Standards, specifications, regulatory requirements, classification societies

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December 14, 2025

1. Introduction

The design, construction, and operation of complicated, and possibly complex, systems such as ships are facilitated through the use of technical documentation produced by technical experts and implemented through law or contractual language. These technical documents include:

- Shipbuilding specifications
- Project peculiar documents (PPD)
- International treaties
- Regulations
- Classification society rules
- Specifications
- Standards
- Manuals
- Handbooks, recommended practices, and guides

These documents are created and maintained by various organizations to include the customer, design agents, international organizations, governments, classification societies, and professional societies.

Shipboard power system designers should understand the opportunities and constraints offered by these various technical documents. In particular, the early-stage and preliminary/contract designers should focus on how to translate knowledge gained in the design process into unambiguous language in the shipbuilding specification and PPDs. Similarly, the shipyard engineers need to understand the implication of each of the applicable technical documents on the details of the electrical power system design.

These technical documents encapsulate a wealth of practical knowledge of shipboard power systems. Marine electrical engineers and students should study these documents to gain an understanding of the particularities of shipboard power systems.

2. Types of requirements / technical documents

2.1. Shipbuilding specification

For a ship being acquired, the shipbuilding specification is part of a legal contract between the customer and a shipyard that details the required properties of the ship and its systems. The shipbuilding specification is the culmination of all the design work starting with the earliest concept studies through the completion of contract design (or baseline design as described in IEEE Std 45.3). The shipbuilding specification governs the work performed by the shipyard during detail design (or product design as described in IEEE Std 45.3) and construction.

The shipbuilding specification usually invokes a number of project peculiar documents, international treaties, regulations, classification society rules, specifications, and standards. By being invoked in the shipbuilding specification, these technical documents become legally binding. Handbooks, recommended practices, and guides are usually not intended to become legally binding; they are intended instead to educate the designer, integrator, or constructor. While not ideal or recommended, one may find handbooks, recommended practices, and guides invoked in a shipbuilding contract.

Generally, only one or a few ships are procured using the same shipbuilding specification. Because of the time required to design and construct a ship after the first contract award and before the next ship contract award, changes to the ship specification will be required to reflect changing requirements, equipment obsolescence, updated specifications, standards, and regulations, and lessons learned.

2.2. Project Peculiar Documents

For new systems, equipment or technologies, standards or specifications may not yet exist. In these cases, Project Peculiar Documents (PPDs) may be used in place of standards and specifications when creating the shipbuilding specification. PPDs are intended to be used for only one or a few shipbuilding specifications; they should be converted to traditional standards or specifications once the PPDs' contents are stable and have been proven through the first several procurements.

Reliance on using PPDs for extended periods of time across many contracts is not recommended. While industry may develop and maintain product lines to fulfill traditional specifications, the uncertainty associated with the market size and stability of the PPDs generally results in industry bidding custom solutions. Unlike traditional specifications, PPDs are not often reused across multiple classes of ships. Over the long term, the over-reliance on PPDs can result in very unique and expensive equipment.

2.3. International Treaties

The International Maritime Organization (IMO) is an agency of the United Nations (UN) responsible for the safety and security of ships as well as the prevention of pollution by ships. Currently, there are 176 countries that are member states of the IMO. For ship design, two categories of IMO regulations are important: The International Convention for the Prevention of Pollution from Ships (MARPOL); and the International Convention for the Safety of Life at Sea (SOLAS).

Each member country is tasked with enforcing the provisions of MARPOL and SOLAS. Both MARPOL and SOLAS require ships to be periodically inspected and surveyed by the flag administration (by an organization within the country in which the ship is registered / flagged). The flag administration often delegates some or all inspections and surveys to approved classification societies. Examples of classification societies include the American Bureau of Shipping (ABS) and DNV. In the United States, the flag administration duties for commercial ships are fulfilled by the Maritime Administration (MARAD) and the U.S. Coast Guard (USCG). Flag administration duties for U.S. naval ships are fulfilled by the U.S. Navy.

2.4. Regulations

Most countries have laws that govern the design, construction, and operation of ships. In the United States, commercial ships are required to adhere to the Code of Federal Regulations (CFR). In particular, the design, construction, and operation of commercial ships are regulated by 46 CFR.

For naval vessels, 10 USC § 8669b requires the designation of a senior technical authority for each vessel class. The senior technical authority is "responsible for, and has the authority to, establish, monitor and approve technical standards, tools, and processes" for their assigned class.

2.5. Classification Society Rules

Classification societies, such as ABS, publish rules that govern design and construction of ships, surveys, maintenance, specialized equipment. The ABS MVR is one example of class rules. These rules are intended to ensure the vessels are safe, are in compliance with regulations and international treaties, and are insurable. Periodic inspections and surveys by the classification society while the ship is operational ensure the vessel continues to adhere to the rules; successfully passing the inspections and surveys is indicated by the ship maintaining "class." Keeping a vessel in class is generally a requirement for obtaining marine insurance.

Having a ship in class does not mean that the ship will fulfill its mission requirements or be profitable. Class rules focus on safety and regulatory compliance, fitness for a mission or vessel profitability are generally not of concern to the classification society.

The design, construction, and operation of naval ships may or may not involve a classification society. Flag administration may elect to employ a classification society for some or all aspects of a naval ship.

To promote commonality across multiple classification societies, the International Association of Classification Societies (IACS) publishes technical rules that are intended to be standard across the various classification societies.

2.6. Specifications

Specifications describe a product or service that is to be procured. Specifications are generally classified as being detail specifications or performance specifications. MIL-STD-961 defines a detail specification to be:

> "A specification that specifies design requirements, such as materials to be used, how a requirement is to be achieved, or how an item is to be fabricated or constructed. A specification that contains both performance and detail requirements is still considered a detail specification."

MIL-STD-961 defines a performance specification to be:

> "A specification that states requirements in terms of the required results with criteria for verifying compliance, but without stating the methods for achieving the required results. A performance specification defines the functional requirements for the item, the environment in which it must operate, and interface and interchangeability characteristics."

A detail specification assumes the design and methods prescribed will achieve the desired requirements. Testing concentrates on conformance; does the end product or process match the specified design within tolerances?

A performance specification provides industry with more flexibility in how the requirements are met. Testing addresses both whether the design will achieve the desired requirements, and whether the end product or process conforms to the design.

The testing associated with a detail specification may be less costly than the testing associated with a performance specification. The additional design flexibility of the performance specification may result in lower costs, even when the more costly testing

is included. In general, a business case analysis is necessary to determine whether a detail specification or a performance specification is more cost effective.

Many times, a specification will include options that the buyer can incorporate in the contract. These options are often indicated through a part identification number (pin) that is uniquely constructed to reflect all of the options. These options are usually specified explicitly in the contract as well.

The specification may also include requirements for technical manuals, packaging, verification (including testing) and incorporating other specifications and standards. The incorporation of other specifications and standards which in turn invoke other specifications and standards may result in an exponentially growing list of applicable specifications and standards.

Some contracts limit the number of tiers of specification references starting with the shipbuilding specification (or specifications and standards referenced in the shipbuilding specification); below the designated tier, all specifications and standards are to be treated as guidance only. This limitation often forces the shipbuilding specification writers to incorporate otherwise important lower tier specifications and standards directly into the shipbuilding specification.

2.7. Standards

Standards are common to multiple specifications. Mil-Std-962 defines the following types of standards (paraphrased):

- **Interface standards**: Interface standards specify the physical, functional, or operational environment interface characteristics of systems, subsystems, equipment, assemblies, components, items, or parts to permit interchangeability, interconnection, interoperability, compatibility, or communications.
- **Design criteria standards**: Design criteria standards specify design or functional criteria that must be adhered to in the development of systems, subsystems, equipment, assemblies, components, items, or parts, but do not relate to interface requirement.
- **Manufacturing process standards**: Manufacturing process standards specify the desired outcome of a manufacturing process or specific procedures or criteria on how to perform a manufacturing process.
- **Standard practices**. Standard practices specify procedures on how to conduct non-manufacturing functions that, at least some of the time, are obtained via contract from private sector firms.

- **Test method standards**. Test method standards specify the procedures or criteria for measuring, identifying, or evaluating qualities, characteristics, performance, and properties of a product or process.

Standards have mandatory requirements that are usually invoked via specifications. In general, one cannot procure a product or service based solely on a standard, a specification and/or statement of work is also required.

2.8. Manuals

Manuals take on many forms. Examples include technical manuals, operations/procedure manuals, training manuals, user manuals, maintenance and service manuals. Manuals are generally produced for training purposes, but some may include requirements that specify how to design, procure, test, or operate equipment and systems. Even manuals that do not include requirements may be useful in developing common definitions, architectures, and procedures.

Usually, the manual itself, or a cover letter, will indicate if the manual includes mandatory requirements. Often, but not always, it is inappropriate to invoke a manual as a requirement within a specification. Many times, extracting language from the manual and inserting it into the specification is more appropriate.

2.9. Handbooks, recommended practices, and guides

Handbooks, recommended practices and guides are not intended to include requirements; they are intended to educate the user. Recommended practices do include a preferred method of accomplishing a task. Guides may present multiple methods for accomplishing a task, but not indicate which one is preferable. A handbook may provide examples and data as well as preferred methods and lessons learned. A handbook may include recommendations on how to implement other standards and specifications.

In general, handbooks, recommended practices, and guides should not be invoked in their entirety by a specification. Where desirable, extracting language from one of these documents and inserting it into the specification is more appropriate. Handbooks, recommended practices, and guides may be referenced in statements of work.

3. Identifying applicable technical documents

3.1. While developing shipbuilding specification

The shipbuilding specification should be complete by the end of contract design / baseline design. It is never too early to start the shipbuilding specification. In

developing the first drafts of the shipbuilding specification, one practice that if performed, should be performed carefully is copying the shipbuilding specification from the previous ship. The previous ship likely had somewhat different requirements and constraints; the shipbuilding specification may not fully address the issues with the current acquisition. Furthermore, specifications and standards in the previous ship may be cancelled or superseded; the replacement specification or standard may not be a one-for-one replacement. The design may have to be altered, or the specification / standard tailored.

The use of requirements tracing software to ensure all specification language can be traced to a requirement is useful. Some requirements however, may not be in the programs acquisition requirements documents, but may be in regulations or international treaty language. It is important that changes to these regulations and international treaties are understood and reflected in the ship design and shipbuilding specification.

Several higher level documents exist that can assist the shipbuilding specification writer in identifying applicable specifications and standards. For commercial ships, one should start with the classification society rules (such as ABS MVR), IEEE Std 45.1, and IEEE Std 45.3. Each of these documents references other specifications and standards that should be reviewed for applicability. For naval ships, the Naval Combatant Design Specification (NCDS) provides example specification language to incorporate into the shipbuilding specification. NAVSEA T9300-AF-PRO-020 Electrical Systems Design Criteria and Practices (Surface Ships) for Preliminary and Contract Design provided guidance for electrical system design and recommends specific specifications and standards to incorporate into the shipbuilding specification. Doerry and Moniri (2013), although somewhat dated, provides a long list of potentially applicable specifications and standards.

In developing the shipbuilding specification for later ships in a class of ships, the specification effectivity date becomes an issue. The specification effectivity date is the date established in the contract which determines which version of a specification or standard to use. Unless otherwise specified in the contract, the shipbuilder is to use the version of a specification or standard in effect on the specification effectivity date. Because the ship design and ship drawings are based on the specification effectivity date in the lead ship contract, changing the specification effectivity date in follow-on contracts adds cost; every specification that has changed between the two specification effectivity dates must be examined and the impact on the design must be evaluated. To avoid this extra engineering work, the customer will often keep the specification effectivity date fixed across multiple contracts. Since the specifications and standards are updated to reflect improvements or new technologies, not using the latest

specification or standard possibly forgoes the benefits of these improvements. Furthermore, as time progresses, it may not be possible to procure components to a very old version of a specification; a contract modification may be required to employ a newer version.

3.2. While implementing shipbuilding specifications

For the shipyard engineer, the contract, including the shipbuilding specification, should be used to identify the required standards and specifications. Additionally, the shipyard engineer should be aware of technical requirements in applicable international treaties and regulations to ensure they are covered in the shipbuilding specifications; the customer should be notified if these technical requirements are not covered.

The shipyard engineer should also be familiar with applicable manuals, handbooks, recommended practices, and guides. While these documents are usually not contractual, they include a considerable amount of useful information that may enable the engineer to effectively and efficiently complete the design work. For commercial ships IEEE Std 45.1, and IEEE Std 45.3 should be consulted. For US naval ships, NAVSEA T9300-AF-PRO-020 should be consulted.

4. Sources of standards and specifications

Standards, specifications, and other technical documents are produced and made available by many organizations. Table I lists shipboard power system relevant standards setting organizations and their websites. Many of the technical documents require purchasing; others are available at no cost. Other than technical documents created by the U.S. government, virtually all technical documents are protected by copyright; one should abide by the licensing agreement in effect when one procured the documents.

Table I: Websites of standards organizations

Organization	Website
ABS	https://ww2.eagle.org/en.html
ANSI	https://www.ansi.org/
API	https://www.api.org/products-and-services/standards/
ASME	https://www.asme.org/
ASTM	https://www.astm.org/
DNV	https://www.dnv.com/
IACS	https://iacs.org.uk/
IEC	https://www.iec.ch/homepage
IEEE	https://ieeexplore.ieee.org/Xplore/home.jsp
IMO	https://www.imo.org
ISA	https://www.isa.org/
NEMA	https://www.nema.org/
NFPA	https://www.nfpa.org/
UL	https://www.ul.com/
US Department of Defense	https://quicksearch.dla.mil/qsSearch.aspx

5. Variances, deviations, and waivers.

A variance is the condition where a product does not conform to specifications. Before the product is installed onboard a ship, engineers should determine that the product is suitable for use. An original equipment manufacturer (OEM) typically requests a variance and an engineering agent for the customer approves or disapproves the variance. An approved variance does not change the specification; future products from the OEM are still expected to adhere to the specification. The approval or disapproval of a variance is typically conveyed from the customer to the OEM through written documentation. Variances are closely managed and can be the source of considerable costs.

A deviation is a variance that is requested and approved prior to the manufacture of the product. A waiver is a variance that is requested and approved after the product has been manufactured. Some organizations do not differentiate between deviations and waivers; a common process for all variances is used.

If a given variance becomes common and normal, consideration should be given to changing the specification to allow the variance condition. Once the specification has been changed in such a manner, the approved variance may be closed out.

If a system has many approved variances, in-service engineers may have difficulty understanding the configuration of the system; all of the variances must be understood in addition to the system specifications. An excessive number of variances is often cited as a contributor in failure review reports. Thus, many organizations strive to minimize variances by either replacing non-conforming parts with conforming parts, or by changing specifications to incorporate the variances.

6. References

ABS MVR, Rules for Building and Classing Marine Vessels

IEEE Std 45.1 IEEE Recommended Practice for Electrical Installations on Shipboard--Design

IEEE Std 45.3 IEEE Recommended Practice for Electrical Installations on Shipboard--Systems Engineering

MIL-HDBK-61 Department of Defense Handbook - Configuration Management Guidance.

MIL-STD-961 Department of Defense Standard Practice – Defense and program-unique specification format and content.

MIL-STD-962 Department of Defense Standard Practice – Defense standards format and content.

Doerry, Dr. Norbert, and Khosrow Moniri, "Specifications and Standards for the Electric Warship," presented at the IEEE Electric Ships Technology Symposium (ESTS) 2013, Arlington, VA, April 22-24, 2013

