Shipbuilding has historically been one of the industries that advances our knowledge of materials, welding, and inspection. From the early days when steam boilers were placed aboard vessels to power paddle wheels, or when the demands of World War II required a fleet of Liberty Ships for carrying cargo, experience has taught us that standards need to be written to avoid loss of life and property. After boiler explosions took many lives on steam-powered vessels, rules were written for the control of design, materials, and safety relief valves. Welding rules for shipboard boilers and piping also evolved. The United States Coast Guard Marine Inspectors enforced these rules until recent times, when the task was transferred to the American Bureau of Shipping Surveyors.

The U.S. Coast Guard (USCG) investigation shortly after World War II of Liberty Ship catastrophic fracture failures resulted in advancements in design, materials, and welding.

Quality control and inspection for producing the first Littoral Combat Ship, USS Freedom, began with the shipyard's craftspeople. (Photo courtesy of Lockheed Martin Corp.)

Quality control in the shipbuilding industry has evolved from inspections at the end of the process to each craftsperson understanding the contract's quality requirements.
methods. The facts, as reported in the 1946 USCG report, assigned about two-thirds of the root cause of brittle fractures experienced by 1500 of the Liberty-class ships, including T2 tankers, to design details and lack of toughness or fracture resistance in steel plate materials. One-third was attributed to welding deficiencies that propagated brittle fractures in plate at low temperatures. Today, however, the majority of the general public believes welding was responsible for all of the failures.

As inspectors, we must be diligent about checking design flaws, material certifications, and welds to ensure a safe vessel for the mariners. All three areas play a role in fabrication and must be correct to ensure safety. Remembering past failures and applying the lessons learned from them are critical to inspectors in every industry. Looking at the past design of quality systems can also help us in our present day assignments to avoid repeating costly errors. Relying on one trained inspector has drawbacks with regard to both quality and cost.

The Evolution of Quality Systems

After World War II, quality control was well defined. General practice was to put an inspector at the end of each process line to sort the good from the bad. There is little debate that that was instrumental in raising the quality of products. However, we know now that attempting to inspect quality into a product at the end of a process is a good way to fail in the modern business world.

Many leaders in the field have written books and manuals on quality. Analysis by these experts has yielded a new approach over the years. What has evolved is our present-day system of quality control and quality assurance to ensure product quality and safety. Redundant inspections and audits have proven highly effective. The shipbuilding industry has followed the same path to produce modern commercial and military vessels in a cost-effective manner. The proliferation of standards after the Second World War installed formal controls on designs, base metals, and welding. The U.S. Navy, Coast Guard, and American Bureau of Shipping led the effort at that time and many of those standards still exist today in updated rules, military standards, or codes.

Commercial shipbuilding standards were less restrictive but still gave a level of design safety to ensure that mariners had reliable hulls and equipment to weather the storms. Mother Nature invariably sends in their path. The baseline of shipbuilding knowledge as recorded in our standards has to be applied during the building process to ensure safety is maintained.

It Starts with the Workers

Many of those who tour a shipyard are amazed to learn that it all starts out as flat plate, structural shapes, and pipe. Through the efforts of many skilled craft workers, these raw materials end up as a finished vessel that sails away and becomes a “home” for the crew. Each vessel, whether commercial or military, is a self-contained, self-supporting floating city when at sea. Everything from propulsion and electrical power to personnel accommodations and sewage treatment is contained in the vessel. Inspection plays an important role in the shipbuilding process from start to finish.

Being cost effective is a key to survival in the shipbuilding industry today. The application of standards as written in the contract for the ship can become very costly if not properly planned for. Producing the quality required for the cost allowed dictates that an inspector for each production step or line is a sure way to fail in business today. The modern approach in shipbuilding starts at the level of each individual worker. It is critical that individual craft workers not only know how to use the tools of their trade, but also how to inspect the work they do in real-time. They are the front line in the battle to achieve economic success for the entire process. Correcting deficiencies early in the process ensures success overall. Many do not understand the integration of quality control and quality assurance into the entire shipbuilding process. That is because most people only consider the formal inspection at the end as a quality step because that is what is visible when the customer or regulatory body is in attendance. They haven’t considered the entire process.

A Step-by-Step Procedure

In truth, if done properly, quality control starts with the worker on the job. The next step in the process in modern yards is to have the Manufacturing Department employ a quality control operation by the lead person or supervisor to check 100% of the work. When that step is completed successfully, it is then passed to the quality assurance inspector who checks the performance of Manufacturing’s quality control efforts. This step is intended to be an audit operation. When that step is successfully completed, the regulatory body and customer representatives are called out for a formal inspection. When the formal inspection is completed, the assembly can progress to the next phase of construction. In most yards, these inspection points are at predetermined milestone events, such as panel construct, module construct, and final erection in the hull for structure. Piping systems, machinery installations, and electrical distribution systems are also inspected at predetermined stages of completion. Redundant inspections ensure defects are caught early and corrected immediately.
In a shipyard, record keeping is critical for the inspector. The records must be compiled and maintained as the hull is built, so documentation exists to prove required testing and inspections were successfully accomplished. The true “final inspection” is during the sea trial period where the ship is put through planned tests while underway to confirm operation and safety of the crew under actual conditions, including hard turns and emergency stop demonstrations.

The Modern Management Approach

Now that the process has been briefly described, it is worth discussing the modern management approach at most shipyards. For example, Marinette Marine Corp. has adopted ISO 9001:2008, Quality Management Systems — Requirements, as a framework for the entire organization to ensure not only a quality product, but a successful business. While the document gives general requirements for the framework of the system, each company must determine the exact details in its own written manual. It should be pointed out that this document drives many companies through the same quality control and quality assurance approach that Marinette Marine has used to produce both commercial and military ships. It has taken time and an investment in training to mature this quality system.

The Littoral Combat Ship

Five years ago, Marinette Marine embarked on building the first Littoral Combat Ship, LCS 1 USS Freedom (see lead figure). At the same time, the company kicked off a worker education process to empower each craft worker with knowledge of the actual contract quality requirements because the ships were to be built under new American Bureau of Shipping Naval Vessel Rules. Welders, for example, not only had to pass their plate and pipe qualifications, but also had a full day of classroom training and a written test to pass to prove knowledge of the ABS rules. The company’s top management directed this approach with the understanding that a learning curve would be encountered, but the end results would pay benefits in the long run. The approach of educating each craft worker to know the inspection standards has proven to be a wise investment. Time and the results obtained from production of USS Freedom have proven the merits of that program.

The Littoral Combat Ship (LCS) is a new class of vessel for the U.S. Navy. The term littoral means shallow water; it is designed for missions in shallow seas. Think of it as a 378-ft-long, scaled-up jet ski with 120,000 hp and four water jets for propulsion. It is as maneuverable as a jet ski, but carries lethal firepower and the most up-to-date electronics. At the time of the writing of this article, USS Freedom has accomplished four drug interdictions, in which more than five tons of cocaine were seized, including chasing down one “go-fast” boat with her speed alone. Lockheed Martin is the prime contractor; if you’d like to know more about the Littoral Combat Ships’ multimission capabilities, visit www.lmlcsteam.com.

What the Past Has Taught Us

Looking back at the heritage of modern shipbuilding, it is important to realize the dependability and knowledge for safe operation were gained at a cost. President Franklin Roosevelt directed the building of Liberty Ships to support the war effort. They were all welded because riveting was determined to be too labor intensive and slow. During the period from 1939 to the end of the war in 1945, 2710 Liberty Ships were built. By 1945, the average build time had been reduced to 42 days per vessel. A few were still in construction or on order at the close of the war. Figure 1 shows the SS Esso Manhattan, a T2 Liberty tanker, one of about 12 that experienced a complete brittle fracture of the midship hull envelope. Designs with sharp notches, materials with little fracture resistance at low temperature, and defects produced by the new submerged arc welding process all contributed to the failures. But even with the failures, the Liberty Ship program was judged a success.

Without the many Liberty Ships to supply the U. S. and Allied forces overseas, the war may have lasted far longer. Only two operational Liberty Ships survive today as a memorial to those who served aboard and to the many who did not return. Because of the large number produced, a meaningful database was established to set rules for materials, design, and welding methods. We owe a debt of gratitude to these ships and the personnel who studied the problems.

Welding rules or codes in particular can trace their roots in many industries to the lessons learned from the Liberty Ships. When you inspect welds in any industry each day, take a moment to remember where the knowledge base started to ensure reliable and safe fabrications. As inspectors, we need to be ever mindful of the lessons learned from the Liberty Ship failures. 

BRUCE HALVERSON (Bruce.Halverson@us.fincantieri.com) is quality assurance manager, Marinette Marine Corp., Marinette, Wis., a division of Fincantieri Marine Group. He is a Life Member of AWS and first qualified as a CWI in 1978. He has held ASNT Level III since 1979 and maintains current certifications in RT, UT, PT, and MT methods. His experience includes 43 major ship hulls up to 1000 ft in length for commercial and military customers. He is a member of the AWS D3 Marine Welding Committee and has recently coauthored articles on friction stir welding of littoral combat ship aluminum structures.

Errata A5.14


The following errata have been identified and incorporated into the current reprint of this document.

Page 7, Table 1: Changed Ti content from 0.04% maximum to 0.4% maximum for AWS Classification ERNiCrMo-21.