HYPERTHERM®
A Hypertherm Associates Brand

Improving safety, productivity and cost containment in the shipbuilding industry

Industry report

Contents

Introduction

A long-standing supplier to the shipbuilding industry, Hypertherm designs and manufactures mechanized and handheld plasma cutting systems. In order to better understand the issues our customers are facing, over the course of 18 months in 2017–2018 we conducted 15 in-depth interviews with shipyard employees and industry executives around the world, in addition to value-stream manufacturing assessments.

This report summarizes the results of our research and looks at some important industry trends, and manufacturing challenges. Where appropriate, it also suggests ways in which plasma cutting technology can address many of the industry's most pressing problems.

Overview

Like all heavy manufacturing today, the shipbuilding and repair industry is operating in an increasingly troublesome economic environment. Consolidation, reduced demand, and political uncertainties are multiplying the challenges of an already difficult business. Add to this an acute shortage of skilled workers – not to mention the recent impact on world trade of the COVID-19 pandemic – and it becomes clear that ongoing profitability is a very real concern. Our respondents were in agreement: The status quo no longer applies; future success is going to hinge on reducing costs and finding better, more efficient ways to conduct day-to-day operations.

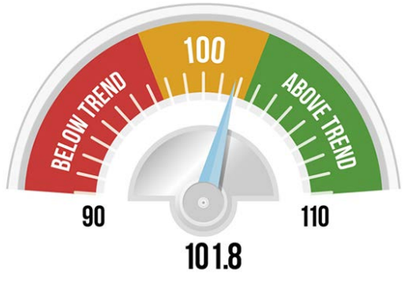
The outlook isn't entirely gloomy, however. While the industry is in the mature stage of the product lifecycle, much of the consolidation has already occurred, and demand is expected to stabilize. Sea transport remains the most economical and most environmentally-friendly method of moving goods around the world. New manufacturing orders are closely linked to the total value of world trade, and post-COVID-19 the total value of world trade is expected to grow. Incremental technology advancements, and the need for lighter, more fuel efficient ships to comply with new environmental regulations will also spur new demand.

Industry trends and drivers

Global economic activity and international trade is the primary factor in ship demand. As a result of the disruption caused by the COVID-19 pandemic, the volume of world merchandise trade is expected to contract sharply in 2020. At this writing (June, 2020), the World Trade Outlook Indicator currently stands at its lowest point since the index was established in 2016.

World Trade Outlook Indicator 101.8

(Index, trend = 100)



Drivers of trade

	Level of Index	Direction of change
Merchandise trade volume (Q4)	102.7	➡
Export orders	98.1	➡
International air freight (IATA)	102.5	⬇
Container port throughput	105.8	➡
Automobile production and sales	97.9	➡
Electronic components	104.2	⬆
Agricultural raw materials	95.9	⬇

Figure 1.
World Trade Outlook Indicator, May, 2020 *(Source: World Trade Organization)*

Manufacturing trends

Automation: In an effort to reduce labor costs, reduce waste, and increase throughput and quality, many shipyards are incorporating some form of cutting and welding automation into their workflows. Many of our respondents indicated that they have trouble fully utilizing welding automation; robots are sometimes not able to accommodate the tolerances produced by their tables. Most of the issues have to do with accuracy of cuts, angularity, and the need for secondary operations to produce a clean edge.

Manufacturing cost reductions: As a mature and consolidated industry, shipyards are facing tremendous pressure to reduce costs and improve quality. This is exacerbated by the challenge of attracting and retaining skilled labor.

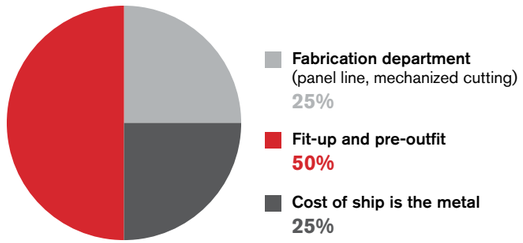


Figure 2.
Cost breakdown in shipyard manufacturing

Labor shortage: The decreasing availability of qualified labor has reached crisis proportions in the industrial shipyard. The highly skilled workers who have formed the backbone of the industry for decades are aging, and there are fewer to take their place. Younger workers are not interested in entering such a physically demanding profession where work must often be done under unfavorable conditions – extreme heat, cold and confined spaces.

Those who do sign on generally stay on the job for only about two years, and then move on. Respondents are having particular difficulty recruiting, training and retaining mechanized operators and welders.

Paint specifications: It is now an expected and standard process to place a 2–3 mm corner radius on all plate edges. Ship owners are demanding the additional step for aesthetic reasons, and it is required in supplier paint specifications for warranty purposes. Ships typically have a one-year mechanical warranty, but paint is warranted from 3–5 years; sharp edges cause the paint/coating to be more likely to fracture, exposing the raw metal to corrosion.

Lighter construction: In a move to reduce weight, operating costs and environmental impact, most new military, cargo and cruise ships are using lighter, thinner plates for hull construction.

- Cruise ships: 32 mm (1.5") below-water hull thickness; topside hull is substantially thinner
- Cargo: Vary by vessel type/use and length
- Military: Confidential and highly varied thicknesses, depending upon type of vessel/use. The trend in the military is to commission fast attack vessels that avoid radar and use speed to their advantage. Weight is being minimized by using thinner gauge steel, as well as aluminum construction.

Changing business models: Many medium to large shipyards are moving from military and cargo vessels to cruise ships, oil platforms and large yachts. This shift is due to reduced military spending in the UK and Europe, as well as intense competition from Chinese and South Korean shipyards.

3D Printing and additive manufacturing: Active research projects are underway at leading shipyards to incorporate innovative new manufacturing technologies into their operations. The goal is to achieve faster ship construction at reduced per-unit costs. This will require substantial changes in manufacturing processes to reduce part counts, consolidate supply chains and enhance ship performance.

IoT (Internet of Things): The "connected factory" connects people, devices and machines to management and yard supervisors, and monitors all activities, including systems utilization, downtime, status of equipment and employee productivity. Shipyards are actively pursuing IoT solutions and partners, driven by the business need for cost reduction and production efficiencies.

Improvements needed in three critical areas

Almost unanimously, the shipyards we visited identified three critical areas for improvement:

- Safety
- Productivity
- Cost containment

Typical of a mature industry, shipbuilding methods are well-established. With a few forward-thinking exceptions–most yards are slow to change their proven processes. Experienced crews are comfortable with current tools and workflows, and inefficiencies are often built right into day-to-day operations. This can have far-reaching consequences – impacting everything from worker safety to build quality, delivery schedules, and ultimately, operating costs and profitability.

While change may come very gradually, shipbuilders are learning that it is possible to reduce injury rates, improve quality, and shorten delivery lead times, even while lowering costs. The key lies in eliminating activities that do not add value – excessive material handling and redundant secondary operations, for example – and adopting newer technology and procedures better suited to the realities of 21st century fabrication.

Many of these issues of safety, productivity and cost reduction are interrelated, and are associated with steel working processes which are central to the shipbuilding value stream (Figure 3). The remainder of this report will focus on these areas.

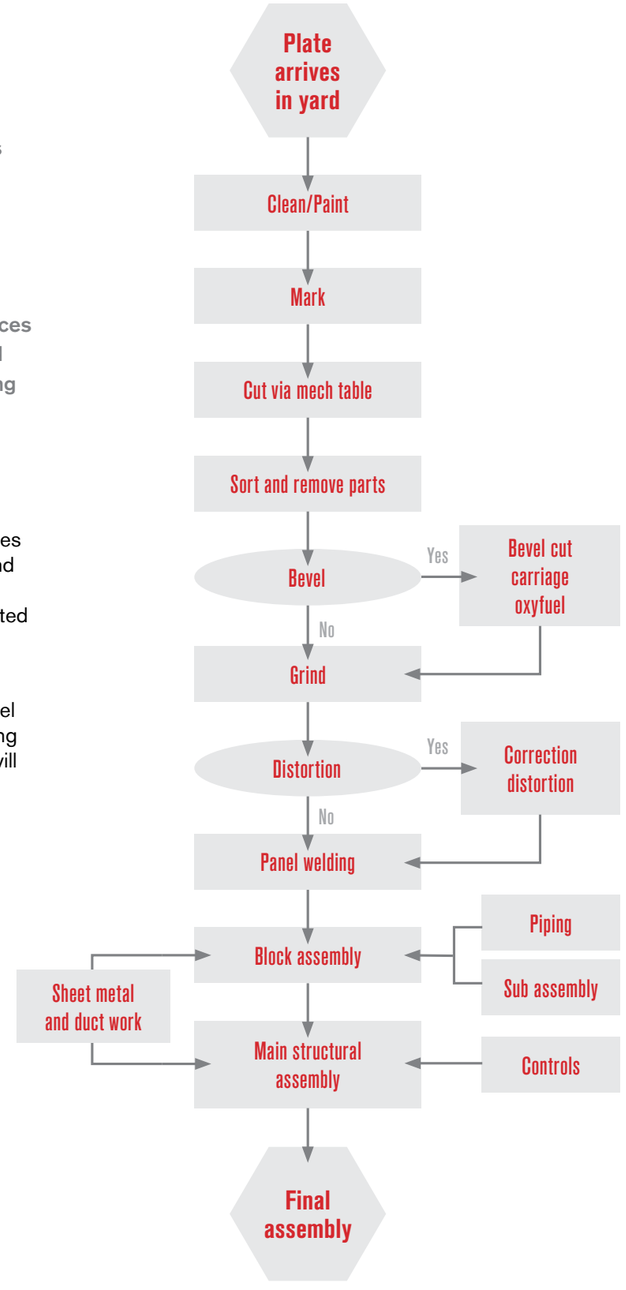


Figure 3.
From raw plates to final assembly, steel handling, cutting and finishing processes are at the heart of every industrial shipyard.

Safety

Ask shipyard operators to name their number one workplace concern. Most will tell you it is safety. Operators expect – and are entitled to – clean and safe working conditions, and it can be impossible to attract and retain skilled help to a yard where safety is not a priority.

Beyond that, safety is simply good business. A safe workplace helps shipyards comply with increasingly stringent government regulations regarding fire hazards, air quality and emissions, repetitive motion/vibratory exposure, and proper ergonomics. And because both short and long-term injuries lead to absenteeism, increased medical bills and compensation claims, a strong focus on safety also helps to keep a cap on rising healthcare costs.

Despite heavy investments in safety programs and growing teams of safety officers and engineers, keeping workers safe is a continuous challenge. A shipyard is a very busy place, with heavy materials and equipment, dozens of crews, and physically demanding jobs that include the use of combustible gases. Much of this work must be done in harsh weather, or in the confined quarters of a vessel.

Shipyard injuries

In order of occurrence, the shipyards we interviewed identified these critical employee safety issues:

1. **Hand injuries:** crushes, cuts, burns
2. **Eye injuries:** metal chips, flash arc from welding
3. **Ergonomics-related injuries:** forceful exertion; shoulder, neck, back
4. **Falling injuries:** tripping hazards and falls
5. **Death:** severe burns, falls, explosions

Where are most of the injuries happening?

Material handling: Even when maximum care is taken, safety is sometimes compromised during material handling, and this is one of the shipbuilding industry's leading causes of worker injuries to the hands and feet, as well injuries due to poor ergonomics. Heavy metal plates can slip or drop from cranes and hoists. Manually moving awkwardly shaped metal such as scrap remnants and cutting table skeletons can lead to strains, as well as crushed hands or feet.

Rework: Employees doing rework are twice as likely to be injured. More often than not, rework must be done in a less controlled environment, sometimes using different tools than the original process called for. Corrective steps such as grinding, welding or cutting might need to be done in confined spaces, with other pieces of the structure already in place – bulkheads, gas piping, electrical wiring, etc. – adding to the difficulty and making the operations much more difficult to control.

Grinding procedures: Grinding is loud and labor-intensive, with extremely poor ergonomics due to vibration, repetitive motion, and the need to manually manipulate heavy tools and work pieces. Grinding disks can also break unexpectedly, resulting in serious eye and hand injuries.

Cutting and welding: In addition to oxy-acetylene welding, many shipyards use oxyfuel torches for cutting applications during block fabrication, fit-up, and final structural assembly. The use of combustible gases, especially in confined workspaces, represents a considerable safety hazard. Fuel gases are a source of combustion and have caused fires and explosions at many shipyards. There is also a risk of asphyxiation in confined spaces, necessitating constant air monitoring. Exposure to fumes can have long-term effects on employee health, and governments are beginning to strictly regulate fumes related to cutting and welding operations.

OSHA Occupational Safety and Health Administration

Shipyard Industry: Most Prevalent Injury Types by Process

= Not a prevalent cause of injury in this process

= Most common cause of injury In this process

A3 = Page Number

Process \ Hazard	Improper Body Position	Repeated Trauma	Over Exertion	Eye Injuries	Lifting	Falls	Burns/ Shocks	Over Exposure	Traumatic Injury / Acute
A1 Hot Work - Welding, Cutting and Brazing	A3	A8		A12			A17	A25	

Figure 4.
OSHA data on shipyard injuries from hot work.

Productivity

Building a modern vessel is a complex manufacturing challenge that typically involves millions of parts and operations, multiple engineering disciplines, extensive reliance on outside partners and expertise, and hundreds of skilled workers across multiple sites. Time-to-market is critical, and efficiency – not to mention profitability – is largely a matter of reducing the number of hours it takes to put a ship together, maintaining an appropriate standard of quality.

In the structural assembly process, there are basically only two types of elements – plates and profiles – that make up a ship's framework. Getting from raw plate steel to finished assembly requires moving and handling, surface preparation and treatment, cutting, bending and welding, as well as several secondary operations. But when there are many tens of thousands of elements to bring together, even small inefficiencies can become huge bottlenecks.

Referring to the plate-to-final assembly value stream, our respondents focused on the following productivity pain points:

1. Material handling
2. Plate buckling and distortion
3. Secondary operations
4. Skilled labor shortage/training time

Material handling

In addition to being a leading cause of shipyard injuries, material handling is a common bottleneck in mechanized fabrication departments. To maintain production schedules, workers must safely and quickly load steel plates, unload cut parts, remove skeletons and place remnants in an appropriate recycling bin or storage location. If not efficiently managed, these tasks can counteract the substantial benefits gained by mechanized cutting operations.

Plate buckling and distortion

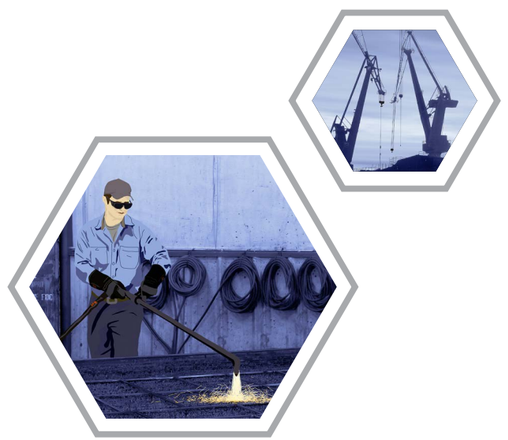
This is an all-too-common problem at every shipyard. It impacts safety, increases cost, and significantly decreases productivity. Rework to correct the distortion requires time and manpower, disrupts the normal workflow and usually involves additional cutting, heating, welding and grinding. Even after rework, extreme force and exertion may be necessary to bring the workpiece back into acceptable tolerances and fit.

Eighty percent of all plate distortion is caused by excess heat generated by welding; oxyfuel cutting accounts for the remaining twenty percent. Typical causes of distortion include:

- Single pass, deep penetration welds on components such as panel stiffeners; other long welds
- Long, slow cuts with oxyfuel
- Beveled plate welds; wide welds at the top are more prone to shrinkage
- Welding and cutting thin-gauge plates
- Submerged arc panel line welds, and multiple pass, long weld beads
- Welding plates of unequal thicknesses

Secondary operations

Secondary operations, especially grinding, add an enormous amount of time and cost, and create yet another production bottleneck. Rather than sending parts straight from the cutting table to the welding team, most yards are forced to add steps in between – a second pass to cut beveled edges, grinding to remove slag or excess dross, bringing a part into tolerance, or weld preparation. In addition to slowing the workflow, the need for abrasive grinding and the additional exposure hours put the health and safety of workers at increased risk.



Typically, secondary operations go hand-in-hand with cutting/welding procedures. The most common include:

Grinding: Cleanup of poor cut quality, using pneumatic or electric grinders

Reasons for grinding	Percent of department's grinding time performed for this reason
Remove paint and rust to prep weld joints for weld	42%
To remove temporary attachments	14%
Cleaning tacks	11%
To cut material ilo saws and torches	10%
Grind rough welds to prep for NDT	10%
Smooth rough cut plate edges to prep for welding	7%
Flush plug welds	3%
Remove spatter from welds and base material	2%
Flush cured PR944 (LWWAA, Chin Array, and FLTA)	1%
Break square edges of plates for paint prep	0%
Fatigue adequacy grinding	0%
Contour grinding	0%
Grinding welds flush iwo deck coverings	0%
Grinding welds on decks to meet a required height	0%
Grinding welds flush on appendages	0%
Grind wide welds flush to prepare them for UT inspection	0%
Flush weld repairs to base material	0%

Figure 5.
Typical grinding operations. *(Source: Newport News Shipyard Study 2013 – Published document)*

Material handling: Skeleton cut-up, part removal, remnant handling

Distortion correction: Correction using propane and/or acetylene

Slag/dross removal: Cleaning up cut plates and profiles

Slag removal: Removing slag from mechanized table slats

Temporary attachment removal: Removal of lifting eyes and temporary support structures

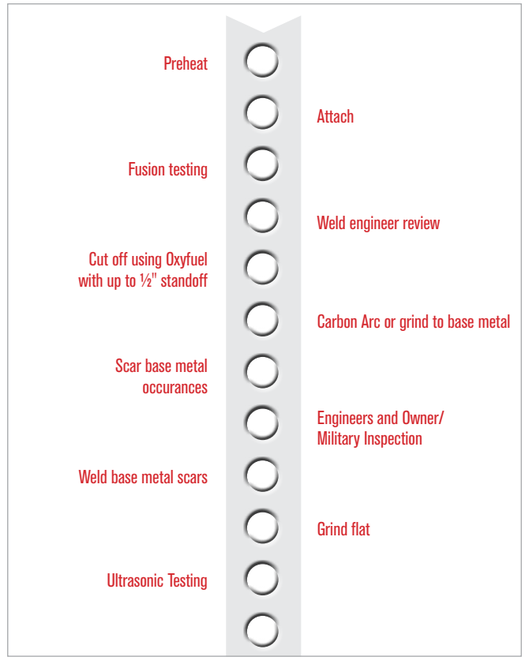


Figure 6.
Typical temporary attachment removal procedure

Cut plate residue removal: As a result of slag build-up, fume extraction is restricted and sediment accumulates on the plates; this must be removed manually

Part preparation for painting: Making sure parts and plates have a 2–3 mm corner radius

Paint removal for weld preparation: Ultra high-solid paints used in modern shipbuilding can produce toxic fumes when heated and must be removed prior to welding

Pre-Paint preparation: Sandblasting to remove rust

Skilled labor shortage

A high turnover rate means shipbuilders are continuously having to find and train new workers, an extensive and inefficient process that adds considerably to labor costs, and negatively impacts quality.

Given the pressing need to meet tight production deadlines, training programs are seldom as thorough as they should be. This creates another bottleneck. It takes time and experience to learn many of the shipyard "arts," particularly cutting and welding, and inexperienced operators are more likely to produce more parts that are out of tolerance or that require additional secondary operations such as grinding.

Cost containment

Every mature industry is under market pressure to reduce costs – to "do more with less" – and shipbuilding is no exception. In view of the issues discussed above, there is little additional room left for economizing without compromising quality – not an option in a heavily regulated and highly competitive market – or adopting new manufacturing strategies.

Automation is one such strategy that can reduce manual labor costs, while also increasing throughput, consistency, and quality. While a mainstay of many other heavy manufacturing operations, automated cutting and welding tables are either not used to full advantage in many shipyards, or their benefits are dissipated by other process inefficiencies.

Ergonomic improvements, as mentioned earlier, can help to reduce injuries, with a corresponding decrease in healthcare costs.

There are two aspects to identifying operational inefficiency. On the positive side, it can represent a huge opportunity for improvement. Given that virtually every operation in the plate-to-assembly value chain is repeated thousands of times every day, even small enhancements in material handling, cutting and welding procedures can result in considerable cost savings over the course of a build.

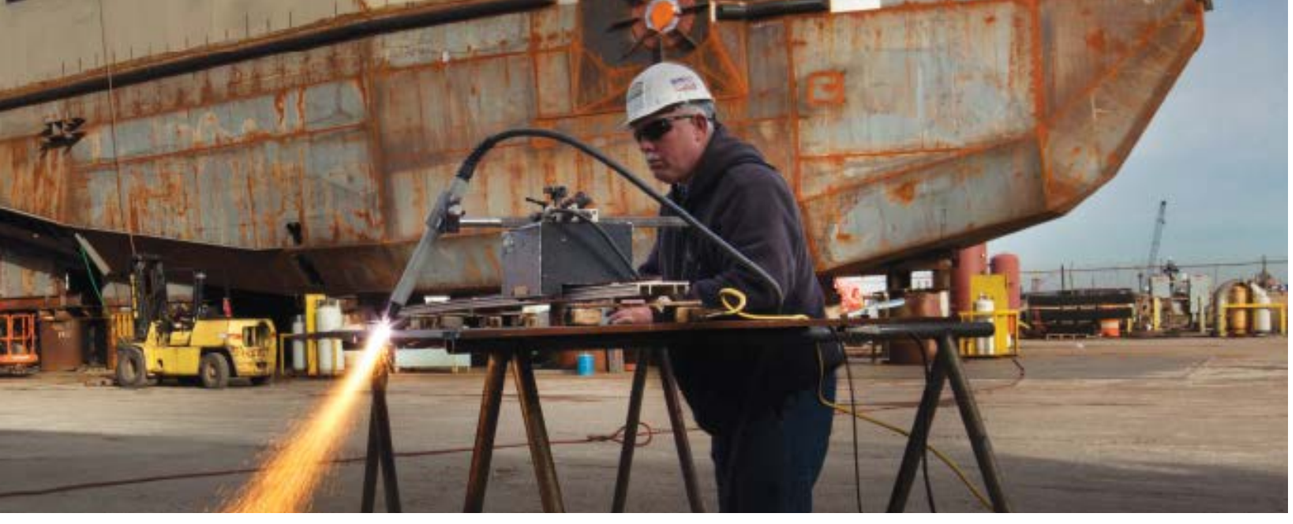


Figure 7.
Track burner performing bevel cut on steel plates.

Incremental improvements: Overcoming challenges and eliminating pain points

By making small changes to how work is done in the most common applications, shipbuilders can address the primary areas of manufacturing excellence – safety, productivity and cost containment.

Skeleton removal

Depending on the thickness of materials, shipyards cutting on oxyfuel tables can benefit from plasma skeleton removal.

Enhanced safety

- Cutting the skeleton into smaller pieces makes it easier for the operator to handle, reducing the likelihood of accidents or injuries
- Extended-length plasma torches let the operator stand next to the table in a natural position, preventing ergonomic issues and minimizing the likelihood of mishap; no bending over, and no need to kneel or stand on the table
- For operations currently using oxyacetylene torches to cut skeletons, switching to plasma makes the workplace safer by eliminating hazardous gas cylinders that can be difficult and dangerous to handle

Improved productivity

- Productivity increase up to 75% or greater (calculations based on 12 mm (1/2") mild steel thickness and standard industry data)
- Quicker unloading of the skeleton means more CNC table uptime and increased throughput
- Reduced training time; operator certification in 4 hours vs. up to 40 hours for oxyfuel

Bevel cutting

Many shipyards start their parts cutting on mechanized CNC tables, followed by bevel cutting for weld preparation using an oxyfuel torch on a carriage that follows along the edge of the plate. These edges typically require additional grinding to clean up rough spots and prepare the edges for welding – a time-consuming, labor-intensive process.

Enhanced safety

- Improves operator comfort, eliminates the use of combustible gases and subsequent risk of fumes, and reduces fire hazards
- Lessens the chance of vibration-related injuries, as well as noise and ergonomic issues, by reducing post-cut grinding
- Reduces injuries from rework, which often must be done in a non-standard manufacturing environment

Improved productivity

- No preheating required
- Significantly reduced material handling and floor space requirements
- Better cut quality within tighter tolerances reduces the amount of grinding required
- Faster cutting speeds – up to 30 ipm, 2–3 times faster than oxyfuel on 20 mm (3/4") mild steel
- Lower operating costs than oxyfuel – as much as 5 times lower

Temporary attachment removal

To aid in handling heavy plates, shipyards use temporary attachments for lifting eyes/lugs, work platform/ground attachments, stud weldments, and to stabilize subassemblies and parts during the manufacturing and assembly phase, oxyfuel or carbon arc gouging are the usual methods for cutting off these temporary attachments, as well as washing away any remaining material; additional grinding is then required to achieve a flush finish.

Plasma requires less overall pre-processing time than oxyfuel – no gas setting, purging or preheating – increasing the efficiency of the operation, and reducing the risk of heat-induced distortion.

Enhanced safety

- Eliminates the use of combustible gases and subsequent risk of explosion or fire
- Lessens the chance of vibration-related injuries, as well as noise and ergonomic issues, by reducing post-cut grinding
- Quieter and cleaner than carbon arc gouging, improving the overall industrial hygiene of the yard
- Reduces injuries from rework, which often must be done in a non-standard manufacturing environment

Improved productivity

- Productivity increase up to 70% or greater (calculations based on 12 mm (1/2") mild steel thickness and standard industry data)
- Smaller heat affected zone allows closer cutting without damage to the base metal, requiring less post-cut grinding and quality control steps, and maximizing reuse of attachments
- No preheating and faster cutting speeds speed up attachment removal – typically by as much as 50% over other methods
- No additional workers are needed to monitor hoses for gas leaks

General hand-held cutting

Many shipyards use hand-held or semi-automated oxyfuel torches for portable cutting applications during block fabrication, fit-up, and final structural assembly. Oxyfuel, while a familiar and generally reliable technology, has some significant drawbacks: it is time- and labor-intensive, introduces unwanted heat into the workpieces, and consumes expensive fuel gases. In addition, the use of combustible gases, especially in confined workspaces, represents a considerable safety hazard.

Replacing oxyfuel torches with plasma systems offers quantifiable advantages in cutting quality, speed of cut and set-up, as well as improving the safety of the yard.

Enhanced safety

- Eliminates the use of combustible gases and subsequent risk of explosion or fire
- Lessens the chance of vibration-related injuries, as well as noise and ergonomic issues, by reducing post-cut grinding
- Quieter and cleaner than carbon arc gouging, improving the overall industrial hygiene of the yard
- Reduces injuries from rework, which often must be done in a non-standard manufacturing environment

Improved productivity

- Productivity increase up to 70% or greater (calculations based on 12 mm (1/2") mild steel thickness and standard industry data)
- Better cut quality produces a better final product and minimizes the need for additional grinding or rework
- Smaller heat affected zone (HAZ) enables more precise cutting, requiring less post-cut grinding; reduced HAZ also minimizes the risk of plate distortion and the need for subsequent rework
- No preheating and faster cutting speeds speed – as much as 3 times faster, depending on metal thickness – dramatically accelerate the cutting process
- No additional workers are needed to monitor hoses for gas leaks
- Reduced training time; operator certification in 4 hours vs. up to 40 hours for oxyfuel

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