitations, and advantages. Steel, for example, has many product forms such as structural steel shapes, rods, plates, forgings, tubes, and castings, and a myriad of alloys designed to perform under different types of loads, over different temperature ranges, and other varying operating conditions.

Engineers rely on national and international material standards to obtain such data as chemistry, tensile and yield strength, and other physical properties in order to properly design components and systems. ASTM standards provide a wealth of material characteristics at room temperature for thousands of metallic and non-metallic materials. In addition, ASME provides material data for several thousand metallic materials at elevated temperatures and requirements for testing for low temperature operations.

1.3.2 Safe design rules

Engineers must often rely on national and international standards for obtaining appropriate material properties and safety factors for their designs. Such standards establish factors of safety based on experience, practical limits, and understanding of material characteristics such as endurance limits, creep, and fatigue crack growth rates. Most engineers do not have the means of establishing such factors on their own. A case in point is the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 allowable stress, referred to in the discussion above. It uses four criteria for establishing the allowable tensile stress. This allowable stress is taken as the

smaller of the values obtained from $2/3$ times the yield stress, 0.286 times the tensile strength, stress that causes rupture at 100,000 hours, or stress at a creep rate of 0.01% in 1000 hours. Division 1 also uses a factor of safety of 3 for lateral buckling of cylindrical shells and a factor of safety of 10 for the axial compression of cylindrical shells. Determination of these values is based on a significant amount of underlying work experience, including assumptions used in the derivation of the basic theoretical equations, practical limits, and life calculations. While not obvious in the simple tables providing allowable stress values, significant discussion goes into determination of these criteria, including the obvious stress failure criteria, but also fatigue life, comparison to success of other codes, and actual success in service.

1.3.3 Guidance for construction details

Details of construction of intricate components such as column-to-beam connections, heat exchangers, and concrete slab reinforcement are obtained from established standards. The details in these standards are based on years of practical experience that are made accessible to the engineer. However, even these standards change sometimes based on new information. A case in point is the considerable changes made in steel construction joint details and other design requirements in construction standards in the years following the Sylmar (1971) and the Northridge (1994) earthquakes in the Los Angeles area.

1.3.4 Available methodologies for inspection and testing

Although some industries depend almost entirely on process control, most components need to be inspected during manufacturing to assure good quality. This is especially true if the manufacturing does not involve mass production. For metallic structures, inspection methods such as radiography, ultrasonic testing, and magnetic particle examination are among those available. All of these methods are covered by standards produced by ASTM and ASME that provide detailed requirements for the person performing the inspection, ensuring consistency in the performance and the results of inspections, and thereby in the final product.

1.3.5 Safe operating parameters

Certain precautions must be followed in order to operate equipment and machinery in a safe manner. Standards are available to assist the engineer and operator in their jobs. Some of these are industry standards put in place to protect employers from liability, while others are jurisdictional standards such as the OSHA regulations.

1.4 Engineering software applications

Certain computer programs used in engineering become internationally recognized because of their wide applicability, use, and reliability in a diverse

range of applications. Thus, they become “standard” tools for use in evaluating certain types of engineering problems. These typically include finite element analysis and the specialty equipment design programs. While not standards themselves, they have become, in many cases, essential to effective implementation of standards.

2. General consensus standards and codes

2.1 Purpose of standards

Engineering standards are normally sets of rules, procedures, and/or requirements developed and approved by general consensus to assure the adequacy of a given product, methodology, or operation. Standards are normally developed in committees whose members have experience in a particular field of endeavor. Generally, standards are written for the following purposes

1. Safety and reliability
2. Reduction of cost
3. Increased flexibility
4. Promotion of business
5. To help society function

2.1.1 Standards for safety and reliability

Much has been learned about how to create effective standards for safety and reliability since the early efforts. Even the codes for protection from fire have evolved and expanded. Much of Baltimore burned in 1904 because fire crews sent to help from other cities found that their hoses could not be connected to the Baltimore fire hydrants. This lesson was learned again in 1991 in Oakland, California, when thousands of houses were burned, in part because fire departments from neighboring jurisdictions found themselves unable to connect with the hydrants in that city. Standards for interchangeability thus play a significant role as safety standards.

The National Fire Protection Association (NFPA) has developed several hundred standards to enhance safety. Some of these are aimed directly at preventing fires, but those standards have evolved to serve other purposes as well. The National Electric Code (NEC) was developed by the NFPA because of the large number of home fires caused by arcing and overheating due to overloaded wiring and unsafe installations. It has evolved, however, to include other aspects of safety, such as requirements for ground fault circuit interrupters to reduce the risk of electrocution. With adoption by most jurisdictions in the United States, it has become the accepted standard guiding the design, installation, and inspection of practically all home and commercial electrical installations in the country. While the primary purpose of the NEC was originally increased safety, this standard now has the added benefits of reducing the costs of construction and insurance, and increasing the confidence of home purchasers.

Another organization that has developed a large number of standards is the American Society of Mechanical Engineers (ASME). In 1883, an ASME committee on standards and gauges was created, and in 1884 the ASME published its first standard to provide uniform test requirements for boilers. ASME is perhaps most known for the Boiler & Pressure Vessel Code (BPVC), first published in 1914, but it also has standards for materials, fasteners, cranes and other lifting devices, and many more. Since that time the BPVC has grown from 114 pages to comprise 28 volumes, including 12 volumes on nuclear components. The ASME B31 piping codes perform a similar role for piping systems in many applications from gas distribution to industrial refrigeration to chemical plants and petroleum refineries.

The BPVC is effective in enhancing safety because it provides a structured way of designing and constructing pressure vessels, including limitations on material stress, standard materials and designs, standard design processes, nomenclature, and symbology. Among its standards are those for materials and materials testing, ensuring predictability of material properties. These lead to greater understanding on the part of engineers using these standards, as well as ensuring designs that effectively serve their intended functions.

The BPVC volumes on welding and non-destructive evaluation help to round out the BPVC, ensuring that implementation of a quality design is performed with proper process control and inspection, resulting in a product that effectively meets and safely performs its intended function.

All volumes of the BPVC are quite prescriptive, and while many choices are still made by the designer, once a design approach and materials are selected, there are many specific requirements that must be met.

Standards from the American Institute of Aeronautics and Astronautics (AIAA), reflecting the more recent development of the aerospace industry and the continued evolution in products used, tend to be less developed, and therefore more performance based, but they still aim to provide for a safe and reliable product. Because weight is of critical importance, aerospace standards provide for increased use of composites and new design concepts, but they still specify safety factors on stress and on life, as well as stringent control of quality. When new challenges are recognized, such as the previously unknown time-dependent failure mode referred to as stress rupture, standards developing committees move to update the standards in order to address them.

Finally, a simple standard of uniformity for the purposes of safety, that most of society takes for granted, is the PRNDL (Park-Reverse-Neutral-Drive-Low). This is the federally mandated order for features in an automobile automatic transmission. Because of the PRNDL we can get in a car,

start the engine, and drive away, confident that we will not accidentally shift into Reverse when we intend put the car in Low or Drive.

The importance of the PRNDL never fully impressed one driver until he had the opportunity to drive a Model T Ford. On a Model T, there are three pedals (just like in a current model manual shift vehicle – almost) and there are two levers on the steering column (again like a current model vehicle – almost). This provides immediate confidence to the driver of cars with a stick shift, until a closer look reveals that the left lever on the steering column does not operate the turn signal and high beams (there are none-no standard required them), and the right lever does not operate the windshield wipers and washers (none of those, either-who needs them?). (That lever on the left is the spark advance-retard, and the one on the right is the throttle (no gas pedal!)). The right pedal is the brake, the middle pedal is forward-reverse, and the left pedal is high, neutral, and low. This particular driver found himself pushing the Model T away from his rental car after a fortunately very low speed collision.

Other more recent standards for safety and reliability include those for biomedical devices, computer hardware and software, and protection of the environment.

2.1.2 Standards to reduce cost

Many standards have been developed to provide predictability and dependability of design, through use of standardized components and standard configurations. This provides for a simplified design process, permits development of pre-approved lists of products and product standards, and avoids the need for requalification for every application.

Component standardization makes possible the specification of pipe sizes, for example, with the designer having confidence that the product will be available, that standard off-the-shelf fittings and flanges can easily be procured for it, that the pipe has a known pressure-temperature capability (given a particular material and wall thickness), and that future modifications will find compatible products as needed. Many of these standards include pressure/temperature ratings as well as the physical characteristics and material properties, eliminating the need for analysis every time that a component is used.

Similarly, standard door, latch, and lock sizes simplify the design process for architects and make it easy for homeowners to purchase hardware replacements and upgrades for their homes. Other standards for such things as wall electrical receptacles, tire sizes, bearings and bushings, and USB ports expand this benefit.

An engineer recently arrived from a less developed country was doing some design work. Her supervisor stopped by her desk one morning to check on progress, and was told that she was designing a bearing for a wind tunnel access hatch. When showed a catalog of standard bearings, she was almost overcome. "You can just order these!?" Because of lack of standards and lack of stock, she was used to designing from scratch essentially every component that she used. She was overjoyed to find that she could now look up standard components, specify them, and apply the standard dimensions to her designs.

The full benefit of the economies of scale that came with the industrial revolution could not be realized until standardization of components allowed manufacture of product components without the producer knowing the end product. While there will always be a need for specialized fasteners, the existence of standard screws, bolts, and nuts, available at the local auto parts or hardware store, has reduced costs immensely.

Relatively recent engineering standards include many of those related to information technology. Printers, scanners, monitors, memory devices, and other components can simply be plugged into the backs of computers, using USB or other plug configurations that are all available at electronics stores. Inkjet printers have become so inexpensive that companies now sell them at little more than the cost of an ink cartridge, just to get the business of selling the replacement cartridges (remember the safety razor?). Even the internal components of a computer have become sufficiently standardized that a novice, after minimal study, can purchase a housing, power supply, motherboard, memory, and other components, and with a reasonable investment of time and effort, produce a working computer capable of running standard operating systems, software applications, and games, often better than the products available as completed assemblies on the open market.

Motors with standard power, torque, and speed ratings are available, with standard mounting configurations, shaft sizes, and power demands. If a manufacturer finds a shortage of a drive component, or a user finds that a component has ceased to work, another can likely be substituted with no decrease in performance and essentially no downtime.

The same standard materials that enhance safety through predictable properties allow designers to work with confidence, without testing materials for themselves. Many materials, after having been subject to rigorous process control, have been tested by the manufacturer (steel mill, plastic manufacturer, etc.) in accordance with accepted industry standards for material chemical and physical properties.

2.1.3 Standards for increased flexibility

Standards developed for increased flexibility and those for reduced cost are often difficult to distinguish, since their roles go hand in hand. Until the 1990s, students wishing to take the train from France to Madrid found that an unexpected drawback to taking the overnight train was that they were awakened at the border in the middle of the night, not just to show their passports, but because the train cars were lifted onto new trucks, or the gauge of the trucks on the cars was adjusted, to accommodate the different rail gauge then in use in Spain. It would be hard to say whether the inability to share rolling stock, the labor to change the trucks, the inability simply to keep the trains rolling, or the inconvenience was the greatest cost. In the early days of railroads in North America rail gauges were not standardized. Because of the economic challenges associated with varying rail gauges, Canada had converted to "standard gauge" by 1880, and by 1886 the railroads in the United States had converted as well.

In some cases, manufacturers have maintained internal standards different from each other or even from an industry standard. This is usually done in hopes of continuing to control a market. There are benefits and drawbacks of this approach. It is a difficult situation to maintain, and most companies that have tried have not been successful. In some cases, the standard is maintained as a secret, as with a large soft drink company, which has maintained a prominent position in the soft drink market for well over 100 years. A prominent computer company has been successful in maintaining its own standard, but it nearly went under because of it during the 1990s. Several manufacturers of tube fittings and other piping components have been fairly successful in maintaining unpublished internal standards due to a reputation for quality, combined in some cases with a certain amount of mystique, but the tendency is for these suppliers to be marginalized as more and more customers opt for the greater level of flexibility that is provided by common industry standards. The ability to purchase with confidence a product, sight unseen, is hard to beat.

2.1.4 Standards for promotion of business

The reader has probably by this time observed that the benefits of a single standard often fall into a number of areas. What makes a product safer, more reliable, less expensive, and more flexible in its application, will typically promote product sales as well. Automobiles are more reliable because the materials of which they are made are well defined, the tolerances are good, and electronic components have been produced using precise process control. Customers who used to expect to have spark plugs replaced every three to five thousand miles now may not have to replace spark plugs during the life of their vehicle.

The same customer is also more willing to make other purchases because she knows how much light to expect from a light bulb, that the battery she orders online will work in her smart phone, and that the sheets she purchases will fit her bed. (The standards for clothing sizes are less well defined, and thereby less effective).

In years past, Swedish knives had a reputation for quality, though for a long time, there was little understanding of why. Now that standards for steel call out how much carbon, sulfur, molybdenum, and other alloying elements and impurities they contain, and how they are worked and heat treated, customers can purchase quality knives from many more sources.

In business, engineering, and industrial settings, similar motivations apply. Consistent expectations allowed by standards drive sales of machine tools, allow faster and easier design and production of heat exchangers, and help chemical producers sell great volumes of their products.

2.1.5 Help society to function

It used to be that the use of credit cards and their billing entailed thousands of keypunch operators keying in millions of credit card numbers and dollar amounts every day. Engineering standards for credit and bank cards and the machines that accept them ensure that consumers can drive into a gas station almost anywhere, purchase a tank of gas, and drive off, usually without even the need to interact with the gas station attendant. The use of barcode scanning and a credit card swipe at a department or hardware store allows customers to purchase, and stores to sell, in much less time than used to be required, including (for better or for worse) a complete record of purchase, time, and other information.

Everyone knows what a stop light means, and the standardization of red light on top ensures that even people who suffer from red-green color-blindness know when to stop.

Mobile phones can be purchased new or used, online or in person, and can be activated and used on any carrier's system, and the apps available for smart phones are endless.

The standards for these items, while also featuring one or more of the benefits noted above, simply make life easier and more enjoyable, allow the traffic to flow, and help a modern society function. Similarly standards give people the ability to purchase components with confidence, sight unseen. Hence a purchaser buying over the Internet a class 150 flange from supplier A or supplier B is assured of having the same quality and performance from either supplier.

2.2 General consensus standards

General consensus engineering standards are normally developed by committee members and then approved by members belonging to diverse interest groups developed. And while the word consensus may mean different

thing to different people, specific procedures have been established in the United States that establish guidelines for consensus approval of standards. These guidelines are developed and enforced by the American National Standards Institute (ANSI).

2.3 American National Standard Institutes (ANSI)

ANSI is a private nonprofit organization founded in 1918 by five engineering societies and three governmental agencies. Part of their published mission is

“ANSI facilitates the development of American National Standards (ANS) by accrediting the procedures of standards developing organizations (SDOs). These groups work cooperatively to develop voluntary national consensus standards. Accreditation by ANSI signifies that the procedures used by the standards body in connection with the development of American National Standards meet the Institute’s essential requirements for openness, balance, consensus and due process”.

There are at least 1100 organizations that are accredited by ANSI for writing general consensus rules. The requirements, as published by ANSI, are:

“In order to maintain ANSI accreditation, standards developers are required to consistently adhere to a set of requirements or procedures known as the “ANSI Essential Requirements,” that govern the consensus development process. Due process is the key to ensuring that ANSs are developed in an environment that is equitable, accessible and responsive to the requirements of various stakeholders. The open and fair ANS process ensures that all interested and affected parties have an opportunity to participate in a standard’s development. It also serves and protects the public interest since standards developers accredited by ANSI must meet the Institute’s requirements for openness, balance, consensus and other due process safeguards”.

ANSI is the only accreditor of organizations developing American National Standards. The Standards Council of Canada, in addition to promoting generally the use of voluntary standards, accredits standards developing organizations and approves Canadian standards as National Standards of Canada, while the International Organization for Standardization (ISO) accredits standards developing organizations internationally. Some of the requirements that must be met in publishing standards are published by ANSI. A short excerpt of these published requirements is:

“In its role as the only accreditor of U.S. voluntary consensus standards developing organizations, ANSI helps to ensure the integrity of the standards developers that use our *ANSI Essential Requirements: Due process requirements for American National Standards*. A separate process, based on the same principles, determines whether standards meet the necessary criteria to be approved as American National Standards. Our process for approval of these standards (currently numbering approximately 10,000) is intended to verify that the principles of openness and due process have been followed and that a consensus of all interested stakeholder groups has been reached.

The hallmarks of this process include:

- ♦ Consensus must be reached by representatives from materially affected and interested parties
- ♦ Standards are required to undergo public reviews when any member of the public may submit comments
- ♦ Comments from the consensus body and public review commenters must be responded to in good faith
- ♦ An appeals process is required”

Some of the organizations that write consensus standards in accordance with the ANSI requirements are listed in Appendix A.

2.4 Codes

2.4.1 National codes

The terms code and standard are often interchanged in conversation. However, a code is generally a body of standards grouped together for ease of reference. Technical codes cover a wide range of disciplines ranging from electrical to mechanical to structural. They form the basis for safe, consistent, and effective designs in various fields. Codes are normally specified in the design documents of a project.

There are instances where two well recognized codes can be used in solving a given engineering problem and the engineer has to decide which one to use. A case in point is that of the National Board Inspection Code (NBIC) and the American Petroleum Institute (API) 579 code both of which address the repairs and alterations of pressure vessels. These two codes have different requirements but the end result is the same for a majority of cases. An engineer repairing a pressure vessel needs to be familiar with both of these codes in order to make an informed decision on which one to use.

2.4.2 International codes

In addition to the United States, many other countries have established codes that are used nationally and internationally. These codes are written by committees assigned by the appropriate jurisdiction. These committees operate in a fashion more or less similar to those in the United States that follow the ANS process. Appendix A lists some international organizations that are engaged in writing standards and codes.

2.5 Some ANSI accredited organizations

2.5.1 American Society of Mechanical Engineers (ASME)

ASME is one of the most prolific organizations in the United States, having developed thousands of general consensus standards, research publications, technical journals, and engineering books and pamphlets. ASME is ANSI accredited, and it relies on a large number of volunteers and numerous staff members for maintaining its activities. The background of the volunteers spans a wide range of disciplines such as engineering, metallurgy, non-destructive examination, welding, and materials. A visit to the ASME web site at www.asme.org reveals a wide array of technical books and pamphlets available to the engineer. ASME also publishes, at regular intervals, over two dozen technical journals, all written by volunteers, with a small production staff that takes care of the mechanics of publishing.

A separate entity, the ASME Standards Technology, LLC (sttlc.asme.org), manages theoretical and experimental research related to mechanical engineering in the areas of analysis, metallurgy, welding, and non-destructive examination. Published reports of the research activities are available from ASME.

A vast amount of standards is developed under the auspices of ASME. Some of the areas where ASME standards are available are

- ✦ Boilers, pressure vessels, and nuclear components
- ✦ Elevators, escalators, and moving walkways
- ✦ Piping and pressure relief devices
- ✦ Flanges, gaskets, valves, and fittings
- ✦ Cableways, cranes, derricks, and hoists
- ✦ Screws, threads, and bolts
- ✦ Pumps

Each of the above areas is addressed by numerous standards and codes. For example the ASME Boiler and Pressure Vessel Code consists of the following sections

- ✦ Section I. Rules for Construction of Power Boilers
- ✦ Section II. Materials
 - ✦ Part A. Ferrous Material Specifications
 - ✦ Part B. Nonferrous Material Specifications

- ✦ Part C. Specifications for Welding Rods, Electrodes, and Filler Materials
- ✦ Part D. Properties
- ✦ Section III. Rules for Construction of Nuclear Facility Components
 - ✦ Subsection NCA. General Requirements for Division 1 and Division 2
 - ✦ Division 1
 - ✦ Subsection NB. Class 1 Components
 - ✦ Subsection NC. Class 2 Components
 - ✦ Subsection ND. Class 3 Components
 - ✦ Subsection NE. Class MC Components
 - ✦ Subsection NF. Supports
 - ✦ Subsection NG. Core Support Structures
 - ✦ Subsection NH. Class 1 Components in Elevated Temperature Service
 - ✦ Appendices
 - ✦ Division 2. Code for Concrete Containment
 - ✦ Division 3. Containments for Transportation and Storage of Spent Nuclear Fuel and High Level Radioactive Material and Waste.
- ✦ Section IV. Rules for Construction of Heating Boilers
- ✦ Section V. Nondestructive Examination
- ✦ Section VI. Recommended Rules for the Care and Operation of Heating Boilers
- ✦ Section VII. Recommended Guidelines for the Care of Power Boilers
- ✦ Section VIII. Rules for Construction of Pressure Vessels
 - ✦ Division 1. Rules for Construction of Pressure Vessels
 - ✦ Division 2. Alternative Rules
 - ✦ Division 3. Alternative Rules for Construction of High Pressure Vessels
- ✦ Section IX. Welding and Brazing Qualifications
- ✦ Section X. Fiber-Reinforced Plastic Pressure Vessels
- ✦ Section XI. Rules for Inservice Inspection of Nuclear Power Plant Components
- ✦ Section XII. Rules for Construction and Continued Service of Transport Tanks

The above twenty eight volumes contain a wealth of information needed in order to design and construct boilers, pressure vessels, and nuclear components. Other examples of ASME standards include:

- ✦ A17.2. Guide for Inspection of Elevators, Escalators, and Moving Walks
- ✦ B16.5. Pipe Flanges and Flanged Fittings
- ✦ B30.16. Overhead Hoists (Underhung)

- ♦ B31.1. Power Piping
- ♦ B31.3. Process Piping
- ♦ Y14.100. Engineering Drawing Practices

ASME uses a wide range of member interest categories, including the following diverse groups as part of its consensus process in developing standards. These groups consist of local as well as international representatives.

- a. Fabricators and manufacturers
- b. Users and operators
- c. Governmental Agencies and Jurisdictions (such as the Nuclear Regulatory Commission (NRC) and the Coast Guard as well as state, and local jurisdictions)
- d. Technical consultants
- f. Research organizations (such as Oak Ridge National Lab and various universities)
- g. Insurance/Inspection agencies
- h. Engineering and construction firms

Personnel from the above seven categories are involved in writing various facets of the boiler code. Hence, standards written for boiler construction as well as standards written for non-destructive examination methods have to be approved by members representing the seven groups listed above.

ASME also performs a unique service by providing a Conformity Assessment process for use in industry. The process steps are generally as follows

- ♦ ASME publishes boiler and pressure vessel standards used by manufacturers to fabricate equipment.
- ♦ ASME certifies users of these standards to ensure that they are capable of manufacturing products that meet those standards.
- ♦ The certification process consists of the following general steps
 - ♦ An ASME authorized team visits the manufacturer's site and audits its Quality Assurance procedures and implementation. These procedures describe many items such as
 - ♦ Material traceability
 - ♦ Internal inspection procedures
 - ♦ Third party inspection provisions
 - ♦ Documentations such as design report, NDE records, and material certification.
 - ♦ The team discusses its findings with an authorized representative of the manufacturer and then files its report with ASME.
 - ♦ The auditing team is usually assembled by ASME or other institutions authorized by ASME such as the National Board of Boiler and Pressure Vessel Inspectors.

- ♦ If the auditing team finds the manufacturer to be in compliance with all of the ASME requirements for a given standard, then ASME provides it with a Stamp. The Stamp provided to the certified manufacturer is affixed onto their products to indicate the manufacturer's certification that a product was manufactured according to the particular standard.
- ♦ If the auditing team finds the manufacturer not in compliance with the ASME requirements, then it files a report with ASME highlighting items that are non-compliant.
- ♦ An ASME committee (Committee on Boiler and Pressure Vessel Conformity Assessment) consisting of members from a wide sector of the industry meets to discuss the non-conformance. A representative of the manufacturer where the non-conformance occurred is given due process by being invited to the meeting to present the user's point of view. Based on its findings, the committee then decides whether or not to grant a Stamp to the manufacturer.

The above conformity process has been in use by ASME for many decades and has proven very effective in the industry. ASME cannot, however, force any manufacturer, inspector, or installer to follow the ASME standards. Unless required by jurisdictional standards (laws, regulations, local building codes, etc.), their use is voluntary.

2.5.2 American Society for Testing and Materials (ASTM)

ASTM is another organization that is accredited by ANSI for writing standards. Like ASME, it maintains a large number of standards covering a wide range of applications. However, unlike ASME, which focuses on mechanical systems, ASTM covers the wide range of testing needs that affect our life. Some ASTM standards are listed below by category name.

- ♦ Section 1 — Iron and Steel products
- ♦ Section 2 — Nonferrous Metal Products
- ♦ Section 3 — Metals Test Methods and Analytical Procedures
- ♦ Section 4 — Construction
- ♦ Section 5 — Petroleum Products, Lubricants, and Fossil Fuels
- ♦ Section 6 — Paints, Related Coatings, and Aromatics
- ♦ Section 7 — Textiles
- ♦ Section 8 — Plastics
- ♦ Section 9 — Rubber
- ♦ Section 10 — Electrical Insulation and Electronics
- ♦ Section 11 — Water and Environmental Technology
- ♦ Section 12 — Nuclear, Solar, and Geothermal Energy
- ♦ Section 13 — Medical Devices and Services

- ✦ Section 14 — General Methods and Instrumentation
- ✦ Section 15 — General Products, Chemical Specialties, and End Use Products

The above 15 categories contain thousands of technical standards available to the engineer. Sections 1, 2, and 3 of ASTM are referenced extensively in ASME. Accordingly, many volunteers are members of both ASME and ASTM in order to properly coordinate the activities of Sections 1, 2, and 3 of ASTM with ASME material and testing needs.

2.5.3 American Petroleum Institute (API)

API publishes hundreds of standards related to the refinery industry. Many of these standards are used at other facilities such as chemical plants, power plants, and other industrial facilities. Some standards of API are

- ✦ API 510. Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration.
- ✦ API 579. Fitness-For-Service.
- ✦ API 620. Design and Construction of Large, Welded, Low-Pressure Storage Tanks.
- ✦ API 650. API Welded Steel Tanks for Oil Storage.
- ✦ API RP572. Inspection of Pressure Vessels.

2.5.4 Underwriters Laboratory (UL)

UL publishes over 1200 safety standards in diverse fields. A complete list of their standards can be obtained via their web site at www.ul.com.

2.5.5 National Board of Boiler and Pressure Vessel Inspectors (NBBI)

NBBI is a non-profit organization consisting of the Chief Boiler Inspectors of most states in the United States as well as the provinces of Canada and many cities and municipalities in North America. They are the repository for all certificates of fabricated boiler and pressure vessels registered in the United States and Canada. They also audit and certify pressure vessel manufacturers, approve manufacturers for repairing pressure vessels and boiler, and certify pressure relief valves in their test labs. NBBI publishes many standards related to inspection and valves. Some of these standards are

- ✦ NB-18. Pressure Relief Device Certification
- ✦ NB-23. National Board Inspection Code
- ✦ NB-235. Boilers and Water Heater Safety

2.5.6 American Society of Civil Engineers (ASCE)

ASCE publishes over 40 publications related to such topics as structures, hydraulics, water management, and soils. A few of their publications are

- ✦ ASCE/SEI 07. Design Loads for Buildings and Other Structures.
- ✦ ASCE/SEI 24. Flood-resistant Design and Construction.
- ✦ ASCE/SEI 48. Design of Steel Transmission Pole Structures.

2.5.7 Institute of Electrical and Electronics Engineers (IEEE)

IEEE has over 3000 standards in such area as

- ✦ Aerospace
- ✦ Electronics
- ✦ Antennas & Propagation
- ✦ Batteries
- ✦ Communications
- ✦ Computer Technology
- ✦ Consumer Electronics Electromagnetic Compatibility
- ✦ Green & Clean Technology
- ✦ Healthcare IT
- ✦ Industry Applications
- ✦ Instrumentation & Measurement
- ✦ Nanotechnology
- ✦ National Electrical Safety Code
- ✦ Nuclear Power
- ✦ Power & Energy
- ✦ Power Electronics
- ✦ Smart Grid
- ✦ Software & Systems Engineering
- ✦ Transportation
- ✦ Wired & Wireless

Like ASME, IEEE sponsors research and seminars worldwide.

Appendix A lists some American and international standards organizations developing general consensus standards.

3. Limited consensus standards

3.1 Types of standards

Limited consensus standards (LCS) are those produced following a process less rigorous and open than the American National Standards Institute (ANSI) process discussed in Chapter 2. They are most often developed to benefit a particular company or other organization, or the members of a particular group. Similar to other standards, benefits accrue in a variety of ways, as described in Chapter 1.

Governmental agency LCS are often developed and used because of needs that are not sufficiently broad in the economy to warrant the interest of National Consensus Standards (NCS) developing organizations, or because even from agency to agency in the same area needs differ. It is, however, US government policy, documented in OMB Circular A119 and the National Technology Transfer and Advancement Act, that NCS be used rather than internal governmental standards whenever practicable. Governmental agency LCS for internal use often follow a process similar to the ANSI process excepting that, since the requirements are intended only for internal use, they are subjected only to a review by the agency “internal public,” not the public at large. Governmental agency jurisdictional LCS vary in the extent to which they incorporate elements of the ANSI process. They are sometimes written with little or no direct input from outside the agency, but they are always subject to a public comment and review period.

It is important to recognize the distinction between governmental standards generally, and jurisdictional standards. Major governmental agencies all have internal standards that define how they perform their jobs. A much smaller number of governmental agencies issues standards that are applicable to the operations of the private sector, enforceable by fines or other governmental sanctions. This latter group of standards is what this book refers to as jurisdictional standards (see Chapter 4).

Private sector LCS are sometimes subject to the same lack of general interest as are governmental agency internal standards, but the benefits associated with sales and control of a market are also often significant factors in the decision not to turn them into NCS.

By maintaining a standard as LCS, the organization(s) receive many of the benefits of an NCS while maintaining greater control, and in some cases reducing the cost and time required to develop the standard, due to the less rigorous process. In some cases the LCS are developed by an organization to supplement an NCS, providing a greater level of detail, more explicit direction, or a more stringent level of quality than provided for in the NCS. An organization using an LCS rather than an NCS usually has greater flexibility to deviate from the standard, should the need arise, as it need not

publicize the fact that a particular product is an exception to its usual compliance with an NCS, something often touted in sales literature.

LCS are frequently developed by an organization to fulfill a special need such as identification of a product line, specification of manufacturing details, or compliance with a given methodology. Examples of standards for product lines are the Taylor Forge and Bonney Forge catalogs for fittings and pipe dimensions. These companies established standards many years ago for numerous reasons, all of which still remain valid. One is to reduce cost by having a fixed number of products. Two is to inform potential customers of the dimensions and configurations of available products to facilitate the design and ordering process. Three, the customer can order the product on line knowing he or she will receive the exact product needed with all the specified tolerances, etc. Four, by having a catalog the potential customer is inclined to order from one of these, rather than other companies, knowing the exact product and quality they are receiving. And five, the company projects an image of being a leader in its field. There are, of course, thousands of limited consensus standards in the market place that cover every product imaginable from lighting fixtures to tools, machinery and construction materials.

An example of an LCS for manufacturing details is the standard published by TEMA for tube and shell heat exchangers. It is published to help heat exchanger manufacturers maintain uniform design methodology and provide consistent fabrication tolerances and dimensions. It also serves to give confidence to customers through a recognized, proven, and credible approach to design.

Many similar standards exist in industry covering various topics such as expansion joints and refractory applications. And while these limited consensus standards are developed for the benefit of a given organization, they are typically used throughout the industry.

An example of an LCS for compliance with a given methodology is NASA-STD-5006, General Fusion Welding Requirements for Aerospace Materials Used in Flight Hardware, the standard developed by NASA for welding of aerospace components. This standard is used internally at NASA, and is often cited as a requirement on contracts for flight hardware. It includes details regarding equipment, calibration, maintenance and records, materials, weld procedure, performance and welder qualifications, and many other aspects of producing a quality weld.

In some cases, LCS become industry standards, and ultimately NCS. For example, Taylor Forge sponsored research at Yale University to develop design rules for flanges. Taylor Forge then published its procedure and provided forms to simplify the design in a small flange design handbook for engineers. Professor Waters and Frank Williams, one of his students who had worked on the development effort and had been hired by Taylor Forge,

were asked to join ASME and help incorporate the rules in the BPVC. The Taylor Forge design process was thereby incorporated in the ASME BPVC many years ago. Similarly, portions of MIL-STD-1522A, Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems, have been incorporated in the American Institute of Aeronautics and Astronautics (AIAA) S-081, Space Systems — Composite Overwrapped Pressure Vessels (COPVs) standard.

3.2 Proprietary versus non-proprietary standards

3.2.1 Proprietary standards

Many organizations have proprietary standards of some sort or another. These standards include

- ♦ Unique product and manufacturing processes
- ♦ Patented products and procedures
- ♦ Intellectual property

While falling under the general category of LCS, these standards are further limited either through patent rights or by maintenance as trade secrets.

A classic example of a standard for a unique product and manufacturing process is the recipe for Coca Cola. The company keeps a tight control on the production of the product without divulging its recipe outside the company. They chose not to patent the product in order to keep the ingredients secret. Many other companies have unique product and manufacturing processes which they do not share outside the company in order to maintain a market advantage.

Many companies have proprietary standards based on a patented technology. The patents give them protection from competition for a given number of years. In the United States, a design patent has a term of fourteen years, a utility patent twenty (17 years before a change in the law in 1995). The companies develop manufacturing standards based on these patents. They then hope that by the end of the term of the patent either they will have been established as the market leader such that competition will have trouble taking a significant portion of the market, or they may view the market as one that will endure for a number of years, but that by patent expiration they will have received enough benefit from their exclusive rights in the market to have justified their initial investment. This is often the case with drugs, which typically become available as generics immediately upon patent expiration.

Some companies, especially engineering companies, develop a process or product upgrade that is marketed as an improvement over existing products or operation. These companies then develop proprietary and non-proprietary Standards based on such intellectual property. Sometimes the whole worth of the company is based on the value of its intellectual property.

3.2.2 Non-proprietary standards

Many non-proprietary limited consensus standards are published by organizations to promote their product or process as discussed in Section 3.1 above. Many such standards provide valuable information to others in the field, but it must be kept in mind that the published information may be slanted toward the interests of this specific organization.

3.3 Governmental and jurisdictional limited consensus standards

Many federal, state, and local governmental agencies as well as local jurisdictions publish non-consensus standards to provide requirements and guidance for performing their work. Some of the more well-known agencies are listed below:

3.3.1 National Aeronautics and Space Administration (NASA)

NASA maintains a library of hundreds of policy directives, procedural requirements, standards, and handbooks. Many of these deal with the administrative and other issues associated with running a large organization, but the list includes dozens of engineering standards ranging from implementing requirements for safety of pressure systems through how to assure the integrity of software developed by or on behalf of the agency. In addition, NASA throughout the years has published a wealth of technical bulletins ranging in scope from buckling, to composites, to stress analysis, and many other topics.

3.3.2 Army Corp of Engineers

The Corp of Engineers includes hundreds of engineering manuals in its list of publications. Their application ranges from how to validate analytical chemistry laboratories, to safety, environmental quality, landfill gas collection and treatments systems, design of flood control structures, calibration of soils testing equipment, and more. It also maintains a wide range of other publications, including engineering circulars, design guides, regulations, technical letters, and engineering graphics standards. These are available on its web site at <http://www.publications.usace.army.mil/Home.aspx>.

3.3.3 National Institute of Standards and Technology (NIST)

NIST publishes numerous standards and other documents in a much wider range of fields that its name would imply. It maintains, for example, a series of Federal Information Processing Standards that range from Personal Identity Verification of Federal Employees and Contractors through Security Requirements for Cryptographic Modules, and it publishes numerous interagency or internal reports (which are, however, generally available for the use of the public), related to information security. Its list of special publications includes categories such as Calibration Services, Standard Reference Materials, and Precision Measurement and Calibration, but also includes Law Enforcement Technology, Computer Systems Technology, and others.

3.3.4 National Science Foundation (NSF)

NSF publishes hundreds of standards (called policies and procedures) in various fields such as biology, computer science, engineering, geoscience, math, and physical science. Many of these provide guidance and/or requirements for researchers performing work under NSF programs. Subtopics range from requirements for research in Antarctica to lab equipment.

3.3.5 U.S. Department of Agriculture (USDA) — Forest Service

The National Forest Service maintains an extensive system of directives, consisting of manuals and handbooks. These are used to provide for internal management and control of programs and as a source of direction to Forest Service employees. They include a number of categories, one of which is engineering, which due to the broad of activities that take place in national forests, includes a comparably wide range of subtopics. These include items such as geotechnical engineering (which references standards from American Association of State Highway and Transportation Officials (AASHTO) and ASTM, to aerial adventure course design and manufacture (largely performance based), passenger ropeways (such as ski lifts, ski tow ropes, etc.), and building design and construction. The Forest Service standards are typically implementing standards for legislation or jurisdictional standards (e.g., OSHA regulations), and therefore largely refer either to regulations or to NCS. Technical details tend to be included in the Forest Service Handbooks rather than the Manuals, but are still written at a generally high level.

3.3.6 United States Food and Drug Administration (FDA)

The FDA regulates products and activities including food products, drugs, medical devices, cosmetics, tobacco products, and more. The standards that it promulgates are in two categories. The detailed requirements in many areas are enshrined in NCS, and FDA takes a significant role in development of these standards, participating in many SDO activities. FDA is also a jurisdictional organization and maintains many regulations (found in Title 21 of the Code of Federal Regulations) covering these areas.

3.3.7 Municipalities

Many municipalities issue their own non-consensus standards regarding compliance with local laws. However, most of these standards consist of a compilation of names and titles of national consensus standards that must be adhered to in order to conduct business with the municipality.

Appendix B lists some Industrial Organizations that Publish Limited Consensus Standards.

4. Jurisdictional standards

4.1 Regulations and jurisdictional requirements

A special category of standards that affects practically all organizations is that group of standards promulgated by Federal, State, and Local jurisdictions such as OSHA, DOT, DOE, EPA, Cal-OSHA, counties, cities, and regional governing bodies that are regulatory. These standards have the distinction of being enforceable by legal sanction, typically fines. This is different from standards that may have been agreed upon by contract between two companies, which do not have the same means of enforcement.



(Courtesy of cartoonstock.com)

A regulation is an implementation of a law established by an official governmental jurisdiction for the purpose of achieving specific public good. It is put in place after action by a legislative body either instructing or authorizing an agency to create regulations in a particular area. The general category of regulations includes both administrative requirements and engineering regulations, the latter of which often have specific engineering requirements, but also almost always reference various local, national, or international codes and standards. As an example, many jurisdictions, especially at the state level, require compliance with the ASME Boiler and Pressure Vessel Code for pressure vessels, the International Building Code (IBC) for general construction, and the National Electrical Code for electrical installations.

Compliance with these codes becomes a legal requirement since they are specified in the regulations.

Because jurisdictions typically have wide responsibilities, are subject to various standards of openness, and for various reasons may not be ready to adopt the latest standard, it is common to have the required code or standard edition out of phase with the most recently published edition of a given code. This is typically the case with the National Electrical Code where reference to a given edition by a jurisdiction often lags the current code edition by several years. Care must therefore be exercised to ensure that the correct edition of the standard is followed as well as identified in any contract documents.

The following table lists some jurisdictional organizations, with brief a discussion of the standards provided by each. Following this listing is a more detailed discussion of one organization (OSHA), its regulations, and their application. This list includes examples of state occupational safety organizations along with a number of organizations at the federal level. It does not attempt to address the myriad of city, county, regional, and other lower level jurisdictions.

Organization	Jurisdiction
Cal-OSHA, VOSH, Oregon OSHA, etc.	(See OSHA). These are state organizations performing the same role within a state that OSHA performs generally. In order for the State program to be recognized by Fed OSHA as a suitable program in lieu of the federal one, each state occupational safety and health organization must demonstrate a program essentially equivalent to the federal program. A number of states have chosen to implement such programs for a variety of reasons, but typically because they believe that they can achieve the same results with less intrusion. In some cases they may choose to be more stringent than Fed OSHA.
CPSC	The Consumer Product Safety Commission maintains many standards for product safety, ranging from architectural glazing materials through bicycle helmets, infant bath seats and baby cribs. Many of the CPSC standards are administrative and relate to product labeling, but there are many performance and other standards for individual products.
DOE	The Department of Energy is a cabinet level department that was created by the Department of Energy Organization Act of 1977, which combined the Federal Energy Administration, the Energy Research and Development Administration, and the Federal Power Commission, and some programs from other agencies. Originally concerned only with nuclear material, DOE

	responsibilities have expanded to include energy conservation, domestic energy production, and a significant amount of research in genomics and other physical sciences. It operates a number of well-known national laboratories, including Argonne, Brookhaven, Lawrence Livermore, Los Alamos, Oak Ridge, Idaho, and others. DOE publishes a wide range of directives used to manage its efforts. Many of these are identified as guides and do not contain actual requirements, so they do not rise to the level of actual standards. It is also responsible for a large number of regulations relating to energy conservation, nuclear safety management, occupational radiation protection, chronic beryllium disease prevention, and worker safety and health for DOE contractors.
DOT	The mission of the Department of Transportation is to, "Serve the United States by ensuring a fast, safe, efficient, accessible and convenient transportation system that meets our vital national interests and enhances the quality of life of the American people, today and into the future." Because of this broad mission, the DOT has equally broad portfolios of responsibilities and regulatory authority. It includes under its authority the National Highway Traffic Safety Administration (NHTSA), the Federal Aviation Administration (FAA), the Federal Highway Administration (FHA), the Pipeline and Hazardous Materials Safety Administration (PHMSA), the Federal Motor Carrier Safety Administration (FMCSA), and others. It has regulations that address such issues as airline scheduling in the air traffic control system and rest requirements for truckers, safety of interstate motor carriers, and construction of roads and bridges. The regulations on truckers' logbooks are purely administrative, but there are also many regulations providing technical standards for concerns such as passenger and commercial vehicle safety devices, ground and aircraft based vessels for transporting pressurized gases, the process by which aircraft type licensing occurs, and minimum requirements for securing certain types of cargo in trucks (generally performance standards). It has teamed up with ASME to publish a national standard for cargo transport tanks (ASME Boiler and Pressure Vessel Code, Section XII, Rules for Construction and Continued Service of Transport Tanks).
EPA	The Environmental Protection Agency is a relatively small government agency (less than 0.5% of the nation's budget), but has a disproportionately large impact on society due to the large number and range of its regulations. Close to 10% of its budget is related to civil and criminal enforcement of

(Continued)

	regulations covering climate change and air quality, water quality, cleanups, and chemical safety and pollution prevention. As with the other agencies listed, some EPA standards are essentially administrative. The general public is perhaps most familiar with EPA vehicle emissions and mileage standards. These affect everything from design of vehicles to the type of fuel that is available at gas stations.
FDA	Food and Drug Administration cover a wide range of areas including, as its name indicates, food and drugs, but also extending to medical devices. Most of its regulations would not be considered standards, but it maintains a significant database of “recognized consensus standards” for medical devices, ranging from test methods for calibration to acceptable materials for various applications.
NRC	The Nuclear Regulatory Commission was established by the Energy Reorganization Act of 1974. It is responsible for enforcement of a number of regulations regarding civilian use of nuclear material and dealing with nuclear waste. Some of these regulations are technical and can justifiably be considered engineering standards, while others fall into the classification of general laws and regulations. Because its operations relate closely to and may overlap with those of other agencies, it has Memoranda of Understanding with those agencies, including the Departments of Justice, Labor, Transportation, and with OSHA. The NRC is heavily involved with the ASME in writing rules for nuclear power plant components (ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction for Nuclear Facility Components and Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components).
OSHA	Created by the Occupational Safety and Health Act of 1970, the Occupational Safety and Health Administration (OSHA), a part of the Department of Labor, is charged with assuring safe and healthful working conditions for employees by setting and enforcing standards, and by providing training, outreach, education, and assistance. OSHA regulations cover most private sector employers and their workers, and many public sector employees. Regulations (standards) cover most aspects of the workplace, and for those areas not specifically addressed elsewhere, the “general duty clause” has requirements for “employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm.” In general, formal interpretations as well as court cases have interpreted this to mean compliance with industry standards, although a responsible, effective, equivalent program is accepted. Specific areas for which standards

are provided include Agriculture, Construction, General Industry, and Maritime employment. In areas where detailed standards are not provided, such as pressurized equipment, OSHA references other national standards such as the ASME Boiler and Pressure Vessel Code.

4.2 Jurisdictional standards implementation

It is typically the responsibility of businesses, including employers, airlines, mine owners, medical device manufacturers, and others, to comply with jurisdictional engineering standards. While each jurisdiction has oversight authority, the extent to which this is exercised varies. In the case of medical devices, for example, the FDA performs a review of each device before accepting it for use. Within DOT, there are various administrations which use varying types and levels of oversight. The FAA has extensive certification procedures for aircraft designs, especially so for those that will be used as passenger aircraft, while the FHWA has highway construction standards whose implementation is most often by contract. OSHA has extensive standards for employee safety, and has authority to inspect workplaces, but with over 100 million workplaces subject to its regulations, OSHA inspections are, on the average, rare. OSHA and the state OSH organizations conducted a total of approximately 100,000 workplace inspections in 2004 meaning that the average workplace will be subject to an OSHA inspection about once every 1000 years. Clearly, in this case, the good faith of most employers is very much depended on, while inspections are targeted toward those organizations identified as posing the greatest risk to employee safety.

Because of the ability of many regulatory agencies to levy fines or other sanctions as well as because of the civil liability that is implied by non-compliance in the event of a mishap, there is incentive (in addition to that of doing the right thing by their employees or customers) for companies to maintain compliance. The truth, however, is that implementation of jurisdictional standards is very much up to those being regulated by them. Thus far, while there have been some notable exceptions, this approach has worked very well.

4.3 Sample jurisdictional standard: The OSHA regulations

Jurisdictional standards can accomplish their purposes by expressing specific items that must be accomplished or they can operate by specifying results to be achieved. The OSHA regulations most often do the former, both for consistency of application and because they were mainly developed at a time (early 1970s) when the safety discipline was not yet as well developed as it is today. They tell a person or employer what to do, often in great detail. When specific requirements are given, each requirement must be complied with, whereas when a standard of performance standard is provided it is the responsibility of the affected party to determine and implement a means of

achieving the required level of performance. The OSHA regulations provide safety standards for almost all fields of employment, however, and the approach does vary, and for the cases in which there is not an applicable regulation, the General Duty Clause (see Section 4.4) is applied.

In the section of the OSHA regulations for General Industry for overhead cranes (29 CFR 1910.179), many particulars of operational limitations and required inspections are specified. For example, there is a fairly detailed discussion of how the end of a wire rope may be attached to the drum. The OSHA section on Process Safety Management (PSM) of Highly Hazardous Chemicals (29 CFR 1910.119) (introduced in 1992, twenty years after most OSHA standards), on the other hand, is somewhat an anomaly in the OSHA regulations, being essentially a performance standard. Rather than providing explicit quantity-distance limits, as is done in the related section on for explosives safety (29 CFR 1910.109), the PSM section requires the employer to perform process hazard analyses on the processes covered by the standard, providing a list of six different suitable analyses methodologies, and allowing for others as well. It lists a number of items that must be addressed in the analysis, and then requires that the employer establish a system to address the findings of the analysis, that the analysis be updated and revalidated at least every five years, that a system be in place to manage changes, and that employees be trained and informed throughout. The employer is allowed wide latitude in implementation, provided the approach is effective.

Regarding another example of a prescriptive requirement, an employer-user purchasing an air receiver, in order to ensure compliance with the OSHA regulations in 29 CFR 1910.169, must purchase a vessel that has been designed and constructed in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII. To meet the letter of the law, the 1968 edition (that edition is cited in the law because it was current at the time the regulation was written) of the code must be used. Flexibility to use a later edition of the code is provided by a formal Letter of Interpretation which allows use of later editions if they provide an equal or greater level of protection, which they are recognized as doing. The user would therefore normally specify current ASME Code construction in the contract with his supplier, and would obtain a vessel designed and constructed, with documentation and an ASME Code stamped nameplate (referred to overall by OSHA as "Nameplate, Records, and Stamping," or NRS), in accordance with the ASME Boiler and Pressure Vessel Code. If the supplier provides a vessel that does not meet these requirements, that is a matter between the user and the supplier, but the user who accepts the noncompliant vessel and puts it into service could be cited for an OSHA violation.

In cases where there is confusion, ambiguity, or simply a question as to the intent and application of a regulatory standard, it is usual for the jurisdiction to accept letters of inquiry (as do other consensus standard

developing bodies). These letters of inquiry are responded to with Letters of Interpretation, formalizing the position of the regulatory body on the issue and publishing it for use of all employers. Such letters of interpretation provide guidance both to the employer and to the inspectors and other personnel in the regulatory organization, helping to ensure uniform application of the regulations.

If an employer other than a federal agency wishes to operate some aspect of its business in a manner that does not comply with the OSHA regulations, then in order to avoid the possibility of citations, fines, or other sanctions, a waiver is normally required. For a federal agency employer an Alternate Standard takes the place of a waiver. Permission to deviate from requirements, which sometimes goes by different names for different standards developing organizations, is discussed in detail in Chapter 7, Standards Interpretation and Relief.

4.4 OSHA general duty clause

Many OSHA standards are quite prescriptive, while others such as the "Process Safety Management of Highly Hazardous Chemicals," which provides performance standards in a specific area, are broadly written, allowing much flexibility to the user. When congress wrote the OSH Act of 1970, creating the Occupational Safety and Health Administration, they included a catch-all statement in section 5(a)(1) of the act, requiring that each employer "shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees." This requirement is generally referred to as the General Duty Clause. Most sections of the OSHA regulations do not repeat this requirement, requiring reference to the law itself when this requirement is to be applied, but the statement is repeated verbatim in 29 CFR 1960 Basic Program Elements for Federal Employees (found in 29 CFR 1910.8(a)).

This statement is applied only to those aspects of an employment that are not covered by more specific regulations. If an employer complies with all of the specific OSHA standards applicable to its operations, then it is considered to be in compliance with the General Duty Clause. Thus, in the General Industry regulations for example, 29 CFR 1910.5(f) states, "An employer who is in compliance with any standard in this part shall be deemed to be in compliance with the requirement of 5(a)(1) of the Act, but only to the extent of the condition, practice, means, method, operation, or process covered by the standard."

Examples of categories falling under the General Duty Clause, for General Industry, are in-plant storage of pressurized nitrogen for process applications, and requirements for lifting hardware not specifically addressed by 29 CFR 1910.184. In these cases the usual OSHA approach would be to apply the most applicable industry National Consensus Standard. Thus for

in-plant pressurized nitrogen storage, OSHA would expect the employer to follow the ASME Boiler Vessel and Pressure Vessel Code unless the employer provides justification for some other approach to ensuring employee safety. For lifting appliances not addressed by the regulations, OSHA would expect compliance with the ASME standard for those particular devices.

Also, when an employer performs operations for which the only OSHA standard is the General Duty clause (i.e., there is no specific applicable OSHA standard for the particular operation or area of operations), there may be an employer responsibility to develop and document its own standard. For operations of covered government agencies the requirement is specifically stated in 29 CFR 1960.18, Supplemental Standards, and the Supplementary Standard (the terms used in the title and in the text of the regulation are not the same) must meet certain review requirements and be submitted to OSHA for approval. For the private sector the responsibility is more generally included in the requirements for company safety plans, job hazard analyses, etc., but reference and enforcement directly to section 5(a)(1) of the OSH Act may be expected if those company documents are found to be inadequate to ensure the safety of employees.

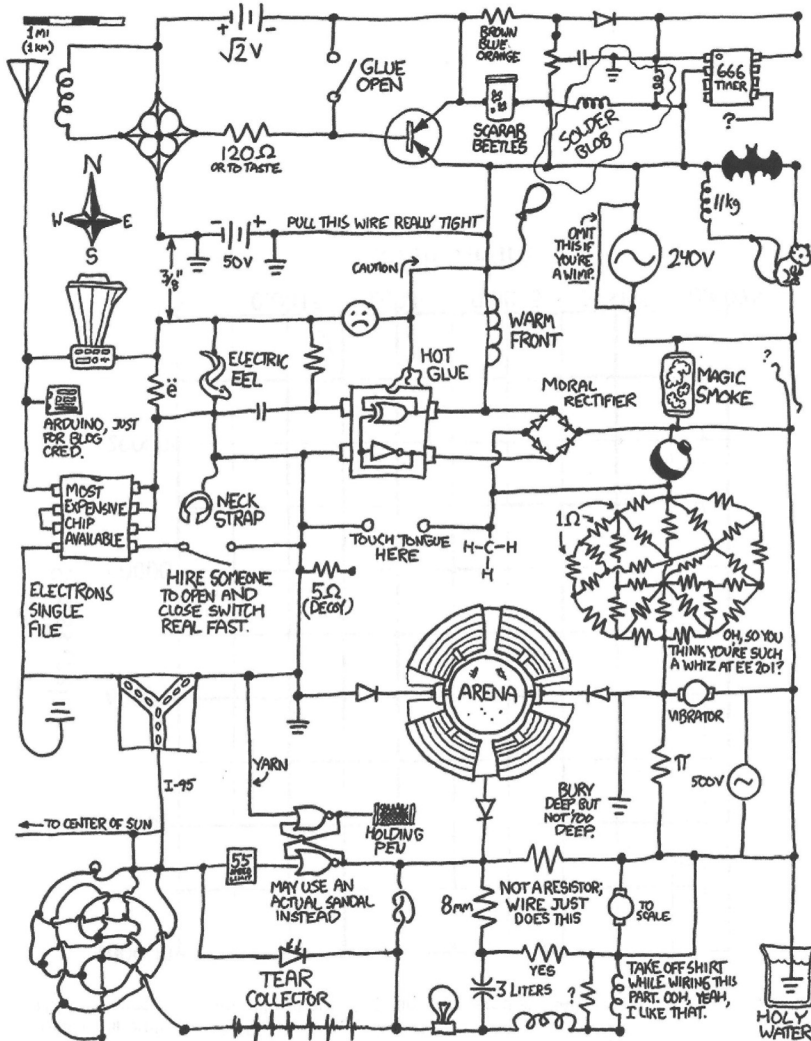
4.5 Summary

The example above describes some of the regulations and operations of a single governmental agency with jurisdictional authority. Details vary from organization to organization, and from standard to standard, with a wide range of regulations and enforcement styles. The most significant reasons for organizations achieving compliance are the desire to do the right thing or a concern regarding liabilities and/or jurisdictional enforcing actions.

Appendix C lists some Jurisdictional Agencies.

5. Standards development process

The need for developing a given standard arises from many sources, such as uniformity, conformity, and safety.



(Courtesy of XKCD, www.xkcd.com)

5.1 ANSI general consensus standards

A general consensus standard is developed as a result of a request that is deemed important to implement. Most organizations in the United States

use ANSI procedures, in some form or another, to develop standards. The following procedure, used by ASME, typifies the process.

- ✦ A request is made to ASME to develop a standard or a new rule within an existing standard.
- ✦ The ASME staff assigns a tracking item to the request and forwards it to the chairman of the appropriate Committee, such as the BPV Committee on Power Boilers (Section I), within one of the Standard Committees mentioned in 2.5.1, Boiler and Pressure Vessel Committee.
- ✦ The Committee chair assigns the proposal to a working subgroup to evaluate it. The subgroup normally consists of people who specialize in a given field such as design, materials, or fabrication.
- ✦ If the evaluation supports the need to develop a standard or a new rule then the subgroup assigns personnel to work on it.
- ✦ After completion, the standard is discussed at the subgroup level with participation from the public. Any comments or suggestions received must be discussed and voted on.
- ✦ The item then moves on to the appropriate Boiler and Pressure Vessel Standards Committee for further consideration. The personnel at the Committee level have a wider diversification in their background than personnel at the Subgroup level. Discussion at the Committee is also open to participation from the public.
- ✦ Following discussion at the Standards Committee, authorization is obtained to ballot the proposal as a standards action.
- ✦ A 30 day ballot is then sent to the appropriate Boiler and Pressure Vessel Committee for their approval. This ballot is also sent for review and comment by Technical Oversight Management Committee (TOMC) and the concerned Supervisory Board for review of the technical content and possible conflicts, etc. For proposals pertaining to the Nuclear Sections of the Code, the ballot is sent to the Board on Nuclear Codes and Standards. All others types of proposals are sent for review by the Board on Pressure Technology Codes and Standards.
- ✦ The public is given a formal review period for all proposed revisions to existing standards or new standards. The announcement for public review is made in the ANSI Reporter and on the ASME website. The public review period is 45 days and the proposals can be downloaded from the ASME website.
- ✦ The proposal is considered approved when two thirds of appropriate Standards Committee return an "Approved" ballot and there are no more than three outstanding "Disapproved" votes.
- ✦ The proposal is then sent to the concerned Supervisory Board for a procedural review. For proposals pertaining to the Nuclear Sections

of the Code, the review is done by the Board on Nuclear Codes and Standards. All others types of proposals are reviewed by the Board on Pressure Technology Codes and Standards. This review is the final step in approval process prior to accepting the proposal as a new Standard or new rule within an existing Standard.

The procedure above involves “due process” in developing the standards by including a wide sector of industry in writing the rules, and even providing for public comment. Many other organizations follow a similar procedure and process.

5.2 Government Non-jurisdictional Standards: DOD, NASA, etc.

In addition to those governmental standards that have force of law, essentially all governmental agencies produce standards used either internally or externally to aid in accomplishing their roles. Those used internally are to document and give structure to policies, procedures, and processes used inside the organization, while others are used in working with other organizations, typically contractors performing work for the government.

Process details vary widely among organizations. The nature of the Department of Defense, for example, leads it to be more hierarchical and top down than some of the other organizations. The Forest Service has a document structure that has standards that apply to different regions. Federal Highway Administration standards, while affecting the private sector, also come with money when they are implemented on a contract, so a less rigorous process may not be objected to by those affected. NASA follows a process so inclusive and rigorous that, except for being internal to the organization, it very nearly mimics the ANS process.

With this variability in process, it is to be expected that there will be a range of qualities among governmental non-jurisdictional standards, and this is indeed the case.

5.3 Corporate standards—public and proprietary

Most large corporations have internal standards used for daily operations. These standards may be categorized as either public or proprietary.

5.3.1 Corporate public standards

Public standards are used by corporations to inform the public and their customer base of information related to their product as discussed in Section 3.2. There are literally millions of such standards in both printed and electronic formats. These standards range in topics from computers and computer chips to pipes and fittings. Many of these company public standards become national standards as time goes on or are incorporated into existing standards. The standards are developed over some time and they may start with one product or service and then slowly increase in volume to cover a wider range of needs. Many of these standards can be accessed over the internet.

5.3.2 Corporate proprietary standards

All corporations have proprietary standards used for their operation as discussed in Section 3.2. Their development is necessitated by the need to operate consistently or deal with products in a systematic manner. These standards are typically kept proprietary in order to give the corporation an advantage over competitors, though it is sometimes a matter of simply not wanting them to be open to question by outside entities. In many cases these standards are purposely not patented for competitive reasons. This is because once a product is patented, that patent is public record, and at the end of the term of the patent others can use information in the patent to produce a competitive product. The development and fine tuning of these standards can take a long time and in many cases proprietary standards are considered intellectual property of the corporation. The development of these standards is done at various levels of the corporation and access to them is sometimes limited to an as-needed basis.

5.4 Limited consensus standards

Limited consensus standards are developed for the benefit of the members of a trade or technical association. Most, but not all, of these standards are accessible to the public. They are developed by various means such as an internal committee, a single individual or a single company within the organization. The formal development process proceeds along the following lines

- ✦ A request is made to the association by one of the members to develop a standard or a new rule within an existing standard for a desired entity.
- ✦ The staff forwards the request to a governing body.
- ✦ The governing body locates a resource for developing the proposed standard or a rule within an existing standard. This resource can be inside or outside the organization.
- ✦ The written proposal is evaluated by the governing body. It may be sent out for a second opinion.
- ✦ The proposal is voted on by members of the association.
- ✦ The standard is developed by the selected resource.
- ✦ The standard is voted on by the members of the association.
- ✦ If approved, the new standard is published.

5.5 International analytical programs

Numerous analytical programs are available for evaluating all sorts of engineering problems such as finite element analysis, fracture and flaw assessment, heat transfer solutions, mechanical designs, and fluid flow calculations. The majority of these programs have started locally and, over time, developed into major software applications, often used world-wide. While the

development processes varies from one program to another, they generally all have the following in common

- ✦ They start small in scope addressing one particular problem.
- ✦ As time goes by, they expand in scope based on input from users needing various solutions.
- ✦ In order to maintain a competitive advantage, many internal manipulations within the program are normally kept proprietary. An example is the inversion methodology of huge matrices in finite element analysis, and material data bases for fracture mechanics and fatigue evaluation.
- ✦ They all have well documented “base line” solutions based on analytical, theoretical and/or experimental analyses to validate the accuracy of solutions.
- ✦ Most of the international programs have technical support staff for helping with existing software or adapting it to problems not readily solvable with the software in its current form.

It should be pointed out that while many of the international programs are powerful and can perform incredible mathematical manipulations, it is still up to the designer to make sure that the results make sense. The adage “garbage in garbage out” must always be kept in mind. This is especially true in checking input and output of these programs.

6. Types of standards

6.1 Introduction

Standards are written differently depending on the culture of the organization developing them, the product or process they are defining, the capabilities or the organization implementing them, and numerous other factors. At one end of the range is the performance standard, at the other, the component standard. Midway between these is the prescriptive standard. While a standard does not typically include a statement of which type it is, each requirement within it typically falls fairly clearly into one of these three categories.

6.2 Performance standards

Performance standards are those that are written to define what must be accomplished. Writing a standard in this way allows the implementing organization a great deal of flexibility in how it chooses to comply. There are benefits to this approach, especially in those cases where the interfaces are minimal and what must be accomplished is easy to define. The risk is that not enough thought may be given to what is actually needed, and certain critical aspects of the product (process, etc.) may be left out of the standard. In this case, a fully compliant product may be produced and yet not fulfill what is truly needed.

For example, a standard for developing automobiles could be produced as a performance standard. It could be written in broad general terms such as:

- ♦ Construct a car that will carry four people in safe, quiet, efficient comfort

Such requirements are all valid, but many more are needed. Carry them where and how far? How big are these people? How heavy? Do they have luggage? Is the car enclosed? Does it have seat belts? How safe is safe, and how do you achieve it? Quiet for the passengers, or for those in the surrounding environment? What does “efficient” mean? Is it made of a particular material? Does it have turn signals? The additional potential requirements go on and on.

Performance standards can be particularly useful when what must be accomplished is known, the ways of accomplishing the task have not been extensively examined and tested through experience, and there are not extensive interfaces or other restricting elements and requirements.

6.3 Prescriptive standards

Prescriptive standards specify in detail what must be done. When the writer of the standard not only knows what must be accomplished, but also knows how it should be accomplished, then a prescriptive standard is likely to be appropriate. Most of the OSHA regulations are quite prescriptive. For

example, in the section on overhead and gantry cranes they say things like, "Fire extinguisher. Carbon tetrachloride extinguishers shall not be used," and "If sufficient headroom is available on cab-operated cranes, a footwalk shall be provided on the drive side along the entire length of the bridge of all cranes having the trolley running on the top of the girders." These are cases in which what is required can be clearly and unambiguously stated, and in which it makes sense to mandate consistency.

6.4 Component standards

Component standards are the ultimate in "prescriptiveness." They are used when the exact product required is known. They specify all the materials, dimensions, and other essential characteristics of the part, such that a component that meets the standard will work in the application, and will be completely interchangeable with all other such parts. Component standards define pipe sizes, bearings, flanges and fittings, electrical components, and many other essentials of daily life. These are the standards that allow one to go to the store and purchase a light bulb, having full confidence that upon returning home again he/she will be able to screw it into essentially any light fixture in the house, turn on the switch, and have light. A person can buy faucets that will fit the sink, and locksets for the doors, with similar confidence.

6.5 Hybrid standards

Other than for component standards, it is very common to use a combination of performance and prescriptive requirements. This is practical when some aspects of a product or process are, or can be, very well defined, while others remain open.

Returning to the example of the automobile above, certain aspects are "non-negotiables," while others are left entirely to the designer. Antilock brakes are required, but the details of the design are not fully defined by regulation. Many specific components are purchased to component standards, others are designed to prescriptive standards, and some aspects of the design are left almost entirely up to the engineer. This hybrid approach tries to take advantage of the strengths of each type of requirement, while minimizing the risks and drawbacks. The following examples illustrate this point:

In the 1970s, one of the large mainframe computer companies had entered the small computer market in the form of word processors to replace their electric typewriters. A small computer start-up company developed a similar small computer which had good graphics and sound capabilities as well as word processing and challenged the large computer company. Independently, from companies manufacturing game computers came the home computers in the early 1980s. Each of these other companies produced low cost computers using off the shelf 8-bit microprocessors with 64KRAM, and custom sound and graphic chips

placed in DIP sockets soldered on a printed circuit board and placed under an alphanumeric keyboard. They used a TV as a monitor and an external 5.25 inch floppy drive for data storage. They also had a slot for game cartridges.

Needless to say there was no attempt to unify the standards and interface between them, so the data stored on a floppy disk by one brand could not be read on a computer of one of the other brands. The exception was the serial port for game controllers and the parallel port for dot matrix printers. These were made compatible with the IEEE standards already in existence for industrial use at that time.

The importance of standards can be illustrated by the large computer company's entry into and exit from the personal computer market. This large computer company, up to that point mostly interested in the main frame computer market, decided to join the personal computer market in 1981 by introducing its own computer. They also decided to use off the shelf electronic components with a modular design. The breakthrough in the personal computers came when this large computer company threw its weight behind the development of the back plane bus architecture standard that independent vendors could use to interface their product to the CPU. These products included the RAM, the video card, the sound card, the hard drives, Modem and Ethernet cards for communications, A/D and D/A converters for industrial control, and other internal devices. Externally, the user interface devices such as keyboard, mouse, touch pad and joystick and other peripherals such as printers would interface through the standard serial and parallel ports. The only part that the large computer company made proprietary was the BIOS (basic input/output system). This was later developed by other vendors and made compatible with the large computer company design, making it possible for other PC compatible (clones) to be manufactured by other companies. So successful and popular was this open bus architecture that when the large computer company introduced the more advanced but proprietary Micro Channel Architecture (MCA) in its Personal System computers, it failed to secure sales and vendors refused to cooperate. In 2005 the large computer company sold its personal computer business to another company and exited the market.

Nevertheless the small challenger computer company held out on its own standard which made it harder for independent vendors to develop hardware for it, especially when some of those challenger company standards changed with model upgrades. Other PC makers changed the standards slightly by, for example changing the definition of one pin on the bus, to exclude independent manufacturers from competing with their hardware. However as the standard for the PC became universally accepted, non-compliant makers of PC makers fell out of favor with the public. Eventually even the small challenger computer company was forced to compromise and make compatible

CD/DVD and hard drive interfaces. Also communication hardware and protocols became universal allowing different computer brands to be networked. Currently there are hundreds, if not thousands of hybrid standards that address the computer market. Most of these are general-consensus standards but some are limited consensus. The following is a partial list of PC Hardware Standards:

- ACPI — Advanced Configuration and Power Interface
- AGP — Accelerated Graphics Port
- ATX — Advanced Technology eXtended
- DVI — Digital Visual Interface
- EISA — Extended Industry Standard Architecture
- Fire Wire (IEEE 1394)
- HDMI — High Definition Multimedia Interface
- IDE — Integrated Drive Electronics. Extended to ATA/ATAPI
- ISA — Industry Standard Architecture
- PCI — Peripheral Component Interconnect
- SATA — Serial ATA
- SCSI — Small Computer System Interface
- VESA — Video Electronics Standards Association
- UDI — Unified Display Interface
- USB — Universal Serial Bus

A partial List of PC Software Standards is as follows

- API — Applications Programming Interface
- CGI — Common Gateway Interface
- HTML — Hyper Text Markup Language
- HTTP — Hypertext Transfer Protocol
- MPI — Message Passing Interface
- ODF — Open Document Format
- PDF — Portable Document Format
- PNG — Portable Network Graphics
- POSIX — Portable Operating System Interface (IEEE)
- PS — Post Script
- RTF — Rich Text Format
- SQL — Structured Query Language
- SVG — Scalable Vector Graphics
- TWAIN — Technology Without An Interesting Name
- UDF — Universal Disk Format
- Unicode — Universal Code for text transfer
- WAP — Wireless Application Protocol
- WML — Wireless Markup Language
- XML — Extensible Markup Language

It must be noted that large companies often develop their own standards. While these must comply with the well-established national and international standards if the product is to be certified, certain process details necessary for use or production often remain proprietary. They deal with procedures and guidelines for design, manufacturing, testing, documenting and quality control. As such, they are the closely guarded intellectual property (IP) that distinguishes one company from another.

Companies making products for the government, especially the military, must often comply with strict specifications and standards referred to as MIL-Specs, though even the military has moved to accept industry standards.

Another example regarding hybrid standards is the Universal Serial Bus (USB) used in computers to communicate with various devices. Initially computer manufacturers used only ports that were compatible with their own peripheral equipment in an effort to control the market. However, the explosion in the peripheral market forced the computer manufacturers to consider adapting ports to fit peripherals made by other manufacturers. Intel came up with a protocol framework for USB which allows various devices to send whatever data they desire. Acceptance of the USB was slow in the beginning. Not everyone was on board. When a USB was plugged in a computer a message used to flash indicating “a driver is needed in order for this device to work.” However, as time went on, all of the operating systems (Windows, Mac, Linux, etc.) incorporated all major drivers by all device manufacturers. Initially a small USB group was formed to develop a standard. Many companies joined the group later, once the benefits of USB became obvious. Today, it is rare to plug in a device and NOT have a driver available to transmit data. The data consists of a well-defined Header packet that is standardized by a USB group. The group also standardized the physical dimensions, then the mechanical and electrical, then the protocol level. The standard was revised many times over the years to take advantage of hardware and software changes that allowed for significantly greater data transmission speeds and to fend off competition from other interface protocols that were also evolving, with issues 1.0, 1.1, 2.0, 3.0, and the current USB3.1. The current standard for the USB is over 600 pages long (www.usb.org).

6.6 Verification and validation process

One definition of Verification and Validation (V&V), given by IEEE standard 610, is

Validation: The process of evaluating software during or at the end of the development process to determine whether it satisfies specified requirements.

Verification: The process of evaluating software to determine whether the product of a given development phase satisfies the conditions imposed at the start of that phase.

Thus, validation deals with the question, “Have we correctly specified the product we are planning to build,” while verification deals with, “Does the product we are building meet the specification.”

Simply put, validation consists of processes implemented throughout the life cycle to ensure that the product being produced is correctly defined and specified, while verification consists of processes to make certain that the product is correctly built to meet the specification, requirements document, statement of work, etc.

Initially, the V&V process was used to assure that complex software programs do what they are supposed to in order to produce correct and accurate results. In recent years this process has been formalized as a quality assurance process used in software development to ensure that the final product does what it is supposed to. While the development of appropriate requirements for a product (software or otherwise) may be for the most part manageable, the complexity of software products, often with millions of lines of code, has become so great that it is often not practical, perhaps not even feasible, to check every possibility of how the product might work. V&V is one tool used to greatly enhance the chances that the product will work as planned.

As new industries develop and grow, it is common for standards to ensure the quality and/or safety of the products of those industries to develop and grow with them. An example of this has occurred with the software industry. ISO/IEC 12207:2008, Systems and Software Engineering — Software Life Cycle Processes, is an international standard used to ensure the quality of software products. It is notable that this standard was first issued in 1995 (relatively recently), and that it first came out as an international standard (as opposed to proprietary, or an individual country standard). The current standard includes 43 system and software processes dedicated to providing a common structure so that stakeholders in the software development process can use a common language in product development, procurement, and assessment, established in terms of the processes.

A portion of ISO/IEC 12207 deals with V&V, two of the processes used to ensure that software products are correctly specified and that they are built to meet the specification. These processes are a formalization by the software industry, tailored to the needs and capabilities of that industry, of an approach that has long been used in a wide range of industries to ensure that a product being developed meets its intended purpose. Whether in the software industry or elsewhere, when a complex product is produced, it is necessary to plan processes to ensure quality and to implement them throughout the life cycle of the product.

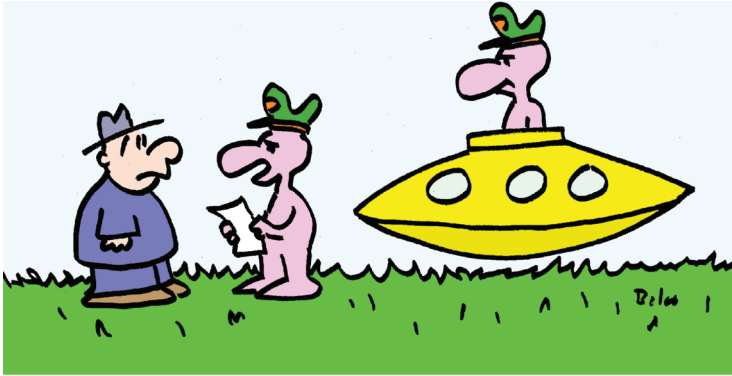
ASME is another organization heavily involved with writing standards related to V&V. Standards such as V&V in Computational Solid Mechanics, V&V in Computational Simulation of Nuclear System Thermal Fluid Behavior, V&V in Computational Fluid Dynamics and Heat Transfer, and

V&V in Computational Modeling of Medical Devices are examples of the V&V standards being developed by the ASME.

Currently, the V&V planning process is used for software development as well as other product development. The process must assure that key parties involved with the product development discuss, at key points during the development state, such items as progress, path-forward direction, and adjustments to the initial plan based on progress of the product. The discussion, by its nature, is based on negotiations and consensus among the primary stakeholders to assure a satisfactory product.

7. Standards interpretation and relief

7.1 General discussion



"We're from the Galactic Bureau of Standards, and this planet is way out of compliance!"

(Courtesy of cartoonstock.com)

As described in Chapter 2, standards are generally produced by experts in the field using a deliberate and rigorous process. The writers and the developing organizations make every effort to produce a product that is clear, concise, and complete. Unfortunately, knowledge is incomplete and even with the best of intentions it can happen that there is a need for further interpretation, explanation, or relief. Both the interpretation process and the process by which relief is acquired depend on the type of standard, the way it was adopted, and whether the standard itself includes provisions for relief.

There are times where an organization or a jurisdiction may need to take an exception to a recognized standard for product manufacturing or operation. This is usually formalized and documented with a variance or waiver (sometimes also referred to as deviations or tailoring). Waivers often involve complex issues and should only be pursued after careful evaluation of consequences as well as the amount of effort involved.

Use of the terms “variance” and “waiver” is somewhat ambiguous. Variance is generally fairly consistently defined, but in common usage the term “waiver” is frequently used in its place. The terms will be used interchangeably in this book:

Tailoring: the fitting of a standard to the particular needs, values, or priorities of a jurisdiction, organization, or program. Details of tailoring are given in Section 7.5.

Variance: an exception to a standard, regulation or ordinance, authorized by the appropriate authority having jurisdiction, such as the Occupational Safety and Health Administration, a planning commission, zoning board, county commissioners, or city council if jurisdictional. In some cases, particularly for non-mandatory standards such as voluntary consensus standards, variances may simply not be issued, and in others a deviation from the standard is addressed through what might be considered an interim or temporary change to the standard such as an ASME "Code Case."

For purposes of this book, mandatory standards are considered to be only those standards with force of law themselves (the law, regulation, ordinance, etc.). NCS invoked by the law, regulation, or ordinance are addressed as non-mandatory because not every jurisdiction requires compliance with them. In the current discussion corporate policies and standards are considered non-mandatory, since the corporation can choose to accept non-compliances from them, or can change them, at any time.

7.2 Standards adoption

Standards cover a wide range of activities, are produced by many different organizations, and are adopted in a number of ways. Company internal standards can be made mandatory within the company either through a formalized process or by simple dictate from a person with suitable authority. Jurisdictional standards become mandatory through action of legislative bodies, have the effect of law, and may in addition invoke application of national consensus standards (NCS). NCS become the standard for companies in several different ways, including company internal decisions, prerequisites for purchase of insurance, references in jurisdictional standards (generally referred to as regulations), and through direct legislative action. Those NCS that are imposed by regulations usually come to have essentially the same authority as the implementing regulation, and are usually accepted in their entirety, often without further comment. Those imposed by direct legislative action or adoption are sometimes accepted with modifications, deletions, or additions by the legislative body (see Section 7.5.2 on legislative tailoring).

7.3 Effect of non-compliance with standards

A variety of factors determine the effect of non-compliance with a standard. These include the type of standard, whether it is truly accepted as in industry standard, whether an organization has adopted it as policy, whether it is mandatory, whether it is regulatory, and how the non-compliance came about.

Under the OSHA regulations, an employer is responsible for the safety of its employees. That entity (assume for discussion that it is the system

owner) therefore has final responsibility with respect to OSHA, but it is usual for the owner to contract with various other organizations for the design and construction of a facility. While final safety responsibility remains with the owner, the form of the contract by which the owner purchases design and construction services can affect how responsibility is allocated among the entities performing design and construction. Unless the owner specifies all details of what standards are to be used in design, it is normally the responsibility of the designer or the entity in charge of the design to comply with jurisdictional requirements where the product is installed or operated. These requirements may specify something other than the latest edition of a code or standard. Also, many standards reference other standards within their text. These internally referenced standards also may not be the latest revision. Conflicts may also arise between two national standards regarding details of construction and the designer needs to be aware of which one controls in the jurisdiction where the product will be used. This situation occurs frequently in the case of alterations to pressure vessels where the original code of construction, say the ASME code, specifies certain radiographic examination, hydrotesting, and other NDT requirements, while the jurisdictional requirement using such standards as the NBIC or API 579 codes requires other provisions due to the particular difficulty or nature of the alteration.

Another example of a possible conflict is the use of building codes in construction. Until 1994 there were at least four major building codes used in the United States. The BOCA code (Building Officials Code Administrators) was used mainly on the East coast and in parts of the Midwest, the SBCCI code (Southern Building Code Congress International) was used mainly in the South and Southeast, and the UBC (Uniform Building Code) and ICBO codes (International Conference of Building Officials) were used mainly on the West Coast and in parts of the Midwest. The designer had to be aware of all of these codes and their regions of applicability. By 1997 all of these codes were combined into one code called the IBC (International Building code). However, some places still have unique requirements. For example, the State of California has its own building code called the CBC (California Building Code) that must be complied with, addressing special requirements for earthquakes and for green construction, for example.

Situations often arise where equipment and components such as pressure vessels built to an international standard, such as the ISO, are imported into some states in the United States. In such cases the laws in the given State are not complied with since the majority of the states in the United States have laws specifying the ASME code as the controlling standard for pressure vessels. The laws require a "variance" be issued prior to operating such equipment. Some states require this variance to be obtained from the State prior to fabrication of the equipment. The variance is granted by the Board on Pressure Vessels for the State and a "State Special" item number is issued

by the Chief Boiler Inspector of the State to be stamped on the name plate of the equipment. In the deliberation for issuing a variance the State Board on Pressure Vessels considers many factors such as

- ✦ Does the foreign standard cover all aspects of manufacturing such as design, materials, inspection, testing, and quality control?
- ✦ Is the foreign standard internationally recognized?
- ✦ Is the foreign manufacturer qualified to build in accordance with the foreign standard?
- ✦ Are the differences in requirements between the foreign code and ASME detrimental to safe operation of the equipment within the State?
- ✦ Are there other ASME requirements needed to supplement the requirements of the foreign code?
- ✦ Are there other State requirements needed to supplement the requirements of the foreign code?

The above process can be lengthy and the user should include a significant amount of time in the schedule for obtaining the required variance.

7.3.1 New products

Aside from the technical and cost issues involved, an important component in the decision whether or not to comply with a standard is the motivation for applying it in the first place. Sometimes, a non-conforming product or process is simply unsuitable and no relief from a standard should be pursued. In some cases a deviation from a standard may have essentially no consequences, with no one outside the organization ever becoming aware of, or caring about it. Other times, while performing its function in a suitable fashion, a product will look, feel, or operate differently from intended and the company itself rejects the waiver because of the image they wish to project to their customers. In still other cases the standard from which the deviation is proposed is jurisdictional. If this is the case, then the company must follow whatever formal relief process is required by the jurisdictional agency. If it does not, it will be at risk for whatever legal sanctions apply (usually fines, in some cases possibly criminal charges).

The related issue of a decision by a jurisdiction not to require compliance with a generally accepted standard illustrates some other consequences of non-compliance with a respected and time tested NCS. The State of Texas has decided not to mandate conformance of pressure vessels with the ASME Boiler and Pressure Vessel code. This is not a waiver or variance, but it involves many of the same issues as a waiver. Companies operating in Texas may install and operate non-code stamped pressure vessels without violating state law, but once this has been done issues other than the law become primary.

Liability can play a major role in decisions regarding equipment purchases. In case of a failure, experts will compare the design and operation of the failed

equipment to available products meeting a recognized standard. Deviation from the standard will almost certainly be questioned as to its appropriateness with respect to safety and engineering judgment. Injured parties may take sue for damages, and a jury is likely to be sympathetic to a plaintiff who can demonstrate that the responsible party was using equipment that did not meet generally accepted, though perhaps not mandatory, industry standards. While this book points out a few areas that may involve legal problems, it is not intended to provide legal advice. If there is a concern in this area, it is important that the user of the standard or product seek out appropriate legal assistance.

In cases in which the OSHA regulations do not specify the industry standard, OSHA can still cite an employer for not maintaining a safe workplace if they can demonstrate that the employer was not meeting industry standards for its operation. Also, while Texas does not require ASME code pressure vessels, in its 2006 report on the Marcus Oil and Chemical Tank Explosion, the United States Chemical Safety Board, which investigates such incidents, recommended that the City of Houston amend city building ordinances to require that newly installed pressure vessels comply with the ASME Boiler and Pressure Vessel Code, Section VIII, and repairs to comply with the National Board Inspection Code.

In addition to the concerns above, equipment in many plants must be insured prior to operation and most insurance companies require compliance with NCS prior to insuring the equipment (Some insurance companies take an active role in the development and maintenance of codes and standards, and even in the inspection of boilers themselves, both in plant for operation, and during manufacture). Thus in most cases pressure vessels operated by responsible organizations even in Texas wind up conforming to the ASME code, though the state does not require it.

Finally, it should be noted that there are certain types of standards from which waivers are probably rarely or never used. Fasteners, for example, either meet or do not meet their standards. Gears either meet or do not meet. Many non-critical applications use fasteners, for example, that are probably nominally in compliance with a standard. In many cases there is probably no verification of such compliance, and because often loads are not high and failure is not critical, many non-compliant fasteners may be in use. No waiver would be processed for fasteners in such an application, and conversely, a substandard component would simply be rejected if identified in a space flight or other critical application.

7.3.2 Post-manufacturing non-compliance

7.3.2.1 *General discussion*

Products manufactured in accordance with a standard may become non-compliant with the standard through aging, wear and tear, damage, or a change in the standard by the standards developing organization. Such non-compliance should be evaluated by the owning/operating organization, and

an assessment should be made of the consequences of the noncompliance, followed by a decision as to whether or not to upgrade the product in order to comply.

7.3.2.2 *Product degradation*

The consequences of degradation with time and usage may vary, depending on the type of system and its application. Two examples will be briefly discussed here: (1) wear in the lead screw of a milling machine, and (2) corrosion of the wall of a piping system.

Lead screws in a milling machine are those screws that drive the table on a milling machine left and right, in and out, or up and down. Such a component is manufactured in accordance with an appropriate thread standard, but it is also subject to wear. Typically, this wear takes place mostly in the center portion of the screw (because a mill is typically used for machining small components mounted at the center of the table). If this occurs, the average pitch of the screw over its length will not change, and depending on the type of wear, even the actual pitch may not change. There may be a change in the effective pitch of the screw, however, since the table location is driven by one side of the screw thread in one direction, and the other side in the other direction, and some portions of each side of the screw will be affected more than others.

If the sole means of ensuring accuracy of table position is by keeping track of turns of the screw (as in conventional machining and low cost numerical control conversions), then it is likely that accurate positioning of the table will suffer. Depending on the size of the component being produced and various choices made by the machinist, component errors may be minimal, but in certain cases the amount of wear on the screw can result in one-for-one variance of the work piece from its intended configuration (If the component is small enough that it is machined entirely within a portion of the screw with equal wear, tolerance errors due to lead screw wear may be insignificant or non-existent). Of course, if location is determined by a separate linear encoder, then the machine can compensate for the wear and the work piece will not be significantly affected by this type of wear. In any case, until the wear is so significant that a problem arises involving out of tolerance parts, such wear may not be a concern. In a case like this a company can make a rational decision to continue using a lead screw long after it is out of tolerance without in any way affecting its product. In addition, even if the product is affected, the company may choose to do nothing because the effects are not catastrophic. Effects on the quality of the product may be minor, if they exist at all, but if decisions on use of such equipment are made judiciously, it is likely that no laws are violated and no one is harmed.

In the case of a corroded pipe wall in a pressurized piping system, corrosion of the wall removes material that may be needed to ensure system integrity. Piping systems are constructed in accordance with appropriate

standards depending on their service. Further, those used in a corrosive environment are typically either built of corrosion resistant materials, or they are built with a corrosion allowance that is intended to provide a reasonable life for the system before safety factors are reduced to the extent that the pipe must be removed from service. The consequences of a piping failure due to degradation are more likely to involve significant injuries, property, and possibly environmental damage than those from something such as wear of a lead screw in a milling machine (the same could be said of wear in a mobile crane). Similarly, the risk associated with such a failure is commensurately greater, and the consequences of a piping failure due to reduced wall thickness are further multiplied by potential legal consequences due to failure to comply with regulations mandating compliance with NCS.

Thus, in each case a company has a need to monitor the state of its equipment as it is used, but in one case a component becoming non-compliant will entail much greater risk than in the other.

7.3.2.3 *Non-compliance due to changes in standards*

It is not unusual for a component or an installation to become noncompliant after purchase or installation due to changes in a standard. A common situation in which this occurs is in electrical wiring. The National Electrical Code (NEC) is continually being updated to keep pace with technology and increased demands for safety of society.

In most cases when a new edition of a standard is issued, a jurisdiction does not require update of existing installations to meet the requirements of the new edition. Thus when the NEC added a requirement for arc-fault breakers for residential electrical circuits serving bedrooms, while millions of homes became immediately non-compliant with the current edition of the standard, most were not non-compliant with laws, and no one had to retrofit their circuit breakers. First, there is almost always a lag between issuance of a code or standard and its implementation as mandatory by a jurisdiction, and second, even when a new edition of a standard is made mandatory, it is highly unusual that a jurisdiction requires upgrade unless a major modification or upgrade to a building or system is made.

Another perspective on this issue is illustrated by a particular change to the ASME BPVC. With the addition of Figure UCS-66 and associated textual changes in 1989, the ASME BPVC made significant changes in material toughness requirements and which service would require testing. When this occurred, while jurisdictions did not specifically require re-evaluation or upgrade of systems, there was ample reason for pressure vessel users at least to assess their pressure vessels. In this case, the change reflected a new awareness of a hitherto unrecognized hazard (brittle fracture at temperatures higher than previously realized), and a responsible user aware of the change would want to ensure the safety of its systems and personnel, and would perform at least a cursory evaluation in order to make rational decisions regarding risk.

7.3.2.4 *Post-manufacturing compliance*

Most engineering standards are created as requirements or guidance for manufacturing of new equipment, but equipment subject to service related degradation may be evaluated against them as well. Thus either the milling machine lead screw or the piping discussed above will be, if necessary, compared to the original standard to which it was produced. In the case of the machine lead screw, there is no jurisdictional requirement to meet the standard, and so a company is free to evaluate any non-conformance, determine its consequences on the components produced by the machine, and decide whether to repair or replace the screw. Certain piping systems are subject to jurisdictional requirements that impose codes and standards, and compliance with the standard in those cases is no longer a matter of choice.

Pressure vessels and piping are somewhat unique, in that there are post construction codes developed by the National Board of Boiler and Pressure Vessel Inspectors and the American Petroleum Industry that apply. These standards provide means of evaluating pressure vessels and piping subject to corrosion, erosion, fatigue, and other service related degradation for which restoration to like-new condition may not be possible, and they provide guidance as to whether the equipment must be repaired or replaced, or can be used as-is.

Repairing and altering such equipment at the present time may require multiple waivers and variances from the current standards. Various jurisdictions in the United States and Canada have provisions for repairing and altering pressurized equipment constructed to an earlier edition of the ASME BPVC. Numerous methodologies currently exist for repairing and altering older pressurized equipment. If one of these is followed, then insurance companies as well as jurisdictions, whether local, state, or federal (as, for example, OSHA), will generally be satisfied.

7.4 **Standards interpretation**

7.4.1 *Informal processes*

While some Standards Developing Organizations (SDO) (e.g., ASME; see 7.4.2 Formal interpretations) have well developed and formalized processes for responding to inquiries and issuing interpretations, others either have none, or they are not well publicized. Because in some cases the SDO and the user community are well known to each other, with some standards it is common for a person with a question simply to call a member of the SDO and solicit an opinion or an explanation of code issues. It should be noted, however, that an interpretation obtained in this manner is actually only an informed opinion from someone who is on the code committee, and such an interpretation cannot be expected to bind the SDO. This same approach is often used for organizational internal standards, where often there is a designated “owner” of a standard with some degree of administrative authority in addition to being, if not the writer, at least one of the writers of the

standard. In this case an informal interpretation may, at least sometimes, be expected to carry more weight.

7.4.2 Formal interpretations

7.4.2.1 *Interpretations of national consensus standards*

Committees in charge of standards often receive inquiries from users requesting interpretation of various aspects of the standard due to ambiguous language or lack of familiarity with the standard on the part of the user. The ASME Boiler and Pressure Vessel Code committee publishes, at regular intervals, interpretations clarifying the intent of the code. The intent of the interpretations is:

- ✦ To assist users to apply the code rules properly by clarifying ambiguous language
- ✦ Not to provide consulting advice
- ✦ Not to change or provide relief from requirements of the code

One drawback of interpretations is that they may be applicable only to a specific edition of a standard. Some interpretations become obsolete when a new edition of a standard is published with corrections to the ambiguity addressed in a given interpretation.

An SDO with a well-developed procedure for processing inquiries and interpretations is ASME. The Foreword (sic) to Section VIII, Division 1 of the ASME BPVC includes the following text:

“The committee meets regularly to consider revisions of the rules, new rules as dictated by technological development, Code Cases, and requests for interpretations. Only the Committee has the authority to provide official interpretations of this Code. Requests for revisions, new rules, Code Cases, or interpretations shall be addressed to the Secretary in writing and shall give full particulars in order to receive consideration and action (see Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees). . .”

The section on Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees clarifies that:

“Code Interpretations provide clarification of the meaning of existing rules in the Code, and are also presented in question and reply format. Interpretations do not introduce new requirements. In cases where existing Code text does not fully convey the meaning that was intended, and revision of the rules is required to support an interpretation, an Intent Interpretation will be issued and the Code will be revised.”

It also provides requirements for submittal of requests for interpretation, with details of what information is required in order for an inquiry to be considered.

Not all organizations are so organized for processing inquiries. In part this is a reflection of the type and content of the ASME BPVC, the fact that this code has been around since nearly the turn of the last century, and the values of the organization. ASME recognizes the respect accorded the ASME BPVC and other ASME standards. It recognizes the importance of users being able to understand their standards, and to receive authoritative interpretations if needed. Thus it has a policy giving priority at its meetings to responding to inquiries. First on the agenda at every meeting of a code committee, after administrative burdens are taken care of, is responding to inquiries. Not every inquiry can be answered at the first meeting after it is received, but every reasonable attempt is made to do so.

Conversely, while an inquiry is sometimes necessary, and SDOs typically try to give them priority, inquirers should also be aware of several issues related to inquiries: First, the nature of SDOs is such that they generally meet two to four times a year. Thus, even with the best of intentions regarding schedule, responses frequently take a year or more. Second, the response may be negative with respect to what the inquirer wants to do. It can be very discouraging to wait two years for an answer, then to find out that that answer is “no.” And, third, while some committees seem to provide particularly useful interpretations (ASME B16.34 Valves—Flanged, Threaded, and Welding End interpretations are particularly informative, for example), others, being particularly careful to avoid acting as consultants, provide interpretations that are sometimes difficult to decipher.

7.4.2.2 Interpretation of governmental regulations

As with NCS, jurisdictional regulations sometimes raise questions as to their exact meaning or application, and similar processes are used to provide interpretations. A letter can typically be sent to a jurisdiction, and a formal response be expected. In the case of OSHA, the letter is addressed to the Director, Directorate of Enforcement Programs. A response is made directly to the enquiring organization, and responses are also made available on the OSHA website (<https://www.osha.gov>). A similar approach is used by the Department of Transportation, with responses also published for general usage.

7.5 Tailoring

Tailoring is the fitting of a standard to the particular needs, values, or priorities of a jurisdiction, organization, or program. This can involve addition, removal, or modification of requirements. It can occur when requirements are costly to implement, when a new technology is not yet readily available, or when the organization decides that certain requirements are not applicable to its particular needs, or do not make sense for it. As discussed below,

tailoring is not without limits, as some standards are made mandatory by regulations, or are regulations themselves, and thus have the force of law.

7.5.1 Non-mandatory standards tailoring

An organization has the greatest flexibility for tailoring when a standard is not mandatory. If it simply chooses to follow a standard, then to some extent it can simply choose not to. Similarly, its own internal standards are written as they are because it best serves the organization, and when needs change, the internal standards can as well. Many governmental agencies have internal standards, and have a policy of revising, updating, or withdrawing them on a regular schedule.

It must be kept in mind that tailoring is typically used for a somewhat different purpose than a waiver, in that it fits the standard to specific needs of the organization, rather than just making an exception for a particular case.

7.5.2 Legislative tailoring

Legislative tailoring is typically done during the adoption process. If a jurisdiction determines that certain requirements of a standard have not demonstrated their value, it may choose to take exception to those particular requirements, while adopting the balance of the document. Similarly, the jurisdiction may choose to adopt the standard either with changes or additions to the published standard. Building departments sometimes produce standard designs to supplement the Uniform Building Code in order to facilitate certain aspects of construction, then allow a simplified permitting process if those designs are followed. When legislative tailoring is performed, the effect is to make the standard mandatory, but with the specified changes, giving the tailored standard the effect of law.

7.5.3 Governmental agency supplemental standards

The regulations of the Occupational Safety and Health Administration (OSHA) provide prescriptive requirements for worker safety in many areas, and top level requirements in others. Various portions of the OSHA regulations address different areas of employment, including general industry, construction, shipyard employment, and safety of federal workers. If a governmental agency employs workers in an area for which there are not specific applicable OSHA safety regulations, then the “general duty clause” applies and the agency must develop safety standards for their work in that area and submit them for approval in accordance with 29 CFR 1910.18. (There is no direct parallel for this for non-federal agency employers, as the employers are required to address the issue, but are not obliged to submit their resolution to OSHA.)

7.6 Waivers and variances

7.6.1 Waivers of corporate standards

While a corporate standard is in effect a policy of the company, and the company can therefore decide whether or not to follow it, there are practical

reasons why a formalized process is used if it is necessary to deviate from full compliance. Corporate standards are often put in place not only to ensure rigor in procedures, but also to give customers confidence in the quality of company products and processes, or as implementations of government regulations. An organization will want to make certain that waiving a policy will not result in either a substandard product or failure to comply with a government regulation, and the formalized waiver process is used to ensure that the consequences of a waiver have been recognized and adequately considered prior to approving the waiver. One undocumented deviation can lead to another, and if care is not taken, there may soon be effectively no policy at all.

Waivers from a corporate standard are typically utilized when a material, product, or process does not meet the standard requirements but can still be used safely and effectively. These waivers are sometimes approved by the person in charge of the particular corporate standard, but often companies use a Material Review Board (MRB) process by which products that would otherwise be considered substandard and be rejected are evaluated by one or more specialists in order to determine adequacy for use or sale. The MRB will consider the likelihood and extent of potential consequences of the deviation from the standard. They are usually most concerned with form, fit, and function. A positive disposition will normally require a positive evaluation in each of these areas. If the product basically looks the same (form), the interfaces are the same (fit), and it works just as if it did not contain the variation from the standard, it will usually be accepted.

Although money is always a consideration, no company should make a short sighted decision to accept a substandard component that will soon require replacement at company expense. Even worse would be a failure resulting in injuries, deaths, or even just property damage or productivity loss. A company is continuously aware of its reputation and will be reluctant to risk it in order to save what is in many cases a relatively small amount of money or time. Even a non-compliance with an internal or a non-mandatory policy that is accepted by a company can result in finger pointing and blame in the event of a mishap.

If a corporate standard is an implementation of a jurisdictional standard such as an OSHA regulation, then the substance of the waiver must be evaluated for compliance with that jurisdictional standard. If the alternate to compliance with the corporate standard is not in compliance with the regulation that it is intended to implement, then a waiver of the jurisdictional standard must be sought as well.

7.6.2 Code cases

Standards are normally updated at specified intervals. However instances arise where a component, a procedure, or a product may not fit exactly the requirements of the current controlling standard, and yet in the considered

opinion of the governing code committee the proposed approach appears reasonable. Sometimes there are no existing rules to cover the situation, or there may be rules, but because the particular issue simply had not been considered or allowed for, the rules may not allow it. There is a need for reasonable flexibility, but a committee may not be ready to change the code, or the need is urgent and the normal course of changing the code may take too long. A code case (the expression used by ASME for this type of relief) is a way of providing some flexibility. It allows new approaches to be tried out without a permanent commitment on the part of the code committee, either while the matter is studied further or just to allow time to assess the effectiveness of the approach. Development of a code case generally allows the submitting organization and any other to use that approach, although some jurisdictions do not automatically accept them. The use of a code case also provides a means of documenting and accepting interim changes prior to the formal scheduled revision of a standard.

Accordingly, many standards have provisions that accommodate such situations. In the ASME BPVC, this provision is accomplished by issuing code cases. These code cases are written at the request of an inquirer. They cover a specific material, product, analytical method, or fabrication process. Generally, the code cases are:

- ✦ Limited in scope.
- ✦ Intended to be temporary until the standard is updated or the need for the code case ceases to exist.
- ✦ Less restrictive (though generally no less safe) than the rules in the body of the standard.
- ✦ Published as a trial for a new analytical procedure or methodology. Comments received from the public will determine whether or not to revise the code case, incorporate it into the body of the code, or eventually annul it.
- ✦ Limited in duration. Rules of the boiler and pressure vessel committee require it either to annul the code case after a period of time or to incorporate it into the body of the code.

Code cases in the BPVC are approved by the same consensus process used to approve other code items. They are published by ASME in two separate documents, one for nuclear components and the other for non-nuclear components.

Because code cases do not typically follow the same schedule as code revisions, they fall outside the normal approval process of jurisdictions that may require use of the code. As a result, many jurisdictions do not accept them in their laws as part of the ASME BPVC, or they require individual approval by the authorized inspector or the jurisdiction itself. Accordingly, the designer has to be aware of the laws in the jurisdiction where the vessel is installed.

One source of information regarding laws in various jurisdictions is the National Board of Boiler and Pressure Vessel Inspectors in Columbus, Ohio. Its web site (<https://www.nationalboard.org/>) lists National Board members and Authorized Inspection Agencies, either of which should be able to provide assistance in various locations in the United States and Canada. If a Code Case is not accepted by a jurisdiction, then in order to apply it legally a company must seek and obtain the approval of the jurisdiction. This is separate from gaining approval of the applicable code committee.

7.6.3 Variances from jurisdictional standards

Jurisdictional standards are regulations, so they carry with them the force of law and associated sanctions for their violation. The governmental agencies promulgating these regulations (for example, OSHA, the Department of Transportation, and local building permitting boards) recognize this fact and their regulations include allowance for variances. The OSHA regulations will be used here as representative of the types of provisions that are made. While the requirements remain mostly the same, OSHA distinguishes between the federal government and other employers. For other than the federal government, relief from OSHA regulations is referred to as a variance, while federal government agencies are required to develop Alternate Standards if they wish to deviate from the standard.

Jurisdictions occasionally permit variances to existing standards in cases where these standards don't directly apply to a given product, in cases where part of the standard is deemed inappropriate by the jurisdiction, or when the variance requester demonstrates an alternate product or methodology that effectively accomplishes the goals of the standard. The following example illustrates this situation:

State laws generally require pressure vessels to comply with the ASME BPVC in order to be operated in the state. In those cases in which it is for some reason impossible to comply with the BPVC but in which the owner can demonstrate an equivalent level of safety, it is usual for the State to accept the vessel as a "State Special." This makes it legal for operation within the jurisdiction of that state, but if such a vessel is moved to another state, it will be necessary to seek another "State Special" authorization.

Similarly, pressure vessels constructed in accordance with the ASME BPVC but with a code case may need explicit approval of the jurisdiction if the jurisdiction has not already accepted that code case.

On occasion, pressure vessels for a proprietary process are built in a foreign country in accordance with that country's pressure vessel standards. The vessels may then be incorporated in a product and shipped to the location of use. In such instances the state frequently grants variances from the requirement to comply with the ASME pressure vessel code and accepts the foreign code of construction for this particular vessel. It should be noted

that in these cases the foreign code is only accepted because it has a level of credibility similar to that of the ASME BPVC, though it differs in details and application.

7.6.3.1 *General industry variances from OSHA standards*

7.6.3.1.1 Temporary variances allow time for an employer to meet a newly published requirement. This is provided for in the Code of Federal Regulations, 29 CFR 1905.10 and allows additional time when changes to a facility cannot be made quickly enough to comply with the specified effective date of the regulation.

7.6.3.1.2 Permanent variances allow an employer to use alternate means, on a permanent basis, if the employer can demonstrate that the workplace is at least as safe and healthful as would be provided by the standard from which the variance is sought (29 CFR 1905.11).

7.6.3.1.3 National defense variances allow reasonable variances, tolerances, or exemptions to avoid serious impairment of the national defense (29 CFR 1905.12).

7.6.3.1.4 Experimental variances are provided in Section 6(b)(6)(c) of the OSH Act of 1970 and authorize an employer to demonstrate new practices. *Note the similarity between an Experimental Variance to the OSHA Regulations and a Code Case to one of the ASME Codes.*

7.6.3.1.5 An Interim order may be granted during review of an application for either a temporary or permanent variance.

While this section describes five different types of variances allowed by the OSHA regulations, it should be noted that each type still requires demonstration that the employer will maintain a workplace at least as safe as that provide for by the regulations.

7.6.3.2 *Governmental agency alternate standards*

Essentially the same as a permanent variance for industry, federal government agencies may apply for an alternate standard to the OSHA regulations, provided they offer a workplace at least as safe as would be provided by compliance with the OSHA Act. Specific details of what must be submitted are provided in 29 CFR 1960.17.

7.7 **Summary**

With standards in existence affecting almost all aspects of engineering, it is inevitable that there will at times be a need for interpretation of, or relief from, standards. Several things should be considered before relief is requested:

1. Is there really a need for relief? This involves a careful reading of the standard to determine precisely what it means, and whether the supposed activity or product is really out of compliance with the standard. Waivers have sometimes been requested for compliant activities.
2. Is a request for interpretation in order rather than, or before, a waiver request?
3. Is there reason to expect that the request for relief will be approved? Is the product as safe and effective as a compliant one?
4. What are the broader implications of the non-compliance? Will it result in a lesser product? Potential liability or damage to a company's reputation? Possible failure to fit with compliant mating products at a later time?

If there is a valid reason to request relief, then such a request can make sense and there a good chance that it will be granted.

8. Characteristics of a good standard

8.1 Introduction

In Chapter 2, it is pointed out that standards are generally written to achieve safety and reliability, to reduce cost and increase flexibility, to promote business, and to help society function. A well written standard will accomplish these goals effectively. A poorly written one will accomplish them less well, and may even impede them. This chapter identifies those characteristics that make for an effective standard. These characteristics help in selection when there is a choice of standards, development when a new standard is needed, and effectively supplementing an existing standard with proper text in a specification, statement of work, or other contract documents.

8.2 Clarity and understanding

In order to achieve its intent, a standard must first be understood. This seems obvious, but since this discussion is related particularly to engineering standards, it may be more difficult to accomplish than it first appears. The nature of many engineering standards is technical, sometimes highly so. While not everyone will be able to understand fully the content of a technical document, a standard should be written, and provided with sufficient definitions, so that a technical competent user can understand it. Further, it should be written such that a person not well versed in the field, but taking time to read it carefully, can comprehend the general concepts and requirements, if not the technical details. In some cases this can be a challenge, as when a standard of limited scope in a specialized field makes reference to and has requirements for compliance with one or more similarly technical and specialized documents.

When responsibilities are assigned, the assignments should be unambiguous both with respect to the person responsible, and what he/she is responsible for. If there are special qualifications that go with assigned duties, these should be clearly indicated.

While a number of standards developing organizations make a practice of using “shall” for requirements, “should” for recommendations, “will” for expected consequences, and “may” for permissions, some organizations have other conventions. Whatever terms are selected should be clearly defined and assiduously used.

8.3 Scope

The scope of a standard ranges from very narrow and specialized to very broad. Whatever the case, it should be clear and well defined. The following two examples illustrate this:

Example 1: ASME SA-20, Specification for General Requirements for Steel Plates for Pressure Vessels, consisting of only 41 pages of the ASME BPVC Section IIA, includes common requirements that apply to 33 steel

plate specifications for fabrication of pressure vessels. It references 50 standards, including the 33 plate specifications as well as 17 standards related to terminology, testing and inspection, welding, marking, and handling. This standard defines within itself the requirements for how plate should be ordered, how it should be manufactured, test methods and reporting and retests, quality and rejection criteria, tolerances, marking, packaging requirements, etc. It leaves to the individual plate specification the actual chemical and physical properties, whether certain tests are required, and it leaves to the purchaser to identify any supplementary requirements, though it specifies many details for the case where supplementary requirements are specified. This standard has a fairly narrow scope.

Example 2: ASME B31.3, Process Piping (originally the Chemical and Petroleum Refinery Piping code), at over 500 pages, was developed “considering piping typically found in petroleum refineries; chemical, pharmaceutical, textile, paper, semiconductor, and cryogenic plants and related processing plants and terminals”. It applies to all fluids, but has clearly defined exclusions. It references hundreds of other standards, and hundreds more by references within those. It includes by reference the ASME SA-20 specification referred to above. This standard has a wide scope.

The difference in scope between these two standards is immense, but a study of each document reveals that the scope is clearly defined, and that each document addresses its scope without straying beyond. Further, across the scope of each document, the depth of treatment is relatively consistent. ASME SA-20 covers only the general requirements for certain steel plate material, while ASME B31.3 addresses the production of piping systems for a wide variety of applications and using a wide range of product forms. In order to maintain a consistent level of detail and to avoid a document running to thousands of pages, B31.3 makes reference to plate, bar, forging, pipe and tube, and other standards. These standards, in turn, reference others, including ASME SA-20, and SA-20, in its turn, requires compliance with other standards dealing with the rolling process, non-destructive evaluation, etc.

This approach allows a fairly concise document addressing the specific concerns of those involved with production of steel plates (in the case of ASME SA-20), or production of process piping (ASME B31.3). The details of how to perform NDE of the steel plates in the case of SA-20, or tolerances, NDE, etc. of those plates, in the case of B31.3, are included in reference standards that address the specific needs of those involved in those particular specialties.

8.4 Terminology

Use of specialized terminology, and of terms with a meaning different in the context of the document than in common speech, should be clarified. In this respect the document should be able to stand on its own. Specialized terms

and expressions may be unfamiliar to the general reader, yet may need to be used in order to convey accurately the intent of the document. The process of standard development typically includes discussions of which terms require definitions, and which ones are sufficiently understood from the common use of language or from definitions understood in the engineering field in general.

8.5 Structure and Organization

The structure of a standard is dependent in part on its content, but just as there is more than one way of structuring a corporation, there is more than one way of arranging information. For a standard addressing design and fabrication of a product, it is usual to provide a design section distinct from those sections addressing fabrication, inspection, testing, qualification, etc. It would, however, be possible to place the inspection requirements in a standard next to the aspect of fabrication to which each applies. Most standards follow the former organization. This approach seems to work well, though its use is partly for historical reasons (this is the way many standards have been written for the last century) and partly because so many of the supporting standards fit better with a document that is arranged this way.

Once a structure and organization is selected, it is important that it be followed, and whatever structure is followed, it should be logical, such that once a person becomes familiar with the standard, he/she will find information where it is expected. There should be no need to go on an extended search for requirements that clearly “must be there somewhere.” At least one standard exists in which not all the design requirements are found in the design section (some are in the testing section), and not all the testing requirements are found in the testing section (some are in the design section). This leads to confusion, much searching around, and the possibility that requirements will be missed by a user who is not thoroughly acquainted with the document. There are plans to correct this situation in the next revision of this particular standard, but the problem should never have arisen in the first place.

8.6 Consistency

Just as it is important to follow the selected structure of a standard, it is important that the standard be consistent. In developing a standard, particularly a complex one of any length, it is not unusual to address different aspects of an item in different places or sections of the document. Because these sections may be separated by a large amount of text, and may in fact be written by different authors because of the way work is divided, care must be taken to examine the document as a whole to ensure consistency. Standards developing organizations often find themselves in the position of addressing inquiries inspired by apparent inconsistencies, and even at times making changes to correct such inconsistencies. A particularly helpful aspect of organization of the ASME B31 piping codes is that each follows the same structure, so that the requirements for a particular aspect of piping design

or fabrication is found in the same paragraph in each of the codes, differing only in the first digit of the paragraph number, which reflects the “X” designation of the respective standards (for example, for ASME B31.3, paragraph numbers begin with 3).

8.7 References to other standards

Most engineering standards will require references to other documents and standards. This need should not prevent a standard being consistent, unambiguous, and fully covering its stated scope. As can be seen from the examples above, a standard need not explain every detail. Further, standards are designed to be used together to achieve their goals. When other standards addressing a particular aspect of the scope of a standard already exist, those other standards can help fill out the scope if properly referenced. This approach avoids both redundancy and contradictions. It saves development time and minimizes the need for deciding among multiple standards covering the same topic; and finally, it allows those already familiar with the referenced standard to proceed without the need to study another document.

8.8 Attention to details

It should perhaps not need mentioning, but the spelling, grammar and syntax, references and cross references, and every other detail of a standard should be thoroughly checked and rechecked. If “shall” has been selected as the term for an imperative, for example, then a word search should be made for every other likely term that may have slipped in, so that each can be corrected if needed. Many people will be depending on the quality of the product.

8.9 Supplementing a standard

When a standard is cited or otherwise put into effect by an organization, there may be a need either to provide additional guidance or to take exception to certain aspects. Whatever contractual terms are used should hew to the same level of quality that is expected of the standard itself. There is little value in having a clear, well thought out and documented standard which is not clearly invoked, leaving it unclear what the actual requirements are for a project or task.

8.10 Timelines

Often a standard is released for distribution prior to it being completely finished due to time constraints. This results in confusion on the part of the user and the end result is a reluctance on the part of the targeted audience to use it. When this situation occurs, the organization in charge of the standard scrambles to rewrite the standard by filling-in the voids and restructuring it. The end result is that it takes longer to release an incomplete standard and fix it than to wait and release a complete standard. Sufficient schedule time must be allowed in order to avoid this situation.

8.11 Summary

The quality of a standard is critical to its usefulness. The characteristics listed above are the basics needed to ensure a useful and effective standard. Each person or group developing a standard should give careful thought to every aspect of the product being produced, then follow through to ensure that their standard is of a quality such that they, and any other users, will find it effective and easy to use.

ACRONYMS

ACRONYM	NAME
A	Aluminum Association, The
AASHTO	American Association of State Highway and Transportation Officials
ABMA	American Bearing Manufacturers Association
ACI	American Concrete Institute
ACMA	American Composites Manufacturers Association
AGMA	American Gear Manufacturers Association
AHRI	Air-conditioning, Heating, and Refrigeration Institute
AIA	Aerospace Industries Association
AIAA	American Institute of Aeronautics and Astronautics
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
AITC	American Institute of Timber Construction
ANS	American National Standards
ANS	American Nuclear Society
ANSI	American National Standards Institute
API	American Petroleum Institute
ASA	Acoustical Society of America
ASABE	American Society of Agricultural and Biological Engineers
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
ASTM	American Society for Testing and Materials
ATIS	Alliance for Telecommunications Industry Solutions
AWC	American Wood Council
AWEA	American Wind Energy Association
AWS	American Welding Society
AWWA	American Water Works Association
BPVC	Boiler and Pressure Vessel Code
CGA	Compressed Gas Association
CISPI	Cast Iron Soil Pipe Institute
COPV	Composite Overwrapped Pressure Vessels
CPSC	The Consumer Product Safety Commission
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy

DOT	U.S. Department of Transportation
EJMA	Expansion Joint Manufacturers' Association
EPA	U.S. Environmental Protection Agency
EPRI	Electrical Power Research Institute
FAA	U.S. Federal Aviation Administration
FDA	U.S. Food and Drug Administration
HI	Hydraulic Institute
HPVA	Hardwood Plywall and Veneer Association
IBC	International Building Code
ICC	International Code Council
IEEE	Institute of Electrical and Electronics Engineers
LCS	Limited Consensus Standards
NACE	National Association of Corrosion Engineers
NASA	National Aeronautic and Space Administration
NBBI	National Board of Boiler and Pressure Vessel Inspectors
NBIC	National Board Inspection Code
NCS	National Consensus Standards
NEC	National Electric Code
NEI	Nuclear Energy Institute
NETA	InterNational Electrical Testing Association
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
NSF	National Science Foundation
OSHA	United States Occupational Safety and Health Administration
PCA	Portland Cement Association
PSM	Process Safety Management
SAE	Society of Automotive Engineers
SDO	Standards Developing Organization
TEMA	Tubular Exchanger Manufacturers' Association
TMS	The Masonry Society
UL	Underwriters Laboratories
USB	Universal Serial Bus

APPENDIX A: SOME AMERICAN AND INTERNATIONAL STANDARDS ORGANIZATIONS DEVELOPING GENERAL CONSENSUS STANDARDS

Acronym	Organization	Web Site
A	Aluminum Association, The	www.aluminum.org
ABMA	American Bearing Manufacturers Association	www.americanbearings.org
ACI	American Concrete Institute	www.aci-int.org
ACMA	American Composites Manufacturers Association	www.acmanet.org
AENOR	Spanish Association for Standardisation and Certification	www.en.aenor.es
AFNOR	Association Francaise de Normalisation	www.afnor.fr
AGMA	American Gear Manufacturers Association	www.agma.org
AHRI	Air-conditioning, Heating, and Refrigeration Institute	www.ahrinet.org
AIA	Aerospace Industries Association	www.aia-aerospace.org
AIAA	American Institute of Aeronautics and Astronautics	www.aiaa.org
AISC	American Institute of Steel Construction	www.aisc.org
AISI	American Iron and Steel Institute	www.steel.org
AITC	American Institute of Timber Construction	www.aitc-glulam.org
ANS	American Nuclear Society	www.ans.org
API	American Petroleum Institute	www.api.org
ASA	Acoustical Society of America	www.acousticalsociety.org
ASABE	American Society of Agricultural and Biological Engineers	www.asabe.org
ASCE	American Society of Civil Engineers	www.asce.org

ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers	www.ashrae.org
ASME	American Society of Mechanical Engineers	www.asme.org
ASNT	American Society for Nondestructive Testing	www.asnt.org
ASTM	ASTM International	www.astm.org
ATIS	Alliance for Telecommunications Industry Solutions	www.atis.org
AWC	American Wood Council	www.awc.org
AWEA	American Wind Energy Association	www.awea.org
AWS	American Welding Society	www.aws.org
AWWA	American Water Works Association	www.awwa.org
BIS	Bureau of Indian Standards	www.bis.org.in
BSI	British Standards Institute	www.bsigroup.com
CENELEC	European Committee for Electrotechnical Standardization	www.cenelec.eu
CGA	Compressed Gas Association	www.cganet.com
CGSB	Canadian General Standards Board	www.tpsgc-pwgsc.gc.ca
CISPI	Cast Iron Soil Pipe Institute	www.cispi.org
DIN	Deutsches Institut für Normung e. V.	www.din.de
EPRI	Electrical Power Research Institute	www.epri.com
EU	European Union	www.ec.europa.eu/enterprise/policies/european-standards
GOST	Russian Federal Agency on Technical Regulating and Metrology	www.gost.ru
HI	Hydraulic Institute	www.pumps.org
HPVA	Hardwood Plywall and Veneer Association	www.hpva.org
ICC	International Code Council	www.iccsafe.org
IEC	International Electrotechnical Commission	www.iec.ch

IEEE	Institute of Electrical and Electronics Engineers	www.ieee.org
IRAM	Instituto Argentino de Normalizacion y Certificacion	www.Iram.org.ar
ISO	International Organization for Standardization	www.iso.org
JISC	Japanese Industrial Standard Committee	www.jisc.go.jp/eng
KATS	Korean Agency for Technology and Standards	www.kats.go.kr
NACE	National Association of Corrosion Engineers	www.nace.org
NBBI	National Board of Boiler and Pressure Vessel Inspectors	www.nationalboard.org
NEI	Nuclear Energy Institute	www.nei.org
NETA	InterNational Electrical Testing Association	www.netaworld.org
NFPA	National Fire Protection Association	www.nfpa.org
PASC	Pacific Area Standards Congress	www.pascnet.org
PCA	Portland Cement Association	www.cement.org
SAC	China Standardization Administration	www.sac.gov.cn
SAE	Society of Automotive Engineers	www.sae.org
SCC	Standards Council of Canada	www.scc.ca
SIS	Swedish Standards Institute	www.sis.se
TMS	The Masonry Society	www.masonrysociety.org
UL	Underwriters Laboratories	www.ul.com
UNI	Italian Organization for Standardization	www.uni.com

APPENDIX B: SOME INDUSTRIAL ORGANIZATIONS THAT PUBLISH LIMITED CONSENSUS STANDARDS

Acronym	Organization	Web site	Standard(s)
ABMA	American Boiler Manufacturers Assoc.	www.abma.com	various boiler publications
EJMA	Expansion Joint Manufacturers Assoc.	www.ejma.org	expansion joint standards
HEI	Heat Exchange Institute	www.heatexchange.org	heat exchange and vacuum apparatus
TEMA	Tubular Exchanger Manufacturers Assoc.	www.tema.org	construction of exchangers

APPENDIX C: JURISDICTIONAL AGENCIES

Acronym	Organization	Web site
CPSC	Consumer Product Safety Commission	www.cpsc.gov
DOE	US Department of Energy	www.doe.gov
DOT	US Department of Transportation	www.dot.gov
EERE	Office of Energy Efficiency & Renewable Energy	www.energycodes.gov
EPA	US Environment Protection Agency	www.epa.gov
FAA	Federal Aviation Administration	www.faa.gov/
FDA	Food and Drug Administration	www.fda.gov
FEMA	Federal Emergency Management Agency	www.fema.gov
FHWA	Federal Highway Administration	www.fhwa.gov/
FMCSA	Federal Motor Carrier Safety Administration	www.fmcsa.dot.gov/
FRA	Federal Railroad Administration	www.fra.dot.gov/
FTA	Federal Transit Administration	www.fta.dot.gov/
NHTSA	National Highway Traffic Safety Administration	www.nhtsa.gov/
NRC	Nuclear Regulatory Commission	www.nrc.gov
OSHA*	Occupational Health and Safety Administration	www.osha.gov
PHMSA	Pipeline and Hazardous Materials Safety Administration	www.phmsa.dot.gov/

*A number of states have their own Occupational Safety and Health Administrations that have been approved by OSHA. These typically have their own version of the OSHA regulations.

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