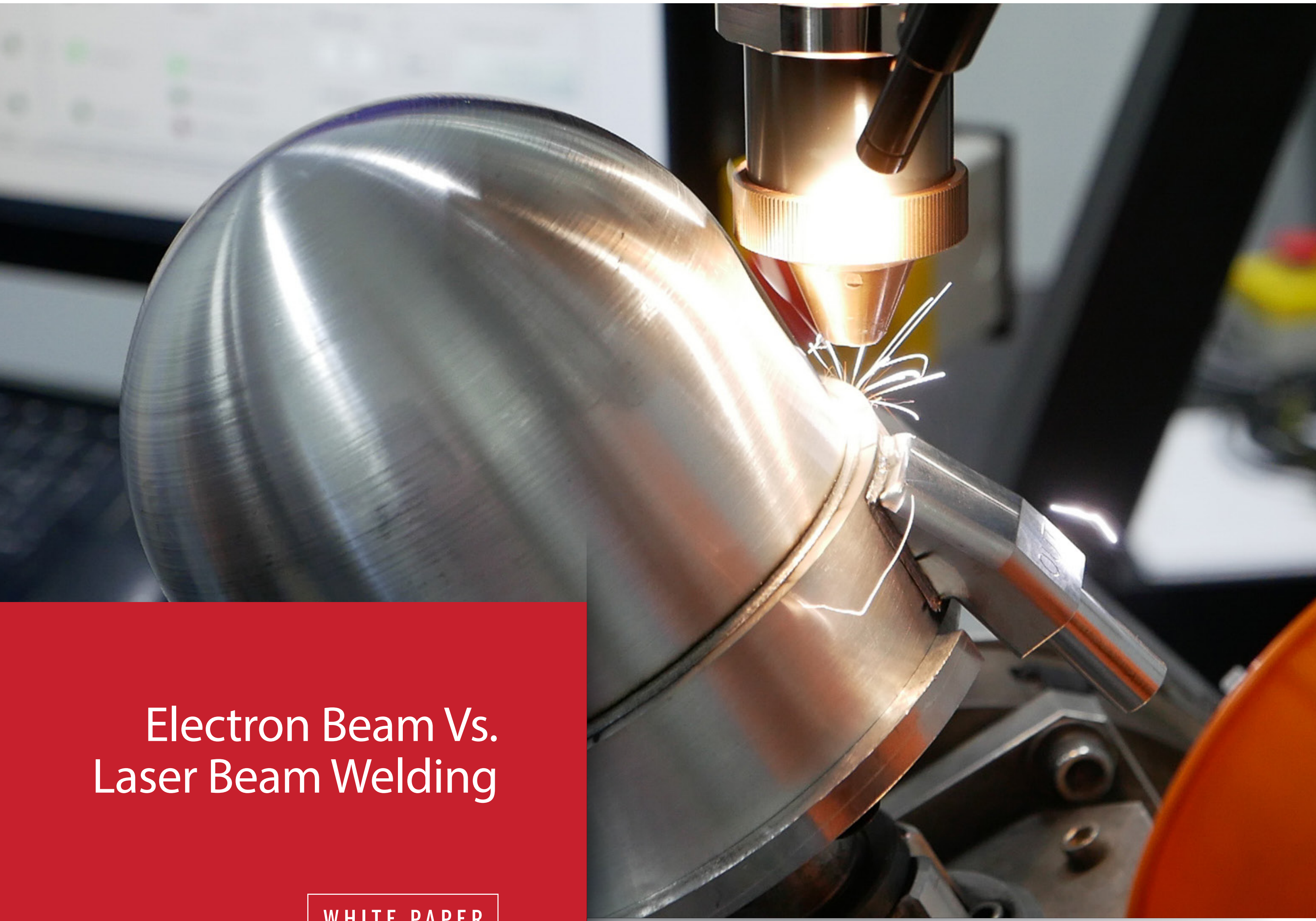
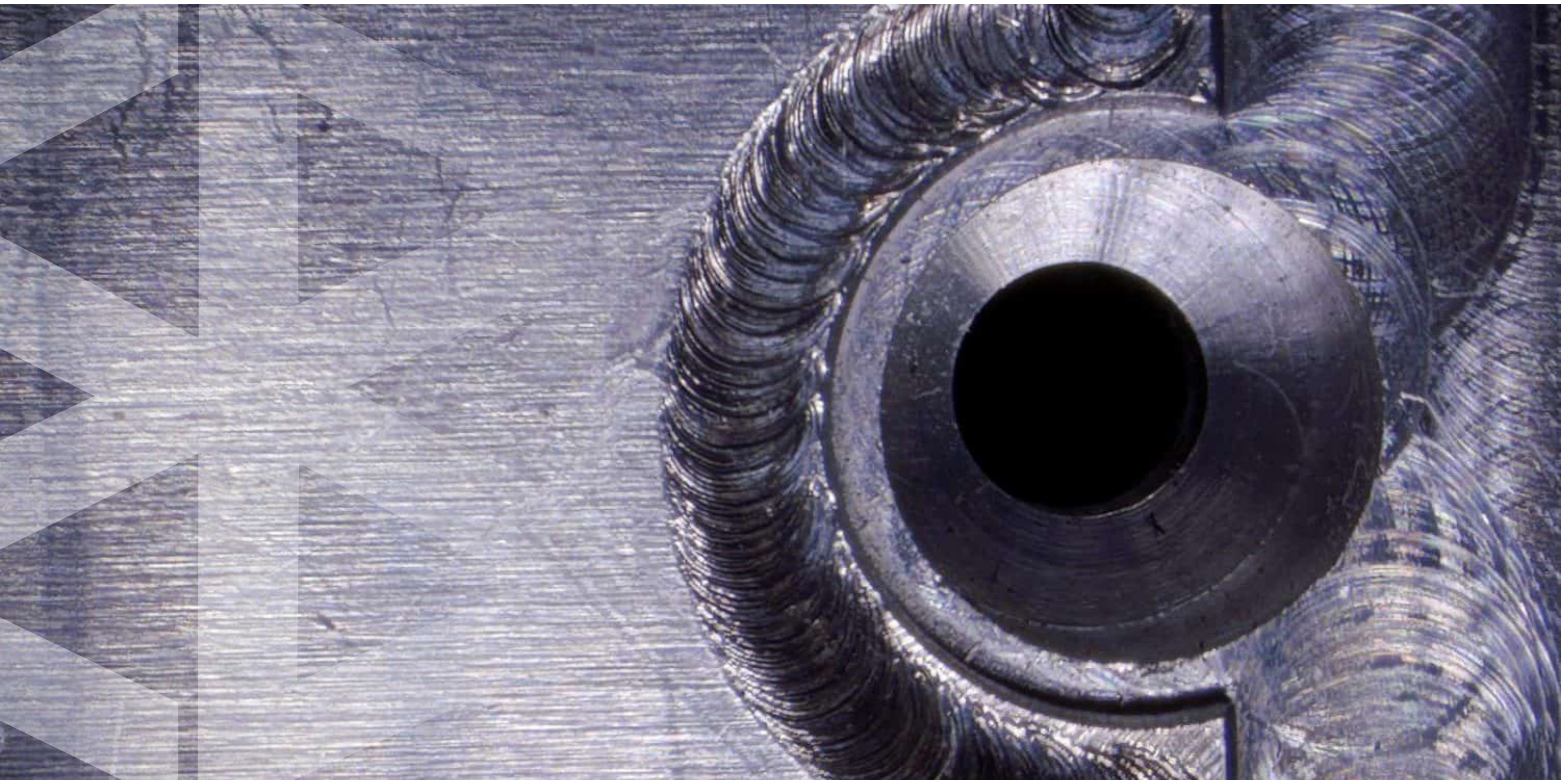
EB INDUSTRIES



Electron Beam Vs. Laser Beam Welding

WHITE PAPER



INTRODUCTION

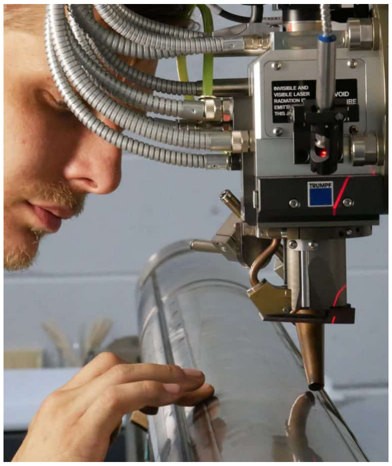
Electron beam and laser welding are fusion processes that can produce high energy precision welds in a wide range of metals, including exotic and dissimilar materials that are hard to weld by conventional welding processes. However, there are significant differences between the two. Based upon the industry specifications, materials involved, the weld joint design/purpose, and cost considerations, typically there is a clear choice when determining which process fits the application.

Other types of fusion welding, such as Arc, tungsten inert gas (referred to as TIG or GTAW), or metal inert gas (referred to as MIG or GMAW) might be an option, but if your requirement is for precision, energy efficient, deep yet narrow, pure (no filler material typically needed), welds, then electron beam (referred to as e.b.) or laser welding are often the best method of joining. Because the physical components that generate electron beams and laser beams can be CNC controlled, you have a highly repeatable, versatile joining technology capable of welding both the smallest of implantable medical devices, and yet also deliver the tremendous amounts of power required to weld large aircraft parts. These welds can meet or exceed all metallurgic, structural, or hermetic sealing requirements, while meeting all cosmetic/aesthetic needs that eliminates or reduces post weld machining. With proper planning and tooling, both processes can many times be more cost effective than conventional joining technologies.

Although e.b. and laser welding both deliver high energy precision welds, they significantly differ from each other in terms of underlying physics and functional operation. It is in these differences that one process might have an edge for a particular application. Let's explore these differences by digging deeper into each technology.

The power delivered by an electron beam can be massive—up to 10,000 kW/mm3. In fact, an electron beam welding system can throw enough power to simply vaporize metal (a process called electron beam machining). EB welding machines generally come in two power classifications: low voltage (60 kV); or high voltage (150 kV). A typical high-voltage machine rated to 15,000 watts can produce a weld in steel 3 in. deep with a width of approximately 10 percent of the penetration depth.

The environment of operating an e.b. welding system is particular. The electrons can only be accelerated in a high vacuum; otherwise, air/gas particles scatter and diffuse the electrons. A vacuum requires a vacuum chamber, so the size of a part to be welded is limited by the size of the chamber. This is a major consideration when electron beam welding. Vacuum chambers can be small or large, but the larger the chamber, the longer it will take to establish the proper vacuum level, which is typically (per aerospace specifications) at a minimum 1.0 x 10-3 torr. The use of a vacuum, as well as the presence of X-radiation (a byproduct of the beam), precludes human handling, so the entire process must be externally controlled, generally using CNC tables. The collusion of all this technology—high voltage, vacuum, and high-tech automation—means that e.b. welding requires well-trained development engineers, operators, inspectors, and maintenance technicians. Electron beam technology is not for the faint of heart. High voltage machines can be in the millions of dollars, and the support to keep these machines running can be extensive, especially if you do not have in house personnel to get you up and running when delivery deadlines are hours away.



Since electron beam welded assemblies are not manipulated in the operator's hand, the part fit-up typically requires a precise fit between the parts being joined. Part designers should have some familiarity with joint design or get help from an experienced service provider. The success and quality of the final weldment will depend on it. Along with the joint design, proper tooling to manipulate the part within the vacuum chamber is critical. Not only to hold the part in-place or together, but tooling can act as a heat-sink to minimize shrinkage and warping by minimizing the heat going into the part. It can also be designed to shield and protect exposed wires and sensitive components of your assembly against vapor and weld splatter.

Although technology has evolved over time and more modern e.b. machines have routines and automated processes for set-up, an experienced engineer or operator is required for initial weld development. The electron beam must be generated, focused, and aligned at setup according to a weld schedule (log) to produce a desired result. It must also be synchronized with your weld feed rate (typically in a CNC program) to produce the width, depth (penetration), heat, and cosmetic finish on the surface you require.

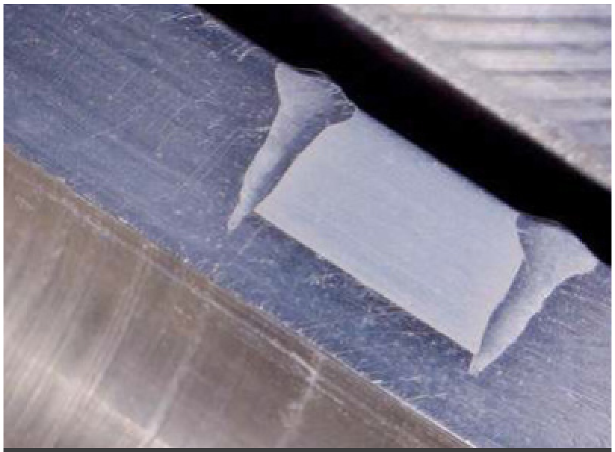
Once one cycle is complete and all parts in the chamber are e.b. welded, the technician or operator unloads the welded parts for inspection and loads another batch until the desired quantity (lot) is complete.

This points out one clear disadvantage of electron beam welding, and that is the need to run in a vacuum chamber. With pump down times (the time from atmosphere to ready to weld vacuum) being from 30 seconds (small chamber) up to over an hour (large chamber), it is imperative that tool design engineers maximize the number of parts run per pump down and that CNC programmers and operators monitor the movement of the part to save costly time.

Electron beam welding systems can weld all weldable metals and some metals that are not typically welded. Electron beam welds are incredibly strong and pure. Impurities in the weld are vaporized, and welding in a vacuum means there are no gases or air to react and cause oxides.

Electron beam welding is a process of choice to join dissimilar materials that would otherwise be un-weldable due to differences in melting points, which result in intermetallic compounds that cause brittleness. The precise nature of the electron beam and tight heat-affected area allow e.b. welding to melt the lower-temperature material onto the un-melted, higher-temperature material, resulting in a homogenous weld.

ELECTRON BEAM WELDING



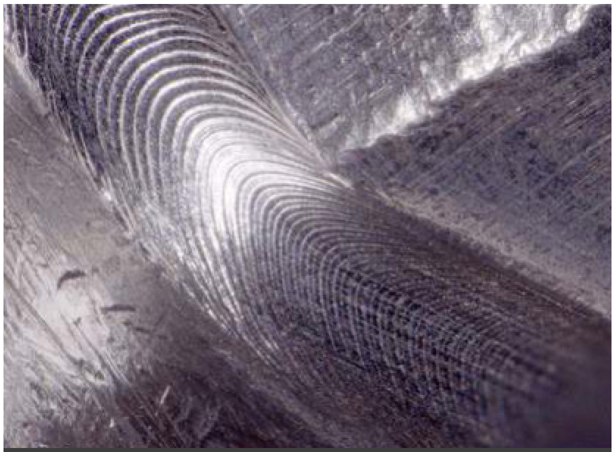
An electron beam cross-sectioned weld spike

Electron beam welding was developed in the late 1950s. It was quickly embraced by high-tech industries, such as aerospace, for the precision and strength of its resultant welds. An electron beam can be very accurately placed, and the weld can retain up to 97 percent of the original strength of the material.

To summarize the science of electron beam welding; free electrons flow through a tungsten filament under vacuum by accelerating the electrons with a high voltage power source. Their path is controlled through magnetic lenses that can deflect (move) the beam or control its shape by controlling its diameter by producing a narrow adjustable cone. By colliding the electrons with metal the kinetic energy is transferred into heat on the workpiece, thereby producing a weld.

"An electron beam welding system can generate power to vaporize metal."

LASER BEAM WELDING



A laser weld in stainless steel

Lasers were developed in the early 1960s, and by the mid-1960s CO2 lasers were being used to weld. A decade later automated lasers were welding on production lines, and the technology has found wide acceptance in many industries and continues to improve. Similar laser welding systems are capable of delivering a tremendous amount of energy very quickly and with pinpoint accuracy. The beam can be focused and reflected to target hard-to-access welds, and it can be sent down a fiber-optic cable to provide a more homogeneous weld (no hot spots).

A laser beam is generated by rapidly raising and lowering the energy state of a "optical gain material," such as a gas or a crystal, which causes the emission of photons.

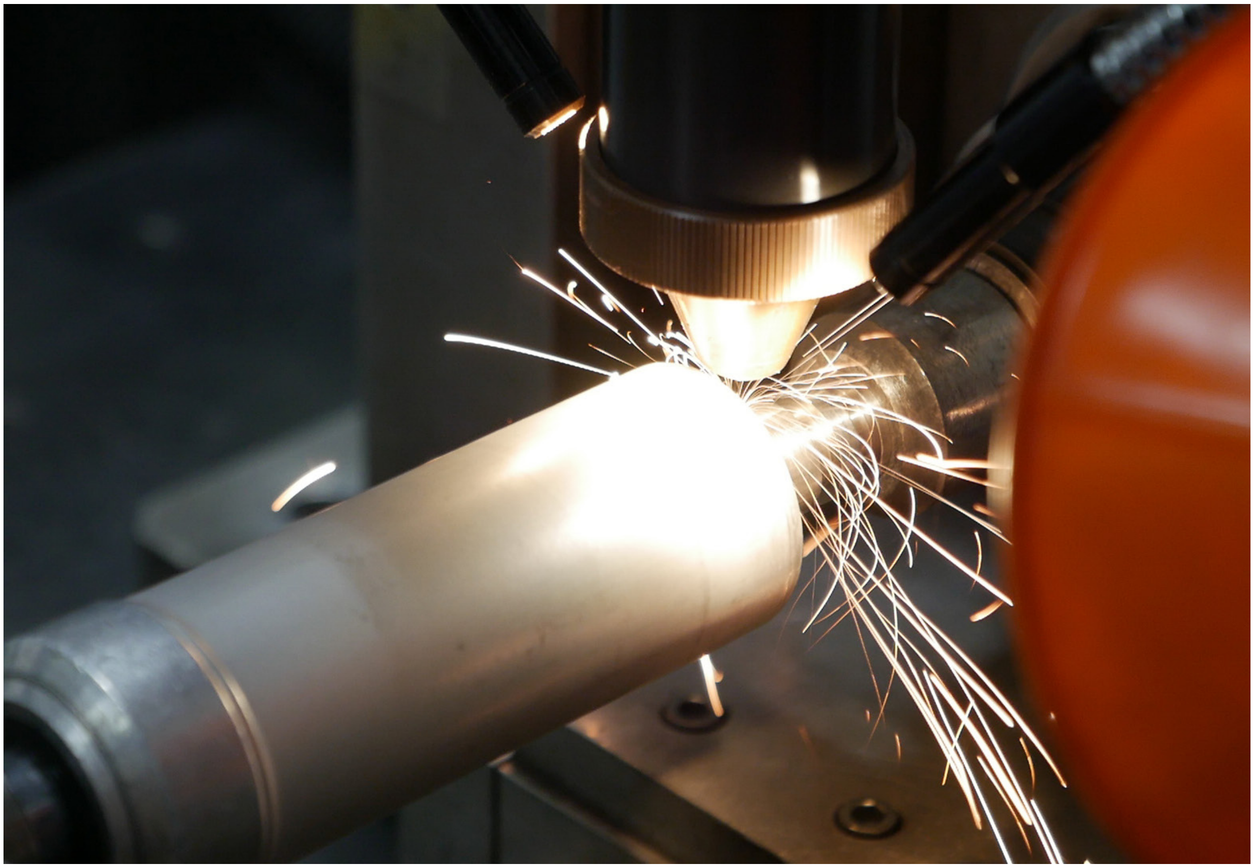
Regardless of how the photons are produced, they are concentrated and made coherent (lined up in phase with each other) and then projected. The photons are focused on the surface of a part, radiant heat "couples" with the material, causing it to melt via conduction. Since the heating of the material starts on the surface and then flows down into the material, the depth penetration per unit of power in a laser weld is less than that of an electron beam weld. The majority of power of a laser weld is wasted on heat and reflected off the surface. To overcome this problem, the laser can be pulsed— varying the power of the laser over time during the weld cycle. By pulsing the laser at high peak powers, the average power can be a fraction of the peak power and the part stays cool, and on highly reflective materials such as copper and aluminum, the peak power is used to "break" the surface and cause weld coupling.

The power output of a laser can vary from a few watts to hundreds of kilowatts, and different types of lasers have different welding characteristics. As an example, the wavelength of the light produced by the laser can make it more suitable for some applications and less for others.

Laser welding generally requires the use of a cover gas to keep oxygen out of the weld area and improve efficiency and weld purity. The type of gas used depends on the type of laser, the material being welded, and the particular application. Some laser welding applications may require a glove box to assure complete gas cover gas when a gas nozzle may not be able to reach areas of a part with complex geometry.

Over the past few years work has been done with laser welding in a vacuum. This method has yielded some positive results, but the cost and complexity of such a system steers many back to the electron beam welding process where vacuum is an ideal environment for the weld efficiency of accelerated electrons.

The alternative to pulsing is continuous wave (CW). As the name implies, CW lasers utilize a laser beam that is on continuously—from the start to the end of the weld cycle. CW lasers are useful for cutting applications or when weld speed is important. For example, an automated GTAW machine might have a welding speed of 10 inches per minute (IPM), while a CW laser could easily run at 100 IPM. When laser welding, high feed rates for CW is necessary in order to keep the part cool, so heat parts often use pulse welding when possible. This makes them a good choice for welding electronics packages, particularly those that are hermetically sealed. Minimal heat means the weld can occur extremely close to sensitive electronic components and solder joints without melting them. Lasers are also popular for medical device applications as the welds can be tightly controlled and consistent which leads to minimal discoloration of the part, and a cosmetically good looking weld that may not need post machining.



Weld Process			
	Electron Beam	**Laser**	**Conventional / Manual**
Typical Weld Cost	$$$	$	$$
Size restrictions	Limited to vac chamber size	Workstation dependant	None if done manually
Dissimilar Metals	Excellent	Good w stir welding	Challenging
Magnetic Materials	Challenging	Excellent	Process dependant
Depth (max penetration)	3 inches	1 inch	Shallow without multipass & notch
Width to Depth ratio (min w/d%)	Extraordinary (10%)	Excellent (25%)	Poor (various)
Heat Generated	Low/medium	Low (pulsed) / High (CW)	High
Purity (no electrode/filler)	100%	100%	Limited based on process
Repeatable	Highly with CNC	Highly with CNC	Limited / manual without CNC
Hard to reach area	Excellent	Good - gas coverage concern	Limited
Capital Investment (barrier to entry)	$$$$$	$$$	$

SO WHICH PROCESS TO USE?

Which process is best usually depends on the particularities of the application.

Electron beam welding was an accepted process in the aerospace industry before lasers were available. As a result, the specifications for e.b. welding for aerospace parts are complete and widely accepted. These specifications control all aspects of the process, including joint design, cleaning, vacuum requirements, machine qualification, operator training and inspection criteria.

The medical device field has embraced laser welding. Although there are much fewer standard medical device welding specifications, large OEMs usually define their own. Without the requirement for vacuum, laser welding is generally less expensive than electron beam welding, and the parts are easier to tool and fixture without chamber.

Other assemblies may have specific requirements that will dictate the process to use. By working closely with an experienced weld or development engineer it is critical to get it right. Choosing the right process, and the right equipment and service provider to help tool and develop the process, is usually the difference between success and failure.

For further assistance with an experienced weld engineer that finds a solution that meets your application requirements, please call us at (631)293-8565. We're here to make your work easier.

ABOUT EB INDUSTRIES

EB Industries delivers on-time precision welding solutions that exceed expectations for quality, technical innovation and customer service.

If you're looking for the best precision welding technology, trust in EB Industries for electron beam or laser welding solutions. With six decades of pioneering welding technology, we consistently deliver precision welding, cutting and processing services designed to make your work easier and schedules tied to when you need it, not when we can do it.

EB Industries offers a wide variety of capabilities that when taken together no one else in the market provides. We offer the advanced technical expertise to solve even the most difficult welding challenges and materials even on exotic materials: titanium, molybdenum, beryllium or dissimilar metals together such as copper to stainless steel.

Our certifications offer the assurance of dependable weld quality, including certifications to AS9100D, ISO 9001:2015, ISO 13485 as well as NADCAP certification for welding.

Find out why we achieved a perfect 100 Net Promoter Score, based on our commitment to the four pillars of the EB Pledge: Trusted Partnerships, Accountability, Technical Innovation and Expertise and Service and Support. Learn more at www.ebindustries.com.