Performance (Technical) Report for The Periods Ending March 31, 2024
The Recipient organization name: Texas A&M university - Kingsville
NIST award number: 70NANB23H239
Reporting period: October 1, 2023 - March 31, 2024
Project Title: Develop, Implement and Integrate Standard Education Modules in Mechanical, Chemical and Electrical Engineering Curricula.

The **goal** of this project is to improve Mechanical, Chemical Engineering and Industrial Management & Technology curricula through developing course modules which will implement and integrate standard and standardization knowledge related to mechanical, chemical and Industrial Management & Technology to educate and prepare engineering undergraduate and graduate students on the impact and value of standards and standardization.

The **objectives** of this project are to: (i) familiarize students with the standard and standardization process. (ii) guide students identifying appropriate standards for a specific component or system design or manufacturing or testing. (iii) educate students to design components or systems using related standards. (iv) enhance students' interest in using standards in future career.

To fulfill the above objectives, sixteen course modules related to standards and standardization was proposed to be developed and integrated in sixteen undergraduate and graduate courses encompassing mechanical, chemical and industrial management & technology curricula. Five webinars on standard and its application in mechanical, chemical and industrial management & technology were proposed to be developed for students as well as other interested individuals from industry.

Activities and Achievements:

1. One Co-principal investigator (Co-PI) has been moved to another university. To replace that Co-PI, another Co-PI has been selected and approved by NIST.
2. Two Graduate students were hired to work with the faculties on this project to assist the development of the modules.
3. Six (6) modules have been developed and implemented in six courses. The modules are attached in Appendix A.
4. Five (5) webinars have been organized and presented. Five speakers from the industry have been selected and invited to present on Standards, their importance, and applications in webinars. The students and faculties were also invited. The attended students were provided with extra credit for their attendance. The students benefited from the webinars about the standards and applications. The webinars flyer and presentations are attached in appendix B.

Recipient Contact Information:
Principal Investigator:
Shah Alam, Ph.D., P.E.
Associate Professor
Dept. of Mechanical and Industrial Engineering
Texas A&M University - Kingsville
Kingsville, TX 78363-8202
Phone: (361)593-2459, Fax: (361)593-4026
Email: shah.alam@tamuk.edu

APPENDIX A

MODULE 1

Implemented Course

MEEN 3360 - Engineering Design and Simulation**:** Introduction to the engineering design process via team-based projects utilizing commercial Computer Aided Engineering software packages. Engineering design process, problem definition, conceptual design, modelling, analysis, system design, and optimization. Communicating the design via drawings, models, verbal, and written reports.

Used Standard and Code

ASME Boiler and Pressure Vessel Code (BPVC), Section VIII, Div. 2.

What are Standards and Standardization?

Standards: These are established benchmarks or rules that define the characteristics, performance or quality of products, services, processes or systems. Standards can cover a wide range of areas, Including technology, safety, manufacturing. Engineering Standards provides uniformity, quality, compatibility, interchangeability and Interoperability among components, systems and processes. Standards ensure the safety, quality and reliability of products and services.

Engineering professionals use these standards as guidelines and reference in design, manufacturing and testing of Mechanical components and systems. Compliance with these standards is critical to ensure products Quality, Safety, Regulatory Compliance in the field of engineering.

Standardization: This Is the process of creating, updating and adhering to standards. It involves Collaboration among experts, organizations, and stakeholders to set common rules and guidelines. Standardization helps to ensure that products and services are compatible and meet certain quality and safety standards.

Standardization is the process of Implementing and developing technical standards based on the consensus of different parties that Include firms, users, Interest groups, standards organization and governments. Standardization is the process of developing, mandating standards-based and compatible technologies and processes within an Industry.

Importance of standards and Standardization

The standards ensure that goods or services produced in a specific industry come with the consistent quality and are equivalent to other comparable products or services in the same industry. Standardization also helps in ensuring the safety, Interoperability, and compatibility of goods produced. Standards and Standardization plays a crucial role in various aspects of our modern world and their Important Is Multifaceted.

1. **Quality and Safety:** Standards help to ensure the quality and safety of products, services and processes. They set benchmarks for performance and reliability, reducing the risks of defects and harm to consumers and users.
2. **Interoperability:** Standards enable different products and systems to work together seamlessly. This is particularly Important in Technology where compatibility ensures that devices and software from various manufacturers can communicate and operate without Issues.
3. **Innovation:** Standards provide a foundation for Innovation by offering a common set of rules and specifications.
4. **Trade and globalization:** International standards facilitate global trade by ensuring that products and services can be easily exchanged across borders. They remove technical barriers to trade and promote economic growth.
5. **Efficiency:** Standardization leads to efficiency improvements in various sectors. When everyone follows the same guidelines, resources are used more efficiently, and processes become streamlined.
6. **Consumers' confidence:** Standards help to build consumer confidence. When consumers know that products and services adhere to recognized standards, they are more likely to trust and purchase them.
7. **Environment Impact:** Standards can promote sustainability and reduce the environmental impact of Industries by setting guidelines for energy efficiency, waste reduction and sustainable practices.
8. **Cost reduction:** It can lead to cost reduction by eliminating the need for a custom solution. Mass production of standardized components often results in economics of sales.

Standards Development and Modification Process

The Development of Engineering Standards is a critical process that ensures the quality, safety and compatibility of engineering products and systems. Developing and Modifying standards typically follows these general steps:

1. **Identifying The Need**: Standards are often developed or modified in response to changing technology, industry needs and practices, safety concerns, or regulatory requirements. The process begins by identifying the specific need for a new engineering standard or a modification to an existing one.
2. **Formation of a Technical Committee**: An organization or standards body, such as the International Organization for Standardization (ISO) or the American National Standards Institute (ANSI), establishes a technical committee or working group with relevant experts and stakeholders. This group is responsible for developing or revising the standard.
3. **Drafting the Standard**: The technical committee begins drafting the standard. This involves researching existing standards, specifying technical requirements, guidelines, conducting technical studies, and seeking input from various stakeholders, including industry experts, government agencies, and consumer groups and procedures that need to be followed in engineering processes.

4. **Public Review and Comment**: The draft standard is typically made available for public review and comment. This allows a broader range of stakeholders, Including Engineers, Industry professionals, to provide feedback and suggestions for improvement.
5. **Revision and Consensus Building**: The technical committee reviews the public comments and revises the standard accordingly. The goal is to achieve a consensus among stakeholders, which may require multiple rounds of revisions and discussions.
6. **Approval and publication**: Once a consensus is reached, the standard is approved by the standards body. It is then published and made available to the engineering community and public. The standard is often updated with a version number and date.
7. **Implementation**: Industries, organizations, engineering firms and regulatory bodies may adopt and implement the new or revised standard. Compliance with these standards can become mandatory in some cases depending on the industry.
8. **Maintenance and Review**: Standards are not static; they need to be periodically reviewed and updated to stay relevant. Technical committees continue to monitor developments and make necessary modifications.
9. **International Adoption** (**International Standards**): In the case of international standards, such as those developed by ISO, member countries may adopt and implement the standard, often with some adjustments to align with local regulations.

It's important to note that the specific steps and processes can vary depending on the standards organization and the nature of the standard being developed or modified.

Major type of standards used in Mechanical Engineering

In mechanical engineering, various types of standards are used to ensure safety, quality, and compatibility. These standards cover a wide range of aspects within the field, including:

1. Material Standards: These standards specify the properties and composition and characteristics of materials used in mechanical components, ensuring that they meet specific materials strength, hardness, material testing, durability, and performance requirements. Organizations like ASTM (American Society for testing and materials) provides Material Standards.

2. Dimensional Standards: Dimensional standards define size, tolerances, fits, and geometric parameters for mechanical parts, ensuring they fit and function properly when assembled. For example - ISO-286 Standards defines the standard system for fits and tolerance.

3. Safety Standards: Safety standards focus on ensuring the safe operation of mechanical equipment and systems, particularly in fields like industrial machinery, pressure vessels, and lifting equipment. Organizations like ANSI (American National Standards Institute) and OSHA (Occupational safety and health administration) provides safety guidelines to prevent accidents and to protect workers.

4. Quality Management Standards: Standards like ISO 9001 provide guidelines for establishing, maintaining and improving quality management systems in engineering processes, ensuring consistent quality and performance. They provide a framework for quality management systems.

5. Testing and Inspection Standards: These standards dictate testing methods and inspection procedures to assess the quality and integrity of mechanical components and systems.

6. Fastener Standards: Standards for bolts, nuts, screws, and other fasteners ensure compatibility and performance in various applications.

7. Piping and Fluid Handling Standards: These standards cover the design and installation of piping systems, including codes for pressure vessels and piping materials.

8. Welding Standards: Standards for welding processes and procedures ensure the structural integrity and safety of welded joints.

9. Electrical and Electronic Standards: In cases where mechanical systems involve electrical or electronic components, standards from organizations like IEEE and IEC may apply.

10. Vehicle and Aerospace Standards: Standards from organizations like SAE cover design, safety, and performance requirements for automotive, aerospace, and transportation-related components.

11. Environmental Standards: In cases where mechanical systems impact the environment, standards may include regulations related to emissions, noise, and other environmental factors.

These standards help to ensure that mechanical engineering projects meet safety, quality, and performance requirements while allowing for interoperability and compliance with regulations in different industries and regions.

Standards database and search standards.

A standards database is a repository or collection of standardized documents that contain specifications, guidelines, and requirements for various industries, products, processes, and services. These databases serve as valuable resources for professionals, organizations, and regulatory bodies to access and reference applicable standards. Here are some key aspects of a standards database:

1. **Types of Standards**: Standards databases encompass a wide range of standard types, including technical specifications, safety standards, quality management standards, environmental standards, and more. These standards can relate to various fields such as engineering, manufacturing, healthcare, and information technology.

2. **Centralized Access**: Standards databases provide a centralized platform for accessing a vast array of standards. They may be hosted by standards organizations like ISO, ASTM, or national standards bodies like ANSI in the United States.

3. **Search and Retrieval:** Users can search for specific standards by title, number, keyword, or industry. Many databases offer advanced search features to help users find relevant standards efficiently.

4. **Document Access**: Users can typically access full-text versions of standards documents, which detail technical specifications, procedures, and requirements. Some databases offer free access to basic information and charge for full document downloads.

5. **Updates and Revisions**: Standards databases often include information about the status of standards, including the latest revisions, amendments, or proposed changes. This ensures that users are aware of the most current versions.

6. **Metadata and Information**: Standards databases include metadata about each standard, such as its title, number, date of publication, and the organization responsible for its development.

7. **Categorization**: Standards are usually categorized by industry, sector, or subject matter, making it easier for users to navigate and find the standards that apply to their specific needs.

8. **Subscription Services**: Some standards databases offer subscription services, which provide access to a broader range of standards and additional features. Organizations often subscribe to these services to ensure they have access to the latest standards relevant to their industry.

9. **Regulatory Compliance:** Many industries and regulatory bodies mandate compliance with specific standards, and standards databases help organizations and professionals stay informed and aligned with these requirements.

Common examples of standards databases include:

ISO Standards Database: Maintained by the International Organization for Standardization, it provides access to international standards in various domains.

ASME Standards: Developed by American Society of Mechanical engineers, these standards covers a wide range of topics, including boilers and pressure vessel codes, piping standards and various mechanical components.

ANSI Standards Portal: Offered by the American National Standards Institute, it provides access to U.S. and international standards.

IEEE Xplore: Focused on standards in the field of electrical and electronic engineering.

SAE Standards: The society of Automotive Engineers, creates standards for automotive and aerospace industries, covering areas such as materials, fastener and Vehicles design.

ASTM Compass: Maintained by ASTM International, it offers access to wide range of standards, Including those related to materials, construction and engineering practices.

NIST Standards Reference Database: Provided by the National Institute of Standards and Technology, it includes various types of standards relevant to science and technology.

Access to standards in these databases often involves licensing, subscription fees, or purchase of individual standards, but some basic information may be freely available to the public.

Searching Standards: Searching for standards involves finding specific documents or technical specifications that apply to a particular industry, product, process, or service. Here are the general steps to search for standards effectively:

1. **Identify Your Needs:**

Determine the subject area or industry for which you need standards. Be clear about the specific standard you're looking for, if applicable.

2. **Choose a Standards Database or Source:**

Select a reputable standards database or source that is relevant to your needs. Common sources include the International Organization for Standardization (ISO), IEEE Xplore, national standards bodies, and industry-specific organizations.

3. **Use Keywords and Phrases:**

If you have a specific standard in mind, search by its title or number. Use relevant keywords and phrases related to your subject. For example, "ISO 9001" for quality management or "ASTM D123" for a specific material testing standard.

4. **Filter and Refine Your Search:**

Many standards databases offer filters to narrow down search results. You can filter by industry, publication date, document type, or organization.

5. **Review Search Results:**

Examine the search results to find standards that match your criteria. Pay attention to the standard number, title, and description to ensure it meets your needs.

6. **Access Full Details:**

Click on the standard of interest to access more detailed information. Check for the publication date to ensure it's the most recent version.

7. **Download or Purchase:**

Depending on the source, you may have options to download the standard immediately, purchase it, or access it through a subscription if required.

8. **Check for Revisions or Amendments**:

Ensure that the standard you're considering is the latest version. Standards are periodically updated, and it's important to stay current with the most recent revisions.

9. **Verify Applicability:**

Confirm that the standard you found is relevant to your project, industry, or regulatory requirements. Not all standards may apply to your specific situation.

10. **Comply with Licensing or Copyright Restrictions:**

Be aware of any licensing or copyright restrictions associated with the standards you access. Compliance with usage terms is important.

10. Keep Records:

Maintain records of the standards you access, including their titles, numbers, and publication dates, for reference and compliance purposes.

It's important to choose the appropriate standards body or organization that aligns with your industry or area of interest. Additionally, consider whether you need to access international standards or national standards, as well as whether a subscription service may be beneficial for ongoing access to standards in your field.

Standards Development Organizations or Societies.

Standards development organizations (SDOs) or societies are entities responsible for creating and maintaining standards that define technical specifications, guidelines, and best practices in various industries and fields. These organizations play a crucial role in ensuring safety, quality, and interoperability across different sectors. Here are some prominent standards development organizations and societies:

1. **International Organization for Standardization (ISO):**

ISO is a global body that develops international standards covering a wide range of industries, from technology and safety to environmental management.

2. **American National Standards Institute (ANSI):** ANSI is the primary standards body in the United States, facilitating the development of standards for numerous sectors, including engineering, IT, and healthcare.
3. **International Electrotechnical Commission (IEC):** IEC focuses on electrical and electronic standards and collaborates with ISO to create standards applicable to a wide array of industries.
4. **American Society for Testing and Materials (ASTM International):** ASTM develops standards for materials, products, systems, and services in industries like construction, manufacturing, and more.
5. **Institute of Electrical and Electronics Engineers (IEEE)**: IEEE is known for its standards in electrical and electronic engineering, including IEEE 802 series for networking and communication.
6. **American Society of Mechanical Engineers (ASME):** ASME creates standards for mechanical engineering, covering pressure vessels, piping, and numerous other aspects of mechanical design and safety.
7. **National Fire Protection Association (NFPA)**: NFPA develops fire and life safety codes and standards, including the National Electrical Code (NEC) and NFPA 70E for electrical safety.
8. **American Petroleum Institute (API):** API is responsible for standards in the oil and gas industry, covering equipment, safety practices, and environmental protection.
9. **International Telecommunication Union (ITU):** ITU specializes in telecommunications and information and communication technologies (ICT) standards.

10. **Society of Automotive Engineers (SAE International):** SAE creates standards for the automotive and aerospace industries, ensuring safety and performance.
11. **International Civil Aviation Organization (ICAO)**: ICAO develops international standards for civil aviation, covering everything from aircraft design to air traffic management.
12. **Pharmaceutical Research and Manufacturers of America (PhRMA):** PhRMA sets standards for the pharmaceutical industry, including guidelines for drug development and manufacturing.
13. **International Maritime Organization (IMO):** IMO establishes international standards for maritime safety, security, and environmental protection.
14. **Food and Drug Administration (FDA):** The FDA in the United States sets standards for food, drugs, and medical devices to ensure public health and safety.
15. **National Institute of Standards and Technology (NIST):** NIST provides standards and guidelines for various industries and technologies, including cybersecurity and metrology.

These organizations collaborate with experts, industry stakeholders, and government bodies to develop, review, and update standards that drive innovation and promote safety and quality in their respective fields. Standards developed by these organizations often serve as the basis for regulations, product certifications, and best practices worldwide.

ASME Boiler and Pressure Vessel Code (BPVC), Section VIII, Div. 2.

The ASME boiler & pressure vessel code (BPVC) is an American Society of Mechanical Engineers (**ASME**) standard that regulates the design and construction of boilers and pressure vessels. Since its first issuance in 1914, ASME's BPVC has pioneered modern standards development, maintaining a commitment to enhance public safety and technological advancement to meet the needs of a changing world. This "International Historic Mechanical Engineering Landmark" now has been incorporated into the laws of state and local jurisdictions of the United States and nine Canadian provinces. The following is an example of use of this code.

Example 1: Design a pressure vessel for design condition given in Table 2 according to ASME boiler and pressure vessel code [4].

Table 2: **Design Conditions**

Design parameters	**Values**
P = Internal pressure	10.34 MPa
D = Inside diameter	1,524 mm
S = Allowable stress	20,000 MPa
E = Joint efficiency	1
Corrosion allowance	1.5 mm
Factor of safety	3.5

Methodology

To design pressure vessel the selection of standard is important to achieve the safety of pressure vessel. The selection of material, design process, and analysis software to obtain the result are described below.

Code Selection

There are many engineering standards which give information on the design and fittings of pressure vessel. For this design, ASME VIII (division 2) "Construction of Pressure vessel Codes" is selected [4].

Material Selection

The selection of material is based on the appropriateness of the design requirement. The materials used in the manufacture of the receivers shall comply with the requirements of the relevant design code, and be identifiable with mill sheets. For this kind of pressure vessel, the selection of material use is based on Appendix B [5]. Material is selected for Head SA- 106 B, Shell SA- 106 B, Nozzle -Relieve Valve SA- 106 B, Pressure Gauge (PG) SA- 106 B, Drain SA-106 B Inlet SA- 106 B, Outlet SA- 106 B.

Design Temperature

Design temperature is the temperature that will be maintained in the metal of the part of the vessel being considered for the specified operation of the vessel. For most vessels, it is the temperature that corresponds to the design pressure. However, there is a maximum design temperature and a minimum design temperature (MDMT) for any given vessel. The MDMT shall be the lowest temperature expected in service or the lowest allowable temperature as calculated for the individual parts. Design temperature for vessel under internal pressure shall not exceed the maximum temperatures, 300ºF [4].

Corrosion Allowance

Corrosion occurring over the life of a vessel is catered for by a corrosion allowance, the value of which depends upon the vessel duty and the corrosiveness of its content. A design criterion of corrosion allowance of 1.5 mm for air receiver in which condensation of air moisture is expected [4].

Shell Design

The minimum thickness or maximum allowable working pressure of cylindrical shells shall be the greater thickness or lesser pressure as given by (1) or (2) below. Circumferential stress (Longitudinal Joints), when the thickness (t) does not exceed one-half of the inside radius R, or P (internal pressure) does not exceed 0.385SE, the following formulas shall apply [4]:

$$t = \frac{PR}{SE-0.6P} \text{ or } P = \frac{SEt}{R+0.6t} \quad (1)$$

S: Allowable stress from annex 3A [1]

E: Weld joint efficiency from Table 7.2 [1]

Longitudinal stress (Circumferential Joints): When the thickness does not exceed one-half of the inside radius, or P does not exceed 1.25SE, the following formulas shall apply [4]:

$$t = \frac{PR}{2SE+0.4P} \text{ or } P = \frac{2SEt}{R-0.4t} \quad (2)$$

Closure Design

The required thickness at the thinnest point after forming of ellipsoidal, torispherical, hemispherical, conical, and tori conical heads under pressure on the concave side shall be computed by the appropriate formulas (UG-16) [1]. In addition, provision shall be made for any of the other loadings given in UG-22 [4]. The thickness of an unstayed ellipsoidal or torispherical head shall in no case be less than the required thickness of a seamless hemispherical head divided by the efficiency of the head-to-shell joint [4].

Ellipsoidal Heads Design

The required thickness of a dished head of semi ellipsoidal form, in which half the minor axis equals one-fourth of the inside diameter of the head skirt, shall be determined by:

$$t = \frac{PD}{2SE-0.2P} \text{ or } P = \frac{2SEt}{R+0.2t} \quad (3)$$

t = 57.4 mm

Circumferential Stress Criterion

Checking for 0.385SE

S: 20015.20 [4]

E = 1, 0.385SE = 7705.77 > 1500, $t = \frac{PR}{SE-0.6P}$, t =59.69 mm

Therefore, the required thickness is 59.69 mm

Nozzle and Reinforcement

Openings in cylindrical or conical portions of vessels, or in formed heads, shall preferably be circular or elliptical. When the long dimension of an elliptical or round opening exceeds twice the short dimensions, the reinforcement across the short dimensions shall be increased as necessary to provide against excessive distortion due to twisting moment. The constraints for the nozzle design were flow rate & standard pipes availability. Due to the standard flow rates, the inlet and outlet diameter were taken as 100 mm and 80 mm respectively [5].

Prototype Modelling:

After design calculations, the prototype model will be created using SolidWorks software and included in the module.

Simulation and Analysis

The prototype model will be analysed using finite element software. The maximum von Misses stresses will be compared with the allowable stress (S). If the maximum stress is lower than allowable stress, the design is ok. If the maximus von Mises stress is higher than allowable stress, the design needs to modify using higher grade material or higher thickness plate.

Modification and Finalize the Design. If the design is under or oversized, the design needs to modify.

MODULE 2

Implemented Course
MEEN 4351 - Design of Mechanical Element**:** Course contents are: Design techniques of pressure vessel, bolted connections, welded connections, journal bearings, roller bearings, brakes, clutches, spur, bevel, worm, and helical gears, flywheels, clutches, brakes, belt and chain drives.

Used standard and Code.
AISC standards for Structural Steel Buildings and the Code of Standard Practice for Steel Buildings and Bridges (AISC Steel Construction Manual)

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ISO Standards Database: Maintained by the International Organization for Standardization, it provides access to international standards in various domains.

ASME Standards: Developed by American Society of Mechanical engineers, these standards covers a wide range of topics, including boilers and pressure vessel codes, piping standards and various mechanical components.

ANSI Standards Portal: Offered by the American National Standards Institute, it provides access to U.S. and international standards.

IEEE Xplore: Focused on standards in the field of electrical and electronic engineering.

SAE Standards: The society of Automotive Engineers, creates standards for automotive and aerospace industries, covering areas such as materials, fastener and Vehicles design.

ASTM Compass: Maintained by ASTM International, it offers access to wide range of standards, Including those related to materials, construction and engineering practices.

NIST Standards Reference Database: Provided by the National Institute of Standards and Technology, it includes various types of standards relevant to science and technology.

Access to standards in these databases often involves licensing, subscription fees, or purchase of individual standards, but some basic information may be freely available to the public.

Searching Standards: Searching for standards involves finding specific documents or technical specifications that apply to a particular industry, product, process, or service. Here are the general steps to search for standards effectively:

1. **Identify Your Needs:**

Determine the subject area or industry for which you need standards. Be clear about the specific standard you're looking for, if applicable.

2. **Choose a Standards Database or Source:**

Select a reputable standards database or source that is relevant to your needs. Common sources include the International Organization for Standardization (ISO), IEEE Xplore, national standards bodies, and industry-specific organizations.

3. **Use Keywords and Phrases:**

If you have a specific standard in mind, search by its title or number. Use relevant keywords and phrases related to your subject. For example, "ISO 9001" for quality management or "ASTM D123" for a specific material testing standard.

4. **Filter and Refine Your Search:**

Many standards databases offer filters to narrow down search results. You can filter by industry, publication date, document type, or organization.

5. **Review Search Results:**

Examine the search results to find standards that match your criteria. Pay attention to the standard number, title, and description to ensure it meets your needs.

6. **Access Full Details:**

Click on the standard of interest to access more detailed information. Check for the publication date to ensure it's the most recent version.

7. **Download or Purchase:**

Depending on the source, you may have options to download the standard immediately, purchase it, or access it through a subscription if required.

8. **Check for Revisions or Amendments**:

Ensure that the standard you're considering is the latest version. Standards are periodically updated, and it's important to stay current with the most recent revisions.

9. **Verify Applicability:**

Confirm that the standard you found is relevant to your project, industry, or regulatory requirements. Not all standards may apply to your specific situation.

10. **Comply with Licensing or Copyright Restrictions:**

Be aware of any licensing or copyright restrictions associated with the standards you access. Compliance with usage terms is important.

20. Keep Records:

Maintain records of the standards you access, including their titles, numbers, and publication dates, for reference and compliance purposes.

It's important to choose the appropriate standards body or organization that aligns with your industry or area of interest. Additionally, consider whether you need to access international standards or national standards, as well as whether a subscription service may be beneficial for ongoing access to standards in your field.

Standards Development Organizations or Societies.

Standards development organizations (SDOs) or societies are entities responsible for creating and maintaining standards that define technical specifications, guidelines, and best practices in various industries and fields. These organizations play a crucial role in ensuring safety, quality, and interoperability across different sectors. Here are some prominent standards development organizations and societies:

16. **International Organization for Standardization (ISO):**

ISO is a global body that develops international standards covering a wide range of industries, from technology and safety to environmental management.

17. **American National Standards Institute (ANSI):** ANSI is the primary standards body in the United States, facilitating the development of standards for numerous sectors, including engineering, IT, and healthcare.
18. **International Electrotechnical Commission (IEC):** IEC focuses on electrical and electronic standards and collaborates with ISO to create standards applicable to a wide array of industries.
19. **American Society for Testing and Materials (ASTM International):** ASTM develops standards for materials, products, systems, and services in industries like construction, manufacturing, and more.
20. **Institute of Electrical and Electronics Engineers (IEEE)**: IEEE is known for its standards in electrical and electronic engineering, including IEEE 802 series for networking and communication.
21. **American Society of Mechanical Engineers (ASME):** ASME creates standards for mechanical engineering, covering pressure vessels, piping, and numerous other aspects of mechanical design and safety.
22. **National Fire Protection Association (NFPA)**: NFPA develops fire and life safety codes and standards, including the National Electrical Code (NEC) and NFPA 70E for electrical safety.
23. **American Petroleum Institute (API):** API is responsible for standards in the oil and gas industry, covering equipment, safety practices, and environmental protection.
24. **International Telecommunication Union (ITU):** ITU specializes in telecommunications and information and communication technologies (ICT) standards.
25. **Society of Automotive Engineers (SAE International):** SAE creates standards for the automotive and aerospace industries, ensuring safety and performance.
26. **International Civil Aviation Organization (ICAO)**: ICAO develops international standards for civil aviation, covering everything from aircraft design to air traffic management.
27. **Pharmaceutical Research and Manufacturers of America (PhRMA):** PhRMA sets standards for the pharmaceutical industry, including guidelines for drug development and manufacturing.
28. **International Maritime Organization (IMO):** IMO establishes international standards for maritime safety, security, and environmental protection.

29. **Food and Drug Administration (FDA):** The FDA in the United States sets standards for food, drugs, and medical devices to ensure public health and safety.
30. **National Institute of Standards and Technology (NIST):** NIST provides standards and guidelines for various industries and technologies, including cybersecurity and metrology.

These organizations collaborate with experts, industry stakeholders, and government bodies to develop, review, and update standards that drive innovation and promote safety and quality in their respective fields. Standards developed by these organizations often serve as the basis for regulations, product certifications, and best practices worldwide.

AISC standards for Structural Steel Buildings and the Code of Standard Practice for Steel Buildings and Bridges (AISC Steel Construction Manual)

The American institute of steel construction, founded 1921, is a non-profit technical specifying and trade organization for the fabricated structural steel industry in the United States. They develop and publish steel construction manuals. The Institute's objective is to make structural steel the material of choice, by being the leader in structural-steel-related technical and market-building activities, including: specification and code development, research, education, technical assistance, quality certification, standardization, and market development. AISC has a long tradition of service to the steel construction industry providing timely and reliable information.

To accomplish these objectives, the Institute publishes manuals, design guides, and specifications. Best known and most widely used is the *Steel Construction Manual,* which holds a highly respected position in engineering literature. Outstanding among AISC standards are the *Specification for Structural Steel Buildings* and the *Code of Standard Practice for Steel Buildings and Bridges.*

The manual has several parts. The dimensions and properties for structural products commonly used in steel building design and construction are given in this Part 1. For availability and proper material specifications for these products, as well as general specification requirements and other design considerations, see Part 2. For the design of members, see Parts 3 through 6. For the design of connections, see Parts 7 through 15. For AlSC Specifications and Codes, see Part 16. For other miscellaneous information, see Part 17. For torsional and flexural-torsional properties of rolled shapes see AISC Design Guide 9, *Torsional Analysis of Structural Steel Members.* for surface areas, box perimeters and areas, *WID* ratios and *AID* ratios, see AISC Design Guide 19, *Fire Resistance of Structural Steel Framing.*

In this module part 1 and part 2 are used to design a steel bridge.

B1. GENERAL PROVISIONS

The design of members and *connection*s shall be consistent with the intended behavior of the framing system and the assumptions made in the *structural analysis*. Unless restricted by the *applicable building code*, *lateral load* resistance and *stability* may be provided by any combination of members and connections.

B2. LOADS AND LOAD COMBINATIONS

The loads and load combinations shall be as stipulated by the *applicable building code*. In the absence of a building code, the loads and load combinations shall be those stipulated in SEI/ASCE 7. For design purposes, the *nominal load*s shall be taken as the *load*s stipulated by the applicable building code.

B3. DESIGN BASIS

Designs shall be made according to the provisions for *Load and Resistance Factor Design* (LRFD) or to the provisions for *Allowable Strength Design* (ASD).

1. Required Strength

The *required strength* of structural members and *connection*s shall be determined by *structural analysis* for the appropriate load combinations as stipulated in Section B2.

2. Limit States

Design shall be based on the principle that no applicable strength or serviceability *limit state* shall be exceeded when the structure is subjected to all appropriate load combinations.

3. Design for Strength Using Load and Resistance Factor Design (LRFD)

Design according to the provisions for *Load and Resistance Factor Design* (LRFD) satisfies the requirements of this Specification when the *design strength* of each *structural component* equals or exceeds the *required strength* determined on the basis of the *LRFD load combinations*. All provisions of this Specification, except for those in Section B3.4, shall apply.

Design shall be performed in accordance with Equation B3-1:

$$R_u \leq \phi R_n \tag{B3-1}$$

where

R_u = required strength (LRFD)
R_n = *nominal strength*, specified in Chapters B through K
ϕ = *resistance factor*, specified in Chapters B through K
ϕR_n = design strength

4. Design for Strength Using Allowable Strength Design (ASD)

Design according to the provisions for *Allowable Strength Design* (ASD) satisfies the requirements of this Specification when the *allowable strength* of each *structural component* equals or exceeds the *required strength* determined on the basis of the *ASD load combinations*. All provisions of this Specification, except those of Section B3.3, shall apply.

Design shall be performed in accordance with Equation B3-2:

$$R_a \leq R_n / \Omega \tag{B3-2}$$

where

R_a = required strength (ASD)
R_n = *nominal strength*, specified in Chapters B through K
Ω = safety factor, specified in Chapters B through K
R_n/Ω = allowable strength

CHAPTER C

STABILITY ANALYSIS AND DESIGN

This chapter addresses general requirements for the stability analysis and design of members and frames.

The chapter is organized as follows:

C1. Stability Design Requirements
C2. Calculation of Required Strengths

C1. STABILITY DESIGN REQUIREMENTS

1. General Requirements

Stability shall be provided for the structure as a whole and for each of its elements. Any method that considers the influence of *second-order effects* (including P-Δ and P-δ *effects*), flexural, shear and axial deformations, geometric imperfections, and member stiffness reduction due to residual stresses on the stability of the structure and its elements is permitted. The methods prescribed in this chapter and Appendix 7, Direct Analysis Method, satisfy these requirements. All component and *connection* deformations that contribute to the lateral displacements shall be considered in the stability analysis.

In structures designed by elastic analysis, individual member stability and stability of the structure as a whole are provided jointly by:

(1) Calculation of the *required strengths* for members, connections and other elements using one of the methods specified in Section C2.2, and
(2) Satisfaction of the member and connection design requirements in this specification based upon those required strengths.

In structures designed by inelastic analysis, the provisions of Appendix 1, Inelastic Analysis and Design, shall be satisfied.

2. Member Stability Design Requirements

Individual member stability is provided by satisfying the provisions of Chapters E, F, G, H and I.

User Note: Local buckling of cross section components can be avoided by the use of compact sections defined in Section B4.

Where elements are designed to function as braces to define the unbraced length of columns and beams, the bracing system shall have sufficient stiffness and strength to control member movement at the braced points. Methods of satisfying

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Where elements are designed to function as braces to define the unbraced length of columns and beams, the bracing system shall have sufficient stiffness and strength to control member movement at the braced points. Methods of satisfying

M_r = required second-order flexural strength using LRFD or ASD load combinations, kip-in. (N-mm)

M_{nt} = first-order moment using LRFD or ASD load combinations, assuming there is no lateral translation of the frame, kip-in. (N-mm)

M_{lt} = first-order moment using LRFD or ASD load combinations caused by lateral translation of the frame only, kip-in. (N-mm)

P_r = required second-order axial strength using LRFD or ASD load combinations, kips (N)

P_{nt} = first-order axial force using LRFD or ASD load combinations, assuming there is no lateral translation of the frame, kips (N)

ΣP_{nt} = total vertical load supported by the story using LRFD or ASD load combinations, including gravity column loads, kips (N)

P_{lt} = first-order axial force using LRFD or ASD load combinations caused by lateral translation of the frame only, kips (N)

C_m = a coefficient assuming no lateral translation of the frame whose value shall be taken as follows:

(i) For beam-columns not subject to transverse loading between supports in the plane of bending,

$$C_m = 0.6 - 0.4(M_1/M_2) \quad \text{(C2-4)}$$

where M_1 and M_2, calculated from a first-order analysis, are the smaller and larger moments, respectively, at the ends of that portion of the member unbraced in the plane of bending under consideration. M_1/M_2 is positive when the member is bent in reverse curvature, negative when bent in single curvature.

(ii) For beam-columns subjected to transverse loading between supports, the value of C_m shall be determined either by analysis or conservatively taken as 1.0 for all cases.

P_{e1} = elastic critical buckling resistance of the member in the plane of bending, calculated based on the assumption of zero sidesway, kips (N)

$$P_{e1} = \frac{\pi^2 EI}{(K_1 L)^2} \quad \text{(C2-5)}$$

ΣP_{e2} = elastic critical buckling resistance for the story determined by sidesway buckling analysis, kips (N)

For moment frames, where sidesway buckling effective length factors K_2 are determined for the columns, it is permitted to calculate the elastic story sidesway buckling resistance as

$$\Sigma P_{e2} = \Sigma \frac{\pi^2 EI}{(K_2 L)^2} \quad \text{(C2-6a)}$$

For all types of lateral load resisting systems, it is permitted to use

$$\Sigma P_{e2} = R_M \frac{\Sigma HL}{\Delta_H} \quad \text{(C2-6b)}$$

where

E = modulus of elasticity of steel = 29,000 ksi (200 000 MPa)
R_M = 1.0 for braced-frame systems;
= 0.85 for moment-frame and combined systems, unless a larger value is justified by analysis
I = moment of inertia in the plane of bending, in.^{4} (mm^4)
L = story height, in. (mm)
K_1 = effective length factor in the plane of bending, calculated based on the assumption of no lateral translation, set equal to 1.0 unless analysis indicates that a smaller value may be used
K_2 = effective length factor in the plane of bending, calculated based on a sidesway buckling analysis

User Note: Methods for calculation of K_2 are discussed in the Commentary.

Δ_H = first-order interstory drift due to lateral forces, in. (mm). Where Δ_H varies over the plan area of the structure, Δ_H shall be the average drift weighted in proportion to vertical load or, alternatively, the maximum drift.
ΣH = story shear produced by the lateral forces used to compute Δ_H, kips (N)

2. Design Requirements

These requirements apply to all types of braced, moment, and combined framing systems. Where the ratio of second-order drift to first-order drift is equal to or less than 1.5, the *required strengths* of members, *connections* and other elements shall be determined by one of the methods specified in Sections C2.2a or C2.2b, or by the *Direct Analysis Method* of Appendix 7. Where the ratio of second-order drift to first-order drift is greater than 1.5, the required strengths shall be determined by the Direct Analysis Method of Appendix 7.

User Note: The ratio of second-order drift to first-order drift can be represented by B_2, as calculated using Equation C2-3. Alternatively, the ratio can be calculated by comparing the results of a second-order analysis to the results of a first-order analysis, where the analyses are conducted either under LRFD load combinations directly or under ASD load combinations with a 1.6 factor applied to the ASD gravity loads.

For the methods specified in Sections 2.2a or 2.2b:

(1) Analyses shall be conducted according to the design and loading requirements specified in either Section B3.3 (LRFD) or Section B3.4 (ASD).

(2) The structure shall be analyzed using the nominal geometry and the nominal elastic stiffness for all elements.

2a. Design by Second-Order Analysis

Where required strengths are determined by a *second-order analysis*:

(1) The provisions of Section C2.1 shall be satisfied.

(2) For design by ASD, analyses shall be carried out under 1.6 times the *ASD load combinations* and the results shall be divided by 1.6 to obtain the required strengths.

User Note: The amplified first order analysis method of Section C2.1b incorporates the 1.6 multiplier directly in the B_1 and B_2 amplifiers, such that no other modification is needed.

(3) All gravity-only load combinations shall include a minimum lateral load applied at each level of the structure of $0.002Y_i$, where Y_i is the *design gravity load* applied at level i, kips (N). This minimum *lateral load* shall be considered independently in two orthogonal directions.

User Note: The minimum lateral load of $0.002Y_i$, in conjunction with the other design-analysis constraints listed in this section, limits the error that would otherwise be caused by neglecting initial out-of-plumbness and member stiffness reduction due to residual stresses in the analysis.

(4) Where the ratio of second-order drift to first-order drift is less than or equal to 1.1, members are permitted to be designed using $K = 1.0$. Otherwise, *columns* and *beam-columns* in *moment frames* shall be designed using a K factor or column buckling stress, F_e, determined from a sidesway buckling analysis of the structure. Stiffness reduction adjustment due to column inelasticity is permitted in the determination of the K factor. For *braced frames*, K for compression members shall be taken as 1.0, unless structural analysis indicates a smaller value may be used.

2b. Design by First-Order Analysis

Required strengths are permitted to be determined by a first-order analysis, with all members designed using $K = 1.0$, provided that

(1) The required compressive strengths of all members whose flexural stiffnesses are considered to contribute to the lateral stability of the structure satisfy the following limitation:

$$\alpha P_r \leq 0.5 P_y \qquad \text{(C2-7)}$$

where

$$\alpha = 1.0 \text{ (LRFD)} \quad \alpha = 1.6 \text{ (ASD)}$$

P_r = required axial compressive strength under LRFD or ASD load combinations, kips (N)

P_y = member yield strength ($= AF_y$), kips (N)

(2) All load combinations include an additional lateral load, N_i, applied in combination with other loads at each level of the structure, where

$$N_i = 2.1(\Delta/L)Y_i \geq 0.0042Y_i \qquad \text{(C2-8)}$$

Y_i = gravity load from the LRFD load combination or 1.6 times the ASD load combination applied at level i, kips (N)

Δ/L = the maximum ratio of Δ to L for all stories in the structure
Δ = first-order interstory drift due to the design loads, in. (mm). Where Δ varies over the plan area of the structure, Δ shall be the average drift weighted in proportion to vertical load or, alternatively, the maximum drift.
L = story height, in. (mm)

User Note: The drift Δ is calculated under LRFD load combinations directly or under ASD load combinations with a 1.6 factor applied to the ASD gravity loads.

This additional lateral load shall be considered independently in two orthogonal directions.

(3) The non-sway amplification of beam-column moments is considered by applying the B_1 amplifier of Section C2.1 to the total member moments.

CHAPTER F

DESIGN OF MEMBERS FOR FLEXURE

This chapter applies to members subject to simple bending about one principal axis. For simple bending, the member is loaded in a plane parallel to a principal axis that passes through the shear center or is restrained against twisting at *load* points and supports.

The chapter is organized as follows:

F1. General Provisions
F2. Doubly Symmetric Compact I-Shaped Members and Channels Bent about Their Major Axis
F3. Doubly Symmetric I-Shaped Members with Compact Webs and Noncompact or Slender Flanges Bent about Their Major Axis
F4. Other I-Shaped Members with Compact or Noncompact Webs Bent about Their Major Axis
F5. Doubly Symmetric and Singly Symmetric I-Shaped Members with Slender Webs Bent about Their Major Axis
F6. I-Shaped Members and Channels Bent about Their Minor Axis
F7. Square and Rectangular HSS and Box-Shaped Members
F8. Round HSS
F9. Tees and Double Angles Loaded in the Plane of Symmetry
F10. Single Angles
F11. Rectangular Bars and Rounds
F12. Unsymmetrical Shapes
F13. Proportions of Beams and Girders

User Note: For members not included in this chapter the following sections apply:

- H1–H3. Members subject to biaxial flexure or to combined flexure and axial force.
- H4. Members subject to flexure and torsion.
- Appendix 3. Members subject to fatigue.
- Chapter G. Design provisions for shear.

For guidance in determining the appropriate sections of this chapter to apply, Table User Note F1.1 may be used.

F1. GENERAL PROVISIONS

The *design flexural strength*, $\phi_b M_n$, and the *allowable flexural strength*, M_n/Ω_b, shall be determined as follows:

(1) For all provisions in this chapter

$$\phi_b = 0.90 \text{ (LRFD)} \qquad \Omega_b = 1.67 \text{ (ASD)}$$

and the *nominal flexural strength*, M_n, shall be determined according to Sections F2 through F12.

(2) The provisions in this chapter are based on the assumption that points of support for *beams* and girders are restrained against rotation about their longitudinal axis.

The following terms are common to the equations in this chapter except where noted:

C_b = *lateral-torsional buckling* modification factor for nonuniform moment diagrams when both ends of the unsupported segment are braced

$$C_b = \frac{12.5M_{max}}{2.5M_{max} + 3M_A + 4M_B + 3M_C} R_m \leq 3.0 \qquad \text{(F1-1)}$$

where

M_{max} = absolute value of maximum moment in the unbraced segment, kip-in. (N-mm)

M_A = absolute value of moment at quarter point of the unbraced segment, kip-in. (N-mm)

M_B = absolute value of moment at centerline of the unbraced segment, kip-in. (N-mm)

M_C = absolute value of moment at three-quarter point of the unbraced segment, kip-in. (N-mm)

R_m = cross-section monosymmetry parameter
= 1.0, doubly symmetric members
= 1.0, singly symmetric members subjected to *single curvature* bending
$= 0.5 + 2\left(\frac{I_{yc}}{I_y}\right)^2$, singly symmetric members subjected to *reverse curvature* bending

I_y = moment of inertia about the principal y-axis, in.^{4} (mm^4)

I_{yc} = moment of inertia about y-axis referred to the compression flange, or if reverse curvature bending, referred to the smaller flange, in.^{4} (mm^4)

In singly symmetric members subjected to *reverse curvature* bending, the *lateral-torsional buckling* strength shall be checked for both flanges. The available flexural strength shall be greater than or equal to the maximum required moment causing compression within the flange under consideration.

CHAPTER E

DESIGN OF MEMBERS FOR COMPRESSION

This chapter addresses members subject to axial compression through the centroidal axis.

The chapter is organized as follows:

User Note: For members not included in this chapter the following sections apply:
- H1. – H3. Members subject to combined axial compression and flexure.
- H4. Members subject to axial compression and torsion.
- J4.4 Compressive strength of connecting elements.
- I2. Composite axial members.

E1. GENERAL PROVISIONS

The *design compressive strength*, $\phi_c P_n$, and the *allowable compressive strength*, P_n/Ω_c, are determined as follows:

The *nominal compressive strength*, P_n, shall be the lowest value obtained according to the *limit states* of *flexural buckling*, *torsional buckling* and *flexural-torsional buckling*.

(a) For doubly symmetric and singly symmetric members the limit state of flexural buckling is applicable.

(b) For singly symmetric and unsymmetric members, and certain doubly symmetric members, such as cruciform or built-up *columns*, the limit states of torsional or flexural-torsional buckling are also applicable.

$$\phi_c = 0.90 \text{ (LRFD)} \quad \Omega_c = 1.67 \text{ (ASD)}$$

E2. SLENDERNESS LIMITATIONS AND EFFECTIVE LENGTH

The effective length factor, K, for calculation of column slenderness, KL/r, shall be determined in accordance with Chapter C, where

L = laterally unbraced length of the member, in. (mm)
r = governing radius of gyration, in. (mm)
K = the *effective length factor* determined in accordance with Section C2

User Note: For members designed on the basis of compression, the slenderness ratio KL/r preferably should not exceed 200.

E3. COMPRESSIVE STRENGTH FOR FLEXURAL BUCKLING OF MEMBERS WITHOUT SLENDER ELEMENTS

This section applies to compression members with *compact* and *noncompact sections*, as defined in Section B4, for uniformly compressed elements.

User Note: When the torsional unbraced length is larger than the lateral unbraced length, this section may control the design of wide flange and similarly shaped columns.

The *nominal compressive strength*, P_n, shall be determined based on the *limit state* of *flexural buckling*.

$$P_n = F_{cr} A_g \quad \text{(E3-1)}$$

The *flexural buckling stress*, F_{cr}, is determined as follows:

(a) When $\frac{KL}{r} \le 4.71\sqrt{\frac{E}{F_y}}$ (or $F_e \ge 0.44 F_y$)

$$F_{cr} = \left[0.658^{\frac{F_y}{F_e}}\right] F_y \quad \text{(E3-2)}$$

(b) When $\frac{KL}{r} > 4.71\sqrt{\frac{E}{F_y}}$ (or $F_e < 0.44 F_y$)

$$F_{cr} = 0.877 F_e \quad \text{(E3-3)}$$

where

F_e = elastic critical buckling stress determined according to Equation E3-4, Section E4, or the provisions of Section C2, as applicable, ksi (MPa)

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2} \quad \text{(E3-4)}$$

User Note: The two equations for calculating the limits and applicability of Sections E3(a) and E3(b), one based on KL/r and one based on F_e, provide the same result.

E4. COMPRESSIVE STRENGTH FOR TORSIONAL AND FLEXURAL-TORSIONAL BUCKLING OF MEMBERS WITHOUT SLENDER ELEMENTS

This section applies to singly symmetric and unsymmetric members, and certain doubly symmetric members, such as cruciform or built-up *columns* with *compact* and *noncompact sections*, as defined in Section B4 for uniformly compressed elements. These provisions are not required for single angles, which are covered in Section E5.

The *nominal compressive strength*, P_n, shall be determined based on the *limit states* of *flexural-torsional* and *torsional buckling*, as follows:

$$P_n = F_{cr} A_g \tag{E4-1}$$

(a) For double-angle and tee-shaped compression members:

$$F_{cr} = \left(\frac{F_{cry} + F_{crz}}{2H}\right)\left[1 - \sqrt{1 - \frac{4F_{cry}F_{crz}H}{\left(F_{cry} + F_{crz}\right)^2}}\right] \tag{E4-2}$$

where F_{cry} is taken as F_{cr} from Equation E3-2 or E3-3, for *flexural buckling* about the y-axis of symmetry and $\frac{KL}{r} = \frac{KL}{r_y}$, and

$$F_{crz} = \frac{GJ}{A_g \bar{r}_o^2} \tag{E4-3}$$

(b) For all other cases, F_{cr} shall be determined according to Equation E3-2 or E3-3, using the torsional or flexural-torsional elastic buckling *stress*, F_e, determined as follows:

(i) For doubly symmetric members:

$$F_e = \left[\frac{\pi^2 E C_w}{(K_z L)^2} + GJ\right]\frac{1}{I_x + I_y} \tag{E4-4}$$

(ii) For singly symmetric members where y is the axis of symmetry:

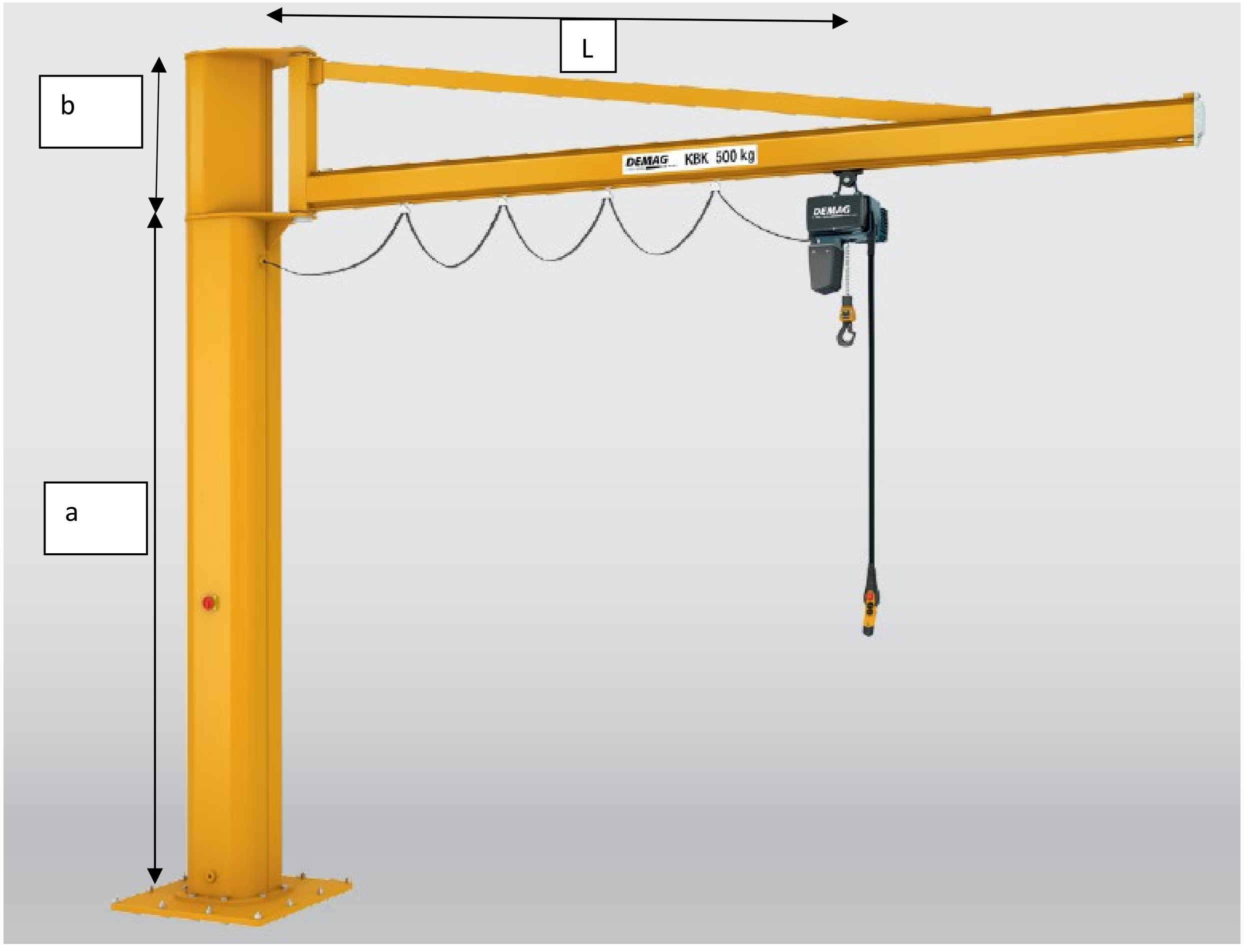
$$F_e = \left(\frac{F_{ey} + F_{ez}}{2H}\right)\left[1 - \sqrt{1 - \frac{4F_{ey}F_{ez}H}{\left(F_{ey} + F_{ez}\right)^2}}\right] \tag{E4-5}$$

(iii) For unsymmetric members, F_e is the lowest root of the cubic equation:

$$(F_e - F_{ex})(F_e - F_{ey})(F_e - F_{ez}) - F_e^2(F_e - F_{ey})\left(\frac{x_o}{\bar{r}_o}\right)^2 - F_e^2(F_e - F_{ex})\left(\frac{y_o}{\bar{r}_o}\right)^2 = 0 \tag{E4-6}$$

Example 1: A free standing **jib crane** similar to one shown is to be designed for a capacity of **5 tons.** The load can swing through a full 360 degrees; **L=10 ft., a=9 ft., b=2 ft.** The crane will be fastened to the floor by 6 equally spaced bolts on a **20 inch bolt circle**, the outside diameter of base is 36 inches. Choose a pipe size for the column such that the maximum stress does not exceed **12 ksi.**

a) Choose an I-beam for the jib such that the maximum stress does not **exceed 12 ksi.**
b) Compute the maximum **external load on a base bolt** and decide upon the size.
c) Complete other details as required, such as calculating Q and choosing bearings (ball or roller), the design in the bearing area, and all other details such that a jib crane could be



Calculations:

Given properties:

Material = ASTM A36 Steel

Factor of Safety (n)=2

Yield Strength (S_y)= 36 ksi

Force (F)= 10 tons = 20 kips

Lengths Given:

L= 10 $ft \cdot 12$ $inches$ = 120 $inches$

A= 9 $ft \cdot 12$ $inches$ = 108 $inches$

B= 2 $ft \cdot 12$ $inches$ = 24 $inches$

Outer Diameter (OD)= 36 inches

Inner Diameter (ID)= 20 inches

Calculation for beam:

$Allowable\ Stress$ ($\sigma_{allowable}$) = Sy/n)=18 ksi

$Moment\ (M) = F \cdot L$

$= 20\ kips \cdot 120\ inches$

$\Rightarrow M = 2,400\ kips \cdot inches$

$S_{\text{required}} = M/\text{Allowable bending stress} = 133.33\ \text{in}^3$

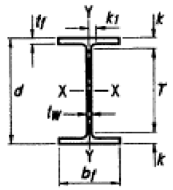


Table 1-1 (continued)
W Shapes
Dimensions

Shape	Area, A	Depth, d		Web			Flange				Distance				
				Thickness, t_w		$\frac{t_w}{2}$	Width, b_f		Thickness, t_f		k		k_1	T	Workable Gage
											k_{des}	k_{det}			
	in.²	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W16×100	29.5	17.0	17	0.585	9/16	5/16	10.4	10 3/8	0.985	1	1.39	1 7/8	1 1/8	13 1/4	5 1/2
×89	26.2	16.8	16 3/4	0.525	1/2	1/4	10.4	10 3/8	0.875	7/8	1.28	1 3/4	1 1/16		
×77	22.6	16.5	16 1/2	0.455	7/16	1/4	10.3	10 1/4	0.760	3/4	1.16	1 5/8	1 1/16		
×67[c]	19.7	16.3	16 3/8	0.395	3/8	3/16	10.2	10 1/4	0.665	11/16	1.07	1 9/16	1		
W16×57	16.8	16.4	16 3/8	0.430	7/16	1/4	7.12	7 1/8	0.715	11/16	1.12	1 3/8	7/8	13 5/8	3 1/2[g]
×50[c]	14.7	16.3	16 1/4	0.380	3/8	3/16	7.07	7 1/8	0.630	5/8	1.03	1 5/16	13/16		
×45[c]	13.3	16.1	16 1/8	0.345	3/8	3/16	7.04	7	0.565	9/16	0.967	1 1/4	13/16		
×40[c]	11.8	16.0	16	0.305	5/16	3/16	7.00	7	0.505	1/2	0.907	1 3/16	13/16		
×36[c]	10.6	15.9	15 7/8	0.295	5/16	3/16	6.99	7	0.430	7/16	0.832	1 1/8	3/4		
W16×31[c]	9.13	15.9	15 7/8	0.275	1/4	1/8	5.53	5 1/2	0.440	7/16	0.842	1 1/8	3/4	13 5/8	3 1/2
×26[c,v]	7.68	15.7	15 3/4	0.250	1/4	1/8	5.50	5 1/2	0.345	3/8	0.747	1 1/16	3/4	13 5/8	3 1/2
W14×730[h]	215	22.4	22 3/8	3.07	3 1/16	1 9/16	17.9	17 7/8	4.91	4 15/16	5.51	6 3/16	2 3/4	10	3-7 1/2-3[g]
×665[h]	196	21.6	21 5/8	2.83	2 13/16	1 7/16	17.7	17 5/8	4.52	4 1/2	5.12	5 13/16	2 5/8		3-7 1/2-3[g]
×605[h]	178	20.9	20 7/8	2.60	2 5/8	1 5/16	17.4	17 3/8	4.16	4 3/16	4.76	5 7/16	2 1/2		3-7 1/2-3
×550[h]	162	20.2	20 1/4	2.38	2 3/8	1 3/16	17.2	17 1/4	3.82	3 13/16	4.42	5 1/8	2 3/8		
×500[h]	147	19.6	19 5/8	2.19	2 3/16	1 1/8	17.0	17	3.50	3 1/2	4.10	4 13/16	2 5/16		
×455[h]	134	19.0	19	2.02	2	1	16.8	16 7/8	3.21	3 3/16	3.81	4 1/2	2 1/4		
×426[h]	125	18.7	18 5/8	1.88	1 7/8	15/16	16.7	16 3/4	3.04	3 1/16	3.63	4 5/16	2 1/8		
×398[h]	117	18.3	18 1/4	1.77	1 3/4	7/8	16.6	16 5/8	2.85	2 7/8	3.44	4 1/8	2 1/8		
×370[h]	109	17.9	17 7/8	1.66	1 5/8	13/16	16.5	16 1/2	2.66	2 11/16	3.26	3 15/16	2 1/16		
×342[h]	101	17.5	17 1/2	1.54	1 9/16	13/16	16.4	16 3/8	2.47	2 1/2	3.07	3 3/4	2		
×311[h]	91.4	17.1	17 1/8	1.41	1 7/16	3/4	16.2	16 1/4	2.26	2 1/4	2.86	3 9/16	1 15/16		
×283[h]	83.3	16.7	16 3/4	1.29	1 5/16	11/16	16.1	16 1/8	2.07	2 1/16	2.67	3 3/8	1 7/8		
×257	75.6	16.4	16 3/8	1.18	1 3/16	5/8	16.0	16	1.89	1 7/8	2.49	3 3/16	1 13/16		
×233	68.5	16.0	16	1.07	1 1/16	9/16	15.9	15 7/8	1.72	1 3/4	2.32	3	1 3/4		
×211	62.0	15.7	15 3/4	0.980	1	1/2	15.8	15 3/4	1.56	1 9/16	2.16	2 7/8	1 11/16		
×193	56.8	15.5	15 1/2	0.890	7/8	7/16	15.7	15 3/4	1.44	1 7/16	2.04	2 3/4	1 11/16		
×176	51.8	15.2	15 1/4	0.830	13/16	7/16	15.7	15 5/8	1.31	1 5/16	1.91	2 5/8	1 5/8		
×159	46.7	15.0	15	0.745	3/4	3/8	15.6	15 5/8	1.19	1 3/16	1.79	2 1/2	1 9/16		
×145	42.7	14.8	14 3/4	0.680	11/16	3/8	15.5	15 1/2	1.09	1 1/16	1.69	2 3/8	1 9/16		

[c] Shape is slender for compression with $F_y = 50$ ksi.

[g] The actual size, combination, and orientation of fastener components should be compared with the geometry of the cross-section to ensure compatibility.

[h] Flange thickness greater than 2 in. Special requirements may apply per AISC Specification Section A3.1c.

[v] Shape does not meet the h/t_w limit for shear in Specification Section G2.1a with $F_y = 50$ ksi.

Table 1–1 (continued)
W Shapes
Properties

W16 – W14

Nom-inal Wt.	Compact Section Criteria		Axis X-X				Axis Y-Y				r_{ts}	h_o	Torsional Properties	
	$\frac{b_f}{2t_f}$	$\frac{h}{t_w}$	I	S	r	Z	I	S	r	Z			J	C_w
lb/ft			in.⁴	in.³	in.	in.³	in.⁴	in.³	in.	in.³	in.	in.	in.⁴	in.⁶
100	5.29	24.3	1490	175	7.10	198	186	35.7	2.51	54.9	2.92	16.0	7.73	11900
89	5.92	27.0	1300	155	7.05	175	163	31.4	2.49	48.1	2.88	15.9	5.45	10200
77	6.77	31.2	1110	134	7.00	150	138	26.9	2.47	41.1	2.85	15.8	3.57	8590
67	7.70	35.9	954	117	6.96	130	119	23.2	2.46	35.5	2.82	15.7	2.39	7300
57	4.98	33.0	758	92.2	6.72	105	43.1	12.1	1.60	18.9	1.92	15.7	2.22	2660
50	5.61	37.4	659	81.0	6.68	92.0	37.2	10.5	1.59	16.3	1.89	15.6	1.52	2270
45	6.23	41.1	586	72.7	6.65	82.3	32.8	9.34	1.57	14.5	1.88	15.6	1.11	1990
40	6.93	46.5	518	64.7	6.63	73.0	28.9	8.25	1.57	12.7	1.86	15.5	0.794	1730
36	8.12	48.1	448	56.5	6.51	64.0	24.5	7.00	1.52	10.8	1.83	15.4	0.545	1460
31	6.28	51.6	375	47.2	6.41	54.0	12.4	4.49	1.17	7.03	1.42	15.4	0.461	739
26	7.97	56.8	301	38.4	6.26	44.2	9.59	3.49	1.12	5.48	1.38	15.3	0.262	565
730	1.82	3.71	14300	1280	8.17	1660	4720	527	4.69	816	5.68	17.5	1450	362000
665	1.95	4.03	12400	1150	7.98	1480	4170	472	4.62	730	5.57	17.1	1120	305000
605	2.09	4.39	10800	1040	7.80	1320	3680	423	4.55	652	5.46	16.8	869	258000
550	2.25	4.79	9430	931	7.63	1180	3250	378	4.49	583	5.36	16.4	669	219000
500	2.43	5.21	8210	838	7.48	1050	2880	339	4.43	522	5.26	16.1	514	187000
455	2.62	5.66	7190	756	7.33	936	2560	304	4.38	468	5.17	15.8	395	160000
426	2.75	6.08	6600	706	7.26	869	2360	283	4.34	434	5.11	15.6	331	144000
398	2.92	6.44	6000	656	7.16	801	2170	262	4.31	402	5.06	15.4	273	129000
370	3.10	6.89	5440	607	7.07	736	1990	241	4.27	370	5.00	15.3	222	116000
342	3.31	7.41	4900	558	6.98	672	1810	221	4.24	338	4.94	15.1	178	103000
311	3.59	8.09	4330	506	6.88	603	1610	199	4.20	304	4.87	14.9	136	89100
283	3.89	8.84	3840	459	6.79	542	1440	179	4.17	274	4.81	14.7	104	77700
257	4.23	9.71	3400	415	6.71	487	1290	161	4.13	246	4.75	14.5	79.1	67800
233	4.62	10.7	3010	375	6.63	436	1150	145	4.10	221	4.69	14.3	59.5	59000
211	5.06	11.6	2660	338	6.55	390	1030	130	4.07	198	4.64	14.2	44.6	51500
193	5.45	12.8	2400	310	6.50	355	931	119	4.05	180	4.59	14.0	34.8	45900
176	5.97	13.7	2140	281	6.43	320	838	107	4.02	163	4.55	13.9	26.5	40500
159	6.54	15.3	1900	254	6.38	287	748	96.2	4.00	146	4.51	13.8	19.7	35600
145	7.11	16.8	1710	232	6.33	260	677	87.3	3.98	133	4.47	13.7	15.2	31700

I-Beam Dimensions - W16 x 77 has section modulus 134 in^3 and it is selected.

Calculation for Column:

$Outer\ Diameter\ of\ Column\ (OD) = 16\ inches$

$Q\ (applied\ load\ on\ Column) = M/D = 2{,}400\ kips \cdot inches/16inch = 150\ kips$

$Pcr = Critical\ Load\ (Pcr) = QColumn \cdot n = 150\ kips \cdot 2 = 300\ kips$

Using K =1 and length 10 ft, the HSS 14 x0.312 in has capacity of 304 kips and it is selected.

F_y = 42 ksi

Table 4–5 (continued)

Available Strength in Axial Compression, kips

Round HSS

HSS16.000–HSS14.000

Shape		HSS16.000×				HSS14.000×							
		0.312		0.250		0.625		0.500		0.375		0.312	
t_{design}, in.		0.291		0.233		0.581		0.465		0.349		0.291	
Wt/ft		52.3		42.1		89.4		72.2		54.6		45.7	
Design		P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$
		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
Effective length KL (ft) with respect to least radius of gyration r_y	0	361	543	290	436	616	926	497	747	376	566	315	474
	6	357	537	287	432	607	913	490	737	371	558	311	467
	7	356	535	286	430	604	908	488	733	369	555	309	465
	8	355	533	285	428	601	903	485	729	367	552	308	462
	9	353	530	284	426	597	897	482	724	365	549	306	460
	10	351	528	282	424	592	890	478	719	362	545	304	456
	11	349	524	280	421	587	883	475	713	360	540	301	453
	12	347	521	279	419	582	875	470	707	356	536	299	449
	13	344	517	277	416	576	866	466	700	353	531	296	445
	14	341	513	275	413	570	857	461	693	349	525	293	440
	15	339	509	272	409	564	848	456	685	346	519	290	435
	16	336	504	270	406	557	837	451	677	342	513	286	430
	17	332	500	267	402	550	827	445	669	337	507	283	425
	18	329	495	265	398	542	815	439	660	333	500	279	419
	19	326	489	262	394	535	804	433	650	328	493	275	414
	20	322	484	259	389	527	791	426	641	323	486	271	408
	21	318	478	256	385	518	779	419	630	318	479	267	401
	22	314	473	253	380	509	766	413	620	313	471	263	395
	23	310	466	250	375	501	752	405	609	308	463	258	388
	24	306	460	246	370	491	739	398	598	303	455	254	381
	25	302	454	243	365	482	725	391	587	297	446	249	374
	26	298	447	239	360	473	710	383	576	291	438	244	367
	27	293	440	236	355	463	696	375	564	285	429	240	360
	28	288	434	232	349	453	681	367	552	280	420	235	353
	29	284	427	228	343	443	666	359	540	274	411	230	345
	30	279	419	225	338	433	650	351	528	268	402	225	338
	32	269	405	217	326	412	620	335	503	255	384	214	322
	34	259	390	209	314	391	588	318	478	243	365	204	307
	36	249	374	201	302	371	557	302	453	230	346	194	291
	38	239	359	192	289	350	526	285	428	218	327	183	275
	40	228	343	184	277	329	494	268	403	205	308	173	259
Properties													
A_g (in.²)		14.4		11.5		24.5		19.8		15.0		12.5	
I (in.⁴)		443		359		552		453		349		295	
r (in.)		5.55		5.58		4.75		4.79		4.83		4.85	

ASD	LRFD
$\Omega_c = 1.67$	$\phi_c = 0.90$

Calculation for Bolts:

Q=150 kips will be taken by 6 bolts. But 3 bolts will be in tension and 3 bolts will be compression.

Tension stress on each bolt= Q/3(pi x d^2)

d= diameter of bolt

Allowable stress on each bolt = Sy/n

Sy= Yield strength of bolt material, n, factor of safety

SAE grade 8 material has yield strength 130 kpsi and using a factor of safety 2, the allowable stress = 130/2 = 65 kpsi.

Now, setting tensile strength equal to allowable stress, the bolt diameter = 0.5 in

MODULE 3

Course Title and Name: ITEN 3313 Energy Systems

Implemented Standards with Example:

Standard 1: IEEE Std 1562™-2021: IEEE Recommended Practice for Sizing of Stand-Alone Photovoltaic (PV) Systems

Introduction

The IEEE Std 1562™-2021 provides guidelines and recommendations to determine the size of the PV array and battery energy storage system to meet the energy needs of the intended applications when the system is not connected to the electrical grid. Usually, the system in remote areas is stand-alone where the power grid is unavailable or impractical. The system also controls the battery energy storage system from being over- or under-charged through a power conversion subsystem (inverter or converter) for optimal performance and reliability.

For accurately sizing the PV array and battery in a stand-alone PV system, two crucial pieces of information are necessary: precise load data and precise solar radiation data. The system's performance depends on the accuracy of these data. For critical applications, it's recommended to utilize a more sophisticated approach.

It's recommended to use this guideline in conjunction with IEEE Std 1361™ and IEEE Std 1013™ for a comprehensive guide to sizing and designing the PV array storage batteries for stand-alone PV systems.

Definition and Acronyms

The terms and definitions provided in this document will help to understand the methodology better. For terms not explicitly defined here, please refer to the IEEE Standards Dictionary Online.

- Array-to-load ratio (A:L): The ratio between the average daily photovoltaic ampere-hours (Ah) available for battery charging and the average daily load in ampere-hours. Note: The average daily PV ampere-hours are calculated by multiplying the average sun-hours for the relevant month with the array current at its maximum power point (I_{mp}) under standard test conditions (STC).
- Autonomy: The duration for which a photovoltaic (PV) system can supply energy to the load without receiving energy from the PV array.
- Charge controller: An electrical control device responsible for regulating battery charging through voltage control and/or other methods.
- Loss-of-load probability (LOLP): The probability (usually expressed as a percentage) of the photovoltaic (PV) power system experiencing insufficient energy to support the load due to inadequate solar radiation.
- Plane of array (POA): A plane aligned with the same tilt angle and azimuth as the photovoltaic (PV) array.

- Solar irradiance: The instantaneous power density of sunlight, typically measured in watts per meter squared (W/m^2).
- Solar radiation: The cumulative measure of solar irradiance over time.
- Standard test conditions (STC): The established conditions used for rating PV devices, typically involving 1000 W/m2 irradiance with a spectral distribution equivalent to air mass (AM) 1.5 and a PV cell temperature of 25 °C.
- Sulfation, excessive or "hard": The abnormal formation of lead sulfate crystals on the plates of a lead-acid battery due to prolonged periods in a fully or partially discharged state.
- Sun hours: The duration, measured in hours, required at a solar irradiance level of 1 kW/m^2 to generate the daily solar radiation accumulated from the integration of irradiance across all daylight hours. Sun hours are sometimes referred to as peak sun hours.
- System availability: A metric represented as 1 minus the loss of load probability (LOLP), expressed as a percentage, indicating the reliability and uptime of a system.

Acronyms and Abbreviations

Ah: ampere-hour

A:L: array-to-load ratio

AM: air mass

a-Si: amorphous silicon

I_{mp}: maximum power current

I_{sc}: short circuit current

LOLP: loss of load probability

MPPT: maximum power point tracker

P_{max}: power at maximum power point

POA: plane of array

ppm: parts per million

PV: photovoltaic

PWM: pulse-width modulation

SOC: state of charge

STC: standard test conditions

V_{dc}: volts direct current

V_{mp}: maximum power voltage

V_{oc}: open circuit voltage

VLA: vented lead-acid

Analytical Framework of Sizing the System

Sizing a stand-alone photovoltaic (PV) system involves determining the necessary PV module quantity and battery capacity. Other aspects like wiring, charge controllers, and inverters are not covered in this document. The sizing process combines worst-case solar radiation, load consumption, and system losses, with ambient temperature factored in for maximum power point tracker (MPPT) charge controller sizing. This differs from hybrid or grid-connected systems, where annual solar energy production is prioritized.

The PV array is sized to replenish ampere-hours (Ah) consumed by the load and compensate for system losses and inefficiencies. Any extra PV array capacity aids in faster battery recharging during low solar radiation periods.

PV system performance hinges on accurate solar radiation and load consumption data; inaccuracies lead to over- or under-designed systems. The application's criticality or load tolerance for downtime is crucial; non-critical loads allow for more cost-effective designs compared to highly critical systems needing high availability.

I. Strategy for PV array sizing

The document utilizes the sun-hour method to size PV arrays. In this approach, the daily module output is determined by converting solar radiation data on the plane of array (POA) into the equivalent number of standard full sun hours at 1 kW/m^2.

For shunt, series, and pulse-width modulation (PWM) regulators, the estimated average available Ah/day production from the PV array is obtained by multiplying the number of sun hours by the rated module peak power current. On the other hand, for MPPT controllers, the estimated average available Wh/day production from the PV array is obtained by multiplying the number of sun hours by the module peak power after temperature derate. This sun-hour method is employed for sizing the PV array.

II. Load calculation

Determining the load correctly is a crucial factor in appropriately sizing a stand-alone PV system. If the actual load exceeds the estimated load used during sizing, the system will be under-designed. Conversely, if the actual load is lower, the system may end up being over-designed. If the load varies across months, calculate the average load for each month. This data will be utilized to compute monthly array-to-load (A:L) ratios.

III. Days of autonomy

The sizing of the array is aimed at replacing the Ampere-hours (Ah) consumed by the load and accounting for system losses, while the battery size is determined to sustain the load during periods of low solar radiation.

The capacity of the battery significantly impacts system availability. A larger battery provides more backup days and usually results in higher system availability. However, there's a trade-off with lead-acid batteries; larger batteries increase the risk of sulfation. To mitigate this risk associated with prolonged low State of Charge (SOC) operation, also known as deficit charging, one can increase the Array-to-Load ratio (A:L) to enable faster battery recharging by the PV array, albeit at a higher system cost. Conversely, a smaller battery will undergo deep cycles more frequently, reducing both availability and battery lifespan.

A general guideline for determining the autonomy days:

- For non-critical loads and regions with abundant solar irradiance, it's recommended to have five to seven days of autonomy.
- For critical loads or regions with limited solar irradiance, it's advisable to aim for seven to 14 days of autonomy or even more.

IV. Battery sizing and selection

Here is a basic formula to calculate the required battery capacity for a stand-alone photovoltaic (PV) system based on IEEE Std 1013™:

$$Battery\ Capacity = \frac{Load\ Demand \times Days\ of\ Autonomy}{Battery\ Voltage \times Depth\ of\ Discharge \times Battery\ Efficiency}$$

Where:

Load Demand (Wh): Total energy consumption of the load in watt-hours per day.

Days of Autonomy: Number of days the system should be able to operate without solar input.

Battery Voltage (V): Nominal voltage of the battery system (e.g., 12V, 24V).

Depth of Discharge (DoD): Percentage of the battery's total capacity that can be safely discharged.

Battery Efficiency: Efficiency factor accounting for losses during charging and discharging processes.

Precise solar radiation data holds the same level of importance as accurate load data in the context of system design. It is crucial to utilize dependable solar radiation data specific to the site location or its closest approximation for optimal system design. Such data can be sourced from various public and private sources.

In scenarios where the load remains consistent throughout all months, it is advisable to utilize solar radiation data from the month with the most adverse solar radiation levels, considering the optimal tilt angle. Typically expressed in kWh/m^2, this value is essentially sun hours. If the sun hour data retrieved is not aligned with the single fixed plane of the array, adjustments for tilt (including possible seasonal variations, azimuth, and tracking mechanisms like motorized or passive tracking) must be made. However, single fixed angle arrays without seasonal adjustments are used as sun hour data already adjusted for the plane of the array single tilt angle.

Conversely, if the load varies across different months, the array and battery sizing must be tailored for each month. The month with the lowest Array-to-Load (A:L) ratio and battery autonomy should be identified as the worst-case scenario for system design. This iterative process ensures an accurate and optimized system design.

V. Finding the size of the array

The array sizing is determined by the solar radiation, A:L, system losses, and load.

Typical values used for A:L are as follows:

- For non-critical loads and areas with high and consistent solar radiation, an A:L of 1.1 to 1.2 is typical.
- For critical loads or areas with low solar irradiance, an A:L of 1.3 to 1.4 or higher is typical.

When choosing PV modules, factors such as cost, available area, module mounting/dimensions, and voltage ratings (including nominal, open circuit, and maximum power) are considered. Different PV modules may offer specific advantages based on factors like array size, performance in different irradiance conditions, and the intended application.

The next stage is to select a charge controller, also known as an output voltage regulator, to prevent battery overcharging during periods of intense solar radiation. Different charge controllers offer varying advantages depending on factors such as PV array size, performance in different irradiance conditions, and specific application requirements. Shunt, series, and PWM regulators lack the capability to adjust solar array current, making it crucial to ensure that the maximum current from the solar array does not exceed the controller's current rating. While some charge controllers can significantly adjust voltage from the input (array) to the output (batteries), others have limited voltage regulation capability. Therefore, it's important to match the array's nominal voltage to the battery's nominal voltage by selecting appropriate panel voltage ratings and considering series connections of panels if necessary.

It is important to account for system losses when calculating battery capacity. These losses encompass factors like dust or snow accumulation on the array, battery coulombic efficiency, as well as parasitic, conversion, and dissipation losses (which may not be included in the average daily load Ampere-hours). These losses are usually quantified as a percentage of the system load, with common ranges falling between 10% and 35%. Underestimating these losses can result in decreased system efficiency. Generally, this information can be derived from data provided by component suppliers.

Photovoltaic (PV) modules are typically rated under standard test conditions (STC). However, in practical systems, modules seldom operate at a cell temperature of 25 °C. The actual module temperatures can vary significantly, ranging from -40 °C to 80 °C, depending on factors such as ambient temperature, mounting structure, wind speed, and other environmental variables. For instance, a module installed in an open rack with airflow around it will generally have lower operating temperatures compared to one directly mounted on a roof. The module operating temperature is crucial because all types of PV modules experience reduced voltage and power output as temperatures rise. In regions with extremely high temperatures, like the desert southwest of the U.S., the voltage output of the PV array may decline to a level where it becomes insufficient to charge the system battery.

The temperature coefficients for photovoltaic modules, which indicate how their voltage and power output change with temperature, can vary from -0.1%/°C to -0.6%/°C, depending on the specific module and material used. A commonly accepted standard for crystalline silicon modules is a temperature coefficient of -0.5%/°C. To determine the temperature coefficients for a particular module, it is recommended to refer to the module literature or consult the manufacturer directly. A more negative temperature coefficient implies that the output of a specific PV technology will decrease more as temperatures rise. Conversely, technologies with a higher negative temperature coefficient will experience a higher module-output voltage at lower temperatures. When selecting and sizing charge controllers, it's essential to consider the maximum module output voltage expected at the lowest temperature.

To calculate the module-output voltage at a temperature other than 25 °C, the translation is calculated using the following Equation

$$V_{mp-new^0} = V_{mp} + (K_{T-V} + (T_{new} - 25^0 C))$$

where,

V_{mp-new^0} is the peak-power voltage at the operating temperature

V_{mp} is the STC rated peak-power voltage of the module

T_{new} is the operating temperature of the module

K_{T-V} is the temperature coefficient of voltage

If K_{T-V} is given in V/°C, then Equation (1) may be used directly. If K_{T-V} is given in %/°C or parts per million (ppm), the following Equation may be used if it is converted to V/°C.

As an example, assume a module has a maximum power voltage (V_{mp}) of 17.0 V. The expected operating temperature, Tnew, is 55 °C. The manufacturer may give the K_{T-V} as −0.085 V/°C or −0.5%/°C or −5000 ppm/°C.

If K_{T-V} is given as −0.085 V/°C, then V_{mp-new^0} is calculated using the following equation directly, as shown below:

$$V_{mp-new^0} = 17.0 \text{ V} + (-0.085 \text{ V} \times (55\ °C - 25\ °C)) = 14.45 \text{ V}$$

If K_{T-V} were given as −0.5%/°C, K_{T-V} translate it to V/°C before using Equation as shown below:

K_{T-V} (V/°C) = K_{T-V} (%/°C) × (V_{mp} ÷ 100%)= -0.5%/°C × 17.0 V ÷ 100% = -0.085 V/°C

If K_{T-V} were given as −5000 ppm/°C, translated it to V/°C before it can be used in Equation, as shown below:

K_{T-V} (V/°C) = K_{T-V} (ppm/°C) × (V_{mp} ÷ 1 000 000 ppm) = -5000 ppm/°C × 17.0 V ÷ 1 000 000 ppm) = -0.085 V/°C

Very similar equations (substituting power or current for voltage) can be used if the temperature coefficients for the power or current are known.

The number PV modules can be determined based on the following equation:

a) For Series Connected:

The number of series-connected PV modules can be determined as follows:

$$n_s = \frac{V_{max}}{V_{mp-new} - V_{losses}}$$

where

n_s is the number of series-connected PV modules

V_{max} is the highest battery charging voltage used

V_{losses} are the voltage losses from wire resistance, charge controllers, etc. from the solar module to the battery

V_{max} should include temperature compensation, equalization, etc.

V_{losses} can be calculated by summing all of the voltage drops through the PV system. Typical voltage drops include wire losses, regulators/charge controllers, shunts, switches, etc.

b) For Parallel Connected:

The formula for parallel connected PV can be determined as follows:

$$N_p = \frac{L_{DA} \times L{:}A}{(1 - \sigma_{L)} \times I_{mp-new} Sh}$$

where

N_p is the number of parallel strings of PV modules

L_{DA} is the average daily load in Ampere-hours

$A{:}L$ is the array-to-load ratio (When sizing a stand-alone PV system, the month with the lowest A:L should be used for sizing calculations)

σ_L are the system losses

I_{mp-new} is the module current at maximum power, corrected for the operating temperature (Maximum current corrected for the operating temperature should be calculated per 9.5 using the highest expected temperature)

Sh is the sun hours

If the outcome of this calculation usually won't yield an integer, it's advisable to round up the result to the nearest whole number. Furthermore, the number of parallel strings is contingent on the chosen module, so opting for a different module might lead to a more economical solution.

Steps in System Sizing

1) System name and description:
2) Nominal system __________ dc voltage.

3) Days of autonomy desired: __________.

4) Total daily load (may be obtained from line 5c of Worksheet —Battery Sizing, from IEEE Std 1013-2019): ____ Ah/day.

5) Max battery voltage (may be obtained from line 8d of Worksheet —Battery Sizing, from IEEE Std 1013-2019): ___ volts direct current (Vdc).

6) Battery capacity (may be obtained from line 12 of Worksheet —Battery Sizing, from IEEE Std 1013-2019): _____ Ah rated at the ____ hour rate.

7) System losses:

7a system loss (percent of system load)	7b Typical % window		7c System loss	7d multiplier
	max %	min %	%	decimal
Parasitic load (losses) of the charge controller [This is only the losses due to the need to keep the electronics and lights of the charge controller in an operating state, and not the dc-dc conversion losses of an MPPT charge controller]	5	1		
Coulombic losses of battery (refer to IEEE Std 1361-2014, Annex A.9) [Additional information on coulombic conversion losses in batteries can be found in Table B.2 of IEEE Std 1635/ASHRAE 21]	20	1		
Wire losses	5	0		
Module mismatch losses	5	0		
Module aging	20	0		
Dust	20	0		
Other				
Other				
Other				

8) Determine the number of peak sun hours: ____.

9) Decide on an A:L: ______.

10) Choose a PV module (manufacturer and model): ______.

a) Maximum power current (I_{mp}): _____ A.

b) Short circuit current (I_{sc}): _____ A.

c) Nominal voltage: ____ Vdc.

Open circuit voltage (V_{oc}): ______ Vdc.

e) Maximum power point voltage (V_{mp}): ______ Vdc.

f) Maximum power (P_{max}): ______ W.

g) Percentage temperature coefficient of Voc: ______%/°C or %/K.

h) Temperature coefficient of Voc [line 10d × 10g ÷ 100]: _____ V/°C or V/K.

i) Percentage temperature coefficient of Pmax: ______%/°C or %/K.

j) Temperature coefficient of Pmax [line 10f × 10i ÷ 100]: _____ W/°C or W/K.

k) Percentage temperature coefficient of Isc: ______%/°C or %/K.

l) Temperature coefficient of Isc [line 10b × 10k ÷ 100]: _____ W/°C or W/K.

m) Maximum operating ambient temperature: _______ °C.

n) Nominal operating cell temperature (NOCT): ______ °C.

o) Maximum operating temperature delta of PV module [line 10m + 10n – 25 °C]: _______ °C.

p) V_{mp} at max. module operating temperature [line 10e + (10h × (10o – 25 °C))]: _______ V_{dc}.

q) P_{max} at max. module operating temperature [line 10f + (10j × (10o – 25 °C))]: _______ W.

r) Imp at maximum module operating temperature [line 10a + (10ℓ × (10o – 25 °C))]: _____ A.

11) Multiply line 4 times line 9: _____ Ah/day.

12) Divide line 7e by 100 (this converts the percentage to a decimal) and subtract from 1: _____. Shunt, series, and PWM controller calculations:

13) Multiply line 12 times line 8 times line 10r: _____ Ah/day.

14) Divide line 11 by line 13: ____.

15) Round line 14 up to the nearest whole number: ____. This is the number of parallel PV module strings required.

16) Divide line 5 by line 10p and round up to the nearest whole number: ____. This is the number of modules to be wired in series in each string.

17) Multiply line 15 by line 16: ____. This is the total number of PV modules required for the system. MPPT controller calculations:

18) Choose a charge controller (manufacturer and model): ___________________________________.

a) MPPT charge controller efficiency: _____%

19) Multiply line 11 times line 2: _____ Wh/day. This is the daily load in Wh.

20) Multiply line 12 times line 8 times line 10q times line 18a divided by 100: _____ Wh/day. This is the individual module daily production.

21) Divide line 19 by line 20: _______.

22) Round line 21 up to the nearest whole number: _______. This is the minimum number of PV modules required for the system.

23) Divide line 2 by line 10c: _______. This is the number of PV modules per PV "string."
24) Divide line 22 by line 23 and round up to the nearest whole number: _______. This is the number of PV "strings."

25) Multiply line 23 by line 24: _______. This is the actual total number of PV modules needed.

An Example of implementing the standard "IEEE Std 1562™-2021: IEEE Recommended Practice for Sizing of Stand-Alone Photovoltaic (PV) Systems"

1. **Project Name and Description**: "Green Initiative for EV Charging"
2. his project aims to create a fully sustainable off-grid energy system using battery megapacks for energy storage and XXX solar panels for energy generation. The system is designed to support the energy needs of a parking lot, including charging for electric vehicles to ensure zero emissions and optimal energy efficiency.
3. **Nominal System DC Voltage**
   The system will operate at a nominal DC voltage of 1500 Vdc, aligning with the high-voltage capabilities of battery megapacks which facilitate efficient power transfer and reduced losses.
4. **Days of Autonomy Desired**
   Here the days of autonomy are considered for 3 days, ensuring enough energy storage to handle variations in solar generation and consumption patterns without grid interaction.
5. **Total Daily Load**

The total daily load needs to be calculated based on the actual consumption of the facility and EV usage, which might typically be around 100 Ah/day (considering Tesla Model), depending on specific energy usage patterns.

6. **Max Battery Voltage**
   The maximum battery voltage is typically 1500 Vdc, the upper limit for the battery megapack. 1,500 VDC is the nominal operating voltage that contributes to the megapack's overall efficiency and effectiveness in large-scale energy storage and distribution applications.
7. **Battery Capacity**
   Assuming the need for a significant capacity, one could consider a system of several megapacks, each with a capacity of about 3500 Ah at a 100-hour rate.
8. **System Losses**
   - 7a. System Loss: 5%
   - 7b. Typical % Window: Between 1% and 20% depending on the specific system components.
   - 7c. System Loss in Decimal: 0.05
   - 7d. Multiplier: Adjust based on total calculated system loss and operational environment.
9. **Peak Sun Hours**
   Typically, about 5 hours on average, depending on the location.
10. **A:L**
    A Tesla Model XXX typically has a battery capacity of around 100 kWh and an efficiency that can be roughly estimated at around 3 miles per kWh. The daily driving distance will directly influence the daily electricity usage. For the sake of calculation, let's assume the vehicle is driven 30 miles per day.

    Load Estimation
    - Daily Energy Consumption=*30 miles3 miles/kWh=10 kWh/day* Daily Energy Consumption=3 miles/kWh30 miles =10 kWh/day
    - Additional Facility Load: Assuming the facility connected to the solar power system (including Tesla Model X charging) requires an additional 40 kWh per day (this figure should ideally be calculated based on real data for accuracy).
      Total Facility and Vehicle Load=10 kWh+40 kWh=50 kWh/day Total Facility and Vehicle Load=10 kWh+40 kWh=50 kWh/day

    Calculation of A:L Ratio
    - Total Daily Solar Energy Production Requirement:
      The total energy requirement is 50 kWh/day.
      Given that the solar panels only produce power effectively during peak sun hours:
      *Required Solar Array Capacity=50 kWh/day5.5 hours/day≈9.09 re*quired Solar Array Capacity=5.5 hours/day50 kWh/day ≈9.09 kW

    Current PV Module Specification
    SunPower YYY panels, each with a maximum power output (P_{max}) of 350 W.

    Total Number of Panels Needed
    - Calculate the number of panels needed to meet the 9.09 kW requirement:
    - *Number of Panels=9.09 kW0.350 kW/panel≈26 panels Number* of Panels=0.350 kW/panel9.09 kW ≈26 panels

    Array to Load Ratio (A:L)

- The A:L ratio is calculated as the ratio of the array's nominal power output to the daily power requirement.
- *A:L Ratio=9.09 kW50 kWh/day≈0.18*A:L Ratio=50 kWh/day9.09 kW ≈0.18

Discussion

- An A:L ratio of 0.18 indicates that the array size is well-suited to meet the daily energy consumption of 50 kWh under the assumption of 5.5 peak sun hours per day.
- It's important to account for days with less sunlight or higher consumption, which might necessitate a larger array or additional energy storage capacity.
- Adjustments to this ratio may be needed based on more precise consumption data, seasonal sunlight variations, and potential future increases in load.

11. **Choose a PV Module**

Manufacturer and Model: SunPower YYY

- a) I_{mp}: 9.8 A
- b) I_{sc}: 10.1 A
- c) Nominal Voltage: 48 Vdc
- d) V_{oc}: 64.9 Vdc
- e) V_{mp}: 56.7 Vdc
- f) P_{max}: 350 W
- g) Percentage temperature coefficient of V_{oc}: -0.29%/°C
- h) Temperature coefficient of V_{oc}: -0.16461 V/°C
- i) Percentage temperature coefficient of P_{max}: -0.39%/°C
- j) Temperature coefficient of P_{max}: -1.365 W/°C
- k) Percentage temperature coefficient of I_{sc}: 0.05%/°C
- l) Temperature coefficient of I_{sc}: 0.005 W/°C
- m) Maximum Operating Ambient Temperature: 85 °C
- n) NOCT: 45 °C
- o) Maximum Operating Temperature Delta: 105 °C
- p) Vmp at max. module operating temperature: 44.56 Vdc
- q) Pmax at max. module operating temperature: 320.73 W
- r) Imp at maximum module operating temperature: 7.205 A

12. **Multiply line 4 times line 9**

- Total Daily Load (from hypothetical line 4): Assuming approximately 100 Ah/day as discussed.
- Days of Autonomy (from line 3): 3 days.
- Total Battery Requirement for Autonomy: *100 Ah/day×3 days = 300 Ah*100Ah/day×3days = 300Ah.

13. **Convert system losses to decimal and calculate**

- System Loss (7d multiplier): 0.05 (5% loss in decimal form).
- Adjusted Storage Requirement: *300 Ah÷(1−0.05)≈316 Ah*300Ah÷(1−0.05)≈316Ah.

14. **Daily Solar Generation Needed**

- Peak Sun Hours in South Texas: Approx. 5.5 hours per day.
- Daily Energy Requirement: 316Ah×48V =15168Wh/day.

15. **PV Module Requirements**

- Pmax per Module (from line 10f): 350 W.

- Total Number of Modules (Simple Calculation): *15168 Wh/day350 W/module×5.5 hrs≈ 8*350W/module×5.5hrs15168Wh/day ≈8 modules.

16. **Number of Parallel PV Module Strings**
    - Adjusted for Real-World Conditions: To account for inefficiencies, temperature effects, and potential shading, round up the number of modules to 10.
17. **Number of Modules Wired in Series**
    - System Voltage: 1500 V_{dc} (Assumed)
    - V_{mp} per Module (from line 10e): 56.7 Vdc
    - Series Modules Needed: *1500 Vdc56.7 Vdc/module≈26*56.7Vdc/module1500Vdc ≈26 modules per string.
18. **Total Number of PV Modules:**

- **Given the series and parallel requirements**: *10 strings×26 modules/string=260*

19. **Choose a Charge Controller:**
    - Manufacturer and Model: Model: Manufacturer: OutBack Power
    - Model: OutBack FlexMax 100 FM100-300VD
    - Specifications:
      - Maximum Input Voltage: Up to 1500 V_{dc} or higher.
      - Maximum Output Current: 110 A (to provide a buffer over the calculated 88.2 A).
      - Efficiency: 98% or higher, to ensure minimal energy losses.
    - Voltage Compatibility: The FlexMax 100 supports system voltages up to 3000 VDC, making it well-suited for high-voltage systems. For the setup we discussed, with a nominal voltage of 1500 Vdc, multiple charge controllers might be configured in parallel to handle sections of the PV array effectively, ensuring that system voltage levels are adequately managed.
    - Current Handling: This model can handle up to 100 amps of continuous charge current, accommodating the large-scale nature of the solar array which includes 279 modules potentially producing substantial currents.
    - Advanced MPPT Technology: It utilizes advanced MPPT technology to ensure maximum energy harvest, especially vital in climates with variable sunlight conditions.
    - Scalability and Integration: The FlexMax 100 integrates well with other OutBack Power components and systems, offering scalability and robust monitoring capabilities, which are essential for large installations.
    - Programmable Settings: It offers programmable settings to optimize charge parameters to match the specific battery chemistry and conditions, further improving the system's efficiency and battery life.
    - Built-In Safety Features: Includes integrated protection systems for overcharge, short circuit, and reverse polarity, ensuring both the safety of the PV system and the connected storage solution.
20. **Daily Load in Wh: Multiply Line 11 Times Line 2**
    - Nominal System DC Voltage (from line 2): 1500 Vdc (assumed for calculation based on typical Tesla Megapack installation).
    - Total Daily Load in Ah (from line 11, recalculation): 316 Ah (adjusted for system loss and days of autonomy).

- Load Calculation: Daily Load in Wh=316 Ah×1500 Vdc=474000 Wh/dayDaily Load in Wh=316Ah×1500Vdc=474000Wh/day

21. **Individual Module Daily Production**
    - Assuming an average peak sun hour of 5.5 hours daily for South Texas:
    - Pmax per Module (from line 10f): 350 W.
    - Calculation: Individual Module Daily Production=350 W×5.5 hours=1925 Wh/day/module Individual Module Daily Production=350W×5.5hours=1925Wh/day/module
22. **Divide Line 19 by Line 20: Minimum Number of Modules**
    - Calculation: Minimum Number of Modules=474000 Wh/day/1925 Wh/day/module≈246 modules
23. **Round Line 21 up to the Nearest Whole Number**
    - For system efficiency and to cater for possible future expansion or less than optimal conditions (such as dust, cloud cover, aging): Rounded Minimum Number of Modules=250modules
24. **Divide Line 2 by Line 10c: Number of Modules per PV "String"**
    - Nominal Voltage per Module (from line 10c): 48 Vdc.
    - Calculation: Number of Modules per PV String=1500 Vdc/48 Vdc/module= 31.25Number of Modules per PV String=48Vdc/module1500Vdc =31.25
25. **Divide Line 22 by Line 23 and round up to the Nearest Whole Number: Number of PV "Strings"**
    - Calculation: Number of PV Strings=250 modules31 modules/string≈8.06Number of PV Strings=31modules/string250modules ≈8.06
    - Round up to ensure full coverage: Rounded Number of PV Strings=9 strings Rounded Number of PV Strings=9strings
26. **Multiply Line 23 by Line 24: Actual Total Number of PV Modules Needed**
    - Calculation: Actual Total Number of PV Modules =31 modules/string×9 strings=279 modules Actual
    - Total Number of PV Modules=31modules/string×9strings=279modules

Standard 2: IEEE 2030.9-2019: IEEE Recommended Practice for the Planning and Design of the Microgrid

Introduction

The "IEEE 2030.9-2019 IEEE Recommended Practice for the Planning and Design of the Microgrid" is a standard published by the IEEE to provide guidance and best practices for the planning and design of microgrids. The Microgrid is becoming popular increasingly in our modern grid systems and is designed to enhance resiliency, efficiency, and green energy integration. The microgrids are small-scale and localized energy systems that can operate independently or in conjunction with the main power grid to provide electricity for a limited number of customers. The standard includes system configuration, electrical system design, safety, power quality monitoring and control, electric energy measurement, and scheme evaluation.

Definitions

The terms and definitions outlined in this document are as follows.

- Distributed Energy Resources (DER): These are sources and collections of electric power that are not directly linked to the bulk power system. They encompass generators as well as energy storage technologies capable of exporting power.
- Distributed Generation (DG): This refers to electric generation facilities that are connected to the local Electric Power System (EPS) via a Point of Common Coupling (PCC), which is a subset of DER.
- Electric Power System (EPS): This encompasses facilities responsible for delivering electric power to a load.
- Grid-Connected Microgrid: A microgrid that physically connects to the EPS but has the ability to disconnect from the grid and operate independently based on physical or economic conditions. This falls under the category of microgrids.
- Microgrid: This comprises a collection of interconnected loads and distributed energy resources within clearly defined electrical boundaries. It functions as a unified and controllable entity concerning the grid, capable of connecting to or disconnecting from the grid to operate in grid-connected or island modes. For more information, see IEEE Std 2030.7™.
- Point of Common Coupling (PCC): This denotes the connection point between the Area EPS and the Local EPS. Refer to IEEE Std 1547-2018 for additional details.
- Stand-Alone Microgrid: A microgrid that lacks a direct physical connection to the EPS and remains in standalone mode consistently, constituting a subset of microgrids.

Acronyms and Abbreviations

EPS: electric power system

DG: distributed generation

PCC: point of common coupling

CHP: combined heating and power

CCHP: combined cooling heating and power

DER: distributed energy resources

Procedures of Microgrid Planning and Design

The primary objective of microgrid planning and design involves defining the arrangement of distributed energy resources (DERs), the electrical network layout, and the configuration of the automation system. When designing a microgrid, planners should carefully assess factors such as the local load profile, energy demand, and available energy resources. The outcome of this planning process should be flexible enough to meet both current and anticipated future demand growth.

This recommended approach outlines the optimal specifications for both the internal setup and external connections of a microgrid. It also outlines a step-by-step procedure for planning and designing a microgrid, depicted in Figure

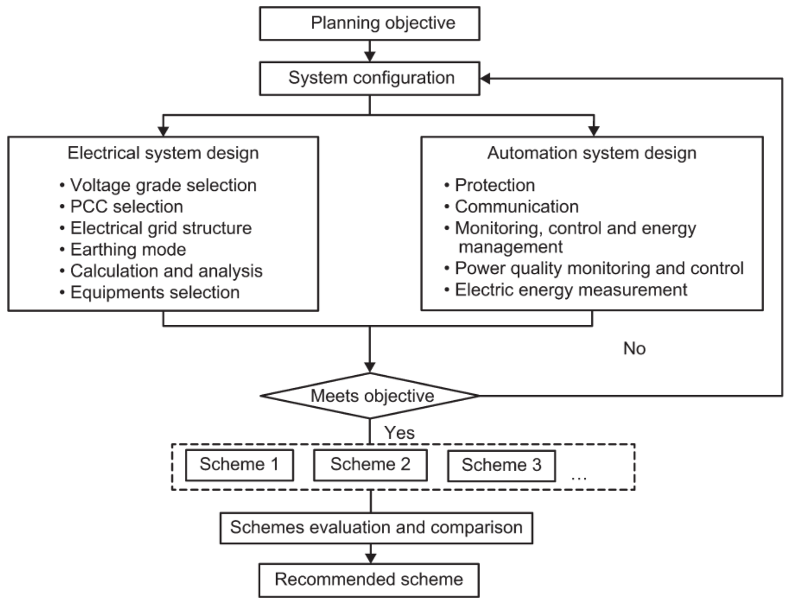


Figure 1: Basic procedure of microgrid planning and design

1. Microgrid planning

The goal of microgrid planning is to devise a construction blueprint that meets the power demand, taking into account the load profile, operating conditions of Distributed Energy Resources (DERs), and overall system status.

Microgrid planning should be executed based on specific application scenarios, objectives, performance requirements, and cost-benefit analysis. This planning process should encompass a thorough analysis of loads and available resources, configuration of Distributed Generators (DGs) and energy storage systems, and the formulation of a system operation strategy.

Furthermore, for microgrids that involve cooling and heating requirements along with thermal resources, it's crucial to determine the output format of non-electric energy based on microgrid operating conditions. For instance, energy supply formats like solar-thermal, ground source heat pumps, and combined cooling/heating and power (CCHP) utilizing gas turbines can be considered. Similarly, various energy storage formats such as electrical energy storage, phase-change heat, compressed air, and hydrogen storage can also be explored.

The objective classifications of the microgrids and the corresponding typical application scenarios can be discussed as follows:

- Economic benefits are life cycle cost, net revenue, payback period, and internal rate of return, etc. Applicable in areas without Electric Power Systems (EPS) service, like islands and remote regions.

- Reliability is measured by the rate of load loss and expected unmet demand. Suitable for customers with specific needs for power supply reliability, such as data centers and hospitals.
- Environmental factors include pollution and carbon emissions, fossil fuel consumption, and the utilization of renewable energy sources. Designed for regions with specific environmental protection requirements.

The planning of the microgrid has the following sections:

I. Load Analysis

A. Load forecasting

The process of load forecasting serves to identify load types and requirements, playing a crucial role in the configuration of Distributed Generators (DGs), energy storage, and power supply selection for microgrids. It involves statistically analyzing the current load conditions within the microgrid's planning, reconstruction, or expansion area, including:

i. Identification of main power load types.
ii. Assessment of peak load demand.
iii. Evaluation of typical daily load curves for each month.

Forecasting load demand for the planning period entails utilizing historical load data and considering the total power development requirements within the microgrid's coverage area. This includes:

a. Projecting the growth trend of peak load.
b. Analyzing types and levels of additional load.
c. Generating data for total annual load demand forecasting.
d. Forecasting typical daily load demand with hourly interval data.
e. Incorporating dynamic load characteristics forecasting data, such as those related to motors, with minute or second-level granularity.

Several influencing factors must be taken into account during load forecasting, including:

- Economic factors, which impact load size.
- Time factors, such as load variations between weekdays and weekends, during major holidays, and across different seasons.
- Meteorological factors like temperature, humidity, cloud cover, rainfall, and comfort requirements, especially during summer.
- Other factors like changes in consumption patterns among large power consumers and fluctuations in electricity prices, which can influence load demand accuracy.

B. Load Classification

Load classification divides load into two categories based on power supply reliability requirements and the impact of power interruptions on safety and economic losses:

i. Uninterruptible load: Includes loads with a high risk of personal injury, potential severe economic losses, or disruptions to key electric power consumers during power interruptions.
ii. Intermittent load: Encompasses loads that can be interrupted or reduced during peak load periods or emergency situations according to contractual agreements.

II. Power Generation Forecasting

Prior to power generation forecasting, resource analysis evaluates solar, wind, biomass, natural gas, etc., resources, and the geographic environment of the planning region to determine a viable DG configuration scheme in terms of type and location.

Power output forecasting forms the basis for calculating electric power and energy balance. For solar and wind power, it involves collecting and analyzing solar radiation and wind speed monitoring data over a minimum of one year to assess annual energy generation, generation curves, and daily generation patterns. Data collected includes:

i. Monthly maximum and average values of irradiance and wind speed.
ii. Hourly radiation, wind speed, and temperature averages for at least a year.
iii. Maximum and extreme wind speeds and associated occurrences.
iv. Extremes weather occurrences like consecutive rainy days, thunderstorms, and sandstorms.

For biomass, natural gas, and diesel-based power generation, besides generator unit characteristics, fuel quality, supply, and price also influence power output forecasting, requiring investigation and historical data collection for evaluation within the planning horizon.

2. Microgrid Components Design

I. Voltage Level Selection:

The determination of voltage levels within the microgrid and its connection to the EPS should adhere to the following guiding principles:

a. Voltage levels within microgrids should be determined comprehensively based on internal energy resources, load size, planned area, and microgrid cost. Typically, the voltage level is capped at 35 kV, encompassing options such as 23 kV, 13.8 kV, 0.48 kV, and others. It is advisable to minimize the number of voltage levels in the series when making selections. In cases where DC loads are present, DC busbars can be established with voltages determined comprehensively based on the load requirements, battery voltage grades, and similar factors. Below the Table 1 outlines the recommended highest voltage levels within the microgrid, aligning with the installed capacity of renewable energy resources.

Voltage levels within microgrid (or stand-alone microgrid) (kV) Installed capacity of renewable energy resources (MW)	Voltage levels within microgrid (or stand-alone microgrid) (kV) Installed capacity of renewable energy resources (MW)
30/34.5/35	≤ 100
20/22/23	≤ 50
6.9/10/11/13.	≤ 20
0.4/0.48/0.69 ≤ 2	≤ 2

b. The voltage level at which the microgrid connects to the EPS (Electrical Power System) should be determined based on the maximum power exchange between the external power grid and the microgrid. The highest permissible voltage level should not exceed 35 kV. Table 2 outlines the recommended voltage levels corresponding to the power exchange between the microgrid and EPS.

Voltage level of the EPS that microgrid accesses to (kV)	Exchange power of PCC (MW)
30/34.5/35	≤ 20
20/22/23	≤ 10
6.9/10/11/13.8	≤ 6
0.4/0.48/0.69	≤ 0.5

II. Selecting the PCC for Grid-Connected Microgrid:

The selection of the PCC and the types of connections for a grid-connected microgrid should adhere to the following principles:

a) The PCC serves as the connection point where one or more customers are linked to the power system. It is generally recommended for a microgrid to have a single PCC. In the case of a microgrid with a step-up substation, a busbar or node on the high-voltage side is suggested to act as the PCC. For a microgrid lacking a step-up station, its convergence point for input/output is advised to be the grid connection point.

b) The common accessing methods for 10~35 kV microgrids to the Electric Power System (EPS) include special line connection, T-type connection, and connection via a switching substation, among others. For 0.4 kV microgrids, typical methods include special line connection and T-type connection. The specific connection type should be chosen comprehensively, taking into account factors such as voltage level, size, cost, and stability of the connected EPS.

3. Electrical Grid Structure

The structure of the electrical grid within the microgrid is planned according to the following guidelines:

a) The microgrid's grid layout and electrical connections should align with the power generation sources and load areas, ensuring ease of connection for resources and users. For critical or highly reliable users, a loop structure design is suitable.

b) The primary wiring of the microgrid should be selected based on factors like reliable power supply, flexible operation, easy control and maintenance, cost-effective investment, and seamless transition or expansion.

c) In a microgrid setup, distributed power sources, energy storage facilities, and loads should connect to the centralized AC busbar. Their primary electrical connections should be determined based on planned capacities, line requirements, transformer connecting units, device characteristics, etc. Options such as unit connection, single-bus connection, sectionalized single-bus connection, etc., should be considered, with ample bays or additional space left for future needs.

d) Microgrids connected to the main grid should have main busbars connecting critical loads and controllable power sources. Wiring at connection points should adhere to EPS (Emergency Power Supply) requirements. Using single-bus or sectionalized single-bus connections, creating an outgoing line to EPS, and incorporating transfer switches between grid-connected and stand-alone modes are appropriate.

e) Stand-alone microgrids can adopt various grid structures. Radial connection may be suitable when the power source is distant from the load. Within the microgrid, a main busbar can link critical loads and energy storage devices. If needed, the grid should be structured to enable connection to the EPS for added reliability.

4. Power Flow Calculations

The power flow calculation for the microgrid should encompass the following considerations:

a) The power flow calculation for the microgrid aimed at the planning/design target year must account for various operating conditions. This includes conducting calculations for the microgrid under typical maximum and minimum loading conditions, during maintenance or faults, and when distributed generators (DGs) operate at their maximum and minimum generation levels.

b) The boundaries for the power flow calculation can be established by combining different typical generation and loading scenarios. This encompasses scenarios such as maximum generation and minimum loading. The minimum generation condition should address extreme scenarios where all intermittent generation resources are offline, and energy storage is fully discharged. For grid-connected microgrids, the power flow calculation should also account for abnormal conditions when the microgrid is disconnected from the main grid. In the case of a 400 V level microgrid, power flow calculations can be simplified by focusing on typical operating conditions, while ensuring that branch power flow or nodal voltage limits are not exceeded.

c) For grid-connected microgrids, the power flow calculation should verify the integration scheme of the microgrid with the main grid, the selection of conductor cross-sections, and the configuration of electrical apparatus.

d) Short-circuit calculations: Short-circuit calculations are essential in the design of microgrids:

i. Short-circuit calculations for the microgrid should address grid connection points, adjacent nodes, and internal nodes under different operational scenarios in current and prospective planning years. Various fault types, including three-phase faults, two-phase faults, single-phase grounding faults, and high-impedance grounding faults, should be considered and calculated.
ii. Short-circuit calculations should take into account the external fault characteristics of different power sources, energy storage devices, AC devices, and the short-circuit capacity of the Electrical Power System (EPS). For major devices such as lines and busbars, the distribution of fault current should also be calculated. In the case of a grid-connected microgrid, short-circuit calculations should be conducted for both grid-connected and stand-alone operation modes.
iii. The selection of electrical devices should align with the requirements derived from the results of short-circuit current calculations.

5. **Monitoring, Controlling, And Managing Energy in Microgrid**

The aim of microgrid monitoring, control, and energy management is to oversee, regulate, and visualize the operational status of the microgrid while achieving optimal scheduling and real-time energy flow management within the microgrid. This typically involves two components: a monitoring and control system, and an energy management system.

The monitoring and control system ensures the stability and security of microgrids by gathering and monitoring data from distributed generators, storage units, and the grid. This information is then displayed in a graphical interface, with related data being stored and updated promptly. On the other hand, energy management ensures the economical operation of power generation, distribution, and consumer equipment in the microgrid.

a. System Setup

Microgrid monitoring, control, and energy management systems are generally configured in two technical approaches: centralized mode and distributed mode. For instance, in the centralized mode, the system configuration may comprise three logical levels: the device, management, and optimization layer (described below as a) to c)). In contrast, in the distributed mode, a) and b) can be integrated.

i. Local monitoring and control layer: Primarily responsible for local data acquisition, information uploading, and command execution. Please refer to Table 5 for main functionalities.
ii. Coordinated control layer: Focused on the coordinated control of distributed energy resources and controllable loads within the microgrid to ensure internal stability and access various types of distributed energy resources.
iii. Energy management layer: Primarily handles real-time information monitoring, historical data storage, system operation control, advanced energy management, report generation, and other related functions.

b. Functionality of Monitoring, Control, and Energy Management

Monitoring and energy management systems can expand their functionalities based on user requirements. These extensions may include coordinated control, protection management, historical data management, web server integration, formula calculation, user process support, remote control and forwarding, on/off grid switch control, grid-connected power control, island operation control, operation mode management, black start control, emergency control, etc.

c. Monitoring and Controlling Microgrids

The monitoring and control system of a microgrid typically comprises a master station, remote terminal unit, and communication system. It establishes monitoring functionalities and configurations based on factors such as distributed generators (DGs), storage units, load capacities, their respective locations, and voltage levels connected to the grid.

d. Master Station of the Microgrid:

- The master station of the microgrid serves various functions, including data acquisition, data processing, interfacing with external systems, event management, monitoring communication networks, and time synchronization.
- Data acquisition functions enable the collection of analog and state-related information. Analog data encompasses parameters like current at DG connection points, voltage levels, active and reactive power, frequency, and electrical energy quality. State information covers switch status, trip signals, protection actions, abnormal signals, etc.
- Data processing functions rationalize inspections, issue over-limit alarms, perform backups, calculations, analysis, and process collected data for emergency control.
- Interfacing with external systems facilitates interactions with systems such as dispatching automation, distribution automation, and power information collection systems.
- Event processing capabilities include recording event sequences, fault location identification, accident recall, etc.
- Monitoring communication networks function involves overseeing the operational status of communication channels.
- Time synchronization functionality receives time sync commands and synchronizes time with the DG monitoring terminal.
- The master station may also encompass display and reporting features through Human-Machine Interface (HMI). This interface enables real-time data display, interactive operations, report management, printing, etc. It can show microgrid operating parameters like power flow, switch statuses, historical and real-time data for each line. Additionally, it allows setting microgrid protection

parameters, selecting operating modes, sending operational instructions to switches, and more.

6. **Technical Evaluation**

   a. **Power Supply Reliability**

Power supply reliability Reliability of power supply serves as an important index in evaluating the microgrid, commonly used indexes include: System average interruption frequency index (SAIFI) It refers to how often the average customer experiences a sustained interruption over a predefined period of time (as referred to IEEE Std 1366-2003 [B7]). Mathematically, this is calculated as:

$$SAIFI = \frac{\sum Total\ Number\ of\ Customers\ Interrupted}{Total\ Number\ of\ Customers\ Served} = \frac{\sum N_i}{N_T} = \frac{CI}{N_T}$$

where N_i is the number of interrupted customers for each sustained interruption event during the reporting period N_T is the total number of customers served for the areas CI is the customers interrupted

System average interruption duration index (SAIDI) refers to the total duration of interruption for the average customer during a predefined period of time (as referred to IEEE Std 1366-2003 [B7]). It is commonly measured in customer minutes or customer hours of interruption. Mathematically, this is calculated as:

$$SAIFI = \frac{\sum Customer\ interruption\ durations}{Total\ Number\ of\ Customers\ Served} = \frac{\sum r_i N_i}{N_T} = \frac{CMI}{N_T}$$

where r_i is the restoration time for each interruption event CMI is the customer minutes interrupted.

Loss of load probability (LOLP) refers to the probability that the available capacity of the DER (including the energy storage) within the microgrid (generally referred to the stand-alone microgrid) fail to meet the maximum annual load demand of the system, and its calculation method is as follows:

L_i refers to the daily maximum load of the known system, *C* refers to the system generating capacity, then the probability is:

$$P(C_n < L_i) = P_n'(C_n - L_i)$$

If the load given is the maximum load per day, the loss of load probability in *N* days is:

$$LOLP = \frac{1}{N}\sum_{i=1}^{n} P_n'(C_n - L_i)$$

Average service availability index (ASAI) refers to the ratio between the available serve hours and the total demanded hours during a specific period, which can be calculated with the following formula:

$$ASAI = (1 - LOLP) * 100\%$$

Microgrid average interruption duration index (MAIDI) refers to the average interruption duration experienced by a general customer on each year within the microgrid. The index can be calculated by the total amount of interruption duration per year dividing the total number of customers powered per year:

$$MAIDI = \frac{\sum N_i U_i}{\sum N_i}$$

where N_i is the number of customers at load point i U_i is the equivalent of annual average interruption time at load point i

For the reliability evaluation of microgrid power supply, the following two points also need to be considered:

- The effect of randomness and intermittence of distributed power output on the reliability of microgrid power supply
- The influence of distributed power on the reliability evaluation of the power supply under stand-alone mode

b. Grid Loss

The distributed energy resource is able to facilitate the reduction of grid loss by powering the local demand and thus decreasing the power flow from the connected EPS. To simplify the calculation, loss reduction rate is normally used to evaluate the beneficial results by the following formula:

$$R_{lr} = p * k\% \sum_{i=1}^{n} E_{DG,i}$$

Where, R_{lr} is the beneficial results of loss reduction, p is the electricity price of power grid, K is the loss reduction rate, and $E_{DG,i}$ is the power generation of distributed power at node i . This index is commonly used to describe the influence of grid-connected microgrid to the EPS. The loss of microgrid is influenced by many factors, such as the length of low voltage line, power factor, threephase unbalance, inverter capacity, and line sectional area, which should be comprehensively considered to improve the loss reduction.

7. Economic Evaluation

a. Total Net Present Cost

The total net present cost can represent the life cycle cost. CNPC is obtained through discounting all of the cost values including initial investments, operation and maintenance costs, the costs of equipment replacing, fuel costs, residual values, grid purchase costs, and fines from now to the initial year.

$$C_{NPC} = C_{initial} + C_{om} + C_{replace} + C_{fuel} - C_{salvage} + C_{pollution}$$

b. Equivalent Annual Cost

Different project varies in life cycle so it is not accurate to compare the economic efficiency of these projects by calculating the net present cost, and the use of the equivalent annual cost is more proper in this case.

$$C_{ANN} = C_{NPC} CRF(i, R_{project})$$

c. Unit Power Supply Cost

Unit power supply cost can be used to analyze the microgrid economic efficiency to compare the economic efficiency of projects with different scale and life cycle.

$$COE = \frac{C_{ANN}}{E_{load} + E_{Grid,sales}}$$

Where E_{load} is the total energy load and $E_{Grid,sales}$ is annual electricity sold to the grid. The unit power supply cost is the average cost of the available energy generated by the microgrid system.

An Example of implementing the standard **"**IEEE 2030.9-2019: IEEE Recommended Practice for the Planning and Design of the Microgrid**"**

Let's consider a fictional microgrid planning scenario for a small island community. The goal is to design a microgrid that can meet the power demand of the community while utilizing renewable energy sources efficiently.

Technical Evaluation:

1. Load Analysis:
   - Peak Load Demand: 500 kW
   - Typical Daily Load Curve:
   - Morning (6 AM - 12 PM): 400 kW
   - Afternoon (12 PM - 6 PM): 600 kW
   - Evening (6 PM - 12 AM): 450 kW
   - Night (12 AM - 6 AM): 300 kW
2. Power Generation Forecasting:
   - Solar Energy Potential: Average daily solar radiation of 5 kWh/m2
   - Wind Energy Potential: Average wind speed of 8 m/s
   - Biomass Energy Potential: Availability of agricultural waste for biomass conversion
   - Natural Gas Backup: Available for continuous power supply

Based on these inputs, let's calculate the estimated power generation and microgrid specifications:

3. Solar Power Generation:
   - Solar Panel Efficiency: 20%
   - Area for Solar Panels: 1000 m^2

- Daily Solar Energy Generation: 1000 m^2 * 5 kWh/m^2 * 20% = 100 kWh

4. Wind Power Generation:
   - Wind Turbine Capacity: 50 kW
   - Daily Wind Energy Generation: 50 kW * 24 hours = 1200 kWh
5. Biomass Power Generation:
   - Biomass Generator Capacity: 200 kW
   - Daily Biomass Energy Generation: 200 kW * 24 hours = 4800 kWh
6. Total Daily Renewable Energy Generation: 100 kWh (Solar) + 1200 kWh (Wind) + 4800 kWh (Biomass) = 6100 kWh
7. Considering a 3-day moving average for load forecasting, the MAD (Mean Absolute Deviation) can be calculated to assess the accuracy of the forecasted load.
8. Load Forecast (3-Day MA):
   - Day 1: 500 kW
   - Day 2: 450 kW
   - Day 3: 550 kW
   - Actual Load (Day 4): 520 kW
9. Absolute Deviation for Each Day:
   - Day 4: |520 kW - ((500 kW + 450 kW + 550 kW) / 3)| = 520 kW - 500 kW = 20 kW
   - MAD = (|20 kW|) / 1 = 20 kW

   This MAD value indicates the average magnitude of error in load forecasting using the 3-day moving average method for the microgrid.

10. System Average Interruption Frequency Index (SAIFI):
    - Assume during the planning period, the microgrid experiences a total of 10 sustained interruption events, and the total number of customers served is 100.
    - SAIFI = (10 interruptions) / (100 customers) = 0.1 interruptions/customer
11. System Average Interruption Duration Index (SAIDI):
    - If the total interruption duration for these events is 300 minutes:
    - SAIDI = (300 minutes) / (100 customers) = 3 minutes/customer
12. Loss of Load Probability (LOLP):
    - Given the daily maximum load is 1000 kW, and the system generating capacity is 1200 kW.
    - Let's assume the load data for 5 days is:
      - Day 1: 950 kW
      - Day 2: 1000 kW
      - Day 3: 1050 kW
      - Day 4: 1100 kW
      - Day 5: 1150 kW
13. Calculate the LOLP using the provided formula:
    - $LOLP = \frac{1}{N}\sum_{i=1}^{n} P_n'(C_n - L_i)$

- LOLP = 1/5 * [(1200 - 950) + (1200 - 1000) + (1200 - 1050) + (1200 - 1100) + (1200 - 1150)]
- LOLP = 1/5 * [250 + 200 + 150 + 100 + 50] = 750 / 5 = 150

14. Average Service Availability Index (ASAI):
    - ASAI = (1 - LOLP) * 100% = (1 - 150/1200) * 100% ≈ 87.5%
15. Microgrid Average Interruption Duration Index (MAIDI):
    - Let's assume the total interruption duration per year is 600 minutes, and the total number of customers powered per year is 200.
    - MAIDI = (600 minutes) / (200 customers) = 3 minutes/customer
    - Grid Loss Reduction:
        - Assume the loss reduction rate (k%) due to distributed energy resources is 10%. Given the electricity price (p) of the power grid is $0.10 per kWh. Calculate the beneficial results of loss reduction (R_lr) using the provided formula:
        - $R_{lr} = p * k\% \sum_{i=1}^{n} E_{DG,i}$
          = $0.10/kWh * 10% * (100 kWh + 1200 kWh + 4800 kWh) ≈ $5.30

By incorporating these technical evaluations and reliability calculations, we can better assess the performance and reliability of our designed microgrid. These metrics provide insights into power supply reliability, interruption frequency and duration, load probability, and the impact of distributed energy resources on grid loss reduction.

Economic Evaluation:

Parameters:

- Initial investment (C_initial): $500,000
- Annual operation and maintenance costs (C_om): $50,000
- Equipment replacement costs (C_replace): $20,000
- Fuel costs (C_fuel): $30,000
- Salvage value (C_salvage): $10,000
- Pollution fines (C_pollution): $5,000
- Project lifespan (n): 10 years
- Discount rate (i): 5%
- Annual energy load (E_load): 100,000 kWh
- Annual electricity sold to the grid (E_(Grid,sales)): 30,000 kWh

Let's calculate the economic evaluation metrics:

a. Total Net Present Cost (C_{NPC}):

$$C_{NPC} = C_{initial} + C_{om} + C_{replace} + C_{fuel} - C_{salvage} + C_{pollution}$$

C_{NPC}= $500,000 + $50,000 + $20,000 + $30,000 - $10,000 + $5,000 = $595,000

b. Equivalent Annual Cost (C_{ANN}):

$$C_{ANN} = C_{NPC} CRF(i, R_{project})$$

Calculate the Capital Recovery Factor (CRF) using the formula CRF(i, n) = i * $\frac{i*(1+i)^n}{(1+i)^{n-1}}$

CRF(5%, 10 years) = (0.05 * (1 + 0.05)^10) / ((1 + 0.05)^10 - 1)

CRF(5%, 10 years) ≈ 0.1124

C_{ANN} = C_NPC * CRF(5%, 10 years)

C_{ANN}= \$595,000 * 0.1124 ≈ \$66,830.00 per year

c. Unit Power Supply Cost (COE):

$$COE = \frac{C_{ANN}}{E_{load} + E_{Grid,sales}}$$

COE = \$66,830.00 / (100,000 kWh + 30,000 kWh)

COE = \$66,830.00 / 130,000 kWh ≈ \$0.514 per kWh

In this example, the total net present cost (C_{NPC}) for the microgrid project is approximately \$595,000. The equivalent annual cost (C_{ANN}) is around \$66,830 per year, and the unit power supply cost (COE) is approximately \$0.514 per kWh. These economic evaluation metrics help assess the economic efficiency and feasibility of the microgrid project.

MODULE 4

Implemented course: CHEN 3310 – Heat Transfer Phenomena
Standard used: ASTM B153 Test Method for the Expansion of copper and Copper-Alloy Pipe and Tubing

What are Standards and Standardization?

Standards: These are established benchmarks or rules that define the characteristics, performance or quality of products, services, processes or systems. Standards can cover a wide range of areas, Including technology, safety, manufacturing. Engineering Standards provides uniformity, quality, compatibility, interchangeability and Interoperability among components, systems and processes. Standards ensure the safety, quality and reliability of products and services.

Engineering professionals use these standards as guidelines and reference in design, manufacturing and testing of Mechanical components and systems. Compliance with these standards is critical to ensure products Quality, Safety, Regulatory Compliance in the field of engineering.

Standardization: This Is the process of creating, updating and adhering to standards. It involves Collaboration among experts, organizations, and stakeholders to set common rules and guidelines. Standardization helps to ensure that products and services are compatible and meet certain quality and safety standards.

Standardization is the process of Implementing and developing technical standards based on the consensus of different parties that Include firms, users, Interest groups, standards organization and governments. Standardization is the process of developing, mandating standards-based and compatible technologies and processes within an Industry.

Importance of standards and Standardization

The standards ensure that goods or services produced in a specific industry come with the consistent quality and are equivalent to other comparable products or services in the same industry. Standardization also helps in ensuring the safety, Interoperability, and compatibility of goods produced. Standards and Standardization plays a crucial role in various aspects of our modern world and their Important Is Multifaceted.

1. **Quality and Safety:** Standards help to ensure the quality and safety of products, services and processes. They set benchmarks for performance and reliability, reducing the risks of defects and harm to consumers and users.
2. **Interoperability:** Standards enable different products and systems to work together seamlessly. This is particularly Important in Technology where compatibility ensures that devices and software from various manufacturers can communicate and operate without Issues.
3. **Innovation:** Standards provide a foundation for Innovation by offering a common set of rules and specifications.

4. **Trade and globalization:** International standards facilitate global trade by ensuring that products and services can be easily exchanged across borders. They remove technical barriers to trade and promote economic growth.
5. **Efficiency:** Standardization leads to efficiency improvements in various sectors. When everyone follows the same guidelines, resources are used more efficiently, and processes become streamlined.
6. **Consumers' confidence:** Standards help to build consumer confidence. When consumers know that products and services adhere to recognized standards, they are more likely to trust and purchase them.
7. **Environment Impact:** Standards can promote sustainability and reduce the environmental impact of Industries by setting guidelines for energy efficiency, waste reduction and sustainable practices.
8. **Cost reduction:** It can lead to cost reduction by eliminating the need for a custom solution. Mass production of standardized components often results in economics of sales.

Standards Development and Modification Process

The Development of Engineering Standards is a critical process that ensures the quality, safety and compatibility of engineering products and systems. Developing and Modifying standards typically follows these general steps:

1. **Identifying the Need**: Standards are often developed or modified in response to changing technology, industry needs and practices, safety concerns, or regulatory requirements. The process begins by identifying the specific need for a new engineering standard or a modification to an existing one.
2. **Formation of a Technical Committee**: An organization or standards body, such as the International Organization for Standardization (ISO) or the American National Standards Institute (ANSI), establishes a technical committee or working group with relevant experts and stakeholders. This group is responsible for developing or revising the standard.
3. **Drafting the Standard**: The technical committee begins drafting the standard. This involves researching existing standards, specifying technical requirements, guidelines, conducting technical studies, and seeking input from various stakeholders, including industry experts, government agencies, and consumer groups and procedures that need to be followed in engineering processes.
4. **Public Review and Comment**: The draft standard is typically made available for public review and comment. This allows a broader range of stakeholders, Including Engineers, Industry professionals, to provide feedback and suggestions for improvement.
5. **Revision and Consensus Building**: The technical committee reviews the public comments and revises the standard accordingly. The goal is to achieve a consensus among stakeholders, which may require multiple rounds of revisions and discussions.
6. **Approval and publication**: Once a consensus is reached, the standard is approved by the standards body. It is then published and made available to the engineering community and public. The standard is often updated with a version number and date.

7. **Implementation**: Industries, organizations, engineering firms and regulatory bodies may adopt and implement the new or revised standard. Compliance with these standards can become mandatory in some cases depending on the industry.
8. **Maintenance and Review**: Standards are not static; they need to be periodically reviewed and updated to stay relevant. Technical committees continue to monitor developments and make necessary modifications.
9. **International Adoption** (**International Standards**): In the case of international standards, such as those developed by ISO, member countries may adopt and implement the standard, often with some adjustments to align with local regulations.

It's important to note that the specific steps and processes can vary depending on the standards organization and the nature of the standard being developed or modified.

Major type of standards used in Chemical Engineering

In mechanical engineering, various types of standards are used to ensure safety, quality, and compatibility. These standards cover a wide range of aspects within the field, including:

1. Material Standards: These standards specify the properties and composition and characteristics of materials used in mechanical components, ensuring that they meet specific materials strength, hardness, material testing, durability, and performance requirements. Organizations like ASTM (American Society for testing and materials) provides Material Standards.

2. Safety Standards: Safety standards focus on ensuring the safe operation of mechanical equipment and systems, particularly in fields like industrial machinery, pressure vessels, and lifting equipment. Organizations like ANSI (American National Standards Institute), OSHA (Occupational safety and health administration), and NFPA (National Fire Protection Association) provides safety guidelines to prevent accidents and to protect workers.

3. Quality Management Standards: Standards like ISO 9001 provide guidelines for establishing, maintaining and improving quality management systems in engineering processes, ensuring consistent quality and performance. They provide a framework for quality management systems.

4. Testing and Inspection Standards: These standards dictate testing methods and inspection procedures to assess the quality and integrity of mechanical components and systems.

5. Piping and Fluid Handling Standards: These standards cover the design and installation of piping systems, including codes for pressure vessels and piping materials.

6. Welding Standards: Standards for welding processes and procedures ensure the structural integrity and safety of welded joints.

7. Electrical and Electronic Standards: In cases where mechanical systems involve electrical or electronic components, standards from organizations like IEEE and IEC may apply.

8. Environmental Standards: In cases where mechanical systems impact the environment, standards may include regulations related to emissions, noise, and other environmental factors.

These standards help to ensure that mechanical engineering projects meet safety, quality, and performance requirements while allowing for interoperability and compliance with regulations in different industries and regions.

Standards database and search standards.

A standards database is a repository or collection of standardized documents that contain specifications, guidelines, and requirements for various industries, products, processes, and services. These databases serve as valuable resources for professionals, organizations, and regulatory bodies to access and reference applicable standards. Here are some key aspects of a standards database:

1. **Types of Standards**: Standards databases encompass a wide range of standard types, including technical specifications, safety standards, quality management standards, environmental standards, and more. These standards can relate to various fields such as engineering, manufacturing, healthcare, and information technology.

2. **Centralized Access**: Standards databases provide a centralized platform for accessing a vast array of standards. They may be hosted by standards organizations like ISO, ASTM, or national standards bodies like ANSI in the United States.

3. **Search and Retrieval:** Users can search for specific standards by title, number, keyword, or industry. Many databases offer advanced search features to help users find relevant standards efficiently.

4. **Document Access**: Users can typically access full-text versions of standards documents, which detail technical specifications, procedures, and requirements. Some databases offer free access to basic information and charge for full document downloads.

5. **Updates and Revisions**: Standards databases often include information about the status of standards, including the latest revisions, amendments, or proposed changes. This ensures that users are aware of the most current versions.

6. **Metadata and Information**: Standards databases include metadata about each standard, such as its title, number, date of publication, and the organization responsible for its development.

7. **Categorization**: Standards are usually categorized by industry, sector, or subject matter, making it easier for users to navigate and find the standards that apply to their specific needs.

8. **Subscription Services**: Some standards databases offer subscription services, which provide access to a broader range of standards and additional features. Organizations often subscribe to these services to ensure they have access to the latest standards relevant to their industry.

9. **Regulatory Compliance:** Many industries and regulatory bodies mandate compliance with specific standards, and standards databases help organizations and professionals stay informed and aligned with these requirements.

Common examples of standards databases include:

ISO Standards Database: Maintained by the International Organization for Standardization, it provides access to international standards in various domains.

ASME Standards: Developed by American Society of Mechanical engineers, these standards covers a wide range of topics, including boilers and pressure vessel codes, piping standards and various mechanical components.

ANSI Standards Portal: Offered by the American National Standards Institute, it provides access to U.S. and international standards.

IEEE Xplore: Focused on standards in the field of electrical and electronic engineering.

SAE Standards: The society of Automotive Engineers, creates standards for automotive and aerospace industries, covering areas such as materials, fastener and Vehicles design.

ASTM Compass: Maintained by ASTM International, it offers access to wide range of standards, Including those related to materials, construction and engineering practices.

NIST Standards Reference Database: Provided by the National Institute of Standards and Technology, it includes various types of standards relevant to science and technology.

Access to standards in these databases often involves licensing, subscription fees, or purchase of individual standards, but some basic information may be freely available to the public.

Searching Standards: Searching for standards involves finding specific documents or technical specifications that apply to a particular industry, product, process, or service. Here are the general steps to search for standards effectively:

1. **Identify Your Needs:**

Determine the subject area or industry for which you need standards. Be clear about the specific standard you're looking for, if applicable.

2. **Choose a Standards Database or Source:**

Select a reputable standards database or source that is relevant to your needs. Common sources include the International Organization for Standardization (ISO), IEEE Xplore, national standards bodies, and industry-specific organizations.

3. **Use Keywords and Phrases:**

If you have a specific standard in mind, search by its title or number. Use relevant keywords and phrases related to your subject. For example, "ISO 9001" for quality management or "ASTM D123" for a specific material testing standard.

4. **Filter and Refine Your Search:**

Many standards databases offer filters to narrow down search results. You can filter by industry, publication date, document type, or organization.

5. **Review Search Results:**

Examine the search results to find standards that match your criteria. Pay attention to the standard number, title, and description to ensure it meets your needs.

6. **Access Full Details:**

Click on the standard of interest to access more detailed information. Check for the publication date to ensure it's the most recent version.

7. **Download or Purchase:**

Depending on the source, you may have options to download the standard immediately, purchase it, or access it through a subscription if required.

8. **Check for Revisions or Amendments**:

Ensure that the standard you're considering is the latest version. Standards are periodically updated, and it's important to stay current with the most recent revisions.

9. **Verify Applicability:**

Confirm that the standard you found is relevant to your project, industry, or regulatory requirements. Not all standards may apply to your specific situation.

10. **Comply with Licensing or Copyright Restrictions:**

Be aware of any licensing or copyright restrictions associated with the standards you access. Compliance with usage terms is important.

10. Keep Records:

Maintain records of the standards you access, including their titles, numbers, and publication dates, for reference and compliance purposes.

It's important to choose the appropriate standards body or organization that aligns with your industry or area of interest. Additionally, consider whether you need to access international standards or national standards, as well as whether a subscription service may be beneficial for ongoing access to standards in your field.

Standards Development Organizations or Societies.

Standards development organizations (SDOs) or societies are entities responsible for creating and maintaining standards that define technical specifications, guidelines, and best practices in various industries and fields. These organizations play a crucial role in ensuring safety, quality, and interoperability across different sectors. Here are some prominent standards development organizations and societies:

1. **International Organization for Standardization (ISO):**

ISO is a global body that develops international standards covering a wide range of industries, from technology and safety to environmental management.

2. **American National Standards Institute (ANSI):** ANSI is the primary standards body in the United States, facilitating the development of standards for numerous sectors, including engineering, IT, and healthcare.
3. **International Electrotechnical Commission (IEC):** IEC focuses on electrical and electronic standards and collaborates with ISO to create standards applicable to a wide array of industries.
4. **American Society for Testing and Materials (ASTM International):** ASTM develops standards for materials, products, systems, and services in industries like construction, manufacturing, and more.
5. **Institute of Electrical and Electronics Engineers (IEEE)**: IEEE is known for its standards in electrical and electronic engineering, including IEEE 802 series for networking and communication.
6. **American Society of Mechanical Engineers (ASME):** ASME creates standards for mechanical engineering, covering pressure vessels, piping, and numerous other aspects of mechanical design and safety.
7. **National Fire Protection Association (NFPA)**: NFPA develops fire and life safety codes and standards, including the National Electrical Code (NEC) and NFPA 70E for electrical safety.
8. **American Petroleum Institute (API):** API is responsible for standards in the oil and gas industry, covering equipment, safety practices, and environmental protection.
9. **International Telecommunication Union (ITU):** ITU specializes in telecommunications and information and communication technologies (ICT) standards.
10. **Society of Automotive Engineers (SAE International):** SAE creates standards for the automotive and aerospace industries, ensuring safety and performance.
11. **International Civil Aviation Organization (ICAO)**: ICAO develops international standards for civil aviation, covering everything from aircraft design to air traffic management.
12. **Pharmaceutical Research and Manufacturers of America (PhRMA):** PhRMA sets standards for the pharmaceutical industry, including guidelines for drug development and manufacturing.
13. **International Maritime Organization (IMO):** IMO establishes international standards for maritime safety, security, and environmental protection.
14. **Food and Drug Administration (FDA):** The FDA in the United States sets standards for food, drugs, and medical devices to ensure public health and safety.
15. **National Institute of Standards and Technology (NIST):** NIST provides standards and guidelines for various industries and technologies, including cybersecurity and metrology.

These organizations collaborate with experts, industry stakeholders, and government bodies to develop, review, and update standards that drive innovation and promote safety and quality in their respective fields. Standards developed by these organizations often serve as the basis for regulations, product certifications, and best practices worldwide.

Engineering Standards
Applicable to Chemical Engineering

Engineering Standards

Requirements developed by consensus methods that must or should be used in engineering design.

- Requirements that ensure safety of parts, units, or systems
- Requirements that ensure product durability or an expected material lifetime
- Testing requirements to verify material content or makeup
- Testing requirements to verify performance

Engineering Standards

Organizations that develop standards

- ASTM: American Society for Testing and Materials
- NIST (fed govt): National Institute for Standards and Technology
- ASME: American Society for Mechanical Engineering
- NFPA: National Fire Protection Association
- NEC: National Electric Code
- ASCE: American Society of Civil Engineers
- IEEE: Institute of Electrical and Electronics Engineers
- AIChE: American Institute of Chemical Engineers

Engineering Standards

Some typical standards that would be applicable to chemical engineering process designs:

<u>EQUIPMENT AND PROCESS RELATED</u>—

- ASTM B543-18: Standard Specification for Welded Copper and Copper-Alloy Heat Exchanger Tube
- ASTM G157-98: Standard Guide for Evaluating Corrosion Properties of Wrought Iron- and Nickel-Based Corrosion Resistant Alloys for Chemical Process Industries
- NFPA 36: Standard for Solvent Extraction Plants
- NFPA 53: Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres
- AIChE B-2: DIER: Technology Summary Emergency Relief Systems For Runaway Chemical Reactions And Storage Vessels: A Summary Of Multiphase Flow Methods
- AICHE G-62 CCPS: Guidelines for Process Safety in Batch Reaction Systems

Engineering Standards

Some typical standards that would be applicable to chemical engineering process designs:

<u>EQUIPMENT AND PROCESS RELATED</u>

- ASME B31 Design, construction, and maintenance of power piping systems--boilers, heat exchangers, and other related components
- ASME STP-PT-006 Guidelines for the installation and calibration of pressure relief devices
- ASME BPVC Design of boilers and pressure vessels

Also, there are numerous NFPA standards on tanks and systems for storage of petroleum products, specifying systems for grounding (spark prevention) and vapor venting systems (to prevent vapor buildup)

Engineering Standards

Some typical standards that would be applicable to chemical engineering process designs:

<u>CHEMICALS AND MATERIALS (non-structural) USED IN MANUFACTURING</u>

- ASTM E2058-19: Standard Test Methods for Measurement of Material Flammability Using a Fire Propagation Apparatus
- ASTM C1274-12: Standard Test Method for Advanced Ceramic Specific Surface Area by Physical Adsorption
- ASTM E3027-18a: Standard Guide for Making Sustainability-Related Chemical Selection Decisions in the Life-Cycle of Products
- ASTM STP 23729S Standards for the Representation of Thermodynamic Data for Inorganic Materials
- ASTM E2535-07(2018): Standard Guide for Handling Unbound Engineered Nanoscale Particles in Occupational Settings

Engineering Standards (non-codified)

ABET Criterion 5-Curriculum states:

Engineering Design. To be categorized as Engineering Design, the General Criteria specifically state that the course (1) ***incorporates appropriate engineering standards*** and multiple constraints, and (2) is based on the knowledge and skills acquired in earlier course work.

In this AIChE (for ABET) document; engineering design is defined, HOWEVER, ……**does not specifically define "appropriate engineering standards"**.

Consequently, "**appropriate engineering standards" may be widely interpreted** in the context of the program's major chemical engineering design experience

Finally, **reference to codified standards is not required to meet ABET requirements**.

Source: AIChE Education and Accreditation Committee, Guidelines for PEVs and Programs (aka ABET Evaluation), July 2023

Engineering Standards (non-codified)

ABET Criterion 5-Curriculum states:

Examples of **appropriate engineering standards** can include any of *(the following)* but are not limited to:

- Recognized and Generally Accepted Good Engineering Practice (RAGAGEP) --- adapted by OSHA from AIChE;
- Hazard identification and management (part of PSM);
- Protective systems;
- Environmental;
- Process design (PFDs, P&IDs);
- Process equipment, instrumentation and process control

Source: AIChE Education and Accreditation Committee, Guidelines for PEVs and Programs (aka ABET Evaluation), July 2023

Engineering Standards (non-codified)

Discussion – based on the above information from AIChE/ABET, what would be some **non-codified appropriate engineering standards** that you have used in your design or intend to use in your design?

Discussion answers (fill two cols of text):

- Enter text

Engineering Standards Example

NFPA 36-17 Standard for Solvent Extraction Plants

This specification provides requirements for design of the layout and operation of vegetable oil solvent extraction plants that utilize flammable solvents, such as hexane. The primary parts of this standard are related to ensuring operating conditions prevent the proximity of ignition sources to the flammable solvent in the process

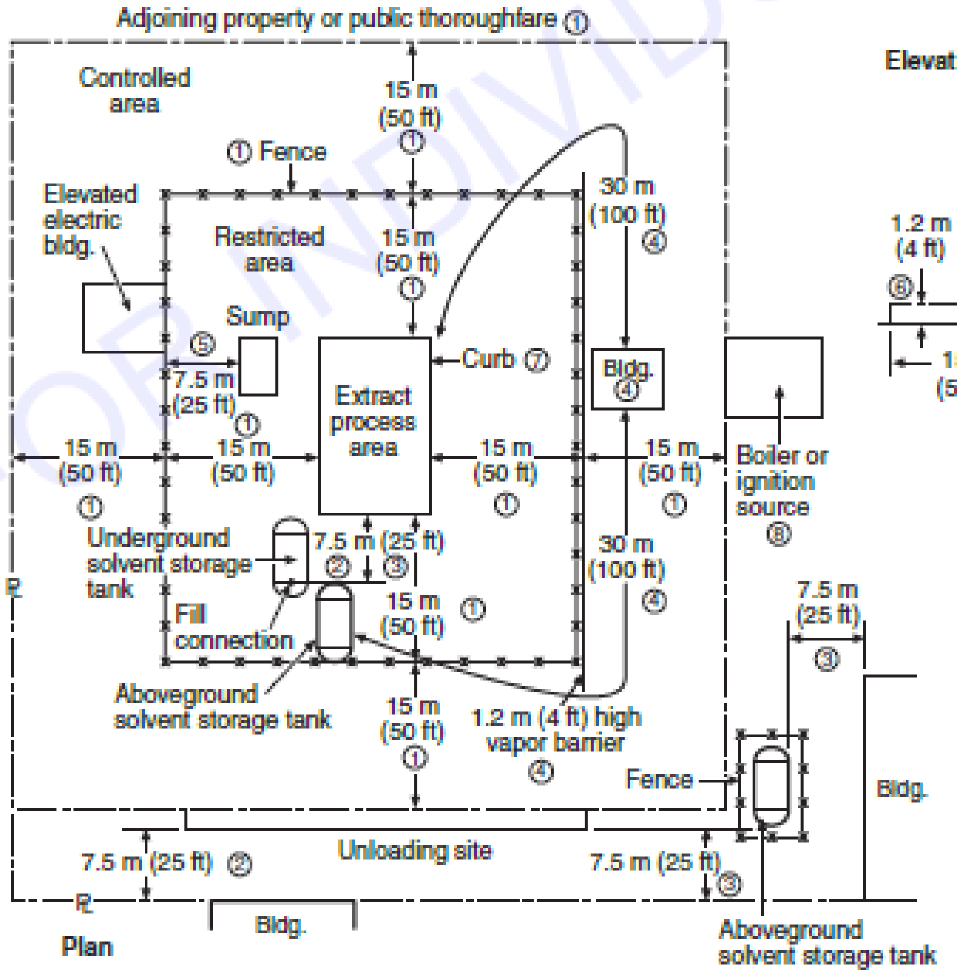


FIGURE 7.2.1 A Typical Distance Diagram.

Engineering Specifications (incorporate standards into design)

What is a “specification”?

- Written text document with a standard, highly prescribed format. The text within a draft or boilerplate spec is edited to meet current design requirements.
- **Engineering standards are frequently cited in a specification** “the part or unit will comply with part YYY of ASTM-BPVC standard”
- Spec documents are written in a very detailed manner, as they frequently serve as a basis for absolute requirements and as a basis for dispute resolution in regards to project adequacy and completeness.
- MIL SPECS—military specifications (also used by gov’t agencies outside the military, e.g. NASA)

Engineering Specifications (incorporate standards into design)

Typical specification components (or outline)

- Spec title & number;
- Scope or importance of spec;
- Terminology, definitions and abbreviatio ns;
- Test methods for specified characteristics;
- Material requirements: physical, mechanical, electrical, chemical;
- Acceptance testing and performance testing requirements;
- Certifications required;
- Safety considerations and requirements;
- Security considerations and requirements;
- Environmental considerations and requirements
- Quality control requirements;
- acceptance sampling, inspections, and acceptance criteria;
- Completion and delivery conditions;
- Provisions for rejection, reinspection;
- References and citations

Engineering Specifications

CSI – Construction Standards Institute provides a Master Format **library of specifications-**--

PROCUREMENT AND CONTRACTING REQUIREMENTS GROUP:
Division 00 — Procurement and Contracting Requirements
SPECIFICATIONS GROUP
General Requirements Subgroup
Division 01 — General Requirements
Facility Construction Subgroup
Division 02 — Existing Conditions
Division 03 — Concrete
Division 04 — Masonry
Division 05 — Metals
Division 06 — Wood, Plastics, and Composites
Division 07 — Thermal and Moisture Protection
Division 08 — Openings
Division 09 — Finishes
Division 10 — Specialties
Division 11 — Equipment
Division 12 — Furnishings
Division 13 — Special Construction
Division 14 — Conveying Equipment
Division 15 — Plumbing + HVAC
Division 16 — Electrical + Lighting
Division 17 — RESERVED FOR FUTURE EXPANSION
Division 18 — RESERVED FOR FUTURE EXPANSION
Division 19 — RESERVED FOR FUTURE EXPANSION
Facility Services Subgroup:

Division 20 — Mechanical Support
Division 21 — Fire Suppression
Division 22 — Plumbing
Division 23 — Heating Ventilating and Air Conditioning
Division 24 — RESERVED FOR FUTURE EXPANSION
Division 25 — Integrated Automation
Division 26 — Electrical
Division 27 — Communications
Division 28 — Electronic Safety and Security
Division 29 — RESERVED FOR FUTURE EXPANSION
Site and Infrastructure Subgroup:

Division 30 — RESERVED FOR FUTURE EXPANSION
Division 31 — Earthwork
Division 32 — Exterior Improvements
Division 33 — Utilities
Division 34 — Transportation
Division 35 — Waterways and Marine Construction
Division 36 — RESERVED FOR FUTURE EXPANSION
Division 37 — RESERVED FOR FUTURE EXPANSION
Division 38 — RESERVED FOR FUTURE EXPANSION
Division 39 — RESERVED FOR FUTURE EXPANSION
Process Equipment Subgroup:
Division 40 — Process Interconnections
Division 41 — Material Processing and Handling Equipment
Division 42 — Process Heating, Cooling, and Drying Equipment
Division 43 — Process Gas and Liquid Handling, Purification and Storage Equipment
Division 44 — Pollution Control Equipment
Division 45 — Industry-Specific Manufacturing Equipment
Division 46 — Water and Wastewater Equipment
Division 47 — RESERVED FOR FUTURE EXPANSION
Division 48 — Electrical Power Generation
Division 49 — RESERVED FOR FUTURE EXPANSION

Additional Background Material

Read through the MS Word document "Reference Document on Introduction to Engineering Standards" for further detailed information on standards organizations and the methods used to develop standards

CHEN 3310
ASTM B543 Heat Exchanger Tubing

Overview

- This specification aims to set the standard for welded tubes and diverse copper alloys, with an inclusive diameter of up to 3 1/8 inches, designed for utilization in surface condensers, evaporators, heat exchangers, and general engineering applications.

- ASTM (American Society for Testing and Materials) introduced certain methods such as the B153 Test Method for the Expansion of copper and Copper-Alloy Pipe and Tubing, B224 Classification of Coppers, B846 Terminology for Copper and Copper Alloys, etc., which helps the purchaser to evaluate the quantity and quality of the product they buy from the manufacturer or supplier.

Welded Copper and Copper Alloy Heat Exchanger Tubes

- Welded copper and copper-alloy heat exchanger tubes are components designed to transfer heat in various industries and commercial applications efficiently. The tubes crafted from welded copper and copper alloy offer high durability, high thermal conductivity, and high corrosion resistance.

Commonly used in:

- HVAC systems
- Water Desalting plants
- Surface Condensers
- Evaporators
- Variety of Engineering Applications

UNS numbering for copper and copper alloys.

Copper or Copper Alloy UNS No.[2]	Previously Used Designation	Type of Metal
C10800[A]	...	oxygen-free, low phosphorus
C12200[A]	...	DHP phosphorized, high residual phosphorus
C19400	...	copper-iron alloy
C23000	...	red brass
C44300	...	arsenical admiralty
C44400	...	antimonial admiralty
C44500	...	phosphorized admiralty
C68700	...	arsenical aluminum brass
C70400	...	95-5 copper-nickel
C70600	...	90-10 copper-nickel
C70620	...	90-10 copper-nickel (Modified for Welding)
C71000	...	80-20 copper-nickel
C71500	...	70-30 copper-nickel
C71520	...	70-30 copper-nickel (Modified for Welding)
C71640	...	copper-nickel-iron-manganese
C72200	...	...

Table 1: Copper UNS Nos.

- What does UNS stand for?

- The Unified Numbering System is an alloy designation system.
- Each UNS number points to a specific metal or alloy, its chemical composition, and its mechanical or physical properties. Table 1 shows the UNS numbers for Copper and its alloys.

Standard for Materials and Manufacture

Material Standard:-

The material of manufacture shall be a strip of one of the Copper Alloy UNS numbers listed in Table 1 of such purity suitable for processing into the product prescribed by the consumer.

Manufacturing Standard:-

- The chosen copper material is manufactured into a tubular shape.
- The tubular-shaped copper is then welded together into the desired length by Forge-welding. This results in external and internal flashing.
- External and Internal flash shall must be removed making it not visible to unaided eyes.
- Internal flash must not exceed 0.006in. [0.152 mm] in height or 10% of nominal wall thickness.
- There shall be no visible weld seam to the unaided eyes.

Chemical Composition

Chemical Composition requirement table:

Copper or Copper Alloy UNS No.	Composition, %											
	Copper[A]	Nickel incl Cobalt	Lead, max	Iron	Zinc	Manganese	Aluminum	Phosphorus	Tin	Antimony	Arsenic	Other Elements
C10800	99.95[B] min	...	...	...	...	...	...	0.005–0.012	...	...	...	...
C12200	99.9 min	...	...	...	...	...	...	0.015–0.040	...	...	...	...
C19400	97.0[C] min	...	0.03	2.1–2.6	0.05–0.20	...	...	0.015–0.15	...	...	...	...
C23000	84.0–86.0	...	0.05	0.05 max	remainder	...	...	...	...	...	...	...
C44300	70.0–73.0[D]	...	0.07	0.06 max	remainder	...	...	...	0.8–1.2	...	0.02–0.06	...
C44400	70.0–73.0[D]	...	0.07	0.06 max	remainder	...	...	...	0.8–1.2	0.02–0.10	...	...
C44500	70.0–73.0[D]	...	0.07	0.06 max	remainder	...	...	0.02–0.10	0.8–1.2	...	...	...
C68700	76.0–79.0[AE]	...	0.07	0.06 max	remainder	...	1.8–2.5	...	...	...	0.02–0.06	...
C70400	remainder[AE]	4.8–6.2	0.05	1.3–1.7	1.0 max	0.30–0.8	...	...	...	...	...	...
C70600	remainder[AE]	9.0–11.0	0.05	1.0–1.8	1.0 max	1.0 max	...	...	...	...	...	...
C70620	86.5 min[AE]	9.0–11.0	0.02	1.0–1.8	0.50 max	1.0	...	.02 max	...	...	...	C 0.05 max s 0.02 max
C71000	remainder[AEF]	19.0–23.0	0.05	0.50–1.0	1.0 max[F]	1.0 max	...	[F]	...	...	...	[F]
C71500	remainder[AE]	29.0–33.0	0.05	0.40–1.0	1.0 max	1.0 max	...		...	...	...	...
C71520	65.0 min[AE]	29.0–33.0	.02	0.40–1.0	0.50 max	1.0 max	...	0.02 max	...	...	...	C 0.05 max S 0.02 max
C71640	remainder[F]	29.0–32.0	0.05[F]	1.7–2.3	1.0 max[F]	1.5–2.5	...	[F]	...	...	...	C.06[F] max S.03 max
C72200	remainder[AFCG]	15.0–18.0	0.05[F]	.50–1.0	1.0 max[F]	1.0 max	...	[F]	...	...	...	[F] Si.03 max Ti.03 max[G]

Table 2: Chemical Requirements

- The material conforms to the compositional requirements in Table 2 for the copper and copper-alloy UNS No.
- The composition can be changed as per the agreement between the manufacturer and the purchaser following certain limits and analysis for unnamed elements.

Mechanical Property Requirement (Tensile and Yield Strength)

Copper or Copper Alloy UNS No.	Temper		Tensile Strength, min, MPA	Yield Strength at 0.5 % Extension Under Load, min, MPA
	Designation	Name		
C10800, C12200	W061	annealed	205	60[A]
	WC55	light cold-worked	220	105
C19400	W061	annealed	310	105
	WC55	light cold-worked	310	150
C23000	W061	annealed	275	85
	WC55	light cold-worked	290	140
C44300, C44400, C44500	W061	annealed	310	105
	WC55	light cold-worked	345	240
C68700	W061	annealed	345	125
	WC55	light cold-worked	[B]	[B]
C70400	W061	annealed	260	85
	WC55	light cold-worked	275	205
C70600	W061	annealed	275	105
	WC55	light cold-worked	310	240
C70620	WO61	annealed	275	105
	WC55	light cold-worked	310	240
C71000	W061	annealed	310	110
	WC55	light cold-worked	345	240
C71500	W061	annealed	360	125
	WC55	light cold-worked	370	240
C71520	WO61	annealed	360	125
	WC55	light cold-worked	370	240
C71640	W061	annealed	435	170
	WC55	light cold-worked	515	275
C72200	W061	annealed	310	110
	WC55	light cold-worked	345	205

Table 3: Tensile Requirements

Tensile Strength and Yield Strength Requirements:

- The final product should match the Tensile and Yield Strength requirement prescribed in Table 3.
- Acceptance or rejection based on mechanical properties will be determined solely based on tensile strength and yield strength.

Chemical Compatibilities with Copper and Copper Alloys:

Corrosion Resistance of Copper and Copper Alloys

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An **R** indicates that the material is resistant to the named chemical up to the temperature shown, subject to limitations indicated by the footnotes.

An **X** indicates that the material is **NOT RECOMMENDED.**

	Aluminium Bronze			Brass (a)			Copper			Copper-Nickel 90/10 alloys (b)			Gunmetal and Bronze (c)		
Temperature, Celcius	**20°**	**60°**	**100°**	**20°**	**60°**	**100°**	**20°**	**60°**	**100°**	**20°**	**60°**	**100°**	**20°**	**60°**	**100°**
Acetaldehyde	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Acetic acid (10%)	R	R	R	X	X	X	R	R	R	R	R	R	R	R	R
Acetic acid (glac./anh.)	R	R	R	X	X	X	R	R	R	R	R	X	R	R	R
Acetic anhydride	R	R	R	X	X	X	R	R	R	R	R	R	R	R	X
Aceto-acetic ester	R	R	R	R (82)	X	X	R	R	R	R	R	R	R	R	R
Acetone	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

Chemical Compatibilities with Copper and Copper Alloys:

Corrosion Resistance of Copper and Copper Alloys

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An **R** indicates that the material is resistant to the named chemical up to the temperature shown, subject to limitations indicated by the footnotes.

An **X** indicates that the material is **NOT RECOMMENDED.**

	Aluminium Bronze			Brass (a)			Copper			Copper-Nickel 90/10 alloys (b)			Gunmetal and Bronze (c)		
Nitric acid (<25%)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Nitric acid (50%)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Nitric acid (90%)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Nitric acid, fuming	R	R	R	R	R	R	R	R	R	X	X	X	X	X	X
Nitrite (Na)	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Nitrobenzine	R	X	X	R	X	X	R	X	X	R	R	R	R	R	R
Oil, diesel	R	R	R	R	R	R	R	R	R	R	X	X	R	X	X
Oils, essential	R	R	X	R	R	X	R	R	X	R	R	R	R	R	R
Oils, lube + aromatic ads.	R	R	R	R	R	R	R	R	R	R	R	X	R	R	X
Oils, mineral	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Oils, vegetable & animal	R	R	R	No data	No data	No data	R	R	R	R	R	R	R	R	R

Chemical Compatibilities with Copper and Copper Alloys:

Corrosion Resistance of Copper and Copper Alloys

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An **R** indicates that the material is resistant to the named chemical up to the temperature shown, subject to limitations indicated by the footnotes.

An **X** indicates that the material is **NOT RECOMMENDED.**

	Aluminium Bronze			**Brass (a)**			**Copper**			**Copper-Nickel 90/10 alloys (b)**			**Gunmetal and Bronze (c)**		
Vinegar	R (53)	R	X	X	X	X	R (53)	R	X	R	R	R	X	X	X
Water, distilled	RR	R	R	R	R	R	R	R	R	R	R	R	R (53)	R	R
Water, soft	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Water, hard	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Wetting agents (to 5%)	No data	No data	No data	No data	No data	No data	R	R	R	R	R	R	R	R	R

QUESTION

What are the primary considerations and criteria that engineers and designers need to evaluate when selecting the most suitable copper or copper alloy for a specific heat exchanger application, and how do these choices impact the overall efficiency and durability of the heat exchanger? And how does ASTM B543 ensure the quality and reliability of the heat exchanger?

ASSIGNMENT

- Chose one classmate to work with, and then discuss and answer the questions posed on the ASTM B543 Worksheet provided to you by the instructor

NAME: ___________________________

CHEN 3310 – Heat Transfer Phenomena
Department of Chemical and Natural Gas Engineering

Answer the 3 questions below, based on the information presented in the ASTM B543 standards lecture, which is complimented with information about compatibility of copper and copper alloys with various process chemicals. You should come up with the best answer based on discussion within your group.

1. Consider a heat exchanger that will be used to exchange energy between cooling water and **glacial or anhydrous acetic acid** with the latter being at temperatures between 50 °C and 150 °C. The compatibility chart on slide 25 indicates that copper / nickel alloys are not compatible with glacial acetic acid at these temperatures. Of the following, **pure copper or brass**, which would be a compatible copper or copper alloy for use in this condition? Note that **admiralty brass is generally defined as a 70% copper / 30% zinc alloy**.

2. Consider a heat exchanger that will be used to cool a **hot (60 – 100 °C) diesel oil stream**. Additionally, the heat exchanger operating pressures between shell side and tube side dictate that the tubing needs to have a **light cold-worked yield strength no less than 170 MPa** (mega Pascals). Which one or more of the following materials is suitable for this application---**brass (UNS 44300, 44400, 44500), copper (UNS 10800, 12200, 19400), or copper-nickel allow (UNS 70400, 70600, 70620)**?

3. Is nitric acid at 25 to 90% aqueous solution compatible with any copper or copper alloy tubing? Is distilled or soft water compatible with any copper or copper alloy tubing?

MODULE 5

Implemented course: CHEN 4317 – Chemical Process Design III
Standard used: ASTM E3027 Standard Guide for Making Sustainability-Related Chemical Selection Decisions in the Lifecycle of Products

What are Standards and Standardization?

Standards: These are established benchmarks or rules that define the characteristics, performance or quality of products, services, processes or systems. Standards can cover a wide range of areas, Including technology, safety, manufacturing. Engineering Standards provides uniformity, quality, compatibility, interchangeability and Interoperability among components, systems and processes. Standards ensure the safety, quality and reliability of products and services.

Engineering professionals use these standards as guidelines and reference in design, manufacturing and testing of Mechanical components and systems. Compliance with these standards is critical to ensure products Quality, Safety, Regulatory Compliance in the field of engineering.

Standardization: This is the process of creating, updating and adhering to standards. It involves Collaboration among experts, organizations, and stakeholders to set common rules and guidelines. Standardization helps to ensure that products and services are compatible and meet certain quality and safety standards.

Standardization is the process of Implementing and developing technical standards based on the consensus of different parties that Include firms, users, Interest groups, standards organization and governments. Standardization is the process of developing, mandating standards-based and compatible technologies and processes within an Industry.

Importance of standards and Standardization

The standards ensure that goods or services produced in a specific industry come with the consistent quality and are equivalent to other comparable products or services in the same industry. Standardization also helps in ensuring the safety, Interoperability, and compatibility of goods produced. Standards and Standardization plays a crucial role in various aspects of our modern world and their Important Is Multifaceted.

1. **Quality and Safety:** Standards help to ensure the quality and safety of products, services and processes. They set benchmarks for performance and reliability, reducing the risks of defects and harm to consumers and users.
2. **Interoperability:** Standards enable different products and systems to work together seamlessly. This is particularly Important in Technology where compatibility ensures that devices and software from various manufacturers can communicate and operate without Issues.
3. **Innovation:** Standards provide a foundation for Innovation by offering a common set of rules and specifications.

4. **Trade and globalization:** International standards facilitate global trade by ensuring that products and services can be easily exchanged across borders. They remove technical barriers to trade and promote economic growth.
5. **Efficiency:** Standardization leads to efficiency improvements in various sectors. When everyone follows the same guidelines, resources are used more efficiently, and processes become streamlined.
6. **Consumers' confidence:** Standards help to build consumer confidence. When consumers know that products and services adhere to recognized standards, they are more likely to trust and purchase them.
7. **Environment Impact:** Standards can promote sustainability and reduce the environmental impact of Industries by setting guidelines for energy efficiency, waste reduction and sustainable practices.
8. **Cost reduction:** It can lead to cost reduction by eliminating the need for a custom solution. Mass production of standardized components often results in economics of sales.

Standards Development and Modification Process

The Development of Engineering Standards is a critical process that ensures the quality, safety and compatibility of engineering products and systems. Developing and Modifying standards typically follows these general steps:

1. **Identifying the Need**: Standards are often developed or modified in response to changing technology, industry needs and practices, safety concerns, or regulatory requirements. The process begins by identifying the specific need for a new engineering standard or a modification to an existing one.
2. **Formation of a Technical Committee**: An organization or standards body, such as the International Organization for Standardization (ISO) or the American National Standards Institute (ANSI), establishes a technical committee or working group with relevant experts and stakeholders. This group is responsible for developing or revising the standard.
3. **Drafting the Standard**: The technical committee begins drafting the standard. This involves researching existing standards, specifying technical requirements, guidelines, conducting technical studies, and seeking input from various stakeholders, including industry experts, government agencies, and consumer groups and procedures that need to be followed in engineering processes.
4. **Public Review and Comment**: The draft standard is typically made available for public review and comment. This allows a broader range of stakeholders, Including Engineers, Industry professionals, to provide feedback and suggestions for improvement.
5. **Revision and Consensus Building**: The technical committee reviews the public comments and revises the standard accordingly. The goal is to achieve a consensus among stakeholders, which may require multiple rounds of revisions and discussions.
6. **Approval and publication**: Once a consensus is reached, the standard is approved by the standards body. It is then published and made available to the engineering community and public. The standard is often updated with a version number and date.

7. **Implementation**: Industries, organizations, engineering firms and regulatory bodies may adopt and implement the new or revised standard. Compliance with these standards can become mandatory in some cases depending on the industry.
8. **Maintenance and Review**: Standards are not static; they need to be periodically reviewed and updated to stay relevant. Technical committees continue to monitor developments and make necessary modifications.
9. **International Adoption** (**International Standards**): In the case of international standards, such as those developed by ISO, member countries may adopt and implement the standard, often with some adjustments to align with local regulations.

It's important to note that the specific steps and processes can vary depending on the standards organization and the nature of the standard being developed or modified.

Major type of standards used in Chemical Engineering

In mechanical engineering, various types of standards are used to ensure safety, quality, and compatibility. These standards cover a wide range of aspects within the field, including:

1. Material Standards: These standards specify the properties and composition and characteristics of materials used in mechanical components, ensuring that they meet specific materials strength, hardness, material testing, durability, and performance requirements. Organizations like ASTM (American Society for testing and materials) provides Material Standards.

2. Safety Standards: Safety standards focus on ensuring the safe operation of mechanical equipment and systems, particularly in fields like industrial machinery, pressure vessels, and lifting equipment. Organizations like ANSI (American National Standards Institute), OSHA (Occupational safety and health administration), and NFPA (National Fire Protection Association) provides safety guidelines to prevent accidents and to protect workers.

3. Quality Management Standards: Standards like ISO 9001 provide guidelines for establishing, maintaining and improving quality management systems in engineering processes, ensuring consistent quality and performance. They provide a framework for quality management systems.

4. Testing and Inspection Standards: These standards dictate testing methods and inspection procedures to assess the quality and integrity of mechanical components and systems.

5. Piping and Fluid Handling Standards: These standards cover the design and installation of piping systems, including codes for pressure vessels and piping materials.

6. Welding Standards: Standards for welding processes and procedures ensure the structural integrity and safety of welded joints.

7. Electrical and Electronic Standards: In cases where mechanical systems involve electrical or electronic components, standards from organizations like IEEE and IEC may apply.

8. Environmental Standards: In cases where mechanical systems impact the environment, standards may include regulations related to emissions, noise, and other environmental factors.

These standards help to ensure that mechanical engineering projects meet safety, quality, and performance requirements while allowing for interoperability and compliance with regulations in different industries and regions.

Standards database and search standards.

A standards database is a repository or collection of standardized documents that contain specifications, guidelines, and requirements for various industries, products, processes, and services. These databases serve as valuable resources for professionals, organizations, and regulatory bodies to access and reference applicable standards. Here are some key aspects of a standards database:

1. **Types of Standards**: Standards databases encompass a wide range of standard types, including technical specifications, safety standards, quality management standards, environmental standards, and more. These standards can relate to various fields such as engineering, manufacturing, healthcare, and information technology.

2. **Centralized Access**: Standards databases provide a centralized platform for accessing a vast array of standards. They may be hosted by standards organizations like ISO, ASTM, or national standards bodies like ANSI in the United States.

3. **Search and Retrieval:** Users can search for specific standards by title, number, keyword, or industry. Many databases offer advanced search features to help users find relevant standards efficiently.

4. **Document Access**: Users can typically access full-text versions of standards documents, which detail technical specifications, procedures, and requirements. Some databases offer free access to basic information and charge for full document downloads.

5. **Updates and Revisions**: Standards databases often include information about the status of standards, including the latest revisions, amendments, or proposed changes. This ensures that users are aware of the most current versions.

6. **Metadata and Information**: Standards databases include metadata about each standard, such as its title, number, date of publication, and the organization responsible for its development.

7. **Categorization**: Standards are usually categorized by industry, sector, or subject matter, making it easier for users to navigate and find the standards that apply to their specific needs.

8. **Subscription Services**: Some standards databases offer subscription services, which provide access to a broader range of standards and additional features. Organizations often subscribe to these services to ensure they have access to the latest standards relevant to their industry.

9. **Regulatory Compliance:** Many industries and regulatory bodies mandate compliance with specific standards, and standards databases help organizations and professionals stay informed and aligned with these requirements.

Common examples of standards databases include:

ISO Standards Database: Maintained by the International Organization for Standardization, it provides access to international standards in various domains.

ASME Standards: Developed by American Society of Mechanical engineers, these standards covers a wide range of topics, including boilers and pressure vessel codes, piping standards and various mechanical components.

ANSI Standards Portal: Offered by the American National Standards Institute, it provides access to U.S. and international standards.

IEEE Xplore: Focused on standards in the field of electrical and electronic engineering.

SAE Standards: The society of Automotive Engineers, creates standards for automotive and aerospace industries, covering areas such as materials, fastener and Vehicles design.

ASTM Compass: Maintained by ASTM International, it offers access to wide range of standards, Including those related to materials, construction and engineering practices.

NIST Standards Reference Database: Provided by the National Institute of Standards and Technology, it includes various types of standards relevant to science and technology.

Access to standards in these databases often involves licensing, subscription fees, or purchase of individual standards, but some basic information may be freely available to the public.

Searching Standards: Searching for standards involves finding specific documents or technical specifications that apply to a particular industry, product, process, or service. Here are the general steps to search for standards effectively:

1. **Identify Your Needs:**

Determine the subject area or industry for which you need standards. Be clear about the specific standard you're looking for, if applicable.

2. **Choose a Standards Database or Source:**

Select a reputable standards database or source that is relevant to your needs. Common sources include the International Organization for Standardization (ISO), IEEE Xplore, national standards bodies, and industry-specific organizations.

3. **Use Keywords and Phrases:**

If you have a specific standard in mind, search by its title or number. Use relevant keywords and phrases related to your subject. For example, "ISO 9001" for quality management or "ASTM D123" for a specific material testing standard.

4. **Filter and Refine Your Search:**

Many standards databases offer filters to narrow down search results. You can filter by industry, publication date, document type, or organization.

5. **Review Search Results:**

Examine the search results to find standards that match your criteria. Pay attention to the standard number, title, and description to ensure it meets your needs.

6. **Access Full Details:**

Click on the standard of interest to access more detailed information. Check for the publication date to ensure it's the most recent version.

7. **Download or Purchase:**

Depending on the source, you may have options to download the standard immediately, purchase it, or access it through a subscription if required.

8. **Check for Revisions or Amendments**:

Ensure that the standard you're considering is the latest version. Standards are periodically updated, and it's important to stay current with the most recent revisions.

9. **Verify Applicability:**

Confirm that the standard you found is relevant to your project, industry, or regulatory requirements. Not all standards may apply to your specific situation.

10. **Comply with Licensing or Copyright Restrictions:**

Be aware of any licensing or copyright restrictions associated with the standards you access. Compliance with usage terms is important.

10. Keep Records:

Maintain records of the standards you access, including their titles, numbers, and publication dates, for reference and compliance purposes.

It's important to choose the appropriate standards body or organization that aligns with your industry or area of interest. Additionally, consider whether you need to access international standards or national standards, as well as whether a subscription service may be beneficial for ongoing access to standards in your field.

Standards Development Organizations or Societies.

Standards development organizations (SDOs) or societies are entities responsible for creating and maintaining standards that define technical specifications, guidelines, and best practices in various industries and fields. These organizations play a crucial role in ensuring safety, quality, and interoperability across different sectors. Here are some prominent standards development organizations and societies:

1. **International Organization for Standardization (ISO):**

ISO is a global body that develops international standards covering a wide range of industries, from technology and safety to environmental management.

2. **American National Standards Institute (ANSI):** ANSI is the primary standards body in the United States, facilitating the development of standards for numerous sectors, including engineering, IT, and healthcare.
3. **International Electrotechnical Commission (IEC):** IEC focuses on electrical and electronic standards and collaborates with ISO to create standards applicable to a wide array of industries.
4. **American Society for Testing and Materials (ASTM International):** ASTM develops standards for materials, products, systems, and services in industries like construction, manufacturing, and more.
5. **Institute of Electrical and Electronics Engineers (IEEE)**: IEEE is known for its standards in electrical and electronic engineering, including IEEE 802 series for networking and communication.
6. **American Society of Mechanical Engineers (ASME):** ASME creates standards for mechanical engineering, covering pressure vessels, piping, and numerous other aspects of mechanical design and safety.
7. **National Fire Protection Association (NFPA)**: NFPA develops fire and life safety codes and standards, including the National Electrical Code (NEC) and NFPA 70E for electrical safety.
8. **American Petroleum Institute (API):** API is responsible for standards in the oil and gas industry, covering equipment, safety practices, and environmental protection.
9. **International Telecommunication Union (ITU):** ITU specializes in telecommunications and information and communication technologies (ICT) standards.
10. **Society of Automotive Engineers (SAE International):** SAE creates standards for the automotive and aerospace industries, ensuring safety and performance.
11. **International Civil Aviation Organization (ICAO)**: ICAO develops international standards for civil aviation, covering everything from aircraft design to air traffic management.
12. **Pharmaceutical Research and Manufacturers of America (PhRMA):** PhRMA sets standards for the pharmaceutical industry, including guidelines for drug development and manufacturing.
13. **International Maritime Organization (IMO):** IMO establishes international standards for maritime safety, security, and environmental protection.
14. **Food and Drug Administration (FDA):** The FDA in the United States sets standards for food, drugs, and medical devices to ensure public health and safety.
15. **National Institute of Standards and Technology (NIST):** NIST provides standards and guidelines for various industries and technologies, including cybersecurity and metrology.

These organizations collaborate with experts, industry stakeholders, and government bodies to develop, review, and update standards that drive innovation and promote safety and quality in their respective fields. Standards developed by these organizations often serve as the basis for regulations, product certifications, and best practices worldwide.

Engineering Standards
Applicable to Chemical Engineering

Engineering Standards

Requirements developed by consensus methods that must or should be used in engineering design.

- Requirements that ensure safety of parts, units, or systems
- Requirements that ensure product durability or an expected material lifetime
- Testing requirements to verify material content or makeup
- Testing requirements to verify performance

Engineering Standards

Organizations that develop standards

- ASTM: American Society for Testing and Materials
- NIST (fed govt): National Institute for Standards and Technology
- ASME: American Society for Mechanical Engineering
- NFPA: National Fire Protection Association
- NEC: National Electric Code
- ASCE: American Society of Civil Engineers
- IEEE: Institute of Electrical and Electronics Engineers
- AIChE: American Institute of Chemical Engineers

Engineering Standards

Some typical standards that would be applicable to chemical engineering process designs:

<u>EQUIPMENT AND PROCESS RELATED</u>—

- ASTM B543-18: Standard Specification for Welded Copper and Copper-Alloy Heat Exchanger Tube
- ASTM G157-98: Standard Guide for Evaluating Corrosion Properties of Wrought Iron- and Nickel-Based Corrosion Resistant Alloys for Chemical Process Industries
- NFPA 36: Standard for Solvent Extraction Plants
- NFPA 53: Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres
- AIChE B-2: DIER: Technology Summary Emergency Relief Systems For Runaway Chemical Reactions And Storage Vessels: A Summary Of Multiphase Flow Methods
- AICHE G-62 CCPS: Guidelines for Process Safety in Batch Reaction Systems

Engineering Standards

Some typical standards that would be applicable to chemical engineering process designs:

EQUIPMENT AND PROCESS RELATED

- ASME B31 Design, construction, and maintenance of power piping systems--boilers, heat exchangers, and other related components
- ASME STP-PT-006 Guidelines for the installation and calibration of pressure relief devices
- ASME BPVC Design of boilers and pressure vessels

Also, there are numerous NFPA standards on tanks and systems for storage of petroleum products, specifying systems for grounding (spark prevention) and vapor venting systems (to prevent vapor buildup)

Engineering Standards

Some typical standards that would be applicable to chemical engineering process designs:

<u>CHEMICALS AND MATERIALS (non-structural) USED IN MANUFACTURING</u>

- ASTM E2058-19: Standard Test Methods for Measurement of Material Flammability Using a Fire Propagation Apparatus
- ASTM C1274-12: Standard Test Method for Advanced Ceramic Specific Surface Area by Physical Adsorption
- ASTM E3027-18a: Standard Guide for Making Sustainability-Related Chemical Selection Decisions in the Life-Cycle of Products
- ASTM STP 23729S Standards for the Representation of Thermodynamic Data for Inorganic Materials
- ASTM E2535-07(2018): Standard Guide for Handling Unbound Engineered Nanoscale Particles in Occupational Settings

Engineering Standards (non-codified)

ABET Criterion 5-Curriculum states:

Engineering Design. To be categorized as Engineering Design, the General Criteria specifically state that the course (1) ***incorporates appropriate engineering standards*** and multiple constraints, and (2) is based on the knowledge and skills acquired in earlier course work.

In this AIChE (for ABET) document; engineering design is defined, HOWEVER, ……**does not specifically define "appropriate engineering standards"**.

Consequently, "**appropriate engineering standards" may be widely interpreted** in the context of the program's major chemical engineering design experience

Finally, **reference to codified standards is not required to meet ABET requirements**.

Source: AIChE Education and Accreditation Committee, Guidelines for PEVs and Programs (aka ABET Evaluation), July 2023

Engineering Standards (non-codified)

ABET Criterion 5-Curriculum states:

Examples of **appropriate engineering standards** can include any of *(the following)* but are not limited to:

- Recognized and Generally Accepted Good Engineering Practice (RAGAGEP) --- adapted by OSHA from AIChE;
- Hazard identification and management (part of PSM);
- Protective systems;
- Environmental;
- Process design (PFDs, P&IDs);
- Process equipment, instrumentation and process control

Source: AIChE Education and Accreditation Committee, Guidelines for PEVs and Programs (aka ABET Evaluation), July 2023

Engineering Standards (non-codified)

Discussion – based on the above information from AIChE/ABET, what would be some **non-codified appropriate engineering standards** that you have used in your design or intend to use in your design?

Discussion answers (fill two cols of text):

- Enter text

Engineering Standards Example

NFPA 36-17 Standard for Solvent Extraction Plants

This specification provides requirements for design of the layout and operation of vegetable oil solvent extraction plants that utilize flammable solvents, such as hexane. The primary parts of this standard are related to ensuring operating conditions prevent the proximity of ignition sources to the flammable solvent in the process

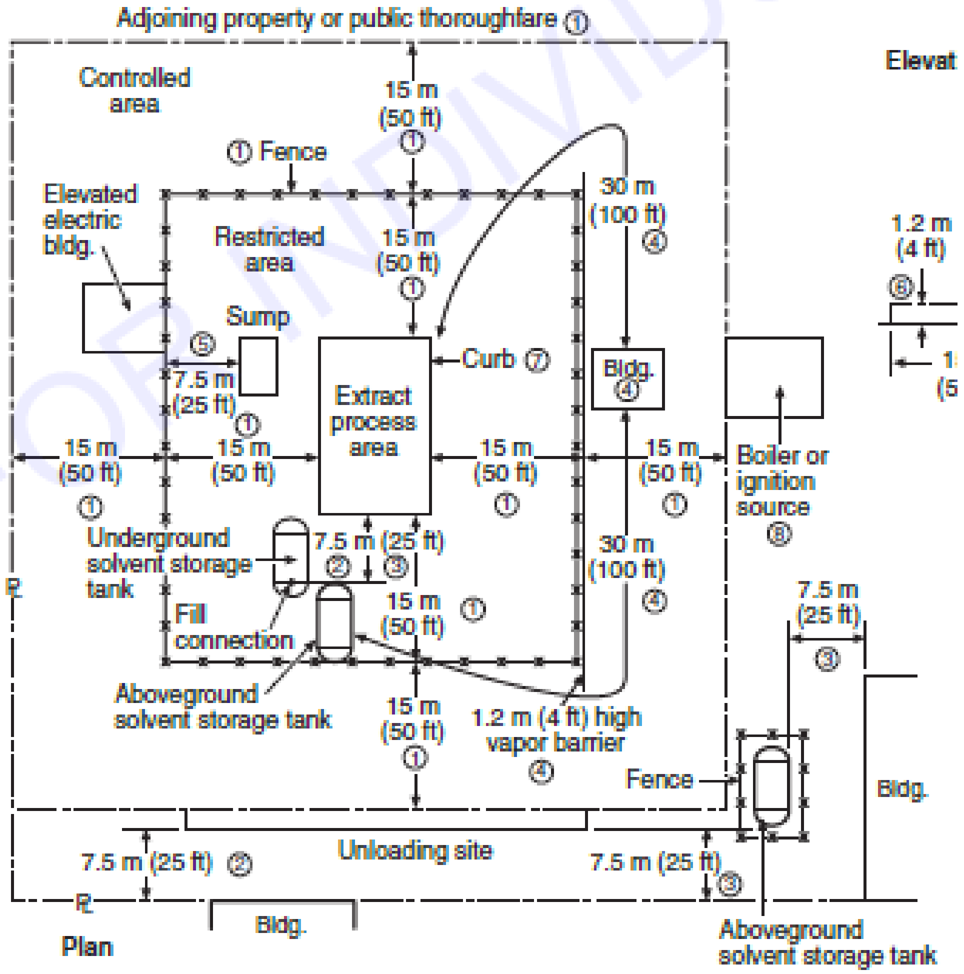


FIGURE 7.2.1 **A Typical Distance Diagram.**

Engineering Specifications (incorporate standards into design)

What is a “specification”?

- Written text document with a standard, highly prescribed format. The text within a draft or boilerplate spec is edited to meet current design requirements.
- **Engineering standards are frequently cited in a specification** “the part or unit will comply with part YYY of ASTM-BPVC standard”
- Spec documents are written in a very detailed manner, as they frequently serve as a basis for absolute requirements and as a basis for dispute resolution in regards to project adequacy and completeness.
- MIL SPECS—military specifications (also used by gov’t agencies outside the military, e.g. NASA)

Engineering Specifications (incorporate standards into design)

Typical specification components (or outline)

- Spec title & number;
- Scope or importance of spec;
- Terminology, definitions and abbreviatio ns;
- Test methods for specified characteristics;
- Material requirements: physical, mechanical, electrical, chemical;
- Acceptance testing and performance testing requirements;
- Certifications required;
- Safety considerations and requirements;
- Security considerations and requirements;
- Environmental considerations and requirements
- Quality control requirements;
- acceptance sampling, inspections, and acceptance criteria;
- Completion and delivery conditions;
- Provisions for rejection, reinspection;
- References and citations

Engineering Specifications

CSI – Construction Standards Institute provides a Master Format **library of specifications-**--

PROCUREMENT AND CONTRACTING REQUIREMENTS GROUP:
Division 00 — Procurement and Contracting Requirements
SPECIFICATIONS GROUP
General Requirements Subgroup
Division 01 — General Requirements
Facility Construction Subgroup
Division 02 — Existing Conditions
Division 03 — Concrete
Division 04 — Masonry
Division 05 — Metals
Division 06 — Wood, Plastics, and Composites
Division 07 — Thermal and Moisture Protection
Division 08 — Openings
Division 09 — Finishes
Division 10 — Specialties
Division 11 — Equipment
Division 12 — Furnishings
Division 13 — Special Construction
Division 14 — Conveying Equipment
Division 15 — Plumbing + HVAC
Division 16 — Electrical + Lighting
Division 17 — RESERVED FOR FUTURE EXPANSION
Division 18 — RESERVED FOR FUTURE EXPANSION
Division 19 — RESERVED FOR FUTURE EXPANSION
Facility Services Subgroup:

Division 20 — Mechanical Support
Division 21 — Fire Suppression
Division 22 — Plumbing
Division 23 — Heating Ventilating and Air Conditioning
Division 24 — RESERVED FOR FUTURE EXPANSION
Division 25 — Integrated Automation
Division 26 — Electrical
Division 27 — Communications
Division 28 — Electronic Safety and Security
Division 29 — RESERVED FOR FUTURE EXPANSION
Site and Infrastructure Subgroup:

Division 30 — RESERVED FOR FUTURE EXPANSION
Division 31 — Earthwork
Division 32 — Exterior Improvements
Division 33 — Utilities
Division 34 — Transportation
Division 35 — Waterways and Marine Construction
Division 36 — RESERVED FOR FUTURE EXPANSION
Division 37 — RESERVED FOR FUTURE EXPANSION
Division 38 — RESERVED FOR FUTURE EXPANSION
Division 39 — RESERVED FOR FUTURE EXPANSION
Process Equipment Subgroup:
Division 40 — Process Interconnections
Division 41 — Material Processing and Handling Equipment
Division 42 — Process Heating, Cooling, and Drying Equipment
Division 43 — Process Gas and Liquid Handling, Purification and Storage Equipment
Division 44 — Pollution Control Equipment
Division 45 — Industry-Specific Manufacturing Equipment
Division 46 — Water and Wastewater Equipment
Division 47 — RESERVED FOR FUTURE EXPANSION
Division 48 — Electrical Power Generation
Division 49 — RESERVED FOR FUTURE EXPANSION

Additional Background Material

Read through the MS Word document "Reference Document on Introduction to Engineering Standards" for further detailed information on standards organizations and the methods used to develop standards

Sustainable Chemical Selection

ASTM E3027

Overview

- Sustainability guides and standards are often developed to assist individuals, businesses, and organizations in making environmentally responsible decisions throughout the life cycle of the products.
- The selection of chemicals needed for sustainability for the life-cycle of the product is determined through certain standards such as:

1) Social Consideration
2) Economic Consideration
3) Ecological Consideration
4) Retrospective

- The standard does not address all of the safety concerns but, it is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations before use.
- The guide includes an outline of the result of the analysis, including an executive summary, detailed report, and retrospective.
- The main goal of the sustainability guide is to help the manufacturers consider comparing alternative chemical ingredients across the product's life cycle.

Social Consideration

This section provides the guidelines for choosing the social sustainability factors that may be used as input into alternative decision-making:

A) Social Consideration of the Raw Material Acquisition:

This stage includes:

a. Wages
b. Safety and Health of Workers
c. Child-labor
d. Salve labor
e. Politics of domestic versus foreign sourcing
f. Other labor-centric issues

- Areas with high human rights concerns, oppressive regimes, and terrorist activity play important roles in raw material availability to any corporation.

B) Social Consideration of the Material Transport:

- This stage includes the safe transport and management of Raw Materials and Waste to protect workers and the public.
- Additional Consideration include:

(a) Access to markets

(b) Transport connectivity

(c) Safety of the transport method

- The Tianjin Explosion (2015) in China is the best example showing the importance of following the proper guidelines in Material Transport.

  Cause: An explosion occurred at the warehouse storing hazardous chemicals.

  Consequences: 173 people died, more than 100 were injured, and extensive property damage.

C) Social Consideration of the Manufacturing Stage:

This stage may differ based on factors such as employer-employee relations, a given facility, or the geographic location of the manufacturer.

Product type also has a significant bearing on which social factors are of importance.

- Product type also has a significant bearing on which factors are important.
- An organization built upon a culture of using a specific technical platform may find it challenging to change technologies to accommodate Social Consideration.

D) Social Consideration of the Use Stage:

- User or intended market perceptions and social mores will be factors of consideration.
- Factors such as age, gender, sensitive populations, and cultural learning intended user are also included in the Social Consideration of Use Stage.
- Potential social sustainability factors may differ widely and be product and market-specific, for example as the product may dictate specific durability or efficiency criteria or rapid access to the most advanced technology with its collateral shorter product life span, etc.
- Organizations also need to consider unintended use or consequences of using a product and how individual ingredients may contribute such as special packaging or precaution for the user should be considered in such instances to minimize risk and their need weighed in the overall analysis.

E) Social Consideration of End-Life:

- Products that are single-use or disposable have different concerns than those that are designed for extended usual life.
- Recyclability, ease of disposal, hazardous nature of waste, and availability to take-back programs are important for Social consideration of End-Life.
- Final disposition process occurs and their impact on the health of employees and the nearby community as well as fair treatment of employees, should also be considered.

Economic Consideration

- Economic considerations include respect towards all financial laws and regulations in all areas in which business activities occur.
- At each phase, the economics, including costs, of ensuring environmental protection through process controls and worker health benefits, compensation, and safety should be included.
- Risk assessment and alternative assessment information should dictate the equipment needed for appropriate handling at each stage/phase
- Micro and macroscale economic factors should be considered

A) Economic Consideration at the Raw Material Acquisition Stage:

→Economic considerations should include employee-related expenses such as personal protective equipment.

→Operational expenses are another major economic factor. The equipment and means of harvesting material significantly impact the cost of acquisition.

→Availability and accessibility of raw materials a major economic considerations.

→Raw materials with limited availability or accessibility may cause a final product to be too expensive to make and sell in the short term.

B) Economic Considerations at the Material Transport Stage:

→Distance of transport will have significant cost on the raw material economics.

→The nature of the material and its packaging will impact transport. For example, dangerous goods may require special handling or insurance.

→Additional considerations may involve the Transport methodology. For Example, an organization may choose to use a mode of transportation where they can negotiate better rates or gain greater fuel efficiency and still meet safety and timing requirements.

C) Economic Considerations of the Manufacturing Stage:

→Capital investments can be an important factor in determining what to produce and with which materials.

→Economics is associated with the need for manufacturing times, processing, and energy and water inputs used because of each alternative.

D) Economic Consideration of the Use Stage:

→Factors such as the number of expected uses versus cost, durability, the efficiency of the product, the need for additional products to use with the product and other secondary economic factors should be included.

→Requires significant stakeholder input through marketing exercises such as the voice of the customer and market studies to estimate consumer preference and behavior.

→End-user input heavily influences the other factors that should be included across all life-cycle stages and all three attributes of sustainability.

E) Economic Consideration of End of Life:

→Disposal methodology will impact the economics

→Compressibility, recyclability, biodegradability, takeback programs, and the ability to repurpose a product or proper disposal cost will have economic considerations.

Ecological Consideration

A) An ecological Consideration at the raw material acquisition stage:

- The effect on the local environment is of great consideration in raw material acquisition which includes, severity, longevity, and extent of impact.
- Ecological impacts deriving from the intrinsic characteristics of raw materials as well as the method by which they are attained should be considered.
- Specific ecological factors may differ greatly depending upon the type of resources

B) Ecological considerations at the material transport stage:

- Means of transport coupled with distance can have significant ecological impacts.
- The nature of material will impact factors such as material handling during transport, packaging choices, distribution options, delivery to the customer, and other related factors.
- Goods harmful to the environment may require special handling and possibly be restricted in transport method.

- Net production of carbon dioxide and other greenhouse gases associated with transport as an organization considers means of transport.

C) Ecological consideration of the manufacturing stage:

- The need for additional environmental controls, can be an ecological factor in determining what to produce and with what materials. Special handling materials will add to these needs.
- Products that transforms significantly during manufacturing through reactions or other transformation processes, considerations shall be made for the intermediate and final product as well.
- Additional impacts such as energy use in the manufacturing, thermal pollution, water use and waste water, should be considered as appropriate.

D) Ecological consideration of the use stage:

- During the use phase certain factors should be identified and evaluated including how the selection of particular alternative affects the amount of product used or product useful life. Use of additional products to use with the product in question and other secondary ecological impacts.

- The user input may influence the other factors across all life-cycle stages and all three attributes of sustainability.

E) Ecological consideration of end of life:

- All products need different types of end-life considerations.
- The release of emissions should be considered.
- If a material is not easily recycled, reclaimed biodegraded, composed taken-back, or otherwise meets end-of-life in what may be geographic areas, then that needs to be considered in the analysis.

Retrospective

- A retrospective is key in the continual improvement of the sustainability of a product
- A retrospective should also include an objective review of the analysis process and how it may be improved for performing future evaluations.
- The retrospective may include areas of improvement that may inform the development or use of future generations of product or technologies derived from products.

DISCUSSION QUESTIONS

1) What are the comparative environmental impacts and sustainability considerations between producing bioethanol from corn in the United States and producing bioethanol from sugarcane in Brazil?
2) Explain the Economic factors such as production costs and market availability that influence the sustainability of choosing between bioethanol production from corn in the US and bioethanol production from sugarcane in Brazil.

ASSIGNMENT

Prepare the writing intensive assignment (WIA) #8 on sustainability, as it relates to your senior design process. You may discuss this within your project group, but the writing response must all be your own.

CHEN 4317 – Chemical Process Design III
Department of Chemical and Natural Gas Engineering
Writing Intensive Assignment #8

Students may work in their assigned senior design project group to collect and discuss the information for this assignment, however this is an individual assignment, and thus all writing must be only your own work.

Due Date: **Friday, March 22nd**
Concepts: **Process Changes for a more Sustainable Process**

Prepare a **500-word project memorandum** (same format as requested for WIA #2) that describes potential sustainability improvements to your process. I encourage your group to hold a brainstorming session to develop ideas regarding how your process could be altered / modified to be more sustainable, and then each student write their individual memo based on results from that brainstorming session. You may include ideas that, upon initial consideration, may be too costly to implement or operate. For chemical processes or refinery processes, sustainability improvements typically involve one or more of the following:

- Heat integration;
- Using recycle loops to feed unreacted reactants back to the front of the process;
- Using recycle loops (with makeup as needed) to reuse chemicals (e.g. solvents, sorbents) added to the process for separation of products, or unreacted reactants, by processes such as LL extraction or absorption;
- Minimizing use of fresh water in the process, or recycle water from the process for use as cooling water feed or boiler feed water;
- Integrating recovered mechanical energy (from gas turbines or hydraulic turbines);
- Use of alternate chemical pathways that result in less noxious or less toxic by-product or waste streams;
- Use of alternative energy (renewable) sources to help satisfy the energy demands of your process.

Create the memo in MS Word and any diagrams in MS Powerpoint or EXCEL (please copy and paste graphics into your Word document. For your electronic submittal, **I will accept only a single MS Word file**). You may prepare and share any graphics as a group for this assignment; however the writing must be entirely your own work.

Reminders:

- Include a list of references for any sources of information that you use.
- A **minimum of 500 words** is required. The instructor will be tallying total word count for each submission across the duration of the semester.
- Your submittal shall be both a hardcopy to the instructor turned in on the due date, as well as **a single electronic file** (MS Word only) copy submitted by e-mail to the instructor, using a file name in the format "LastName_WIA3.docx".

MODULE 6

Implemented course: CHEN 4317 – Chemical Process Design III
Standard used: NFPA 36 Standard for Solvent Extraction Plants

What are Standards and Standardization?

Standards: These are established benchmarks or rules that define the characteristics, performance or quality of products, services, processes or systems. Standards can cover a wide range of areas, Including technology, safety, manufacturing. Engineering Standards provides uniformity, quality, compatibility, interchangeability and Interoperability among components, systems and processes. Standards ensure the safety, quality and reliability of products and services.

Engineering professionals use these standards as guidelines and reference in design, manufacturing and testing of Mechanical components and systems. Compliance with these standards is critical to ensure products Quality, Safety, Regulatory Compliance in the field of engineering.

Standardization: This Is the process of creating, updating and adhering to standards. It involves Collaboration among experts, organizations, and stakeholders to set common rules and guidelines. Standardization helps to ensure that products and services are compatible and meet certain quality and safety standards.

Standardization is the process of Implementing and developing technical standards based on the consensus of different parties that Include firms, users, Interest groups, standards organization and governments. Standardization is the process of developing, mandating standards-based and compatible technologies and processes within an Industry.

Importance of standards and Standardization

The standards ensure that goods or services produced in a specific industry come with the consistent quality and are equivalent to other comparable products or services in the same industry. Standardization also helps in ensuring the safety, Interoperability, and compatibility of goods produced. Standards and Standardization plays a crucial role in various aspects of our modern world and their Important Is Multifaceted.

1. **Quality and Safety:** Standards help to ensure the quality and safety of products, services and processes. They set benchmarks for performance and reliability, reducing the risks of defects and harm to consumers and users.
2. **Interoperability:** Standards enable different products and systems to work together seamlessly. This is particularly Important in Technology where compatibility ensures that devices and software from various manufacturers can communicate and operate without Issues.
3. **Innovation:** Standards provide a foundation for Innovation by offering a common set of rules and specifications.

4. **Trade and globalization:** International standards facilitate global trade by ensuring that products and services can be easily exchanged across borders. They remove technical barriers to trade and promote economic growth.
5. **Efficiency:** Standardization leads to efficiency improvements in various sectors. When everyone follows the same guidelines, resources are used more efficiently, and processes become streamlined.
6. **Consumers' confidence:** Standards help to build consumer confidence. When consumers know that products and services adhere to recognized standards, they are more likely to trust and purchase them.
7. **Environment Impact:** Standards can promote sustainability and reduce the environmental impact of Industries by setting guidelines for energy efficiency, waste reduction and sustainable practices.
8. **Cost reduction:** It can lead to cost reduction by eliminating the need for a custom solution. Mass production of standardized components often results in economics of sales.

Standards Development and Modification Process

The Development of Engineering Standards is a critical process that ensures the quality, safety and compatibility of engineering products and systems. Developing and Modifying standards typically follows these general steps:

1. **Identifying the Need**: Standards are often developed or modified in response to changing technology, industry needs and practices, safety concerns, or regulatory requirements. The process begins by identifying the specific need for a new engineering standard or a modification to an existing one.
2. **Formation of a Technical Committee**: An organization or standards body, such as the International Organization for Standardization (ISO) or the American National Standards Institute (ANSI), establishes a technical committee or working group with relevant experts and stakeholders. This group is responsible for developing or revising the standard.
3. **Drafting the Standard**: The technical committee begins drafting the standard. This involves researching existing standards, specifying technical requirements, guidelines, conducting technical studies, and seeking input from various stakeholders, including industry experts, government agencies, and consumer groups and procedures that need to be followed in engineering processes.
4. **Public Review and Comment**: The draft standard is typically made available for public review and comment. This allows a broader range of stakeholders, Including Engineers, Industry professionals, to provide feedback and suggestions for improvement.
5. **Revision and Consensus Building**: The technical committee reviews the public comments and revises the standard accordingly. The goal is to achieve a consensus among stakeholders, which may require multiple rounds of revisions and discussions.
6. **Approval and publication**: Once a consensus is reached, the standard is approved by the standards body. It is then published and made available to the engineering community and public. The standard is often updated with a version number and date.

7. **Implementation**: Industries, organizations, engineering firms and regulatory bodies may adopt and implement the new or revised standard. Compliance with these standards can become mandatory in some cases depending on the industry.
8. **Maintenance and Review**: Standards are not static; they need to be periodically reviewed and updated to stay relevant. Technical committees continue to monitor developments and make necessary modifications.
9. **International Adoption** (**International Standards**): In the case of international standards, such as those developed by ISO, member countries may adopt and implement the standard, often with some adjustments to align with local regulations.

It's important to note that the specific steps and processes can vary depending on the standards organization and the nature of the standard being developed or modified.

Major type of standards used in Chemical Engineering

In mechanical engineering, various types of standards are used to ensure safety, quality, and compatibility. These standards cover a wide range of aspects within the field, including:

1. Material Standards: These standards specify the properties and composition and characteristics of materials used in mechanical components, ensuring that they meet specific materials strength, hardness, material testing, durability, and performance requirements. Organizations like ASTM (American Society for testing and materials) provides Material Standards.

2. Safety Standards: Safety standards focus on ensuring the safe operation of mechanical equipment and systems, particularly in fields like industrial machinery, pressure vessels, and lifting equipment. Organizations like ANSI (American National Standards Institute), OSHA (Occupational safety and health administration), and NFPA (National Fire Protection Association) provides safety guidelines to prevent accidents and to protect workers.

3. Quality Management Standards: Standards like ISO 9001 provide guidelines for establishing, maintaining and improving quality management systems in engineering processes, ensuring consistent quality and performance. They provide a framework for quality management systems.

4. Testing and Inspection Standards: These standards dictate testing methods and inspection procedures to assess the quality and integrity of mechanical components and systems.

5. Piping and Fluid Handling Standards: These standards cover the design and installation of piping systems, including codes for pressure vessels and piping materials.

6. Welding Standards: Standards for welding processes and procedures ensure the structural integrity and safety of welded joints.

7. Electrical and Electronic Standards: In cases where mechanical systems involve electrical or electronic components, standards from organizations like IEEE and IEC may apply.

8. Environmental Standards: In cases where mechanical systems impact the environment, standards may include regulations related to emissions, noise, and other environmental factors.

These standards help to ensure that mechanical engineering projects meet safety, quality, and performance requirements while allowing for interoperability and compliance with regulations in different industries and regions.

Standards database and search standards.

A standards database is a repository or collection of standardized documents that contain specifications, guidelines, and requirements for various industries, products, processes, and services. These databases serve as valuable resources for professionals, organizations, and regulatory bodies to access and reference applicable standards. Here are some key aspects of a standards database:

1. **Types of Standards**: Standards databases encompass a wide range of standard types, including technical specifications, safety standards, quality management standards, environmental standards, and more. These standards can relate to various fields such as engineering, manufacturing, healthcare, and information technology.

2. **Centralized Access**: Standards databases provide a centralized platform for accessing a vast array of standards. They may be hosted by standards organizations like ISO, ASTM, or national standards bodies like ANSI in the United States.

3. **Search and Retrieval:** Users can search for specific standards by title, number, keyword, or industry. Many databases offer advanced search features to help users find relevant standards efficiently.

4. **Document Access**: Users can typically access full-text versions of standards documents, which detail technical specifications, procedures, and requirements. Some databases offer free access to basic information and charge for full document downloads.

5. **Updates and Revisions**: Standards databases often include information about the status of standards, including the latest revisions, amendments, or proposed changes. This ensures that users are aware of the most current versions.

6. **Metadata and Information**: Standards databases include metadata about each standard, such as its title, number, date of publication, and the organization responsible for its development.

7. **Categorization**: Standards are usually categorized by industry, sector, or subject matter, making it easier for users to navigate and find the standards that apply to their specific needs.

8. **Subscription Services**: Some standards databases offer subscription services, which provide access to a broader range of standards and additional features. Organizations often subscribe to these services to ensure they have access to the latest standards relevant to their industry.

9. **Regulatory Compliance:** Many industries and regulatory bodies mandate compliance with specific standards, and standards databases help organizations and professionals stay informed and aligned with these requirements.

Common examples of standards databases include:

ISO Standards Database: Maintained by the International Organization for Standardization, it provides access to international standards in various domains.

ASME Standards: Developed by American Society of Mechanical engineers, these standards covers a wide range of topics, including boilers and pressure vessel codes, piping standards and various mechanical components.

ANSI Standards Portal: Offered by the American National Standards Institute, it provides access to U.S. and international standards.

IEEE Xplore: Focused on standards in the field of electrical and electronic engineering.

SAE Standards: The society of Automotive Engineers, creates standards for automotive and aerospace industries, covering areas such as materials, fastener and Vehicles design.

ASTM Compass: Maintained by ASTM International, it offers access to wide range of standards, Including those related to materials, construction and engineering practices.

NIST Standards Reference Database: Provided by the National Institute of Standards and Technology, it includes various types of standards relevant to science and technology.

Access to standards in these databases often involves licensing, subscription fees, or purchase of individual standards, but some basic information may be freely available to the public.

Searching Standards: Searching for standards involves finding specific documents or technical specifications that apply to a particular industry, product, process, or service. Here are the general steps to search for standards effectively:

1. **Identify Your Needs:**

Determine the subject area or industry for which you need standards. Be clear about the specific standard you're looking for, if applicable.

2. **Choose a Standards Database or Source:**

Select a reputable standards database or source that is relevant to your needs. Common sources include the International Organization for Standardization (ISO), IEEE Xplore, national standards bodies, and industry-specific organizations.

3. **Use Keywords and Phrases:**

If you have a specific standard in mind, search by its title or number. Use relevant keywords and phrases related to your subject. For example, "ISO 9001" for quality management or "ASTM D123" for a specific material testing standard.

4. **Filter and Refine Your Search:**

Many standards databases offer filters to narrow down search results. You can filter by industry, publication date, document type, or organization.

5. **Review Search Results:**

Examine the search results to find standards that match your criteria. Pay attention to the standard number, title, and description to ensure it meets your needs.

6. **Access Full Details:**

Click on the standard of interest to access more detailed information. Check for the publication date to ensure it's the most recent version.

7. **Download or Purchase:**

Depending on the source, you may have options to download the standard immediately, purchase it, or access it through a subscription if required.

8. **Check for Revisions or Amendments**:

Ensure that the standard you're considering is the latest version. Standards are periodically updated, and it's important to stay current with the most recent revisions.

9. **Verify Applicability:**

Confirm that the standard you found is relevant to your project, industry, or regulatory requirements. Not all standards may apply to your specific situation.

10. **Comply with Licensing or Copyright Restrictions:**

Be aware of any licensing or copyright restrictions associated with the standards you access. Compliance with usage terms is important.

10. Keep Records:

Maintain records of the standards you access, including their titles, numbers, and publication dates, for reference and compliance purposes.

It's important to choose the appropriate standards body or organization that aligns with your industry or area of interest. Additionally, consider whether you need to access international standards or national standards, as well as whether a subscription service may be beneficial for ongoing access to standards in your field.

Standards Development Organizations or Societies.

Standards development organizations (SDOs) or societies are entities responsible for creating and maintaining standards that define technical specifications, guidelines, and best practices in various industries and fields. These organizations play a crucial role in ensuring safety, quality, and interoperability across different sectors. Here are some prominent standards development organizations and societies:

1. **International Organization for Standardization (ISO):**

ISO is a global body that develops international standards covering a wide range of industries, from technology and safety to environmental management.

2. **American National Standards Institute (ANSI):** ANSI is the primary standards body in the United States, facilitating the development of standards for numerous sectors, including engineering, IT, and healthcare.
3. **International Electrotechnical Commission (IEC):** IEC focuses on electrical and electronic standards and collaborates with ISO to create standards applicable to a wide array of industries.
4. **American Society for Testing and Materials (ASTM International):** ASTM develops standards for materials, products, systems, and services in industries like construction, manufacturing, and more.
5. **Institute of Electrical and Electronics Engineers (IEEE)**: IEEE is known for its standards in electrical and electronic engineering, including IEEE 802 series for networking and communication.
6. **American Society of Mechanical Engineers (ASME):** ASME creates standards for mechanical engineering, covering pressure vessels, piping, and numerous other aspects of mechanical design and safety.
7. **National Fire Protection Association (NFPA)**: NFPA develops fire and life safety codes and standards, including the National Electrical Code (NEC) and NFPA 70E for electrical safety.
8. **American Petroleum Institute (API):** API is responsible for standards in the oil and gas industry, covering equipment, safety practices, and environmental protection.
9. **International Telecommunication Union (ITU):** ITU specializes in telecommunications and information and communication technologies (ICT) standards.
10. **Society of Automotive Engineers (SAE International):** SAE creates standards for the automotive and aerospace industries, ensuring safety and performance.
11. **International Civil Aviation Organization (ICAO)**: ICAO develops international standards for civil aviation, covering everything from aircraft design to air traffic management.
12. **Pharmaceutical Research and Manufacturers of America (PhRMA):** PhRMA sets standards for the pharmaceutical industry, including guidelines for drug development and manufacturing.
13. **International Maritime Organization (IMO):** IMO establishes international standards for maritime safety, security, and environmental protection.
14. **Food and Drug Administration (FDA):** The FDA in the United States sets standards for food, drugs, and medical devices to ensure public health and safety.
15. **National Institute of Standards and Technology (NIST):** NIST provides standards and guidelines for various industries and technologies, including cybersecurity and metrology.

These organizations collaborate with experts, industry stakeholders, and government bodies to develop, review, and update standards that drive innovation and promote safety and quality in their respective fields. Standards developed by these organizations often serve as the basis for regulations, product certifications, and best practices worldwide.

Engineering Standards Applicable to Chemical Engineering

Engineering Standards

Requirements developed by consensus methods that must or should be used in engineering design.

- Requirements that ensure safety of parts, units, or systems
- Requirements that ensure product durability or an expected material lifetime
- Testing requirements to verify material content or makeup
- Testing requirements to verify performance

Engineering Standards

Organizations that develop standards

- ASTM: American Society for Testing and Materials
- NIST (fed govt): National Institute for Standards and Technology
- ASME: American Society for Mechanical Engineering
- NFPA: National Fire Protection Association
- NEC: National Electric Code
- ASCE: American Society of Civil Engineers
- IEEE: Institute of Electrical and Electronics Engineers
- AIChE: American Institute of Chemical Engineers

Engineering Standards

Some typical standards that would be applicable to chemical engineering process designs:

<u>EQUIPMENT AND PROCESS RELATED</u>—

- ASTM B543-18: Standard Specification for Welded Copper and Copper-Alloy Heat Exchanger Tube
- ASTM G157-98: Standard Guide for Evaluating Corrosion Properties of Wrought Iron- and Nickel-Based Corrosion Resistant Alloys for Chemical Process Industries
- NFPA 36: Standard for Solvent Extraction Plants
- NFPA 53: Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres
- AIChE B-2: DIER: Technology Summary Emergency Relief Systems For Runaway Chemical Reactions And Storage Vessels: A Summary Of Multiphase Flow Methods
- AICHE G-62 CCPS: Guidelines for Process Safety in Batch Reaction Systems

Engineering Standards

Some typical standards that would be applicable to chemical engineering process designs:

<u>EQUIPMENT AND PROCESS RELATED</u>

- ASME B31 Design, construction, and maintenance of power piping systems--boilers, heat exchangers, and other related components
- ASME STP-PT-006 Guidelines for the installation and calibration of pressure relief devices
- ASME BPVC Design of boilers and pressure vessels

Also, there are numerous NFPA standards on tanks and systems for storage of petroleum products, specifying systems for grounding (spark prevention) and vapor venting systems (to prevent vapor buildup)

Engineering Standards

Some typical standards that would be applicable to chemical engineering process designs:

CHEMICALS AND MATERIALS (non-structural) USED IN MANUFACTURING

- ASTM E2058-19: Standard Test Methods for Measurement of Material Flammability Using a Fire Propagation Apparatus
- ASTM C1274-12: Standard Test Method for Advanced Ceramic Specific Surface Area by Physical Adsorption
- ASTM E3027-18a: Standard Guide for Making Sustainability-Related Chemical Selection Decisions in the Life-Cycle of Products
- ASTM STP 23729S Standards for the Representation of Thermodynamic Data for Inorganic Materials
- ASTM E2535-07(2018): Standard Guide for Handling Unbound Engineered Nanoscale Particles in Occupational Settings

Engineering Standards (non-codified)

ABET Criterion 5-Curriculum states:

Engineering Design. To be categorized as Engineering Design, the General Criteria specifically state that the course (1) ***incorporates appropriate engineering standards*** and multiple constraints, and (2) is based on the knowledge and skills acquired in earlier course work.

In this AIChE (for ABET) document; engineering design is defined, HOWEVER, ……**does not specifically define "appropriate engineering standards"**.

Consequently, "**appropriate engineering standards" may be widely interpreted** in the context of the program's major chemical engineering design experience

Finally, **reference to codified standards is not required to meet ABET requirements**.

Source: AIChE Education and Accreditation Committee, Guidelines for PEVs and Programs (aka ABET Evaluation), July 2023

Engineering Standards (non-codified)

ABET Criterion 5-Curriculum states:

Examples of **appropriate engineering standards** can include any of *(the following)* but are not limited to:

- Recognized and Generally Accepted Good Engineering Practice (RAGAGEP) --- adapted by OSHA from AIChE;
- Hazard identification and management (part of PSM);
- Protective systems;
- Environmental;
- Process design (PFDs, P&IDs);
- Process equipment, instrumentation and process control

Source: AIChE Education and Accreditation Committee, Guidelines for PEVs and Programs (aka ABET Evaluation), July 2023

Engineering Standards (non-codified)

Discussion – based on the above information from AIChE/ABET, what would be some **non-codified appropriate engineering standards** that you have used in your design or intend to use in your design?

Discussion answers (fill two cols of text):

- Enter text

Engineering Standards Example

NFPA 36-17 Standard for Solvent Extraction Plants

This specification provides requirements for design of the layout and operation of vegetable oil solvent extraction plants that utilize flammable solvents, such as hexane. The primary parts of this standard are related to ensuring operating conditions prevent the proximity of ignition sources to the flammable solvent in the process

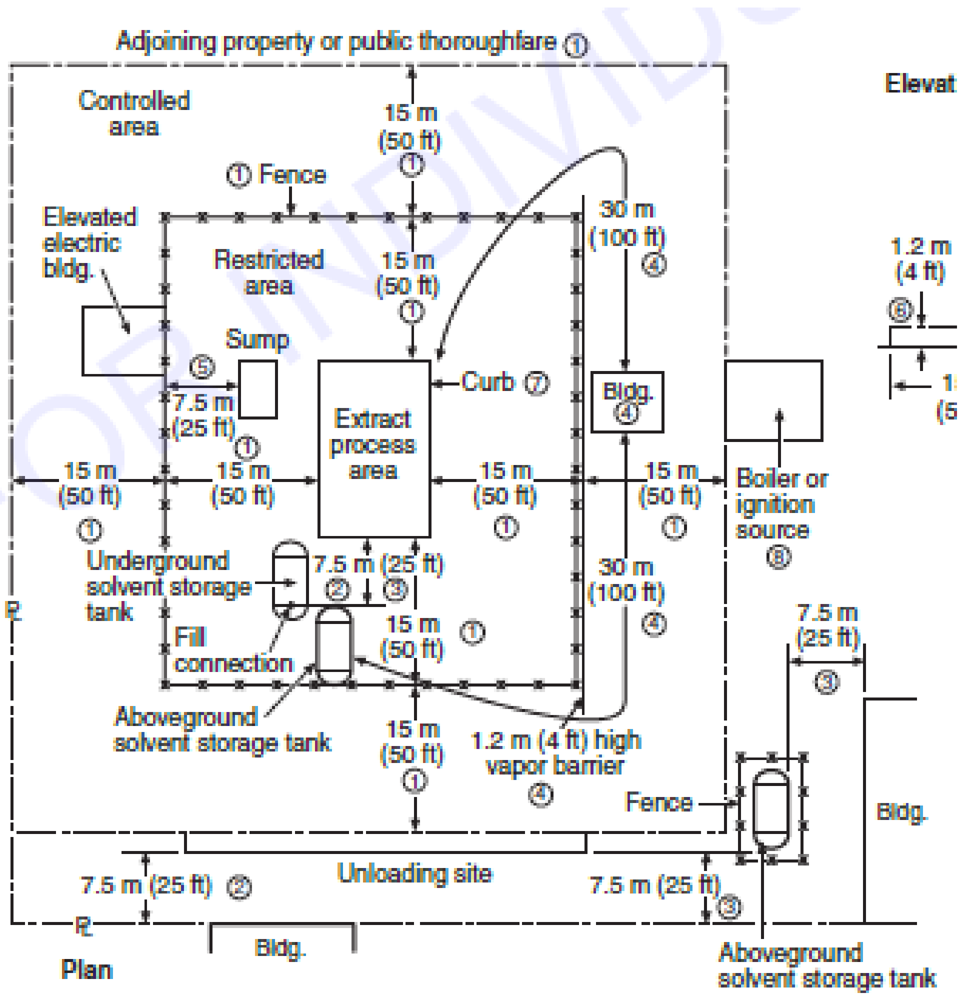


FIGURE 7.2.1 A Typical Distance Diagram.

Engineering Specifications (incorporate standards into design)

What is a “specification”?

- Written text document with a standard, highly prescribed format. The text within a draft or boilerplate spec is edited to meet current design requirements.
- **<u>Engineering standards are frequently cited in a specification</u>** “the part or unit will comply with part YYY of ASTM-BPVC standard”
- Spec documents are written in a very detailed manner, as they frequently serve as a basis for absolute requirements and as a basis for dispute resolution in regards to project adequacy and completeness.
- MIL SPECS—military specifications (also used by gov’t agencies outside the military, e.g. NASA)

Engineering Specifications (incorporate standards into design)

Typical specification components (or outline)

- Spec title & number;
- Scope or importance of spec;
- Terminology, definitions and abbreviatio ns;
- Test methods for specified characteristics;
- Material requirements: physical, mechanical, electrical, chemical;
- Acceptance testing and performance testing requirements;
- Certifications required;
- Safety considerations and requirements;
- Security considerations and requirements;
- Environmental considerations and requirements
- Quality control requirements;
- acceptance sampling, inspections, and acceptance criteria;
- Completion and delivery conditions;
- Provisions for rejection, reinspection;
- References and citations

Engineering Specifications

CSI – Construction Standards Institute provides a Master Format **library of specifications-**--

PROCUREMENT AND CONTRACTING REQUIREMENTS GROUP:
Division 00 — Procurement and Contracting Requirements
SPECIFICATIONS GROUP
General Requirements Subgroup
Division 01 — General Requirements
Facility Construction Subgroup
Division 02 — Existing Conditions
Division 03 — Concrete
Division 04 — Masonry
Division 05 — Metals
Division 06 — Wood, Plastics, and Composites
Division 07 — Thermal and Moisture Protection
Division 08 — Openings
Division 09 — Finishes
Division 10 — Specialties
Division 11 — Equipment
Division 12 — Furnishings
Division 13 — Special Construction
Division 14 — Conveying Equipment
Division 15 — Plumbing + HVAC
Division 16 — Electrical + Lighting
Division 17 — RESERVED FOR FUTURE EXPANSION
Division 18 — RESERVED FOR FUTURE EXPANSION
Division 19 — RESERVED FOR FUTURE EXPANSION
Facility Services Subgroup:

Division 20 — Mechanical Support
Division 21 — Fire Suppression
Division 22 — Plumbing
Division 23 — Heating Ventilating and Air Conditioning
Division 24 — RESERVED FOR FUTURE EXPANSION
Division 25 — Integrated Automation
Division 26 — Electrical
Division 27 — Communications
Division 28 — Electronic Safety and Security
Division 29 — RESERVED FOR FUTURE EXPANSION
Site and Infrastructure Subgroup:

Division 30 — RESERVED FOR FUTURE EXPANSION
Division 31 — Earthwork
Division 32 — Exterior Improvements
Division 33 — Utilities
Division 34 — Transportation
Division 35 — Waterways and Marine Construction
Division 36 — RESERVED FOR FUTURE EXPANSION
Division 37 — RESERVED FOR FUTURE EXPANSION
Division 38 — RESERVED FOR FUTURE EXPANSION
Division 39 — RESERVED FOR FUTURE EXPANSION
Process Equipment Subgroup:
Division 40 — Process Interconnections
Division 41 — Material Processing and Handling Equipment
Division 42 — Process Heating, Cooling, and Drying Equipment
Division 43 — Process Gas and Liquid Handling, Purification and Storage Equipment
Division 44 — Pollution Control Equipment
Division 45 — Industry-Specific Manufacturing Equipment
Division 46 — Water and Wastewater Equipment
Division 47 — RESERVED FOR FUTURE EXPANSION
Division 48 — Electrical Power Generation
Division 49 — RESERVED FOR FUTURE EXPANSION

Additional Background Material

Read through the MS Word document “Reference Document on Introduction to Engineering Standards” for further detailed information on standards organizations and the methods used to develop standards

NFPA 36
Standard for Solvent Extraction Plants

What is NFPA 36?

A) NFPA 36 is the National Fire Protection Association standard for solvent extraction plants.

B) The primary purpose is to establish the safety requirements for the design, construction, operation, and maintenance.

C) Solvent extraction plants are facilities that use flammable liquids and solvents to extract essential oils, flavors, and other substances from raw materials.

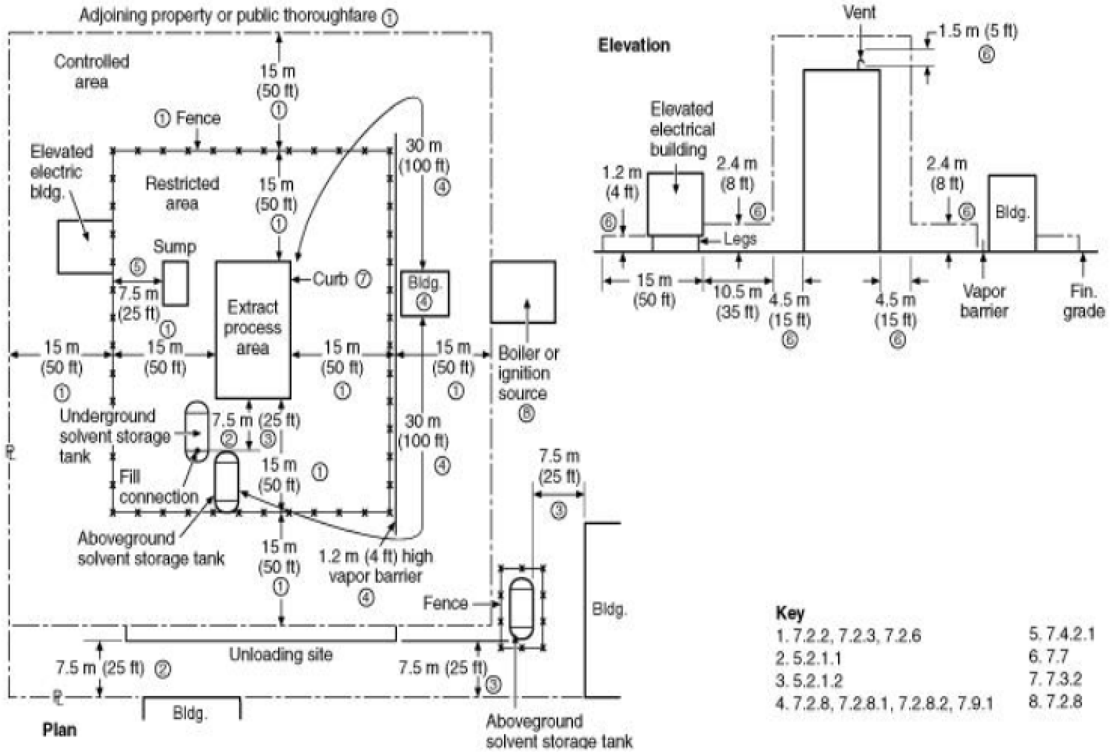
D) Some of the key objectives of NFPA 36 include:

- Fire prevention and protection
- Equipment design and installation
- Hazardous materials handling
- Emergency response.

1. Extraction Process

1.1 Location and siting

→The extraction process shall be located in the open or in a building suitable for the purpose, as shown in figure 1.1.



Fencing

- Industrial-type fencing shall be placed not less than 15m from the extraction process.
- All entrances and exits into the fenced area shall be secured to prohibit unauthorized entrance.
- Provisions shall be made for emergency ingress and egress.
  - A controlled area shall extend from 15m to not less than 30m from the extraction process
  - Restricted and controlled areas shall be posted with signs around the perimeter warning of the possible flammable vapor hazard
  - Basements, tunnels, pipe trenches, and pits shall be prohibited within 30m of the extraction process
- This requirement shall not apply to separation sumps and the drainage troughs connected to them.
- The slope of terrain and the prevailing winds shall be considered in locating the extraction process

- Structures and equipment essential to the operation of the extraction process, other than boilers and other open flame operations, shall be permitted to be located less than 30m but not less than 15m from the extraction process.
- The barrier shall be located between the extraction process and the possible source of vapor ignition and shall be at least 15m from the extraction process.
- The barrier shall be of noncombustible vapor-tight construction without gates or other openings and shall be at least 1.2m high and designed so that there is at least 30m of vapor travel around its end to possible sources of ignition.

2. Design and Construction

- The building or structure housing the extraction process shall be of fire-resistive or noncombustible construction with the first floor at or above grade.
- Solid sections of the upper floors of the extraction process and concrete pads under the entire extraction process shall be curbed and sloped to drain directly to an outside separation sump
- Drainage lines under the ground floor slab of the extraction process shall be prohibited
- Explosion relief at least $1m^2$ for each $15m^3$ of building volume shall be provided by one or more of the following methods

1. Open-air construction with a minimum area enclosed
2. Light noncombustible wall panels and roof hatches
3. Light noncombustible walls and roof lightly attached to steel frame

- Drainage and spill control:

  -Provisions shall be made to guard against the introduction of solvent into the sewer system.

  -The separation sump shall be located within the restricted area but not closer than 7.5m (25 ft) to the fence surrounding the restricted area.

  -The separation sump shall be concrete or of equivalent noncombustible construction.

3. Ignition source and Heating

- Ignition source shall not be permitted within the extraction process building or 30m of the process unless the unit and building are purged except as provided.
- Space heating, if required shall be provided by indirect means. Temperatures on heated surfaces shall be limited to 120C
- If steam tracing or jacketing is provided, temperatures on both internal and external heated surfaces shall not exceed 120C
- Process temperature shall be permitted to exceed 120C, provided the temperature is reduced to 120C during shutdown periods.
- Process vent fans, purge fans, and building ventilation fans that might handle solvent vapors, including any fans that have air intake should be spark-resistant construction or better.

QUESTION for DISCUSSION

- How does NFPA 36 address potential ignition sources and heating equipment within solvent extraction plants to make fire risks less severe, and what are the recommended practices and operations to ensure safety?

ASSIGNMENT

- Chose one classmate to work with, and then discuss and answer the questions posed on the NFPA Solvent Extraction Worksheet provided to you by the instructor

NAME: ___________________________

CHEN 4317 – Chemical Process Design III
Department of Chemical and Natural Gas Engineering

Based on the information presented in the NFPA 36 standards lecture, along with information you know about flammable hydrocarbons (and the hydrocarbon properties given in the lecture), answer the 4 questions below. You should come up with the best answer based on discussion within your group.

1. Why is there a barrier, only 4 ft tall, between the solvent extraction tower and a boiler / similar ignition source?

2. Why is the on-site electrical building to be located on legs and 4 ft off the ground?

3. Why are underground structures or pathways prohibited on this site?

4. What are heated surface temperatures required to be no more than 120 C in temperature?

APPENDIX B

Spring 2024 Webinar Series on Standards, their importance, and applications

Mr. Richard N Berry, PE

CDS Muery

Sr. Project Engineer

Date: March 27, 2024

Time: 12:00 PM (Noon)

Place: EC 109 and Online (Zoom)

https://tamuk-edu.zoom.us/j/95106798777?pwd=dVlQSG5iRWk4UDJkSnl0L2NNMXhwZz09

Standards and Codes in Construction: Adhering to specific minimum standards and building codes is crucial in ensuring the safety of structures and machines in workplaces and neighborhoods, particularly considering the destructive power of natural forces. The evening news often showcases the harmful effects of such calamities, highlighting the importance of extensive research on events like earthquakes, tornados, and other disasters. The knowledge gained of Codes and Standards are used to design structures or machines to prevent such losses in the future.

The Speaker: Rick is a licensed professional engineer with 38 years of specialized experience in the design and construction of fuel stations. He has completed the design of fuel stations for more than 25 years.

For 29 years, Rick's experience has been associated primarily with environmental engineering, fuel system designs, stormwater pollution prevention plans, and soil and groundwater contamination remediation. He has performed the design and installation of aboveground and underground storage tanks throughout the state and the re-installation of underground and aboveground storage tanks and other infrastructure projects.

Rick graduated from Texas A&M University in 1983 with a Bachelor of Science in Civil Engineering.

Standards and Codes in Design and Construction

Richard N. Berry, P.E.'82 TX PE 66756
Sr. Project Manager
CDS Muery TBPE F-1733
San Antonio, Texas

Richard N. Berry, P.E. ‘82
Senior Project Manager
CDS Muery
San Antonio, Texas

TBPE No. F-1733

Issue 02/13/24

Goals of Presentation

- Understand the Definition and Use of Standards and Codes in Design and Construction Activities.
- Understand When a Standard or Code Applies and When it does not; (for example, no mixing codes in one book with those of another.)

A Standard is

Something established for use as a rule or basis of comparison in measuring or judging capacity, quantity, content, extent, etc.

For example, a standard size for fasteners, pipe threads, connections for fluid transfers. (1/4 – 20 bolts, 2 inch NPT pipe, etc.). This allows the use of components of a normal size and manufacturer which is especially helpful during repairs or construction.

Example of a Standard

A task where steps are followed in the same order, manner, etc. regardless as to location so that results can be compared from day to day.   An example is a “White bucket test” followed by a Specfic Gravity test.

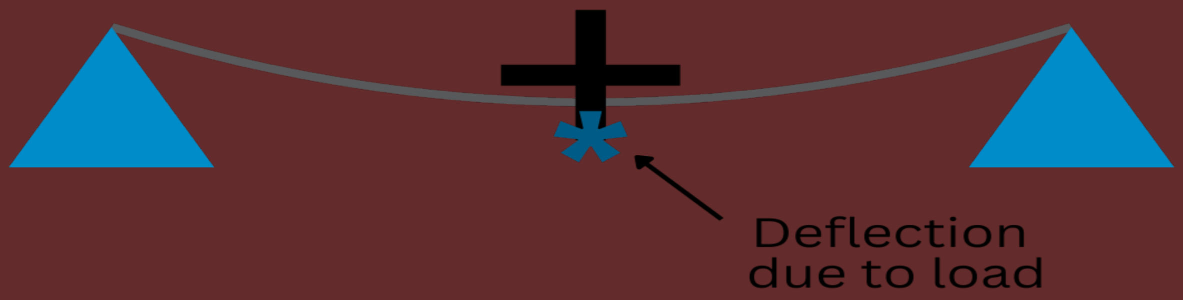
A Code is

A body of laws, as of a nation or city organized for easy reference.

Examples of Code Reference

- International Building Code (IBC)
- International Fire Code (IFC)
- National Electric Code NFPA 1 (NEC)
- These codes are revised and published every two to five years. Sometimes with major revisions, sometimes with minor revisions. These three code books are in use at most major cities and municipalities. Some cities have amended the books and these amendments must be followed as well.

Examples of a Code
IBC Maximum Deflection



Calculations

- Load applied in the center of the simply supported beam. Reactions found at supports and deflection at midpoint calculated. (Shear and Moment diagrams)
- A check based on the allowable deflection and other factors (IBC, current addition) indicates the selected beam will support the load, however the movement vertically is excessive. (On the 50th floor of a building and as you walk the floor is moving. The SE is called, the problem is explained, and the response is "Don't worry, the deflection is within code.)

Calculations

1. Reactions for simply supported beam = P/2 = R = V

   where P is the load, R is the reaction, and V is the shear

2. Shear and Moment is determined (Shear and Moment Diagrams)

3. Size beam based on this data.

4. The deflection is calculated. The deflection is too high as determined by the IBC.

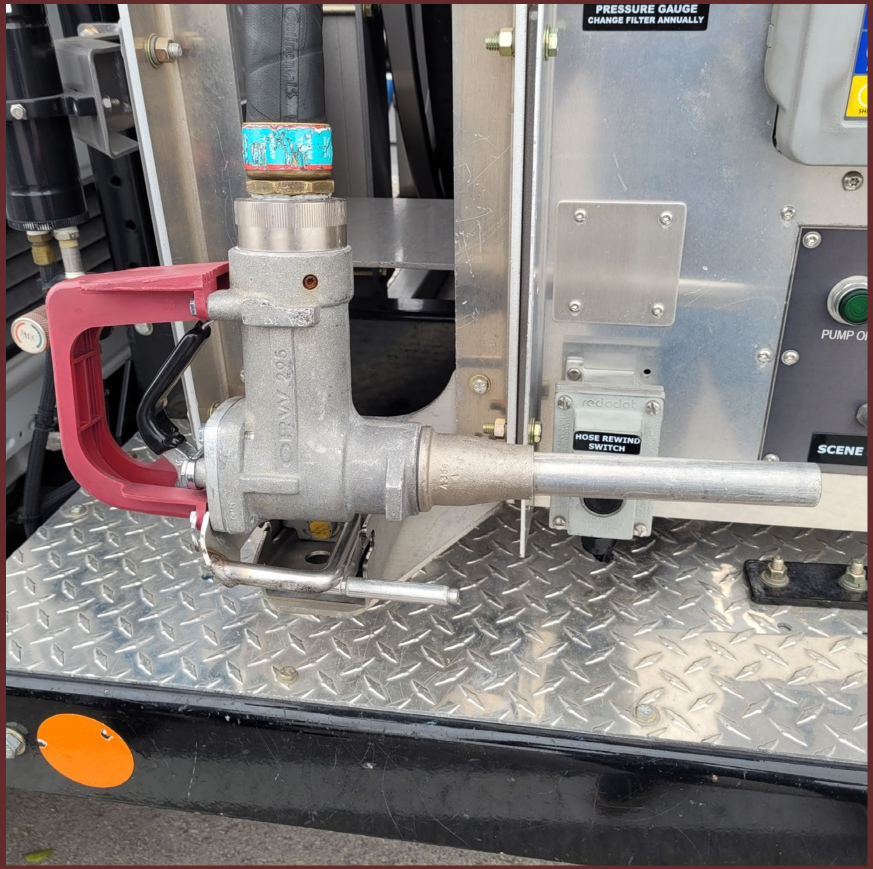
5. Beam resized based on code from the IBC, e.g., l/180 (maximum allowable deflection.)

Fuel Connection Point Configurations

- **Types of connections**
  - a) Round nozzle spouts, General Use, mostly Avgas
  - b) Duckbill Spouts for use in Jet A
  - c) Single Point, Solid High Flow Connection

Fuel Connection Point Configurations

- a) Round nozzle spouts,
- General Use, mostly Avgas



Fuel Connection Point Configurations

- Duckbill Spouts for use in Jet A

Fuel Connection Point Configurations

- **Types of connections**

  c) Single Point, Solid High Flow Connection

Disastrous Misfuelling Outcomes

- Could cause a fire in the engine(s)
- Engines fueled with the wrong fuel will shut down.
- Turbine engines with Avgas will run wild and destroy itself.

Sent Air Ambulance Down. All On board were killed.

Factors in the Crash:

- Pilot not paying attention while refueling.
- FBO turned on Avgas not Jet A pump.
- Duckbill nozzles were not being used.
- Experience Level was NOT a factor.

Questions?

Spring 2024 Webinar Series on Standards, their importance, and applications

Mr. Travis Murdock
Manager, Technical Committee Operations
ASTM International
Date: April 3, 2024, Time: 12:00 PM (Noon)
Place: EC 109 and Online (Zoom) https://tamuk-edu.zoom.us/j/97288678924?pwd=UE1PNDhpT3NKWlVHMHhRWFNORmE2dz09

Meeting ID: 972 8867 8924
Passcode: 053246

Title: Introduction to Voluntary Consensus Standards

Abstract: During this session, we will explore the world of voluntary consensus standards: what they are; how they are created; who's responsible for developing them; and why all of this matters.

The Speaker: Travis Murdock is the Manager of Technical Committees Operations at ASTM International. His primary function at ASTM is the management of numerous technical committees responsible for developing various standards related, but not limited to, bio/pharmaceutical product manufacturing, occupational health and safety, pedestrian/walkway safety, and footwear. Prior to joining ASTM in 2016, Travis began his standards career in 2010 with the Society of Cable Telecommunications Engineers (SCTE), where he managed the development and continued maintenance of coaxial and fiber optical cabling standards and practices. Travis is also responsible for the ASTM Academic Outreach program designed to promote awareness and education of standards to the next generation. From 2018-2020, he served as chair of the ANSI Committee on Education. Travis holds a bachelor's in Telecommunications from Penn State and an MPA in Nonprofit Administration from West Chester University.

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Texas A&M Kingsville
Intro to Technical Standards

Travis Murdock
Manager
Technical Committee Operations

www.astm.org

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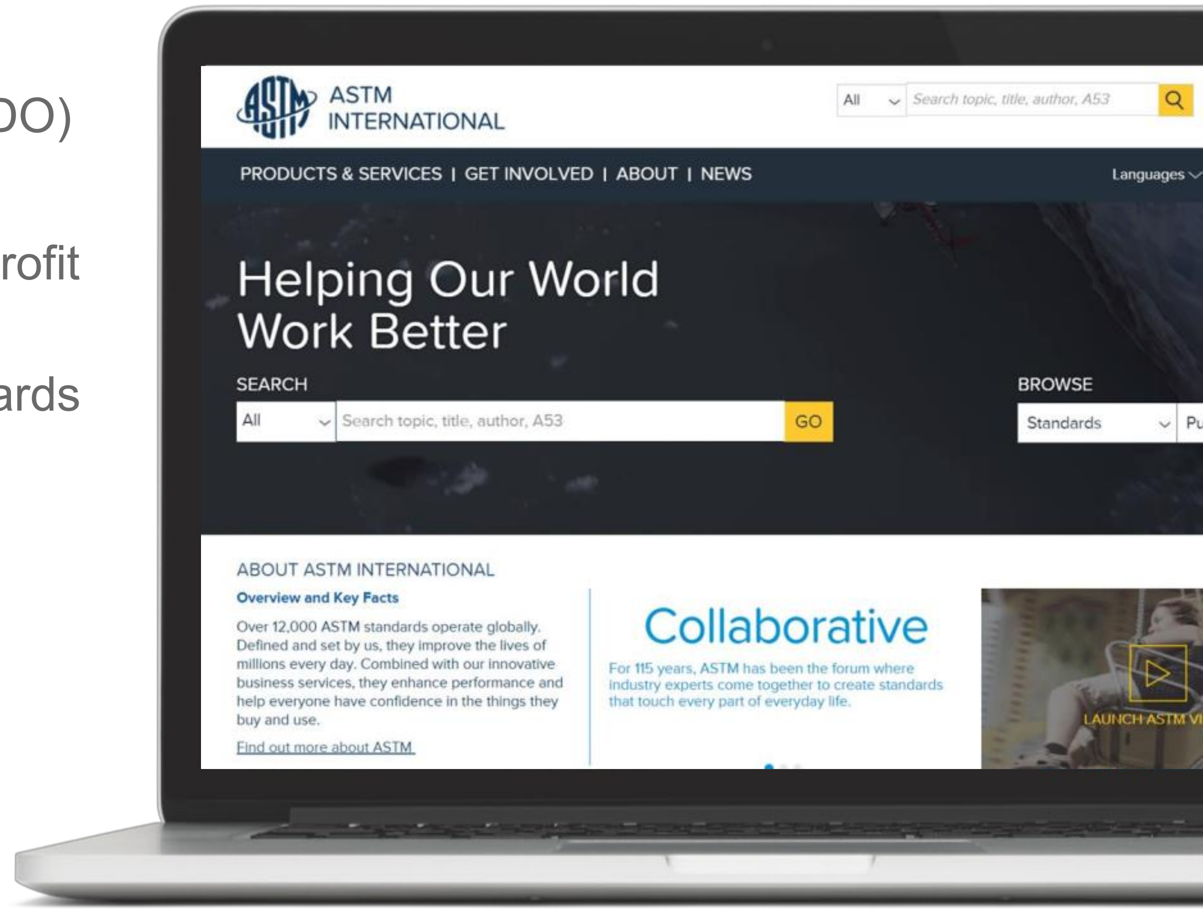
What is ASTM International?

ASTM International

– International Standards Developing Organization (SDO)
– Founded in **1898**
– Non-governmental, not-for-profit organization
– **+12,900** International Standards
– **+35,000** Members
– **+140** Technical Committees
– **90** Industry Sectors



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What is a Standard?

ASTM Standards

A technical document developed by consensus and under certain procedures and regulations

This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

ASTM INTERNATIONAL

Designation: F2412 – 18a

Standard Test Methods for Foot Protection[1]

This standard is issued under the fixed designation F2412; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

For more than sixty years, the predecessor to these test methods, ANSI Z41, established the performance criteria for a wide range of footwear to protect from the hazards that affect the personal safety of workers. The value of these standards was recognized early in the history of the Occupational Safety and Health Administration (OSHA) and incorporated as a reference standard in the Code of Federal Regulation (CFR) Section 1910.

1. Scope

1.1 These test methods measure the resistance of footwear to a variety of hazards that can potentially result in injury.

1.2 These test methods may be used to test for compliance to minimum performance requirements in established safety standards.

1.2.1 By agreement between the purchaser and the supplier, or as required by established safety standards, these test

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B117 Practice for Operating Salt Spray (Fog) Apparatus

2.2 *CSA Standard:*[3]

CAN/CSA Z195 Protective Footwear

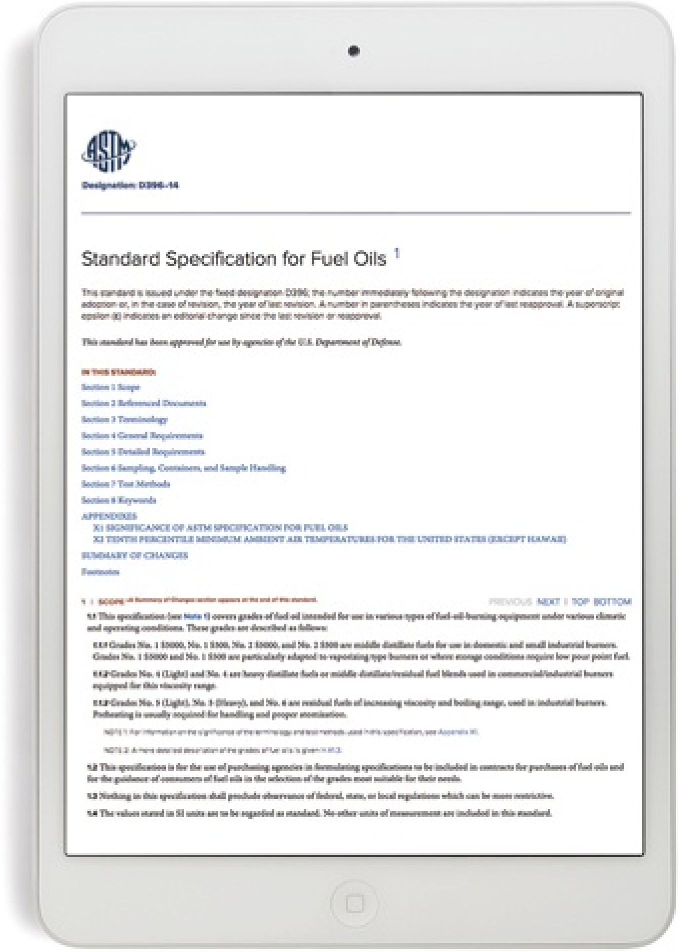
3. Terminology

3.1 *Definitions:*

Effective and Relevant Around The World

The Role of Standards

- Ensures safety, quality, and reliability
- Consensus process allows all stakeholders to participate equally
- Embraces the World Trade Organization's Agreement on Technical Barriers to Trade
- Incorporated into contracts, regulation, codes
- Constantly responding to new challenges, new technology, and new markets



ASTM Standards Cover

- Aerospace
- Asset Management
- Automotive
- Building and Construction
- Chemicals
- Consumer Products
- Energy
- Environment
- Medical Devices
- Manufacturing
- Metals
- Nanotechnology
- Oil and Gas
- Plastics
- Quality
- Safety and Security
- Sports and Leisure
- Textiles and Leather
- Transportation

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Who creates ASTM Standards?

ASTM Members

- ASTM Standards are developed by volunteer members
- Membership is open to everyone with material interests
- Technical experts from industry, governments, academia, professional societies, trade associations, and the general public
- Serve on any of our 140+ technical committees across a broad range of fields
- Over 150 countries represented

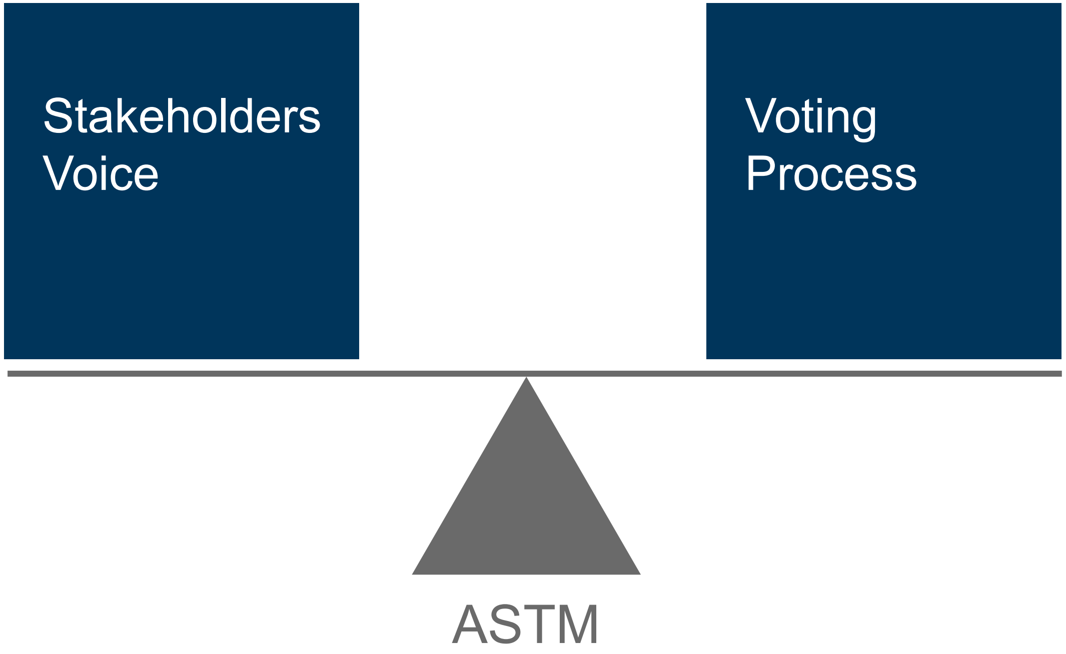
140+

technical committees

Openness and Balance

Equal Voice, Equal Vote

- All stakeholders have an equal voice
  - 1 vote per voting interest (org/company)
- Fair and balanced voting process
  - 90% affirmative
  - Negatives must be addressed
  - No Producer dominance
- Widespread acceptance of ASTM standards



Classification of Members

Members are Classified based on what "*voting interest*" (organization) they represent

- **Producer** – produces or sells a material, product, system or service
  - *Manufacturer, Raw Materials*
- **User** – purchases or uses a material, product, system or service
  - *Buys from Producers to make their own product/service*
- **Consumer** – primarily purchases or represents those who purchase products and services for household use
  - *End User*
- **General Interest** – if not otherwise classified
  - *Gov't Regulators, NGOs, Industry Organization, SDOs, Trade Associations, Academia*

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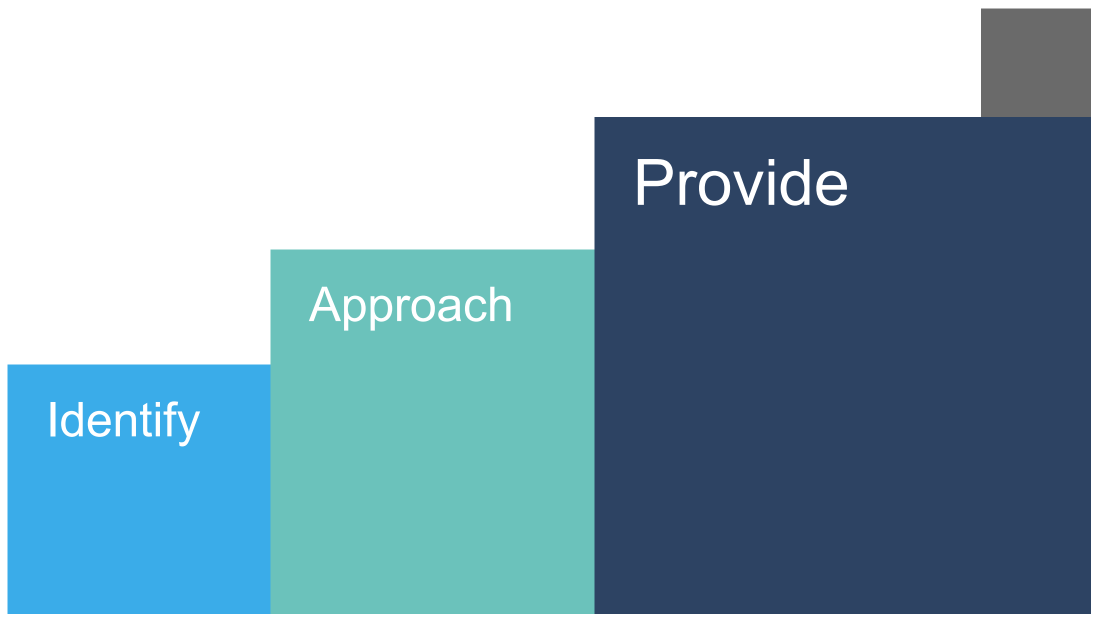
How are ASTM Standards developed?

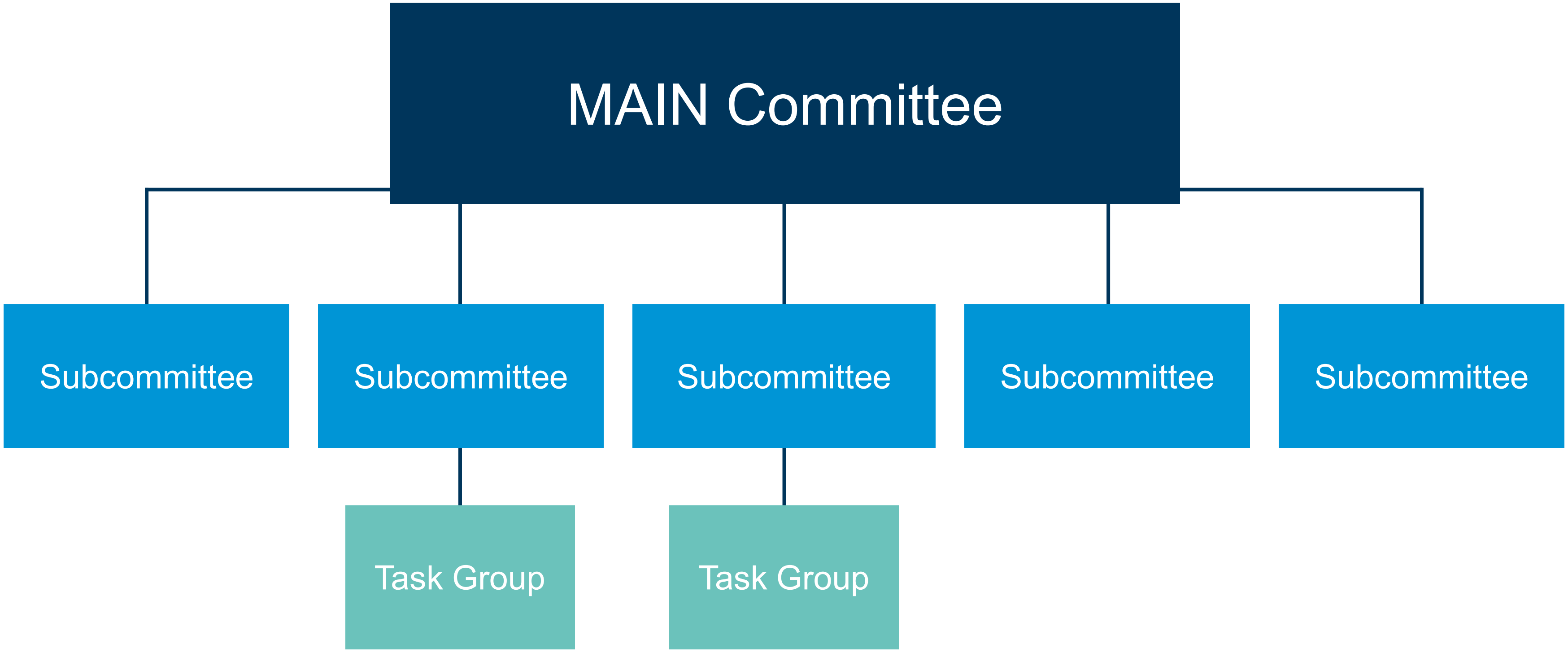
From an Idea… to a Standard

Starting the Process

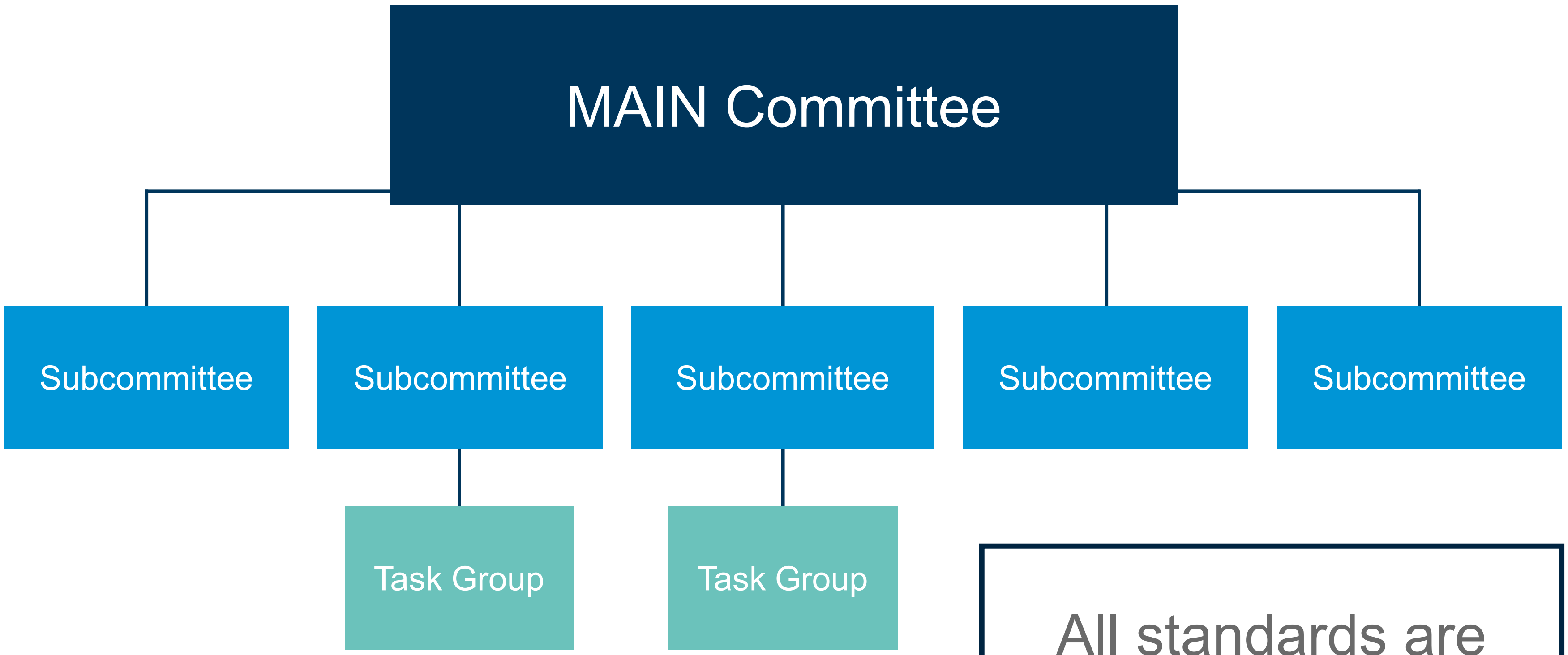
– Members identify a standards need
– Outside stakeholders may approach ASTM
– ASTM Technical Committees provide the forum for consensus and collaboration



ASTM Technical Committee Structure

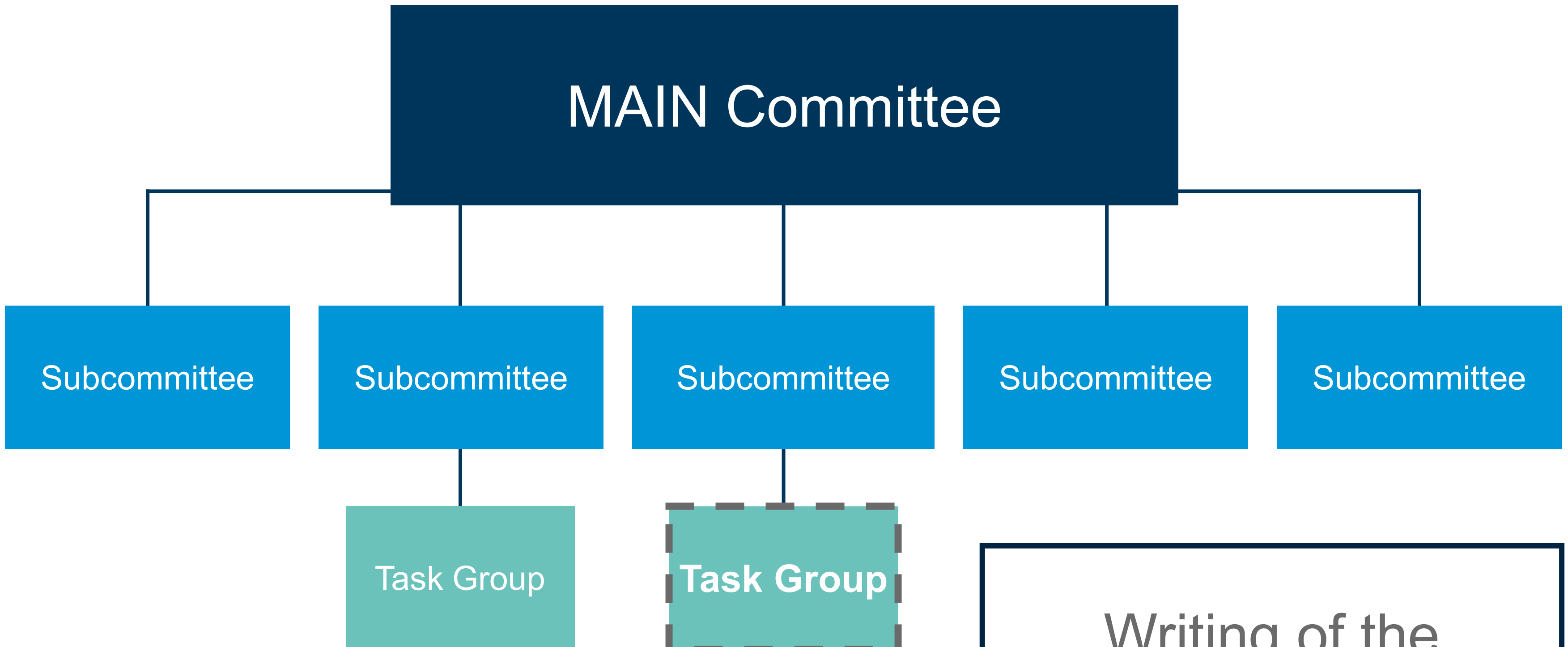


ASTM Process



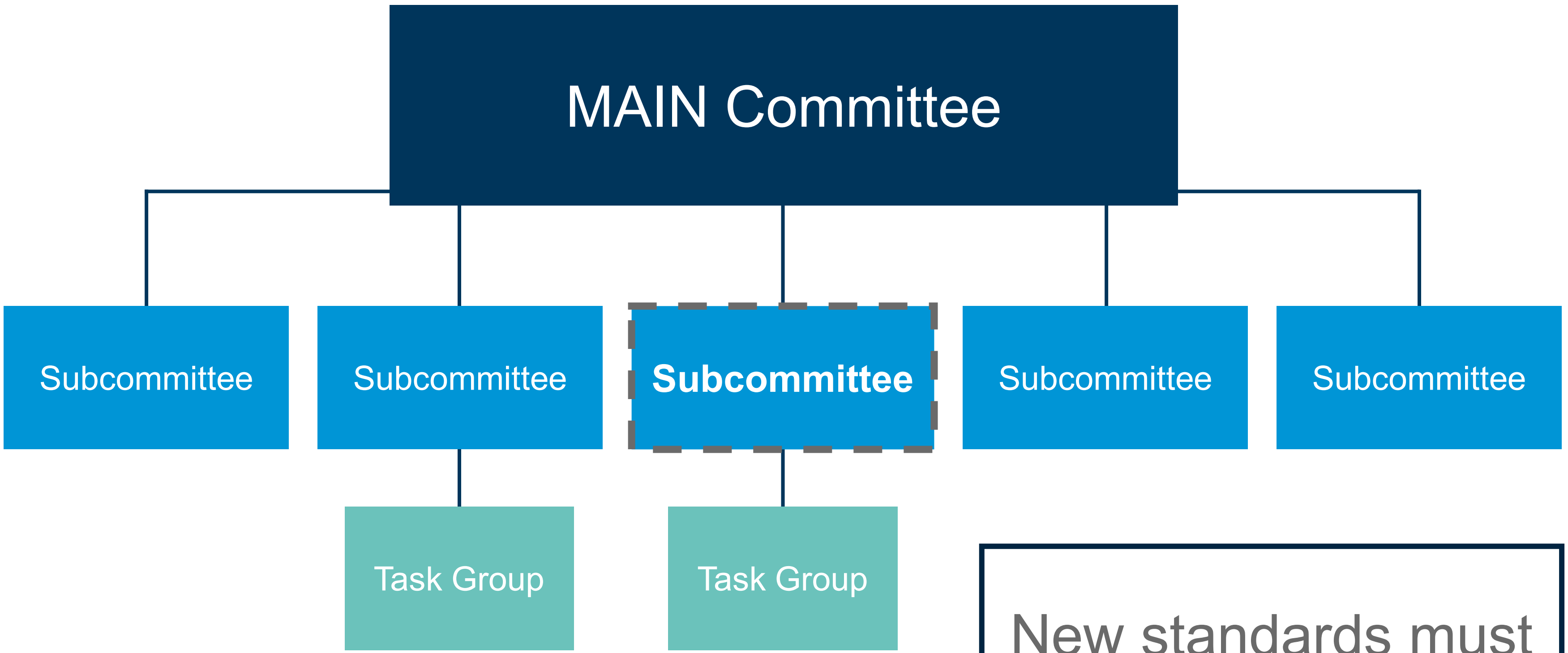
All standards are assigned to a technical committee

ASTM Process



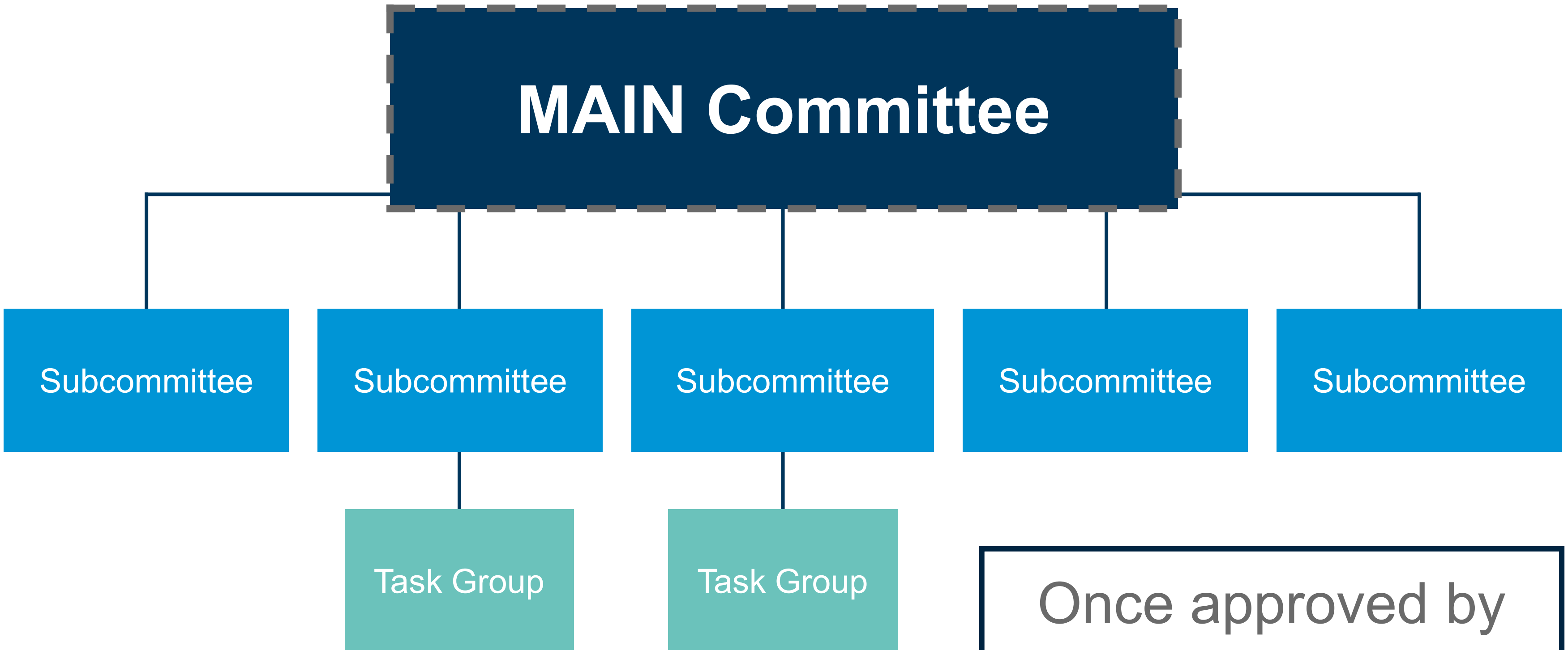
Writing of the standard is handled by a Task Group

ASTM Process



New standards must be approved by the Subcommittee first

ASTM Process



Once approved by the Subcommittee, the standard goes to the Main Committee

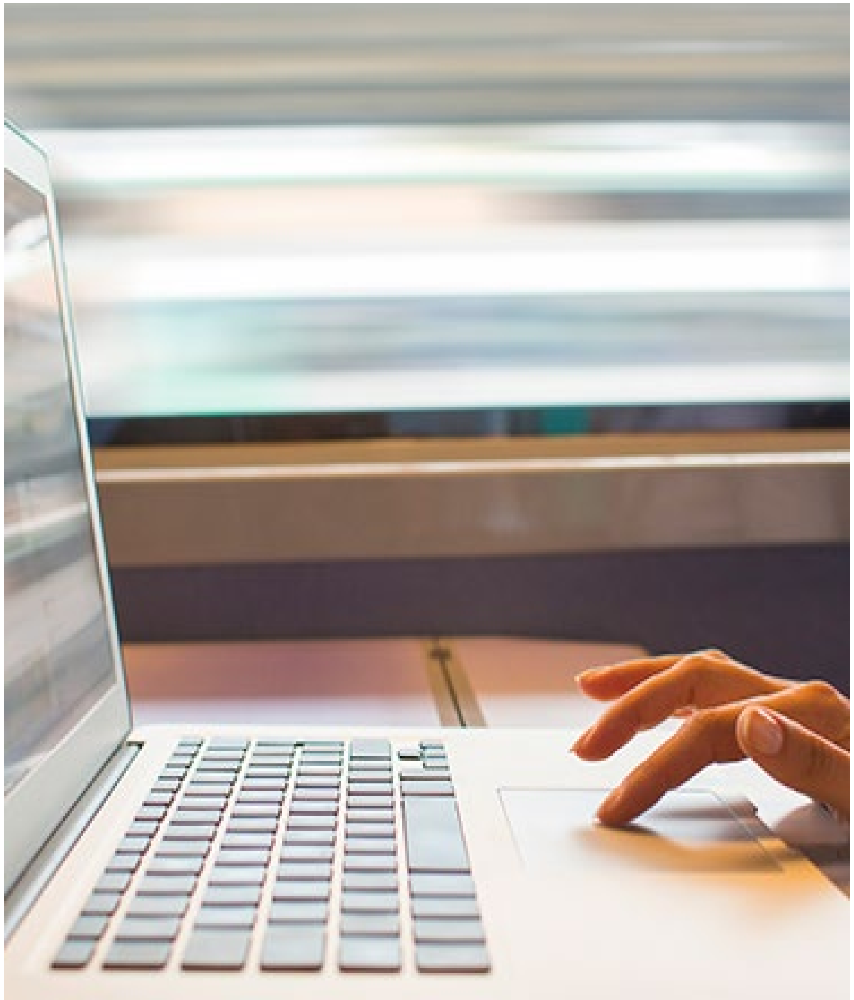
Balloting and Review Process

– All new and revised standards must be approved by the sub and main committee
– All objections received during the approval process must be addressed
– Any technical changes made to the standard during approval restarts the process
– Standards must be reviewed every 5 years

Result is high quality, market relevant standards

Timely Standards Development

- Development and approval can take as little as six months
- ASTM provides electronic access to standards once approved
- Virtual tools allow for global participation right from anywhere



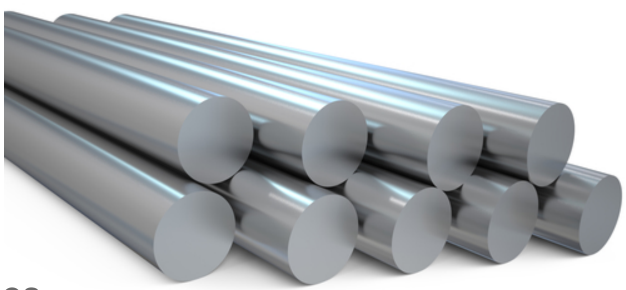
ASTM Committees Examples

A01 on Steel, Stainless Steel and Related Alloys

- Established in 1898
- 26 subcommittees; 1200+ members; 495 published standards
  - A267 Standard Specification for Stainless Steel Bars and Shapes
  - A380 Standard Practice for Cleaning, Descaling, and Passivation of Stainless-Steel Parts, Equipment, and Systems
  - A941 Standard Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

E08 on Fatigue and Fracture

- Established in 1993
- 12 subcommittees; 420 members; 34 published standards
  - E466 Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials
  - E606 Standard Practice for Strain-Controlled Fatigue Testing



F42 on Additive Manufacturing Technologies

- Established in 2009
- 6 subcommittees; ~600 members; 22 published standards
  - F2792 Standard Terminology for Additive Manufacturing Technologies
  - F2971 Standard Practice for Reporting Data for Test Specimens Prepared by Additive Manufacturing

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Why should students care?

Why do Students need to know about Standards?

- Awareness of current industry practices
- Means to innovate new and existing technology
  - Standards are living documents
- Competitive advantage
  - Global marketplace
  - Industry networking
- Coursework requirement
  - ABET
  - Used in coursework
  - Capstone/Senior Design

Resources for Students

ASTM Student Members may be eligible for scholarships, grants, summer internship, and committee-specific awards offered throughout the year

Learn more at:

https://www.astm.org/get-involved/students-and-professors/for-students/memstudent23.html

ASTM International Academic Outreach

- **Free Student Membership**
- **Stay informed via ASTM *Standardization News***
- **$10,000 Graduate Scholarship** Applications due April 30
- **$500 ASTM Project Grants** Applications due Oct 31
- **ASTM Student Chapters Program**
- **Committee-specific Awards and Events**

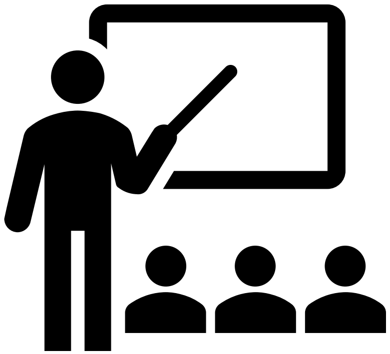
Benefits of Free Student Membership

- Qualify for ASTM scholarships, project grants and contests
- Free event attendance; networking
- Keep up-to-date on new technology through electronic editions of ASTM magazines and newsletters
- Reduced membership fee upon graduation
- Resume builder

Resources for Faculty

Incorporating Standards in Class

- Professor Tool Kit
  - Free course material; videos, handouts, presentations, etc.
- On-Campus events
  - Committee meetings
  - Workshops
- Guest lecturing opportunities
- **New ASTM 101 e-Course**
  - http://astm101.training.astm.org/
- Access to Standards
  - ASTM Compass
- Professor of the Year Award



Contact Information

Academic Outreach

Travis Murdock

Manager, Technical Committee Operations

(610) 832-9826

tmurdock@astm.org

www.astm.org

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Thank you

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Title: Effective Use of Plans and Specs for Design Definition

Mark Roetzel,
P.E., RPLS, CFM
CDS Muery Engineers
Date: April 17, 2024
Time: 12:00 PM (Noon)
Place: EC 109 and Online (Zoom)
https://tamuk-edu.zoom.us/j/95106798777?pwd=dVlQSG5iRWk4UDJkSnl0L2NNMXhwZz09

Abstract: Engineered products and facilities are commonly manufactured and constructed using drawings (Plans) and technical specifications (Specs), defining required features, configurations, parameters, and performance. Effective use of Plans and Specs best assures that intended results are consistently achieved. Mark Roetzel will discuss the engineering standards applied to Plans and Specs, recommended features and formats, and common mistakes to avoid for related risk mitigation.

The Speaker: Mr. Roetzel has over 40 years' experience in the design, permitting, construction administration and operations support of numerous civil infrastructure, utility, and flood control facilities. He has managed more than $1.5B of projects and is licensed as a professional engineer in 14 states. He is a CSI Construction Documents Technologist, USACE Construction Quality Manager, and technical consultant to the Texas Board of Professional Engineers. He also provides expert witness support for various dispute resolutions, often including issues related to Plans and Specs. Mr. Roetzel graduated with a BSCE from Notre Dame in 1980.

Effective Use of Plans and Specifications for Engineered Products and Facilities

Engineering Function

What Function Does Engineering Serve?

Engineering is the practical application of science and technology, allowing products and facilities to be consistently provided for broad application.

The practice of Engineering extends back to the Romans, Greeks, Persians and before, as civilizations developed recognizing the need for infrastructure.

Engineering standards then developed over time to help realize the benefits of repeating successful applications while avoiding failed or ineffective attempts.

Engineering now is applied to a wide range of products, facilities, infrastructure and emerging technologies to bring these advances to society at the lowest practical cost, safest definition, and consistently highest dependability.

Drawings & Specifications

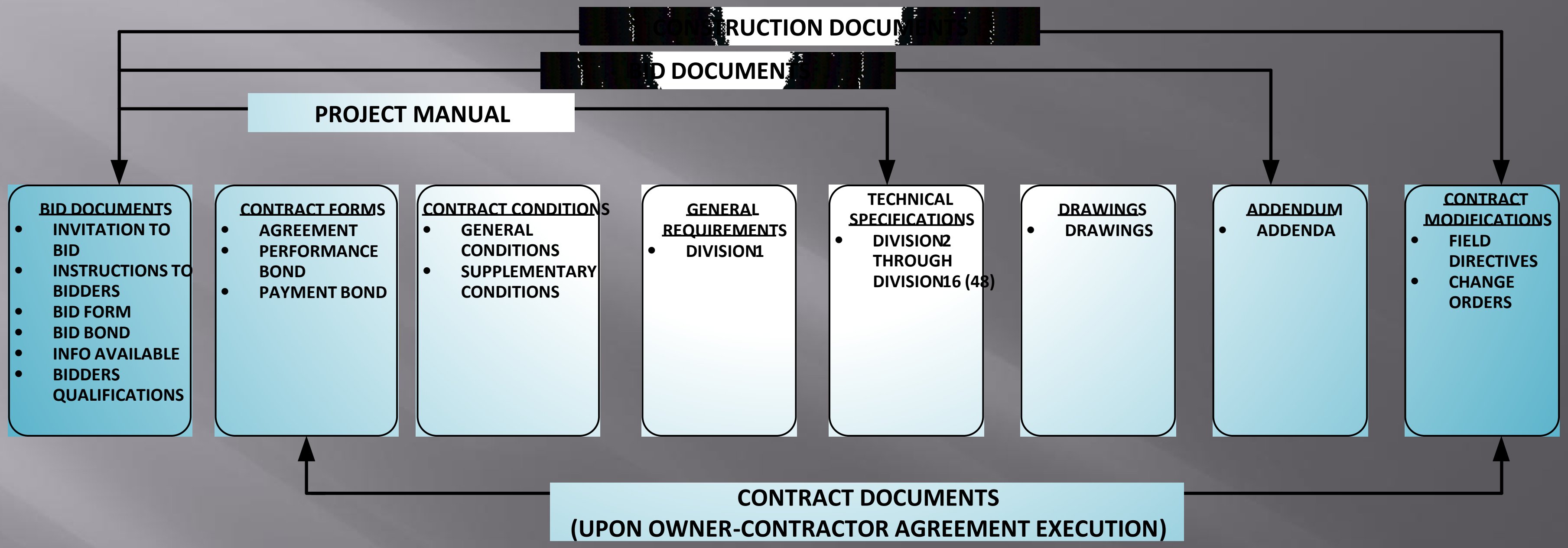
What Function Do Drawings & Specifications Serve?

Engineered products and facilities must be defined and communicated in a clear, concise and complete manner to ensure accurate, repeatable and dependable delivery.

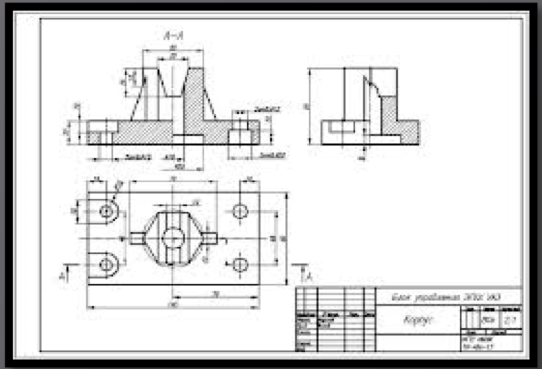
Drawings (Plans) and Specifications (Specs) are the primary tools used by engineers to show and describe these products and facilities.

Plans and Specs must therefore be clear, concise and correct to ensure that the intended products and facilities are consistently delivered, that related materials and features are defined, and that associated delivery services and obligations are met.

Relationship of Drawings and Specifications to Construction Contract Documents



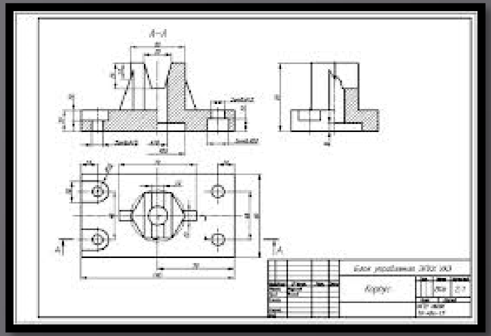
Based on standard industry Format Documents (EJCDC, CSI). Municipal and governmental agency owners often use modified or alternate documents, but always include Drawings and Specifications



Drawings

- **Drawings**: Graphic representation of the intended product or facilities.
- Drawings present a 2-D graphic (visual) representation of intended 3-D products or facilities.
- Drawings are normally prepared for presentation on standard sheet sizes (Full Size 24x36, Half-Size 11x17, Detail-Size 8.5x11) and increasingly transmitted electronically (.dwg, .pdf)
- The information presented on Drawings needs to be neatly, clearly and cleanly presented to avoid misunderstanding or interpretation of the engineer's intent.
- Because Drawings typically undergo several rounds of revision, review, approvals and release for fabrication/construction, it is important to clearly indicate the intended use with Drawing release notes "This Drawing is released under the authority of John Smith, P.E. #123456 on June 15, 2024, and is intended for regulatory review only. Not approved for bidding or construction."

Drawings



- **Drawings**: Effective Use Practices:

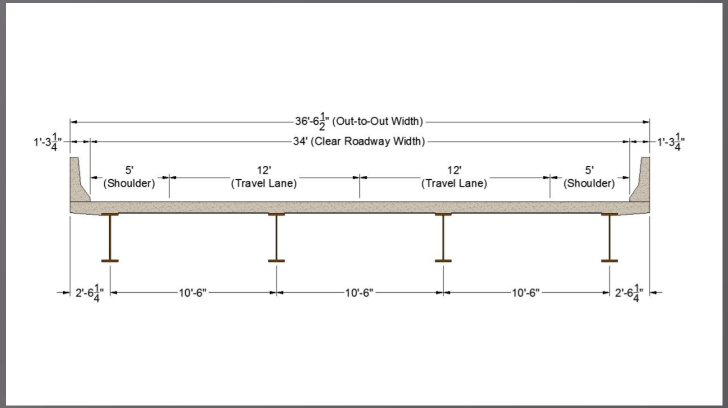
- Careful with cut-and-paste generic details. Common use of AutoCAD allows presentations and details to be easily repeated. Confirm that Drawings are accurate for the intended application.

- Avoid duplicate information in the Specs or elsewhere on the Drawings. Narrative descriptions should typically be presented in the Specification and minimized on the Drawings. Where Drawing notes are used, they should be specific to information presented on that sheet.

- Avoid Drawings notes that would be better included in the Specifications. ('*Say it clearly once, and reference to that definition elsewhere*' – common source of errors).

  Example: "Base plate shall be ASTM - A53 steel" is likely better presented as "Base plate material shall be in accordance with Specification 05100 – Miscellaneous Metals." Here, if a design change is made in specification definition, the drawing note follows without any needed revision.

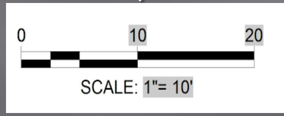
Drawings



- **Drawings**: Effective Use Practices:

- Avoid CAD 'false accuracy' ('32.7395 feet') – presents an implied design warranty. Here this number implies that the engineer is highly certain of the length, so any subsequent variance can be presented as an implied warranty of this accuracy by the engineer.

- Be careful of annotated scales ('1-inch = 100-feet'), since they are distorted with different print sizes. Best to use a graphic bar scale, and if annotated scale is used note related plot size ("1-inch = 100-feet (Full Scale)')



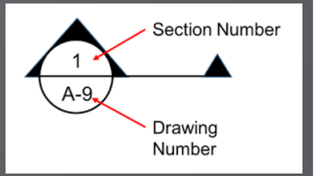
- Include Drawing Index and Standard Symbols/Abbreviations lists to clearly define information presented.

Drawings

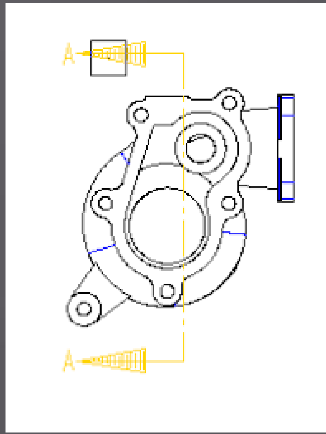
- **Drawings**: Effective Use Practices:

- Avoid excessive information on any Drawing sheet. Use Section and Detail references to direct user to supplemental graphic information.

- Section number, orientation, and presentation sheet must be identified.



- Detail number and presentation sheet must be identified. Typically a square box without orientation directional view arrow – with Detail Number (top) and presentation sheet (bottom).



- Engineers often develop Drawing Quality Control (QC) checklist to assist with accuracy and completeness of designs. Use 30/60/90% Standard Drawing Production QC checklists where available.

Specifications

- **Specifications**: Narrative description of the intended product or facilities.

- Specifications present a detailed description of general requirements, materials, assembly, performance and obligations associated with intended products or facilities.

- The information presented in Specifications needs to be clearly and concisely presented to avoid misunderstanding or interpretation of the Engineer's intent.

- Several engineering specification formats have been developed over time to encourage consistency. The most common engineering format is the Construction Specification Institute (CSI) specifications. CSI uses standard Divisions to classify work types (16 Divisions, or more recent 48 Divisions)

Specifications

- The CSI specifications then define each Division item using three specification sections: Part 1- General Requirements, Part 2 – Materials, and Part 3 – Execution. This formatting supports a consistent presentation of intended products and facilities.

- Because Specifications also typically undergo several rounds of revision, review, approvals and release for fabrication/construction, it is important to clearly indicate the intended use with Specification cover sheet release notes "These Specifications are released under the authority of John Smith, P.E. #123456 on June 15, 2024, and are intended for regulatory review only. Not approved for bidding or construction."

Specification - General Requirements (Division 1)

- General Requirements: Expansion of the Contract Conditions, Contract Forms and Specifications for specific project needs(1). Typically include:
  - Work Summary/Sequence
  - Schedule of Values (2)
  - Environmental Protections
  - General Coordination
  - Construction Management
  - Submittals (3)
  - Temporary Construction Facilities
  - Measurement and Payment
  - Worker Safety
  - Meetings
  - Quality Requirements
  - Work Execution Requirements

(1) Caution: Be aware of General Requirements implied costs - could exceed 10%.

Don't use them if you don't need them. Example: Temporary Construction Facilities – Site Trailers, may be unnecessary for small scope or short duration projects.

(2) Schedule of Values: A detailed pricing breakdown (by Spec section or comparable definition) prepared by Contractor before Work begins. Supports progress payments, and assists with potential Change Order pricing – particularly for Lump Sum work

(3) Submittals: Should be approved prior to related Work payments. Best to use detailed Submittals Log, checked with each payment application. Frequent source of conflict.

General Requirements (Typical Submittal Log)

Main Street – PWS Well No.7 Project Required Submittals Summary		
Section	Title	Required Submittal Timing
00700-2.01.B	Insurance Certificates	Before Work begins
00700-5.01	Performance/Payment Bonds	Before Work begins
00700-2.05	Prelim. Progress/Submittals/Value Schedules	Within 10 days of Execution
00700-10.05	Claims (Contract Price or Time)	Within 30 days of event
00800-6.06.B	Subcontractors (>5% of the Work)	Within 5 days of Bid Opening
01046	Connection to Existing Utilities	At least 5 days prior to scheduled event
01300	Submittals – Schedule of Values	Within 30 days of Execution
01300	Submittals – Shops/Samples/Product Data	Prior to executing related Work
01300	Submittals – Payment Application/Certs.	Monthly (if >$5,000)
01300	Submittals - RFIs	As reqd, prior to executing related Work
01300	Submittals – Change Order Proposals	Within 30 days of event
01300	Submittals – O&M Manuals (Ref 01730)	Within 90 days of approved Shops
01300	Submittals – Lesson Plans (Ref 01731)	At least 30 days prior to training
01300	Submittals – Record Documents (Ref 01720)	With written Notice of Completion
01300	Submittals – Guarantees, Warranties, Bonds	With written Notice of Completion
01620	Manufacturers' Installation Certificates	Prior to Substantial Completion
01630	Substitution Requests	Within 30 days of Execution
02830	Chain Link Fences and Gates	Prior to executing related Work
01700	Closeout Documents	Prior to Substantial Completion
01720	Record Documents	Within 14 days of Subst. Completion
01730	Operations and Maintenance Manuals	Prior to Substantial Completion
01731	Lesson Plans	Within 14 days of scheduled training
02830	Chain Link Fence and Gates	Prior to executing related Work
03300	Cast-In-Place Concrete	Prior to executing related Work
03600	Grout	Prior to executing related Work
04100	Mortar	Prior to executing related Work
04150	Masonry Accessories	Prior to executing related Work
04220	Concrete Masonry Units	Prior to executing related Work
05051	Anchor Systems	Prior to executing related Work
05500	Miscellaneous Metal Fabrications	Prior to executing related Work
07920	Caulking and Sealants	Prior to executing related Work
09900	Painting	Prior to executing related Work
10400	Identification Devices	Prior to executing related Work
11100	Electric Motors	Prior to executing related Work
11213	Vertical Turbine Pumps	Prior to executing related Work
11215	Water Well	Prior to executing related Work
11260	Chlorination Equipment	Prior to executing related Work
11260	Chlorination Equipment – Manuf. Cert.	Following Installation
11261	Chlorination System Dry Scrubber	Prior to executing related Work
11261	Cl2 System Dry Scrubber – Manuf. Cert.	Following Installation
11264	Booster Pump System	Prior to executing related Work
11970	First Aid Equipment	Prior to executing related Work
13600	Instrumentation and Control Systems	Prior to executing related Work
13620	Primary Sensors and Field Instruments	Prior to executing related Work
13650	Control Panels and Enclosures	Prior to executing related Work
13700	Radio Telemetry Control System	Prior to executing related Work

Specifications

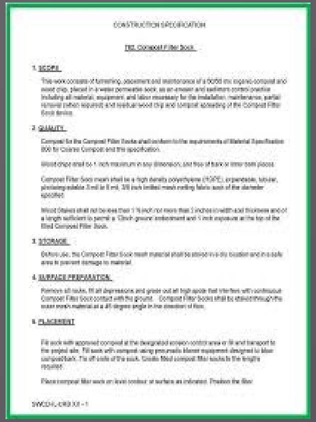
- **Specifications**: Effective Use Practices:

- Careful with cut-and-paste generic reuse of specifications - review for each project. If master specs are used, review and edit as needed to confirm scope and current definitions.

- Where manufactured products are defined in a specification, advisable to share draft spec with named manufacturers to confirm accuracy and completeness of products described (exercise judgement in applying review comments to avoid unintended sole-source descriptions when multiple manufacturers are allowed to respond – solicit multiple source reviews)

- Avoid duplicate information on Drawings - leads to errors & omissions. Drawings should generally refer narrative descriptions to the Specifications.

- Specs often refer to reference standards (ASTM, AISC, ACI, NEC, etc.). Be adequately familiar with reference standards to avoid potential conflicts with the specification descriptions.


CONSTRUCTION SPECIFICATION

1. SCOPE

2. QUALITY

3. STORAGE

4. SURFACE PREPARATION

5. PLACEMENT

Technical Specifications


CONSTRUCTION SPECIFICATION

1. SCOPE

2. QUALITY

3. STORAGE

4. SURFACE PREPARATION

5. PLACEMENT

- Specifications: Effective Use Practices:

- Clearly define required submittals for needed engineer's approval, support services, warranties, and any other obligations to be provided.

- 'Prescriptive' vs. 'Performance' specifications
  (know the difference, and appropriate use)

- Be Clear, Correct, Complete and Concise (C4) in your specifications.

Precedence of Documents

- **Precedence**: Order of importance and weight in resolving potential conflicts between various definitions in the Contract Documents.

- Typically discussed in General Conditions. Often defined generally as: Contract Documents supersede referenced standards and codes

- Advisable to provide more detailed precedence through Supplementary Conditions to avoid wide interpretation during subsequent potential disputes (i.e. 'Descending order of precedence includes: Drawings > Technical Specs > General Requirements> General-Supplementary Conditions >Referenced Standards > General Codes)

- May be a significant issue during dispute resolution, and courts will consider this precedence as defined in the Contract Documents in resolving potential conflicts.

Prescriptive vs. Performance Specifications

- **Prescriptive Work Requirement**: Detailed definition of Work requirement components, standards and functioning (i.e. 'Base plate shall be ½-inch ASTM-A53 new billet steel, measuring as shown on the Drawings, with ¼-inch continuous E-70 fillet welds, and four 3/8-inch anchor holes centered 1-inch from each corner") Most appropriate for well defined, time-tested Work components needing exact definition or needing close coordination with other aspects of the project. This is the most common engineering specification Work definition.

- **Performance Work Requirement**: Definition based on needed functional performance and required standards, with minimal components description (i.e. "Base plate shall be sized and designed to meet AISC Class-B loading conditions, based on the design criteria presented on the Drawings, and shall meet all applicable local, state and federal codes.') Most appropriate for proprietary systems, or items which can't be adequately defined during design due to options available to the Contractor. Trench Safety design is a common performance assignment example. Difference is often misunderstood by engineers and owners.

- Performance Work requirements typically include Professional Services assignment to the Contractor (i.e. 'Contractor shall retain a Texas P.E. to…….'). Not the same as final P.E. design of Shop Drawings, etc. This misunderstanding often is key to disputed claims.

- Engineers cannot transfer core project responsibilities (i.e. Engineer-of-Record items) to the Contractor. Courts consistently reject such inappropriate assignment.

Means and Methods

- **Means and Methods**: The tools, equipment, labor, processes, sequences and procedures used by the Contractor to complete the Work as defined in the Contract Documents – Drawings and Specifications.
- Contract Document Drawings and Specifications should present the required finished product and performance and avoid defining related Means & Methods as much as possible.
- Disputes arising from Work products resulting from engineer-defined or owner-defined Means and Methods will support Contractor's claims
- Describe 'what needs to be done' not 'how to do it'

‘Or Equal’ and Substitutions

- Prescriptive specifications often include ‘or equal’ allowance. General Conditions (and SCs, Div-1) should clearly define allowable ‘Or equal’ and substitution definitions and related request procedures. Recommended definition includes:

  - If several named products are specified, simplest to define all requested “Or Equal’ products as substitutions (using SC’s or Div-1 *Substitutions* Spec to clarify), or clearly state ‘No Substitutions Allowed’.
  - ‘Or Equal’ substitution requests must be submitted promptly (i.e. ‘within 30 days of award’)
  - Burden to demonstrate ‘Or Equal’ is on Contractor
  - Engineer’s decision is final
  - Engineer’s related substitution review costs may be charged to Contractor (if so defined)

- Shop Drawing submittals <u>should not</u> be used to request substitutions (unless specified product is not available within reasonable time, or other circumstances beyond Contractor’s control require latent substitution). Best to clearly define in Division 1, review associated procedures at Preconstruction Conference, and repeat as needed

- Don’t delegate junior staff to make critical ‘Or Equal’ decisions

Engineer's Responsibilities and Limits

- Engineer is responsible for project design definitions (except for allowable Performance Specification assignments), and responsible for any bid-phase, construction-phase and operations-phase services assigned by the Owner (Owner's Agent), subject to Professional Standard-of-Care obligations.

- Engineer cannot obligate Owner for any Contract Change Orders, and cannot direct the Contractor's Work execution (except in the case of eminent danger when all parties must protect workers or public safety – i.e. potential utility trench cave in.)

- Engineer's RPR (Inspector) should only coordinate with Project Engineer, and not direct or administer construction-phase services (i.e. Engineer's Field Rep) Use Suppl. Conditions to clearly define authority and limitations if needed beyond Gen. Condition definitions

Take Aways

- The proper use of Drawings and Specifications as part of the larger Contract Documents best ensures that intended products and facilities will be realized with greatest reliability and value.
- Careful understanding, preparation, assembly and use of Drawings and Specifications as part of the Contract Documents best ensures success and protects all parties from potential disagreement and conflict.

The Illusive Simple Project

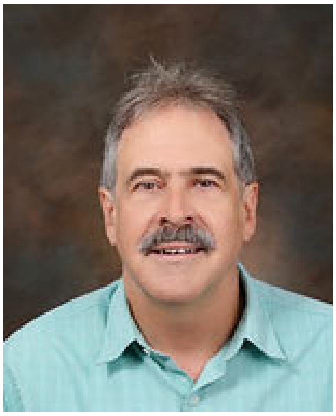
MARK ROETZEL, P.E., RLS, CFM

CDS Muery

mark.roetzel@cdsmuery.com

(210) 581-1111

Engineering and Survey Services



Dr. Matthew Alexander, PhD, PE, BCEE

Texas A&M University-Kingsville
Associate Professor
Date: April 19, 2024
Time: 12:00 PM (Noon)
Place: EC 109 and Online (Zoom)
https://tamuk-edu.zoom.us/j/96611595263?pwd=dDlkQ25QZjltajYxc2R1amZZNE8yZz09

Application of Engineering Standards in Environmental Engineering Design: One may think that the design of an environmental remediation systems does not require the application of engineering standards, since members of the public will presumably never come into contact with said systems. However, when one considers the safety of the site worker, safety is of paramount importance in dealing with hazardous waste sites, and so adherence to standards is important. Examples of the standards commonly applied to environmental remediation system design will be explored in this webinar.

The Speaker: Dr. Alexander is a licensed professional engineer in Texas and Alabama, with 34 years of experience in environmental remediation, hazardous waste site remediation, and chemical and environmental engineering education. He is also a Board-Certified Environmental Engineer (Site Remediation specialization) of the American Academy of Environmental Engineers and Scientists.

For 25 years, Dr. Alexander's experience has been associated primarily with environmental engineering applications for hazardous site remediation. His work has involved the analysis and design of treatment systems for excavated wastes and soils, recovered groundwater, and in situ treatment of contaminated soil and groundwater. He has performed numerous feasibility studies, performance evaluations, and remedial system designs for hazardous waste sites across the entire contiguous United States.

Dr. Alexander graduated from Trinity University in Engineering Science and Chemistry in 1985, and subsequently from The Georgia Institute of Technology (Masters in Chemical Engineering) in 1986 and Purdue University (PhD in Chemical Engineering) in 1990.

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Application of Engineering Standards in Environmental Engineering Design

Matthew Alexander

Dept. of Chemical & Natural Gas Engineering
Texas A&M University-Kingsville, Texas

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Application of Engineering Standards in Environmental Engineering Design

Purpose of this presentation:
To introduce how standards and codes are utilized in environmental engineering designs

Wayne H. King Dept of Chemical and Natural Gas Engineering
Frank H. Dotterweich College of Engineering

Application of Engineering Standards in Environmental Engineering Design

Standards and codes are applied in environmental engineering designs primarily for:

- worker and public safety,
- Preventing catastrophic events (fire, explosion),
- protection of the environment

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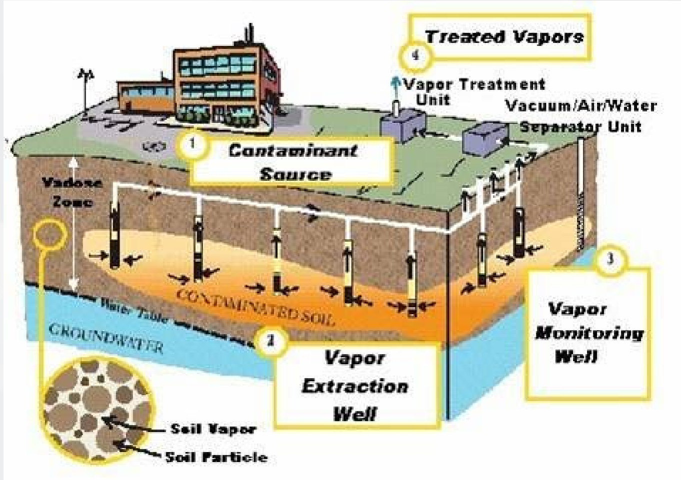
Focus on environmental engineering designs for hazardous waste remediation systems



[controlling or removing chemicals previously released into the environment]

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What is a Hazardous Waste Site?
(and why do we need to be concerned about it)

Historic and uncontrolled leaking of chemicals into the soil and groundwater

Improper disposal of drums containing chemical waste, and subsequent leakage of chemicals from the drums

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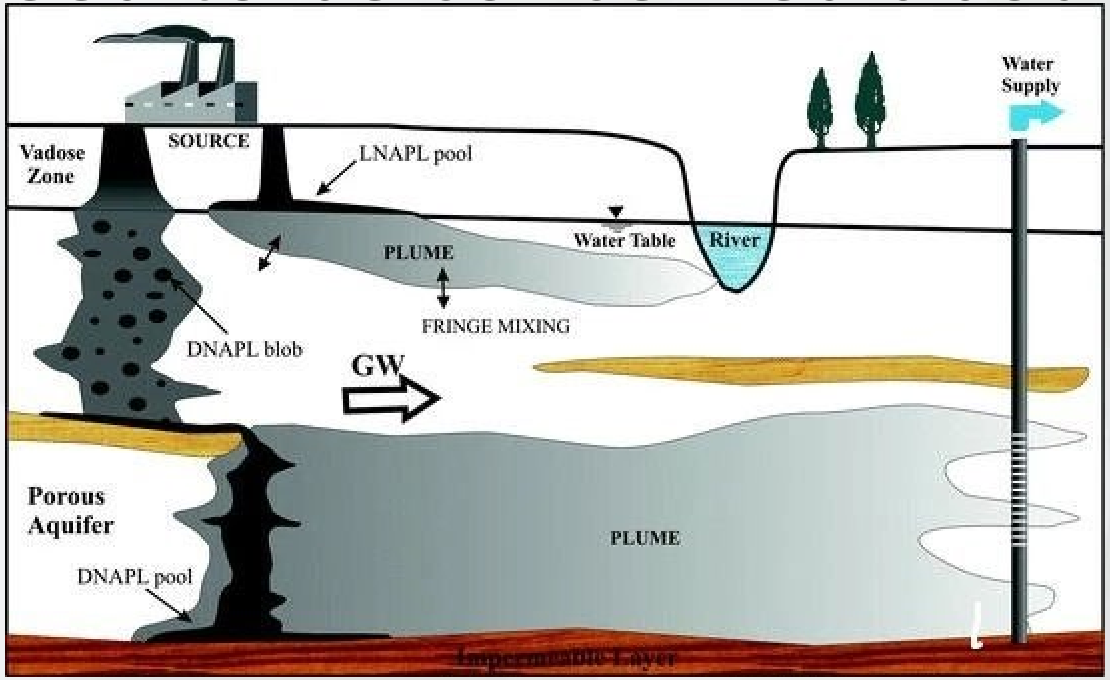
What is a Hazardous Waste Site?
(and why do we need to be concerned about it)

Historic and uncontrolled leaking of chemicals into the soil and groundwater

Impact to underground soils and to groundwater that may serve as drinking water source



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Risks controlled by proper adherence to applicable standards and codes in the design:

- Release of chemicals to the environment
- Development of faulty conceptual site model
- damage to existing underground utilities while drilling for investigation and remediation
- Leaks in landfill linings and caps
- exposure of flammable vapors to electrical sparks
- Use of proper adsorbent (activated carbon) to remove chemicals from water

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Release of chemicals to the environment

- Code of Federal Regulations (CRF) – ***40 CFR Part 112***. Spill Prevention, Control, and Countermeasures (SPCC)
  - USEPA Guidance document https://www.epa.gov/oil-spills-prevention-and-preparedness-regulations/overview-spill-prevention-control-and
  - Requires berm or secondary containment around petroleum and chemical tanks sufficient to hold 100% of volume + precipitation volume
  - Requires an SPCC plan prepared by a PE

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Release of chemicals to the environment

- Code of Federal Regulations (CRF) – 40 CFR Part 112. Spill Prevention, Control, and Countermeasures (SPCC)

Containment Berms

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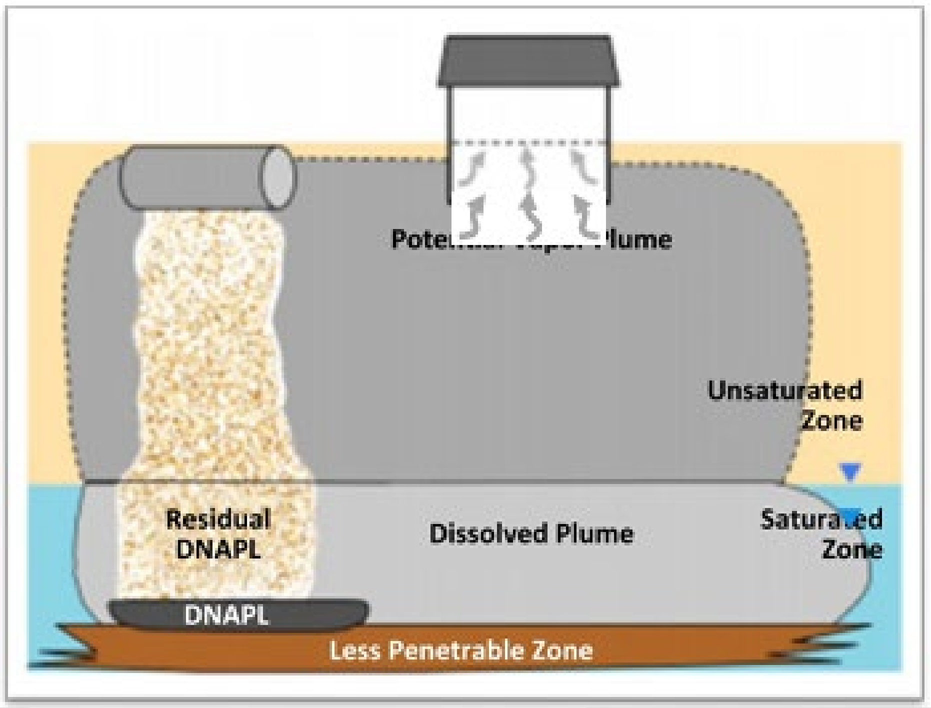
Release of chemicals to the environment

- USEPA Guidance https://www.epa.gov/ust/technical-guide-addressing-petroleum-vapor-intrusion-leaking-underground-storage-tank-sites
  - Petroleum Vapor Intrusion at Leaking Underground Storage Tanks Sites
  - Measure or estimate vapor inside building
  - May require vapor mitigation in building by---
    - Vapor vacuum extraction of soils
    - Additional ventilation inside building



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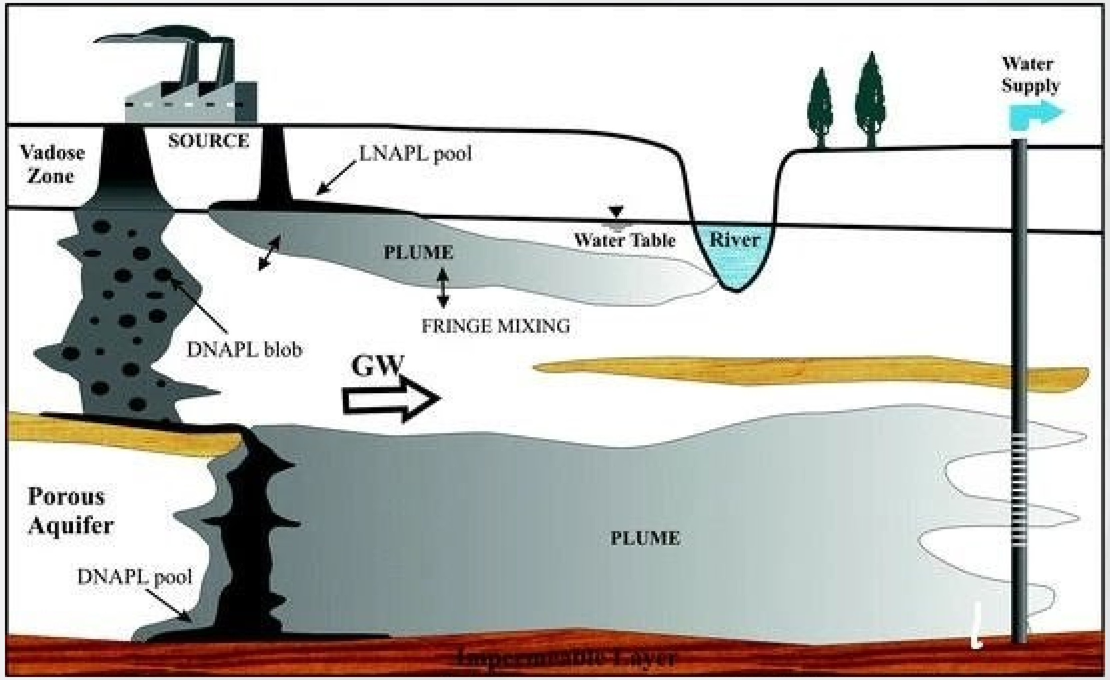
Development of Site Conceptual Model

- ASTM Standard

Historic and uncontrolled leaking of chemicals into the soil and groundwater
Impact to underground soils and to groundwater that may serve as drinking water source



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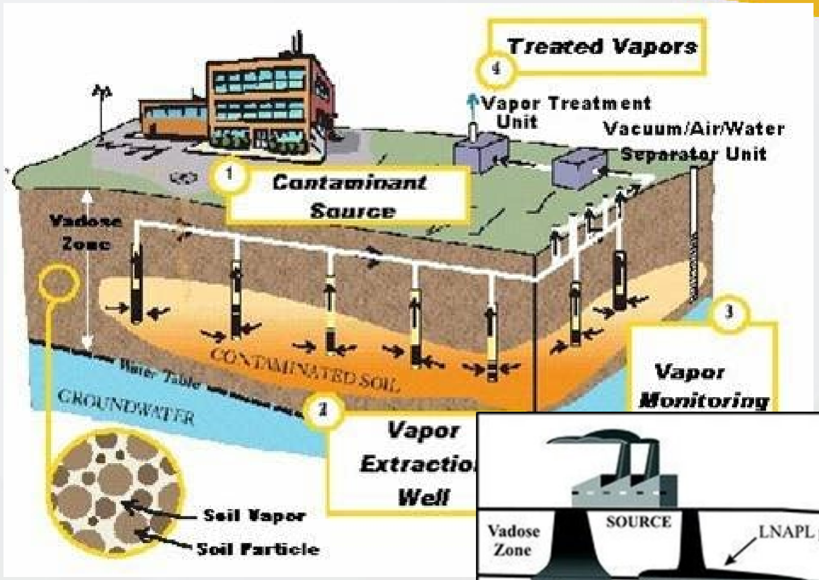
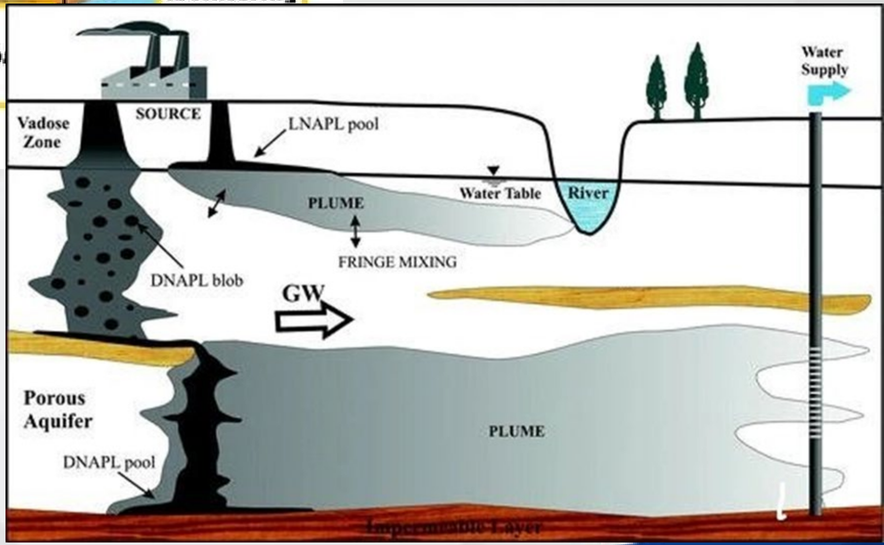
Site Conceptual Model

- ASTM E1689-20 Standard Guide for Developing Conceptual Site Models for Contaminated Sites
- https://www.astm.org/e1689-20.html
- Concept for the site can be confusing when majority of the “problem” is below ground and not visible





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Protection of Underground Utilities

- Hazardous waste site investigation and remediation work requires extensive subsurface drilling, frequently in utility congested areas
- State regulations and codes for utility protection
- https://statutes.capitol.texas.gov/Docs/UT/htm/UT.251.htm
- Locating utilities prior to work helps to prevent damage to those utilities while drilling vertically
- Soil vacuuming techniques to 5-10 ft BGS helps
- Vendors such as USIC and state 800 "no dig" numbers

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and Natural Gas Engineering
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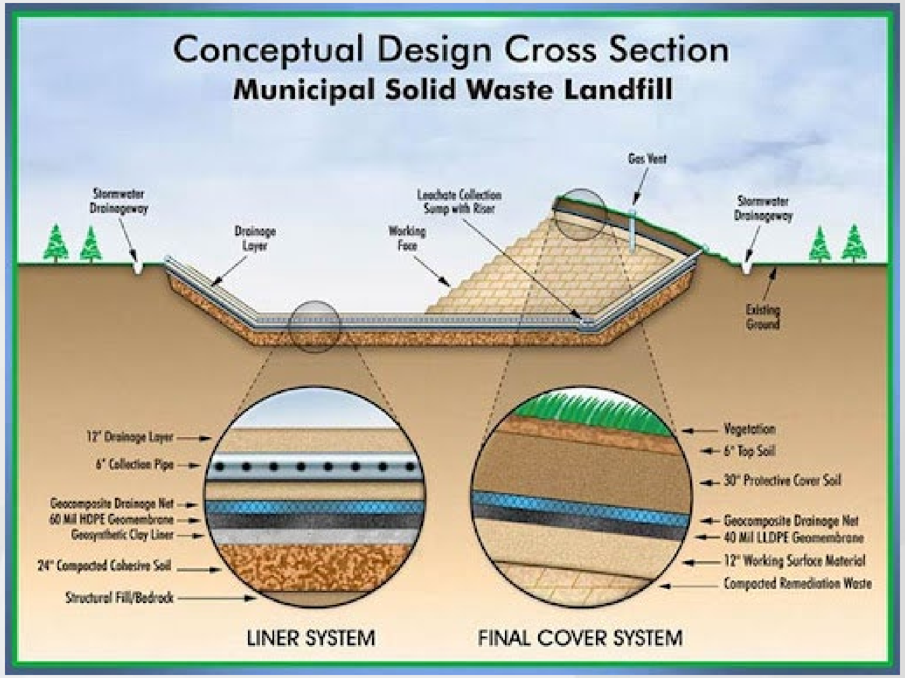
Prevention of rain infiltration or leakage into/from new or existing landfills (liner and cap)

- ASTM Standards for geomembranes (PE plastic thickness, durability, seams)
- ASTM Standards for natural clay or geosynthetic clay compaction and permeability



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Preventing exposure of flammable vapors to sources of electrical sparks

- IEEE standard ISEE-SA 841-2021
- Standard for electric motors (pumps, fans, compressors, etc) that are TEFC (totally enclosed fan-cooled) or TENV (totally enclosed non-ventilated)
- This construction prevents any possible contact between flammable vapor and the sparks occurring inside of the electric motor housing

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Proper adsorbent materials for water treatment (activated carbon)

- AWWA and ASTM standards for GAC / PAC

Granular activated carbon (GAC)

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Proper adsorbent materials for water treatment (activated carbon)--standards

- AWWA B604-21
- Numerous ASTM Standards---D6586, D4607, D6781, etc for GAC characteristics

Activated carbon filter vessels

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Application of Engineering Standards in Environmental Engineering Design

Matthew Alexander

Dept. of Chemical & Natural Gas Engineering
Texas A&M University-Kingsville, Texas

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Spring 2024 Webinar Series on Standards, their importance, and applications

Dongchun Mary Qiao, Ph. D.
ABS Corporate Technology
Principal Engineer, Materials, Welding and NDT
Date: April 24, 2024, Time: 12:00 PM (Noon)
Place: EC 109 and Online (Zoom link)
https://tamuk-edu.zoom.us/j/97288678924?pwd=UE1PNDhpT3NKWlVHMHhRWFNORmE2dz09

Meeting ID: 972 8867 8924
Passcode: 053246

Title: Standards for Design, Material and Testing for Marine and Offshore Applications

Abstract: As a class society, ABS addresses the life cycle of a ship or offshore structure from design to decommissioning. This talk will discuss standards for marine and offshore application, the importance of standards for safety of life, asset and environment, and applications of standards for design, material and testing for well-maintained structural integrity.

The Speaker: Dr. Mary Qiao is currently working as a principal engineer at American Bureau of Shipping (ABS). She focusses on development of requirements for materials, welding and non-destructive testing for marine and offshore applications. Prior to ABS, Mary used to work as a senior metallurgist at Schlumberger to support engineering, manufacturing and sustaining of drilling tools and drill bits. She received her PhD from department of Materials Science and Engineering of The University of Tennessee, Knoxville in 2008.

Design, Material and Testing for Marine and Offshore Applications

Dongchun, Mary, Qiao | April 24, 2024
Email: mqiao@eagle.org

Agenda

Introduction to ABS

- Mission – promote the security of life, property and preserve the natural environment
- Classification addresses the life cycle of a ship or offshore unit from design to decommissioning
- Machinery and equipment certificates may be issued by class or other organizations and even by the manufacturer of the certified product

Bulk Carrier

Containership

Oil Tanker

LNG/LPG

Jackups

Drill Ship

FPSO

Wind Farm

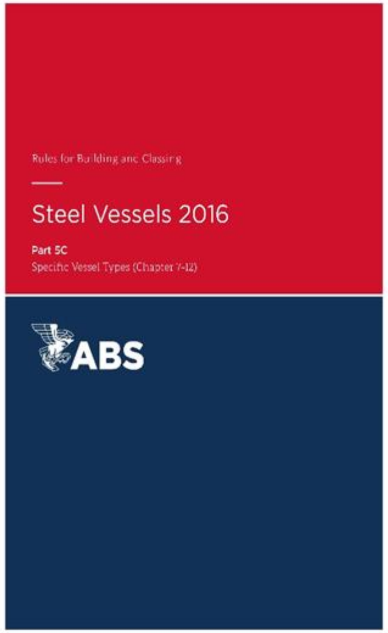
ABS Service

Establish Design Rules and Standards

Review Designs against Rules and Standards

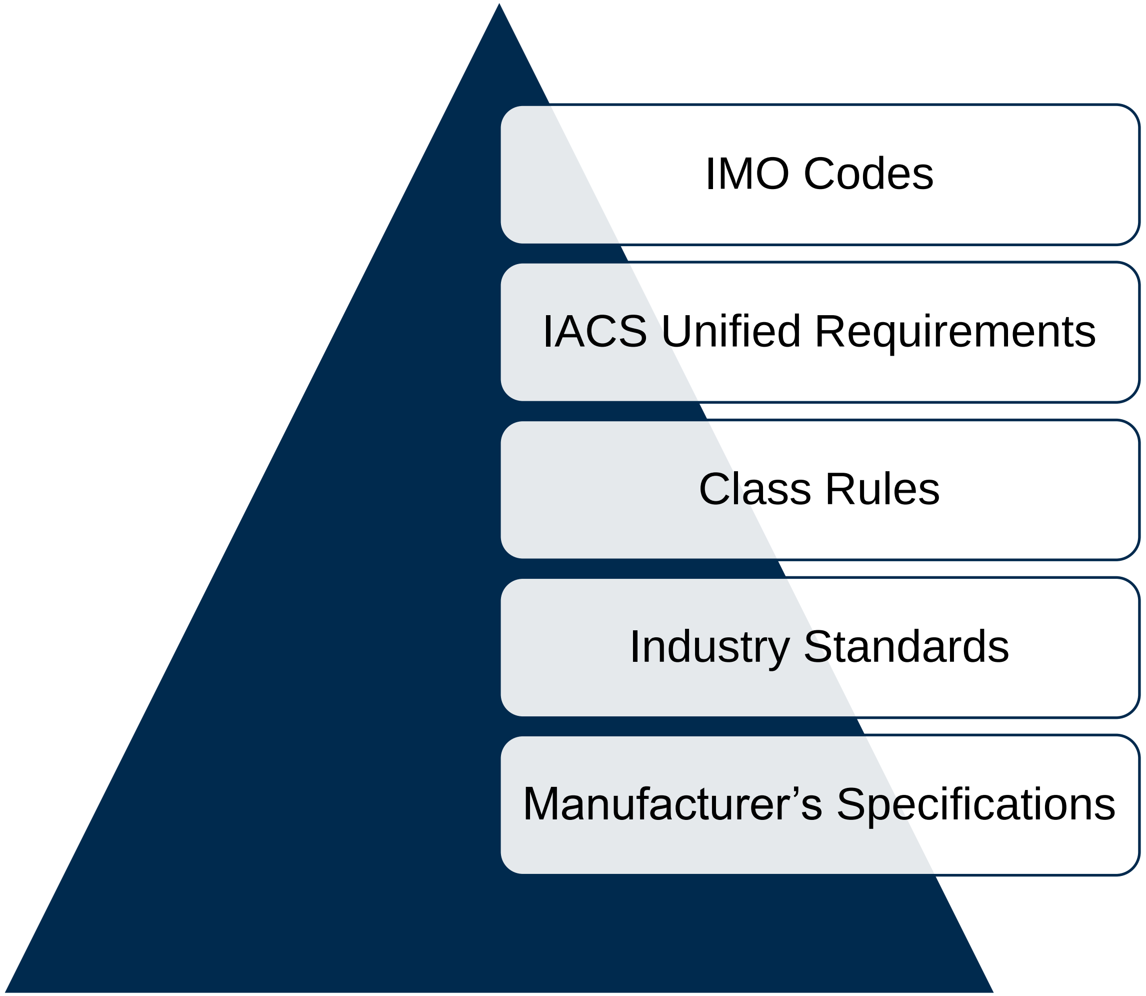
Confirm Vessel and Equipment Built in accordance with Approved Plans

Verify Vessels and Equipment Maintained to Accepted Standards



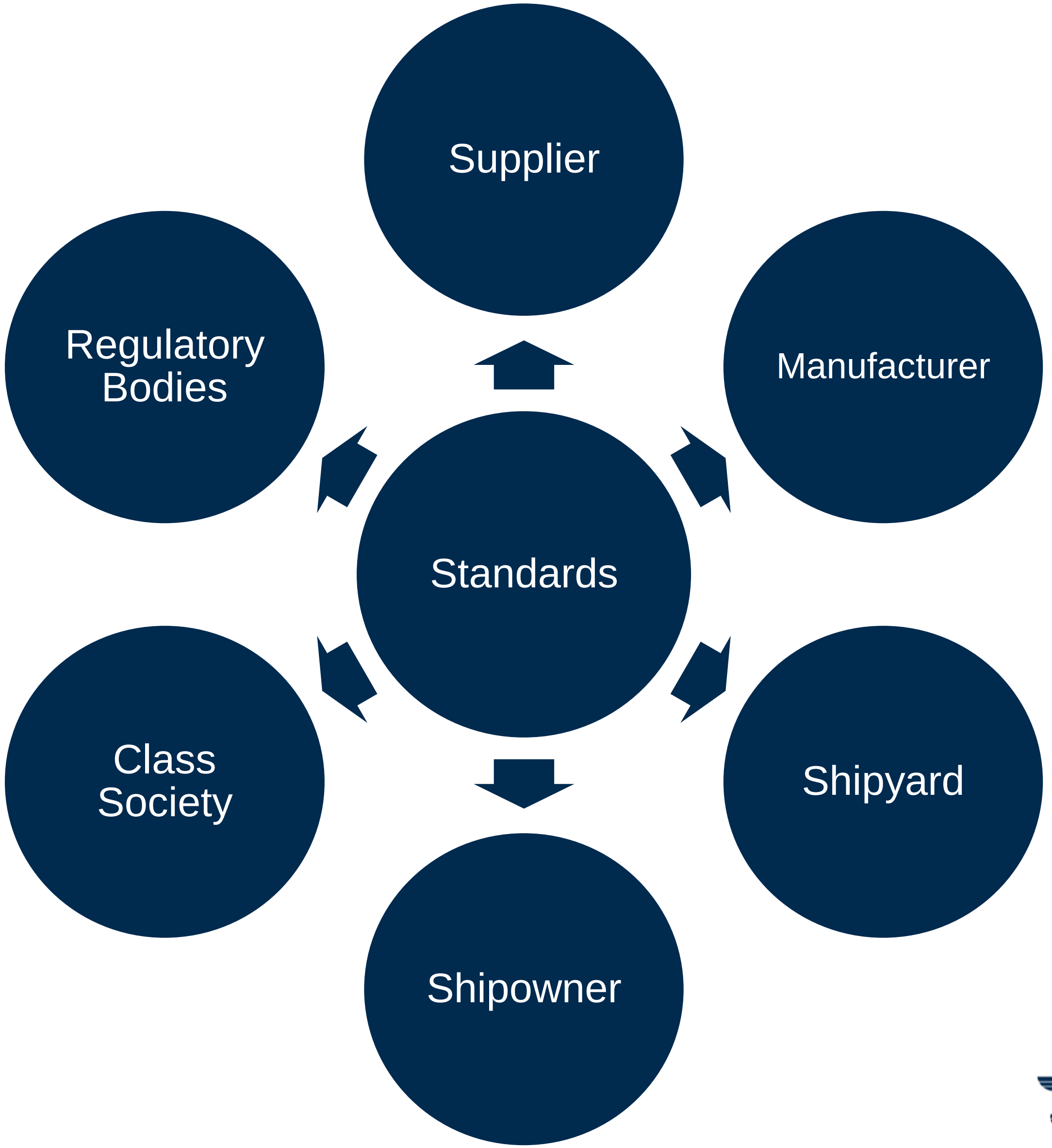
Standards for Marine and Offshore Applications

- Stakeholder in the network of maritime safety – ship design, building, ship ownership, operation and maintenance
- IMO (International Maritime Organization) Code
- IACS (International Association of Classification Societies) Unified Requirements
- ABS Class Rules
- Industry Standards, such as API, ASME, ASTM
- Specifications



Importance of Standards

- Meets specified criteria for processes, products, and services with standard test methods and reliable test results
- Provides a framework of consistency, quality, and interoperability across industries
- Fosters efficiency, reliability, and trust of suppliers, manufacturers, shipyards, shipowners, class societies, and regulatory bodies
- Drives innovation and promotes safety, environment suitability, and social responsibility

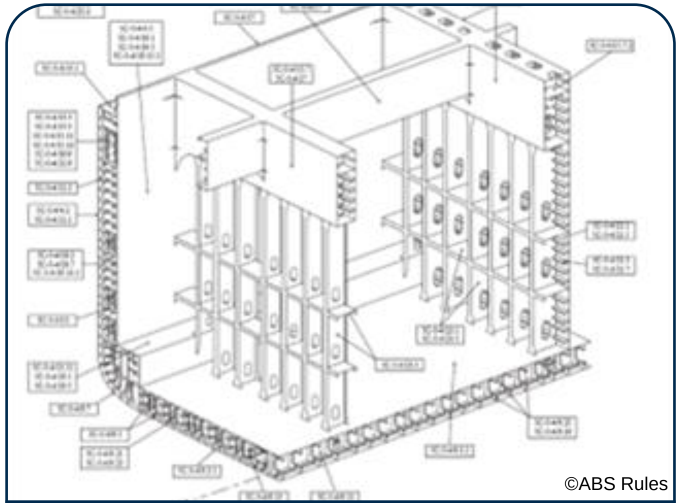


Applications of Standards for Design, Material and Testing

- Product Design Package
  - Technical Specification
    - ABS Rules or Industry Standards
    - Specifications by Owners/Designers
  - Engineering Design
    - Solid Models/Drawings
    - Engineering Calculations/Simulations
    - Approval for Alternative Design
  - Materials Specification
    - Requirements for Mechanical Properties
    - Requirements for Other Properties such as Fatigue, Corrosion etc
    - Non-destructive Testing
    - Approval for Alternative Materials
  - System/Equipment to be Installed for Functional Requirements
    - Load Tests
    - Pressure Tests
    - Balance Tests etc.

Applications of Standards for Design, Material and Testing

- Materials for Marine and Offshore Applications



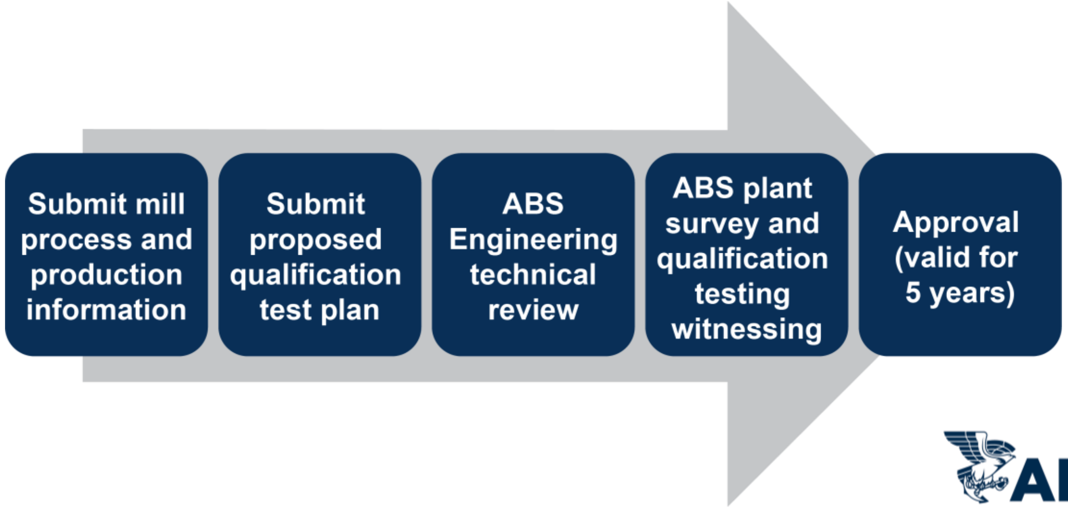
Hull Structure

Equipment

Machinery

Applications of Standards for Design, Material and Testing

- Material Manufacturer Approval
  - Steel, Aluminum, and Pipe (Structural) Mills
  - Forge
  - Foundry
  - Welding Consumables
  - Tailshaft (Repair and Cladding)
  - Ship Anchor Chain and accessories
  - Offshore Mooring Chain and accessories
  - Rolled Bar-Machinery
  - Heat Treatment Facility
  - Additive Manufacturing



Applications of Standards for Design, Material and Testing

Material Composition	Process	Properties
• Carbon Steel • Carbon-Manganese Steel • Low Alloy Steel • Nickel Steel • Stainless Steel • NiAl-bronze	• Rolling • Casting • Forging • Heat Treatment	• Ordinary Strength • Higher Strength • Extra High Strength • Low Temperature Toughness • Corrosion Resistance • Wear or Erosion Resistance

ABS

Applications of Standards for Design, Material and Testing

Maximum Allowable Stress

- Strength, ASME BPVC II D

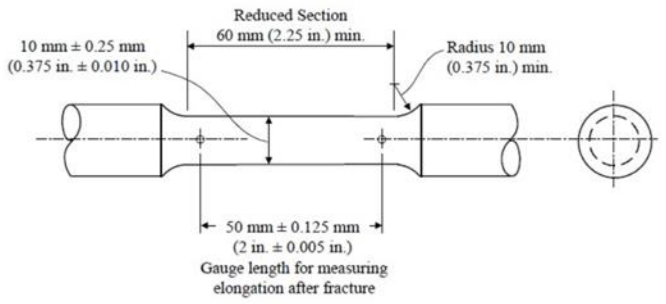
$$\sigma_{max} = \frac{\sigma}{f}$$

- σ_{max}: The maximum allowable stress
- σ: The specified material property, such as yield or tensile strength
- f: The safety factor

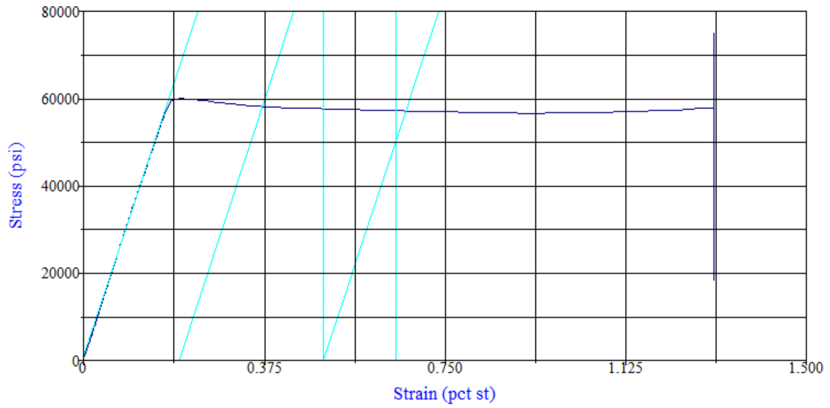
Criteria for Establishing Allowable Stress Values of Non-Bolting Materials [1]

Product or Material	Room Temperature and Below: Tensile Strength	Room Temperature and Below: Yield Strength	Above Room Temperature: Tensile Strength		Above Room Temperature: Yield Strength		Above Room Temperature: Stress Rupture		Above Room Temperature: Creep Rate
Wrought or Cast Ferrous and Nonferrous	$\frac{S_T}{3.5}$	$\frac{2}{3}S_Y$	$\frac{S_T}{3.5}$	$\frac{1.1}{3.5}S_T R_T$	$\frac{2}{3}S_Y$	$\frac{2}{3}S_Y R_Y$ or $0.9S_Y R_Y$ [2]	$F_{avg}S_{R\,avg}$ or specifically agreed	$0.8S_{R\,min.}$ or specifically agreed	$1.0S_c$ or specifically agreed

1.The maximum allowable stress shall be the lowest value obtained from the criteria in this Table.
2. For austenitic stainless steels, nickel alloys, copper alloys and cobalt alloys, S_Y/S_T is less than 0.625, the higher alternative allowable stresses can be specifically agreed up to $0.9S_Y R_Y$. These higher stresses are not recommended for the design flanges or other strain-sensitive applications.
3. Special condition for corrosive environment, abnormal temperature, stress conditions or other design considerations are not included.



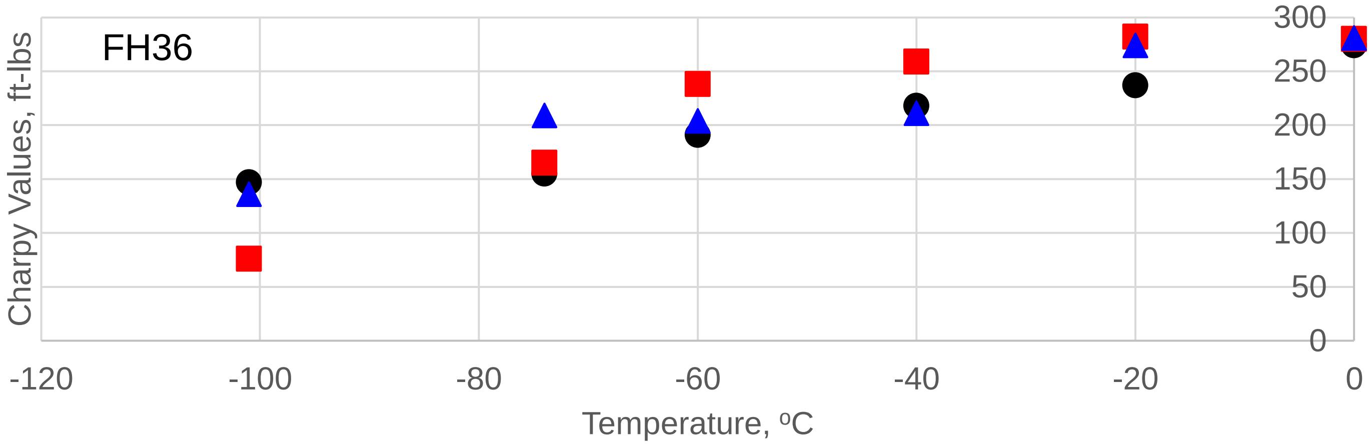
https://www.youtube.com/watch?v=D8U4G5kcpcM

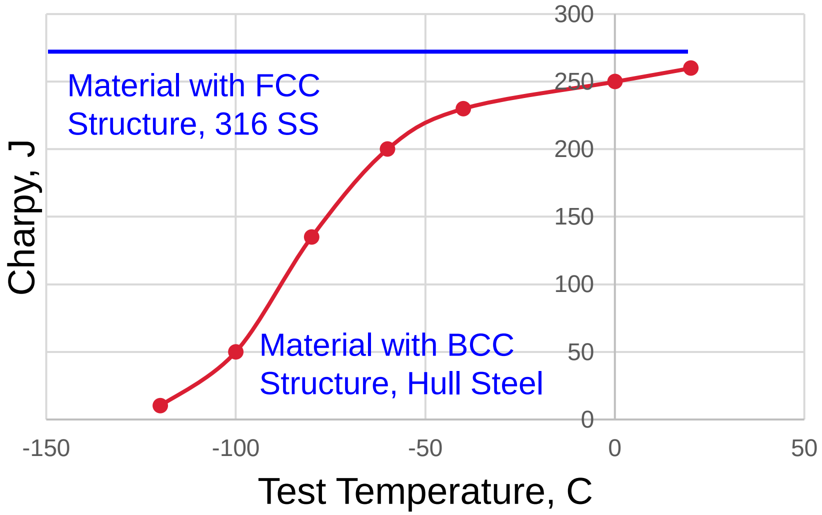


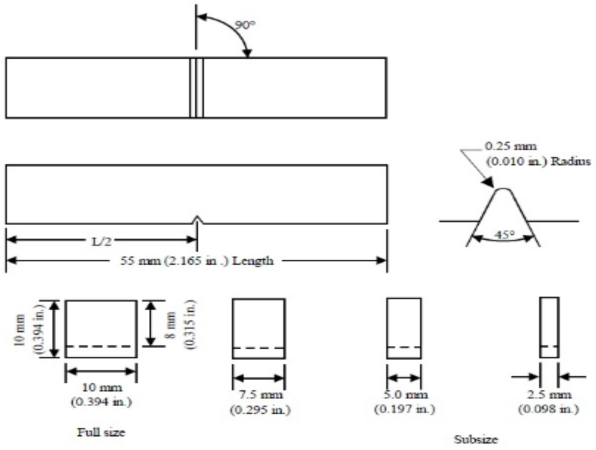
ABS

Applications of Standards for Design, Material and Testing

- Minimum Charpy Values
  - Depending on thickness
  - Determine the minimum design temperature







https://www.youtube.com/watch?v=tpGhqQvftAo

$$KV = mgH - mgh$$

Applications of Standards for Design, Material and Testing

Fatigue Design Curves

- Fatigue Curve

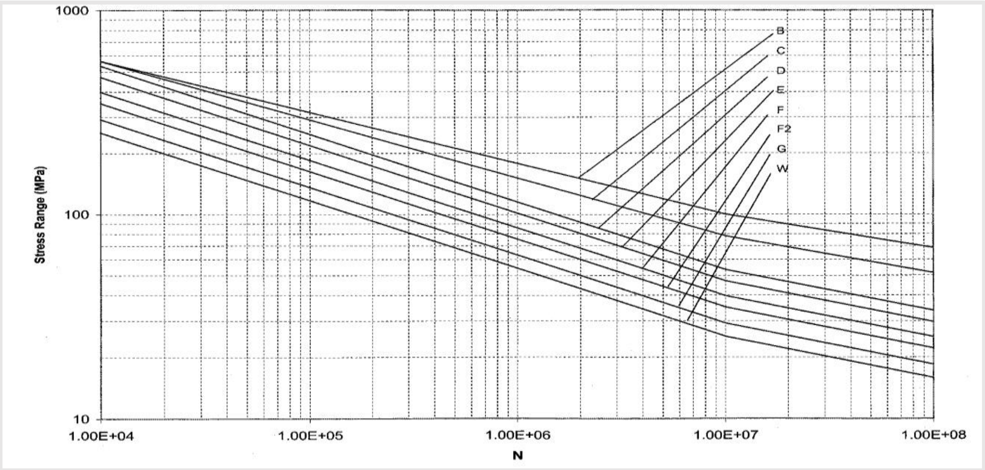
$$N = A \times S^{-m}, \text{ for N < } 10^7 \text{ Cycle}$$

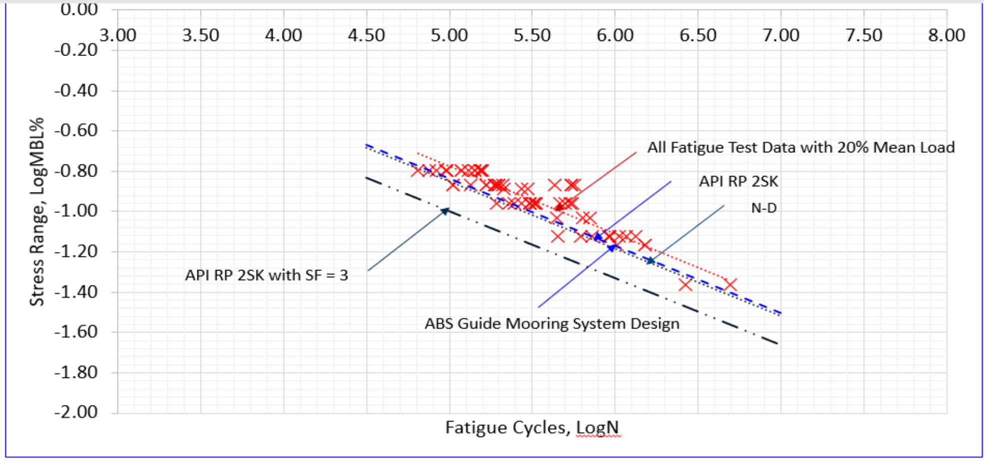
$$N = C \times S^{-r}, \text{ for N < } 10^8 \text{ Cycle}$$

- Section Thickness Effect

$$S_f = S\left(\frac{t}{t_R}\right)^{-q}$$

t_R = 22 mm, q = 0.25 for plate, t_R = 38 mm, q = 0.15 for casting





https://www.youtube.com/watch?v=XkJ_VyLEcps

ABS

Applications of Standards for Design, Material and Testing

Hardness

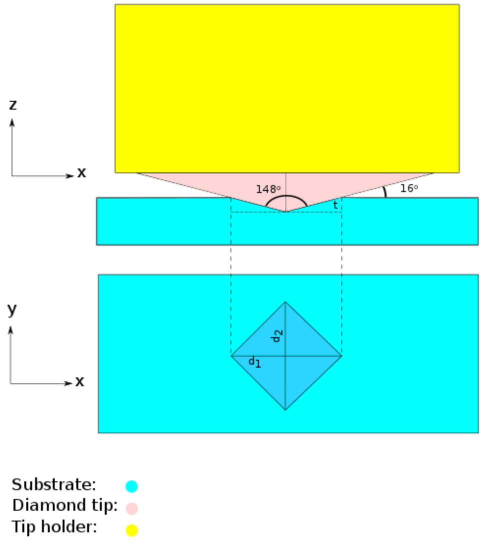
- Brinell Hardness
- Vicker's Hardness
- Rockwell Hardness A, B, C
- Knoop Hardness
- MicroHardness

A370 – 18

TABLE 2 Approximate Hardness Conversion Numbers for Nonaustenitic Steels[A] (Rockwell C to Other Hardness Numbers)

Rockwell C Scale, 150-kgf Load, Diamond Penetrator	Vickers Hardness Number	Brinell Hardness 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness: 15N Scale, 15-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness: 30N Scale 30-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness: 45N Scale, 45-kgf Load, Diamond Penetrator	Approximate Tensile Strength, ksi (MPa)
68	940	. . .	920	85.6	93.2	84.4	75.4	. . .
67	900	. . .	895	85.0	92.9	83.6	74.2	. . .
66	865	. . .	870	84.5	92.5	82.8	73.3	. . .
65	832	739	846	83.9	92.2	81.9	72.0	. . .
64	800	722	822	83.4	91.8	81.1	71.0	. . .
63	772	706	799	82.8	91.4	80.1	69.9	. . .
62	746	688	776	82.3	91.1	79.3	68.8	. . .
61	720	670	754	81.8	90.7	78.4	67.7	. . .
60	697	654	732	81.2	90.2	77.5	66.6	. . .
59	674	634	710	80.7	89.8	76.6	65.5	351 (2420)
58	653	615	690	80.1	89.3	75.7	64.3	338 (2330)
57	633	595	670	79.6	88.9	74.8	63.2	325 (2240)
56	613	577	650	79.0	88.3	73.9	62.0	313 (2160)
55	595	560	630	78.5	87.9	73.0	60.9	301 (2070)
54	577	543	612	78.0	87.4	72.0	59.8	292 (2010)
53	560	525	594	77.4	86.9	71.2	58.6	283 (1950)
52	544	512	576	76.8	86.4	70.2	57.4	273 (1880)
51	528	496	558	76.3	85.9	69.4	56.1	264 (1820)
50	513	482	542	75.9	85.5	68.5	55.0	255 (1760)
49	498	468	526	75.2	85.0	67.6	53.8	246 (1700)
48	484	455	510	74.7	84.5	66.7	52.5	238 (1640)
47	471	442	495	74.1	83.9	65.8	51.4	229 (1580)
46	458	432	480	73.6	83.5	64.8	50.3	221 (1520)
45	446	421	466	73.1	83.0	64.0	49.0	215 (1480)
44	434	409	452	72.5	82.5	63.1	47.8	208 (1430)
43	423	400	438	72.0	82.0	62.2	46.7	201 (1390)
42	412	390	426	71.5	81.5	61.3	45.5	194 (1340)
41	402	381	414	70.9	80.9	60.4	44.3	188 (1300)
40	392	371	402	70.4	80.4	59.5	43.1	182 (1250)
39	382	362	391	69.9	79.9	58.6	41.9	177 (1220)
38	372	353	380	69.4	79.4	57.7	40.8	171 (1180)
37	363	344	370	68.9	78.8	56.8	39.6	166 (1140)
36	354	336	360	68.4	78.3	55.9	38.4	161 (1110)
35	345	327	351	67.9	77.7	55.0	37.2	156 (1080)
34	336	319	342	67.4	77.2	54.2	36.1	152 (1050)
33	327	311	334	66.8	76.6	53.3	34.9	149 (1030)
32	318	301	326	66.3	76.1	52.1	33.7	146 (1010)
31	310	294	318	65.8	75.6	51.3	32.5	141 (970)
30	302	286	311	65.3	75.0	50.4	31.3	138 (950)
29	294	279	304	64.6	74.5	49.5	30.1	135 (930)
28	286	271	297	64.3	73.9	48.6	28.9	131 (900)
27	279	264	290	63.8	73.3	47.7	27.8	128 (880)
26	272	258	284	63.3	72.8	46.8	26.7	125 (860)
25	266	253	278	62.8	72.2	45.9	25.5	123 (850)
24	260	247	272	62.4	71.6	45.0	24.3	119 (820)
23	254	243	266	62.0	71.0	44.0	23.1	117 (810)
22	248	237	261	61.5	70.5	43.2	22.0	115 (790)
21	243	231	256	61.0	69.9	42.3	20.7	112 (770)
20	238	226	251	60.5	69.4	41.5	19.6	110 (760)

https://commons.wikimedia.org/wiki/File:Vickers_Hardness_Indent.svg



$$HV \approx 0.1891 \frac{F}{d^2}$$

ABS

Applications of Standards for Design, Material and Testing

Design for Fracture

- Stress Intensity Factor

$$K = \sigma\sqrt{\pi a} < K_{IC}$$

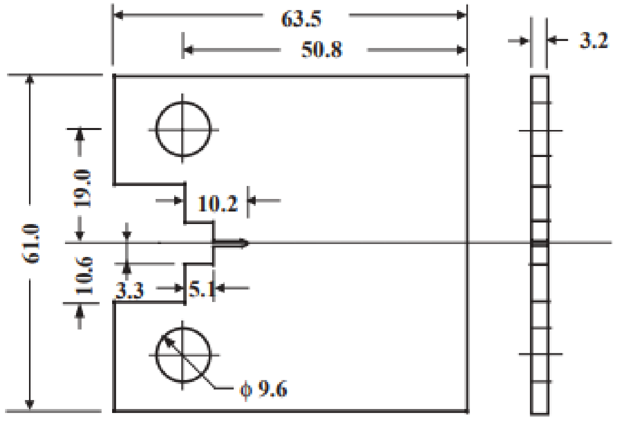
- Allowable Flaw Size

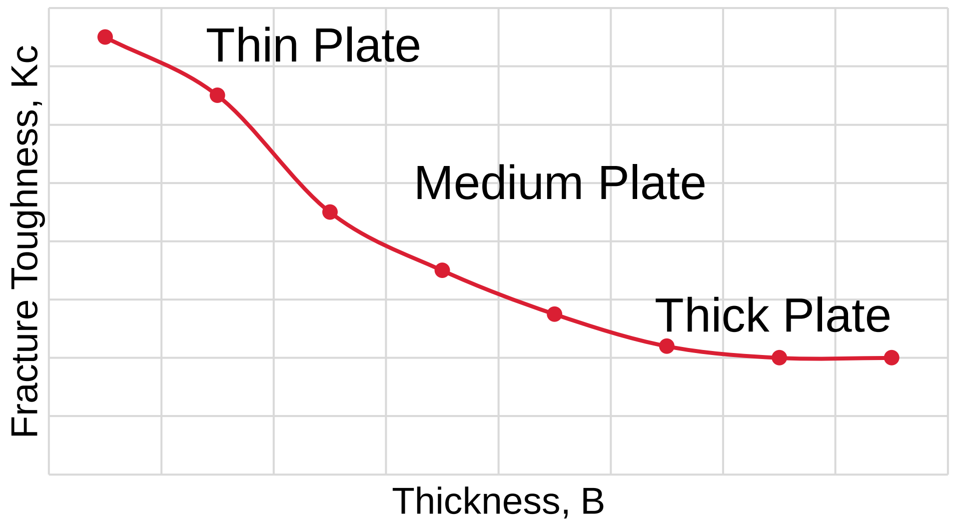
$$a \leq \frac{1}{\pi}\left(\frac{K_{IC}}{\sigma_{max}}\right)^2$$

- Section Thickness Effects

$$\frac{a_{max}}{B} \approx 0.71, \text{ for thin section,}$$

$$\frac{a_{max}}{B} \approx 0.28, \text{ for thick section}$$





Applications of Standards for Design, Material and Testing

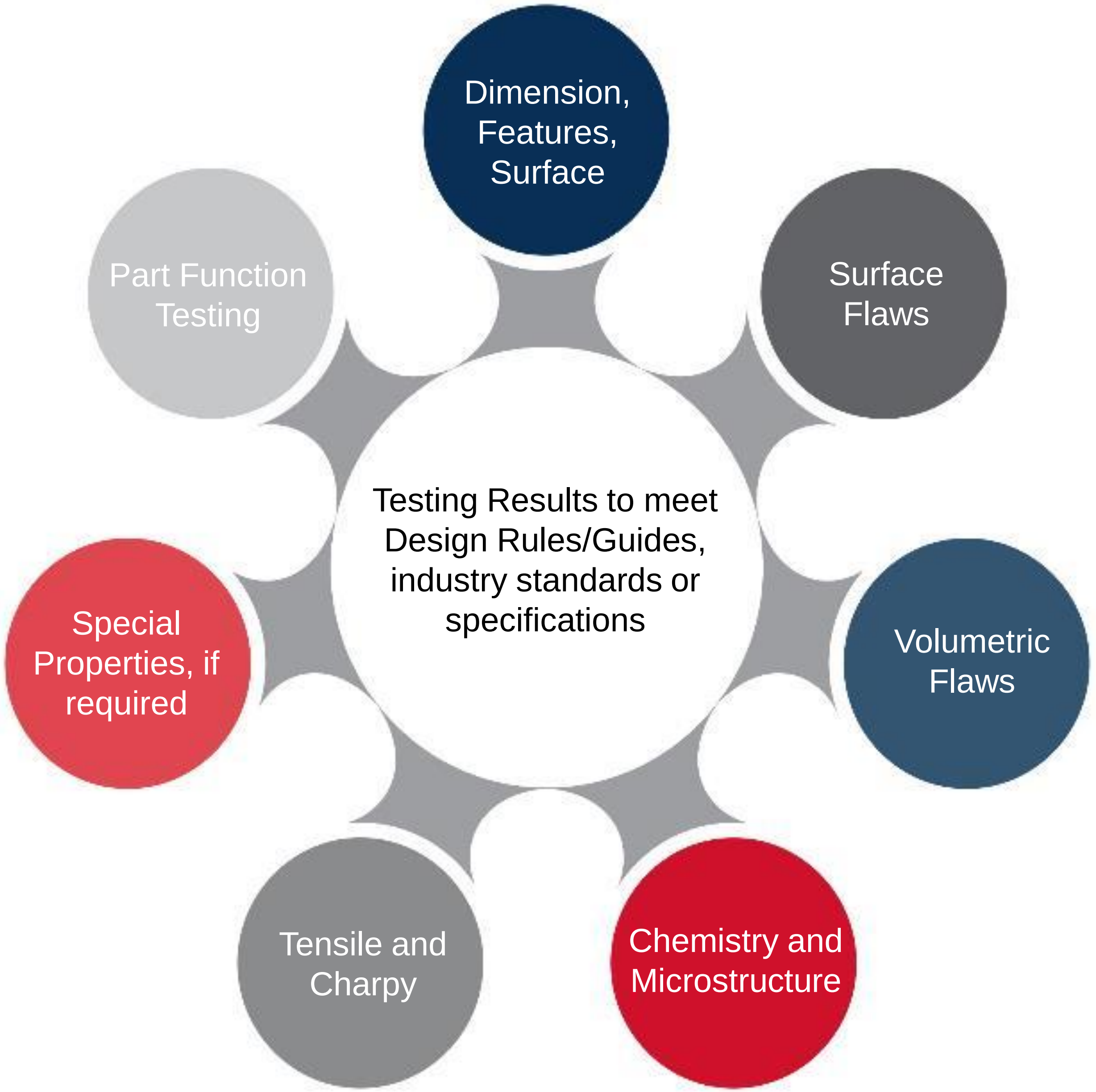
Allowable Flaw Size per Industry Standards

- Surface and Internal Flaws
- ISO 5817, Level B, C, D
- ISO 10675-1, Level 1, 2, 3
- IACS UR W33, W34, Rec. 68 and Rec. 69
- ASTM standards for non-destructive testing procedures

- NDT for Surface Defects
  - Visual Testing
  - Magnetic Particle Testing
  - Liquid Penetrant Testing
- NDT for Internal Defects
  - X-Ray
  - Ultrasonic Testing
  - CT (Computed Tomography)
  - TOFD (Time-of-flight Diffraction Ultrasonics)
  - PAUT (Phased Array Ultrasonic Testing)
- Other NDT Techniques
  - Eddy Current
  - Acoustic Emission
  - Etc.

Inspection and Testing Standards

- ABS Rules for Materials and Welding and the applicable sections enclosed in other ABS Rules for application
- ASTM A751 for Chemical Analysis
- ASTM E407 for Micro etching Metals and Alloys
- ASTM A370 for Mechanical Testing
- ASTM E8 for Tensile Testing
- ASTM E23 for Notched Bar Impact Testing
- ASTM E466 for Metallic Materials Fatigue Testing
- ASTM E1820 for Measurement of Fracture Toughness
- ASTM E10 for Brinell Hardness of Metallic Materials
- ABS Guide for Non-Destructive Inspection or ISO 5817, ISO 10675-1
- Other recognized standards, such as ISO, ASTM, API, ASME



Other Sectors

ASME

LIST OF SECTIONS

SECTIONS

I Rules for Construction of Power Boilers

II Materials
- Part A — Ferrous Material Specifications
- Part B — Nonferrous Material Specifications
- Part C — Specifications for Welding Rods, Electrodes, and Filler Metals
- Part D — Properties (Customary)
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III Rules for Construction of Nuclear Facility Components
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X Fiber-Reinforced Plastic Pressure Vessels

XI Rules for Inservice Inspection of Nuclear Power Plant Components

XII Rules for Construction and Continued Service of Transport Tanks

API

Specification for Rotary Drill Stem Elements

ANSI/API SPECIFICATION 7-1
FIRST EDITION, MARCH 2006

API MONOGRAM PROGRAM EFFECTIVE DATE:
SEPTEMBER 2006

ADDENDUM 1, MARCH 2007
ADDENDUM 2, AUGUST 2009
(API MONOGRAM PROGRAM EFFECTIVE DATE: FEBRUARY 1, 2010)
ADDENDUM 3, APRIL 2011
(API MONOGRAM PROGRAM EFFECTIVE DATE: OCTOBER 1, 2011)
ADDENDUM 4, FEBRUARY 2019
(API MONOGRAM PROGRAM EFFECTIVE DATE: AUGUST 1, 2019)

ERRATA 1, JULY 2020

REAFFIRMED, JANUARY 2021

ISO 10424-1:2004 (Modified), Petroleum and natural gas industries—Rotary drilling equipment—Part 1: Rotary drill stem elements

API American Petroleum Institute

ANSI ISO

SAE

SAE INTERNATIONAL

AEROSPACE MATERIAL SPECIFICATION	AMS2774™	REV. G
	Issued 1995-07 Reaffirmed 2001-11 Revised 2020-12 Superseding AMS2774F	

Heat Treatment
Nickel Alloy and Cobalt Alloy Parts

RATIONALE

AMS2774G corrects an error in Table 3.

1. SCOPE

1.1 Purpose

This specification specifies the engineering requirements for heat treatment, by part fabricators (users) or subcontractors, of parts made of wrought or additively manufactured nickel or cobalt alloys, of raw materials during fabrication, and of fabricated assemblies in which wrought nickel or cobalt alloys are the primary structural components.

1.2 Application

1.2.1 Alloys

Detailed heat treating instructions are specified for the age-hardenable (precipitation-hardenable) and non-age-hardenable alloys listed in 8.2. However, this specification also may be used for alloys other than those listed in 8.2, provided that temperatures, soaking times, and cooling requirements are specified by the cognizant engineering organization.

1.2.2 Heat Treatments

Heat treatments covered by this specification are as follows:

Solution Treating (see 8.4.7)
Annealing (see 8.4.8)
Stabilization Annealing (see 8.4.10)
Interstage Annealing (see 8.4.13)
Stabilization (see 8.4.11)
Precipitation (see 8.4.12)
Equalization (see 8.4.14)
Stress Relief (see 8.4.9)

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For more information on this standard, visit https://www.sae.org/standards/content/AMS2774G/

ASTM

ASTM E8/E8M-24 ⓘ

Standard Test Methods for Tension Testing of Metallic Materials

Significance and Use

4.1 Tension tests provide information on the strength and ductility of materials under uniaxial tensile stresses. This information may be useful in comparisons of materials, alloy development, quality control, and design under certain circumstances.

4.2 The results of tension tests of specimens machined to standardized dimensions from selected portions of a part or material may not totally represent the strength and ductility properties of the entire end product or its in-service behavior in different environments.

4.3 These test methods are considered satisfactory for acceptance testing of commercial shipments. The test methods have been used extensively in the trade for this purpose.

Scope

1.1 These test methods cover the tension testing of metallic materials in any form at room temperature, specifically, the methods of determination of yield strength, yield point elongation, tensile strength, elongation, and reduction of area.

1.2 The gauge lengths for most round specimens are required to be 4D for E8 and 5D for E8M. The gauge length is the most significant difference between E8 and E8M test specimens. Test specimens made from powder metallurgy (P/M) materials are exempt from this requirement by industry-wide agreement to keep the pressing of the material to a specific projected area and density.

1.3 Exceptions to the provisions of these test methods may need to be made in individual specifications or test methods for a particular material. For examples, see Test Methods and Definitions A370 and Test Methods B557, and B557M.

1.4 Room temperature shall be considered to be 10 °C to 38 °C [50 °F to 100°F] unless otherwise specified.

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Contact Us

Visit Us Online
www.eagle.org

Send Us an Email
WorldHQ@eagle.org

Telephone
1-281-877-6000

World Headquarters
1701 City Plaza Drive
Spring, TX 77389 USA

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