Electron Beam welding process
The principle of electron beam welding is relatively simple: electrons are accelerated by a high difference electrical potential and concentrated on a target. The electron’s kinetic energy is then transformed, for the most part, into thermal energy melting the metal and producing welds.

**The electron emission**
Some materials such, tantalium or hexaboride of lanthanum allow to get an appropriate quantity of free electrons when they are heated up to a high temperature, and are used for emissive gun elements manufacturing.

Inside electron guns these emissive elements can be heated up by two different modes:
- direct heating by joule effect,
- indirect heating by use of an electron bombardment from a filament.

**Vacuum environment necessity**
The emissive element and the electrodes are placed in the gun. The piece to be welded is located in the welding chamber.

Since the collision of free electrons and gas molecule which would induce beam dispersion and a decrease in the carried power density, the gun and the piece to be welded are vacuum pumped.

The dimension of the welding chamber depends on the dimension of the parts to be welded with its positioning equipment and can vary from few litres up to few ten m³.

**The electron acceleration**
In order to be extracted from the surface of the emissive element, the free electrons need to be submitted to a strenuous electrostatic field. The potential difference between the emissive element (cathode) and the opposite electrode (anode) allows to create this field, which accelerates the electrons by giving them a kinetic energy.

**Electron Beam creation**
In the inter-electrode space, the electrodes geometry defines the electron trajectories. First, the electron beam converges in the anode drilled in its center.

Then, the beam continues by inertia and diverges. In order to be used for welding, the beam is focused by an exciting coil placed in the gun. The focus length is set up by current adjustment inside the focusing coil.

![Diagram of Air Liquide Welding indirect heating gun](image_url)
Since the beginning of the Electron Beam Welding process 40 years ago and its first dedicated application; the welding of tubular fuel elements of nuclear cells; Electron beam welding has since being used world-wide and its range of applications extends from welding thin foil to workpieces with walls over 100 mm thick.

**Electron Beam process**

The electrons are small particles of matter with small mass. When they are accelerated they hit the piece transferring their kinetic energy into thermal energy ensuring metal melting creating plasma of metallic vapours.

The E.B. welding process is a high energetic process allowing to use very high power up to ten’s of kW on small surfaces of 5/10 of mm diameter. However, the total heat input is actually much lower than that of any arc welding process.

- 13% chrome steel
- 20 mm thickness
- One pass penetration butt welding
- Welding speed 1 m/min
- Power 10.3 kW

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**Principals advantages of the electron beam welding process:**

- **very small deformations** after welding,
- **very thick materials** (exceeding 60 mm with steel) in **one pass**,
- possibility to weld all the **steel, copper, nickel** materials, **aluminium**, metals sensitive to oxygen and other gases as **zirconium, titanium**…
- **no filler metal** and **no gas**,
- **high welding quality**. The welds obtained are **exceptionally pure**,
- **high reliability**,
- **high reproducibility**,
- **high productivity**.

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**2 strips stainless steel of 0.1 mm thickness**

**Overlapping welds**

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**Zirconium Zr2 of 10 mm thickness**

**Fillet weld**

**Total penetration 14.2 mm**

**Welding speed 1 m/min**

**Power 7.2 kW**
Air Liquide Welding answer: Electron Beam welding equipment

A large range of solutions

The specific chamber, tools and vacuum system have to be defined according to the piece characteristics and the needs in term of quality and quantity.

For that, we will define jointly your specific requirement in term of:

- piece characteristics with drawing and especially joint definition,
- grade steel (chemical composition),
- the required quantity (pieces/hour),
- criteria of acceptability.

Air Liquide Welding offers:

- In term of production rate some Turn tables to load in masked time, robot for handling...
- In term of process quality, Recorder, Video control (process), Beam deflection.

Thanks to our experienced teams, we can respond to yours specifics need.

Central system control by CNC

Based on its long experience, Air Liquide Welding developed a specific software dedicated to the E.B.W process which controls the overall machine operation. Through a C.N.C, it manages:

- The operation cycle,
- The vacuum system,
- The numerised axis,
- The main parameters through the E.B. Generator.

A control panel will receive the general controls of the machine (Automatic cycle start/stop, welding chamber venting…) and can on demand be modified to accept the specific control required by the customer.

A very useful remote control box permits to modify the current of the focalisation and the current beam closed to the welding chamber. Thus, through the viewing window, it makes easier set up of welding parameter.
Intensive working for over 35 years in industries

All our E.B generators are low voltage triode gun. It gives many advantages as:

- A beam a little bit thicker and consequently a much larger tolerance in the preparation of the edge to be welded.
- Low emission of X rays parasite.

Moreover, our solid cathodes are heated indirectly and are made from W in some case (Zirconium welding) and more generally in LaB6 material. These last materials present the characteristic to work at low temperature compared to other materials such as W or Ta. It offers a very long life from 1000 hours up to 2000 hours in comparison with the common consumable parts of industrial electron beam generator. Moreover, the electrodes have a short coupling. It confers to the gun a very good stability of electronic trajectories and a good repeatability of the impact position.

ST Standards series: autonomous E.B generator

Air Liquide Welding proposes a large range of autonomous electron beam welding generator from 6 kW - 45 kV to 100 kW - 100 kV made up of:

- Our triode gun with indirect cathode heating,
- Our high voltage resonance power supply assembly with oil free and auxiliary tank,
- A high voltage cable with low capacitance.

An electrical cabinet with all the control loop of the process, a P.L.C, and a control box to set all the fundamentals E.B.W parameters.

Thus, our E.B.Generator can work alone or under control of our C.N.C. In this way, the maintenance is made easier and on the other hand, we can on demand realize refurbishment on existent machine.
Think different: Think Electron Beam welding

A new fashion to design your pieces
The wide range of energy density of the electron beam allows to readily obtain sound welds, presenting satisfactory mechanical characteristics and almost without any deformation, on materials for which a conventional welding process would be extremely complex, or even impossible, to perform:

**100 mm thickness titanium butt weld**

**Fillet welds of stainless steel**
**Total penetration without deformation**

**Integral machined piece**

**Cost Reduction**

**The same piece welded by E.B.W**

Up to 2 pieces welded by minute possible on this kind of application.
Electron Beam welding activity

Air Liquide Welding is part of the Air Liquide group the world leader in industrial and medical gases and related services. The group offers innovative solutions based on constantly enhanced technologies to help manufacture many indispensable products and preserve life.

Air Liquide Welding experience

The electron beam welding installations offered by Air Liquide Welding is the result of the integration of the technologies developed and the experience gained from our industrial achievements over the last thirty five years in electron beam technology.

Air Liquide Welding has many more references in electron beam welding in technological environment known through the trademark SAFMATIC as varied as:

- aeronautics,
- mechanic, hydraulic, pneumatic components,
- motorcar automobile,
- nuclear,
- boiler construction.

Consequently the elements of our installation have already met the many functioning criteria required in those demanding industrial contexts.

The optimization of technical characteristics due to those different applications has lead to a high level of stability and reliability which is well appreciated by our Customer.

Electron Beam welding workshop

Project feasibility and small size production

Our means of production and our means of control are at your service for prototypes and small quantities production.

<table>
<thead>
<tr>
<th>Machine</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 kW maxi. Controlled by micro-computer</td>
<td>Enclosure: 24 dm³ Controlled axis for radial welding</td>
</tr>
<tr>
<td>10 kW maxi. Controlled by micro-computer</td>
<td>Enclosure: 900 x 400 x 400 Controlled axis for axial and radial welding</td>
</tr>
<tr>
<td>6 kW maxi. Controlled by micro-computer</td>
<td>Enclosure: 520 x 410 x 460 Controlled axis for axial and radial welding</td>
</tr>
</tbody>
</table>

Benefit from the research department of Air Liquide Welding

Our research and development team is composed of more than 140 persons working to develop innovative solutions in:

- metallurgy,
- health and safety,
- productivity,
- gas, equipment,
- consumables and tool combinations.

Innovation is a state of mind for the group employees. This is clearly illustrated through the many patented inventions developed by our researchers in the CTAS (Technical Centre for Welding Applications) the largest private research centre for welding and cutting technologies.
Founded in 1902, Air Liquide is the world leader in industrial and medical gases and related services. The company has offices in 75 countries and employs a workforce of 43,000. Drawing on constantly renewed technologies, Air Liquide develops groundbreaking solutions used in making countless everyday products and in helping to preserve life.