Shipbuilding Trends

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On the cover: Keel blocks positioned in Dry Dock 12, Newport News, Va., in preparation for John F. Kennedy’s (CVN 78) move west. Huntington Ingalls Industries christened the vessel on December 7, 2019. (Photo by Matt Hildreth. Courtesy of Huntington Ingalls Industries.)
Closing the Gap

As we begin a new decade, we will be able to find many opportunities for growth.

The welding industry is quite diverse with processes and applications that are increasingly more sophisticated. From a manufacturing and fabrication standpoint, we have countless welding and joining obstacles to overcome. As far as the mechanical and materials sides of the industry go, we must join them together for a lasting bond.

Another critical gap to close is the talent acquisition gap. When I say “closing the gap,” I’m referencing the generational gap. And more specifically, as we move forward into a new decade, we will not only be confronted with an ever-changing workplace, but a communication revival to implement. As we continue to create robots, lasers, welding equipment, etc., we will also need to upgrade our human processors. At the speed we all function, it’s increasingly difficult to navigate through a day without the need to comprehend more data, faster. With this being said, it’s evident that the ability to communicate our needs and expectations is quite challenging within the generational gap.

At this point, I would like to share some interesting facts that will shed some light on how to move forward. Currently, there are four generations in the workplace, with the 5th (Generation Z) entering the workplace in 2020. Each has their own set of values and work philosophy.

1. Traditionalists. Born between 1922 and 1945, the “silent generation” values hard work and commitment. They are loyal to a cause and a company. “Whatever it takes” can be heard as their motto, and they will do just that to get a job done. However, traditionalists like things to be the way they’ve always been. They believe what worked for them will work for others. They are not excited about technology and can be slow to see it as an advantage, much less a necessity.

2. Baby Boomers. Born between 1946 and 1964, the boomers shaped American life. They value peer competition and find fulfillment in work. They tend to dislike restrictive regulations, but respect knowledge. Boomers believe in saying “thank you,” and they value optimism and involvement. They prefer traditional learning and the mission and vision concept. They desire face-to-face communication, are good team players, and enjoy team meetings. Boomers tend to question authority.

3. Generation X. Born between 1965 and 1976, the Xers want variety, fun, and independence. They prefer freedom and independence, and although they dislike being micromanaged, they desire direct communication with leaders. Xers value responsibility and they like to contribute, offer input, and give back to the workplace and society. They learn by doing and are eager to attain more skills. They are technologically adept and have disdain for authority and structured work hours.

4. Millennials or Generation Y. Born between 1977 and 1995, millennials value work-life balance and flexibility. They enjoy working in teams, diversity, and collaboration. They embrace multiple learning styles, are good at multitasking, and are goal oriented. Because they have a distaste for boredom, millennials impatiently seek challenges and opportunities. Freedom and equality are highly desired from day one on the job. Of the current generations, this group is the most tech-savvy, and they prefer to communicate quickly via text or social media. This generation doesn’t fear authority.

5. Generation Z. Born between 1996 and 2012, this generation has been technologically connected from birth. They will earnestly enter the workforce in 2020. Generation Z will live and work in a highly sophisticated media and computer environment, and they will have more tech savviness and expertise than their millennial forerunners.

Clearly, each of these generations has different values, different goals, and vastly different ways of communicating. It isn’t enough to simply recognize these differences. We must learn to identify them, appreciate them, and tailor our work and organizational environments to them. It is also important to find common ground between the generations.

Let’s turn challenges into opportunities. We should actively recognize, but not dwell, on our differences while understanding the big picture and positive outcome potential of cooperating generations.

“We should actively recognize, but not dwell, on our differences while understanding the big picture and positive outcome potential of cooperating generations.”

Dennis Eck
AWS Vice President
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“Necessity is the mother of invention.” This old proverb would have been an anchor statement during the years of World War I (WWI). At the beginning of the war, there was an air about how this war would prove to be different from any war fought previously or any war that would be fought in the future. New technologies that shaped the way infantry engaged caused manufacturers to drastically alter production tactics to keep up with increasing demand for more of everything at a faster rate than ever before.

Metal was a basic need for products and equipment, from guns and bombs, to torpedoes and mines, to railroads and ships. Every type of metal fabrication process was pushed to double and triple production in the fastest time frame possible. This high demand for metal during WWI is recorded in the Journal of the American Welding Society:

“Mining equipment and handling devices are at all times subjected to extremely rough usage and breakdowns. In normal times plenty of spares are carried and broken parts can speedily be replaced, but during the war, in most cases, spare parts were unprocurable and as a result repair and not replacement had to be resorted to” (Ref. 1).

The Great War would require great ingenuity in production and transport if the Allied Powers were to win against the Central Powers, and this was the backdrop for the research, development, and implementation of welding for military applications.

Welding before WWI

To have a deeper appreciation on this topic, the author wishes to, first and foremost, bring the reader up to speed on the history of welding to show how it became a viable option for repairs, construction, and production during this critical time in history.

One of the very first people to experiment with electricity, with the intentions of melting metal, was Martinus van Marum of Leipzig, Germany. He published a detailed book on the matter in 1786 (Ref. 2). In 1810, Sir Humphrey Davy conducted some experiments in London “using various metallic bodies,” and, five years later, J. G. Children recorded “a process for welding iron with the electric arc obtained from batteries” (Ref. 2). Nearly a century later, Ukrainian Nikolai Nikolaevich Benardos, with the help of other inventors, patented the first functioning electric arc process using carbon electrodes and a battery system (Ref. 3).

In 1888, Russian Inventor Nikolay Slavainoff took the process a step further by using a bare metal electrode instead of the carbon electrode (Ref. 4) — Fig. 1. Although Benardos’ process was better suited for cutting heavy plate or general repair work because of its higher amperage (roughly 200–500 A) and ability to produce a longer arc, Slavainoff’s method used a lower amperage (typically between 50 and 175 A) and created a shorter arc, which allowed the operator to successfully weld in the overhead and vertical positions (Ref. 4).

Despite its usefulness, the process still had a ways to go before it would be accepted as a viable means of joining large components. In 1911, a publication by Machine Shop Library stated that of “a large number of so-called perfect welds [produced with the electric arc welding process] that were examined, very few showed a strength equal to 50% of the unwelded section” (Ref. 5). It also stated that electric arc welding proved to be “a slow, laborious process when large pieces were to be welded, and [with] the efficiency of the welds being low, it became necessary to abandon welding, in many cases, as a commercial possibility, or to
Embraces Electric Arc Welding

The Shipbuilding Industry

results. It would give faster or more reliable methods. Its big break came at a time when it was eventually developed into the industry.

Additionally, in 1903, Charles Pi-card's invention "of the oxy-acetylene blowpipe . . . led to the rapid development of the acetylene industry as a result of the many uses of the oxyacetylene flame in steel welding, scarfing, hardfacing, surface cementation, and oxygen cutting" (Ref. 7). This process produced better results more consistently and was a trusted form of joining metal by the time the aforementioned 1911 publication made its way into the industry.

Despite the benefits of using oxy-fuel and electric arc welding, riveting was the tried-and-true way of joining steel for boilers, locomotives, ships, and other major steel structures in a fast-paced manner. The industry's reliance on riveting left both oxyfuel and electric arc welding processes only for small repairs and miscellaneous work.

Consequently, electric arc welding spent the next several years primarily in garages and labs all over the world, where it was eventually developed into a trusted and superior metal-joining method. Its big break came at a time when no other existing technology would give faster or more reliable results.

The Shipbuilding Industry Embraces Electric Arc Welding

At the beginning of WWI, ships and U-boats were being employed by the Central Powers to take on the Allied Powers at sea. Kaiser Wilhelm II, Germany's political monarch at the start of WWI, agreed with his foreign minister, Alfred von Tirpitz, that Germany needed to control the seas to have a commanding economic influence as a world power. Thus, the sinking of ocean liners belonging to Allied Powers by German U-boats at the outset of the war, at a rate faster than they could be reproduced, played a major part in the development of the shipbuilding industry. One memorandum reported that roughly 326,000 tons of shipping products were destroyed by German U-boats in late 1916 (Ref. 8).

Trying to keep up with this rate of replacing ships became one of the most urgent needs of transporting goods and military supplies to the Allied Powers from the United States. As a result, in 1917, "The U.S. Shipping Board incorporated the Emergency Fleet Corporation (EFC) to build, own, and operate a merchant fleet for the U.S. government" (Ref. 9). The EFC also included a committee, The Electric Welding Committee, for the application of electric arc welding and its use in shipbuilding. The committee was headed by Comfort A. Adams, a professor at Massachusetts Institute of Technology and the future founder of the American Welding Society (AWS) — Fig. 2. After reviewing studies performed by Captain James Caldwell, the committee was "convinced that a considerable saving in time and material can be brought about by the introduction of electric welding in shipbuilding" (Ref. 10). They also resolved that the EFC "be urged to authorize its committee on electric welding to prepare immediately a modification of the plans of a standard ship, to the end that it may be most readily assembled by electric welding" (Ref. 10). In stark contrast to the 1911 publication by the Machine Shop Library, this statement helped make electric arc welding the technology that catapulted a fleet of ships into the Atlantic faster than the German U-boats could sink them.

During this time, new developments were being made to the electric arc welding process that would cement its importance for shipbuilding applications. Oscar Kjellberg, the founder of Elektriska SvetsningsAktiebolaget (ESAB) (Ref. 11), was a Swedish inventor who "improved upon the Slavainoff process by surrounding the metal pencil [electrode] with a sleeve of non-conduction and refractory material, which is dissipated by the arc automatically in a gaseous form" (Ref. 4). This coating drastically improved the characteristics of the arc and soundness of the weld.

Additionally, the Quasi-Arc Co., a supplier of arc welding equipment and consumables, built upon this process by adding sodium silicate and aluminum silicate to the coating. "Aluminum . . . is applied in the form of a fine wire wrapped in a blue asbestos [yarn] covering. The aluminum . . . absorbs the small amount of oxygen which may be present in the slag, and so prevents oxidation of the fusing metal" (Ref. 12). This is what we now know as a deoxidizing ingredient in flux. The company also used reverse polarity, or direct current electrode positive, to produce better results, whereas before it was common practice to use straight polarity or direct current electrode negative with the bare electrode (Ref. 4).

As the electric arc welding process continued to evolve, the industry began to consider it over other proven methods, including riveting. A cost analysis conducted by the Electric Welding Committee found "that four welded ships can be built for the cost of three riveted ships, and the welded ship will require about half the time for complete fabrication" (Ref. 13). The EFC also received plans for an electrically welded ship to be used in merchant marine transportation. This 7500-ton vessel would be built in a specially designed shipyard (Ref. 13).

Electric Arc Welding Becomes the Go-To for Military Repairs

During WWI, electric arc welding found its main purpose in repairs. For example, it was heavily used in the foundries, where "mistakes the begin-
ners make can in nine cases out of ten be remedied, and one or two welders can take care of the work for a fairly large foundry” (Ref. 13). Repairs to foundry equipment were essential to the war effort so that steel production could continue without long periods of delay. Some of the equipment repairs took 48–72 h of welding and kept equipment running when procuring new equipment was not possible.

As the electric arc welding process continued to showcase its capabilities, the industry took notice and started to consider its use in transportation repair. In 1918, The Lincoln Electric Co. of Ohio published an investigation into the uses of electric arc welding in all forms of transportation. One section of this publication strictly focused on the uses of electric arc welding in shipbuilding and repairing — Fig. 3. At the time this report was written, “welding of any strength members on the vessel, that is, the welding of plates or ribs, or the welding of the plates to the ribs” was not permitted (Ref. 13). The company subsequently listed the parts on the ship that electric arc welding was permitted to be applied to, namely tanks, deck railing, coal chutes, engine and boiler room stairs and gratings, framing and supports for engine and boiler room flooring or grating, and cargo cleats (Ref. 13).

Although riveting was the most commonly used method for heavy steel construction, the process showed its Achilles’ heel when it came to repairing war-torn structures. This preference for electric arc welding in repair applications was recorded in a 1918 issue of The Journal of the Engineers Club of Philadelphia: “When the great war started and our dockyards commenced to fill with damaged steamers and naval units crippled in their riveting and caulking as the result of vibration from gunfire, the possibility of electric arc welding as a means for their rapid and effective repair came to be realized” (Ref. 12).

This added credence to the case for using electric arc welding in ships, as stated in Caldwell’s report (Ref. 10). Caldwell explained that as many as 3000 welders could be trained and added to the ranks of the labor force within three months and that all of the ships under construction could be welded as soon as possible so that there would be the greatest saving of labor and material. This confidence in the method made it the preferred metal-joining method, even though it wasn’t yet used for assembling ship hulls.

This confidence in electric arc welding led to shipyards embracing the process. One such shipyard that took on electric arc welding for military repairs was known as Hog Island, Philadelphia, Pa. The land for this shipyard, which started out as a “semi-wasteland of dredge spoils, provided an ideal opportunity to create the planned industrial shipbuilding facility” (Ref. 14). This land was devoid of any infrastructure, including no running water, roadways, or railways, making it a completely inaccessible production facility from the start. From its inception in December 1917 to its completion in 1918, the government developed the facility along with a labor force of more than 35,000 people (Ref. 14). Men who signed up for working in the shipyard were promised to be exempt from the military draft (Ref. 15). Other shipyards that were recorded in Caldwell’s report to the Electric Welding Committee were the Brooklyn Navy Yard, Brooklyn, N.Y.; Quincy Shipyard, Quincy, Mass.; The River Works of the General Electric Co., Lynn, Mass.; Chester Shipbuilding Co., Philadelphia, Pa.; and Newport News Shipbuilding and Drydock Co. in Virginia (Ref. 10).

Just as ships provided transportation across the sea to the war front, locomotives provided transportation across our country’s railway system. Getting products and resources from one factory to another was just as important as the steps in the manufacturing process. In light of the demand for trafficking products across the railways, locomotives could not be produced fast enough to keep up, which also meant that repairs needed to be made as quickly as possible — Fig. 4. Worn down parts, broken frames, fire boxes, and even broken shop tools were among the most common repairs that were performed using electric arc welding. Without having to disassemble the entire locomotive to make a repair, turnaround times were improved from a week or more to around a day or two (Ref. 13).

The Role of Oxyfuel Welding and Other Processes in WWI

Considering the welding industry in general, oxyacetylene welding was used...
as a main method of joining for some products. For example, mines were planted in the North Sea to prevent U-boats from venturing toward the United States. The mines were put together as two halves with “a ten-foot gas weld at the equator seam of each” (Ref. 1). A crucial part of manufacturing these types of weapons was a “gas-tight” seam, which meant that “longitudinal and circumferential seams and all bushings were welded, as also was much of the interior mechanism” (Ref. 1). Airplanes also utilized oxyfuel welding on many of their engine components, including “inlet and exhaust valve cages, spark plug holes, and valve stem guides,” which would be machined later in the manufacturing process (Ref. 1). The importance of oxyfuel welding for the war effort was captured in the Journal of the American Welding Society: “What gas welding and cutting did to help win the war in this country and abroad will probably never be fully appreciated. An attempt to detail the ramifications of the metal industry vital to the conduct of the war, into which gas welding and cutting entered as an essential, would be to cover the entire field of industry” (Ref. 1).

Additionally, it is important to mention how resistance welding drastically increased chain production. Known previously as the Thomson process (Ref. 6), resistance welding uses electricity to super heat a metal rod to semiliquid temperatures and then applies force to create a weld. Resistance welding improved upon the laborious process of forge welding every chain link, leading to the production of 10–18 chain links per minute, depending on the diameter of the rod (Ref. 4).

Welding processes also spanned a variety of other applications during the war. Its use in boilers, tanks, piping, machinery, and a variety of repairs throughout the construction industry allowed for the Allied Powers to adapt to the ever-evolving needs presented by the war — Fig. 5.

Although welding was not the preferred metal joining method of the military before World War I, the desperation caused by the Imperial German Navy to ocean liners in the Atlantic required that any and all technologies be seriously considered to counter a problem never before seen on a global scale. Welding was an answer to that desperate need. From the time of World War I through the second World War, welding of ships as a standard method of production increasingly became the technology of choice, instrumental in America’s domination on the sea and, in time, a capstone technology for transporting fossil fuels over land, which, ultimately, allowed the United States to continue to supply its naval shipyards with the fuel they needed during World War II (Ref. 16).

**WWI Efforts Lead to Welding Training and Standards**

Welding training became a hot commodity during WWI as it was being used more frequently throughout many different industries. “Welding work in France rallied for the services of a small army of all-around welders, and naturally such men in the quantities required were not to be found amongst the enlisted men, for statistics show that in each 10,000 men drafted into the Army, only seven men were welders” (Ref. 1). As in the case with Hog Island, welders across any industry were not forced to enlist, leading to this shortage of welders in the Armed Forces. As a result, the Army started its own welding school while also looking to industry for help in training infantry men. The Lincoln Electric Welding School started to support this effort with 40 soldiers in 1917, and it recently celebrated 100 years of continued training for enlisted Army personnel and thousands of civilians since its opening (Ref. 17).

Welding for WWI also spawned the birth of AWS, which was, and still is, instrumental in devising standards and best practices for the welding trade. What was once experimental processes are now standard methods of fabrication and construction on large and small scales, and have become the foundation for further advancements in the field.

**Concluding Thoughts**

In closing, the reader should consider a few things. First, appreciation should be given to the many people who took the time to record this information more than a century ago so that the history of this vital trade in matters of national crisis would not be lost. Second, AWS’s depth of purpose and mission should be recognized. When the Great War ended, the government dropped the Electric Welding Committee from the EFC, and it was Comfort A. Adams along with the other committee members who pushed for research and development to go on for generations to come. Because of the work of many people, we find ourselves here, as one poet put it, sitting in the shade of a tree that someone planted a long time ago.

One final consideration for the
Acknowledgments

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