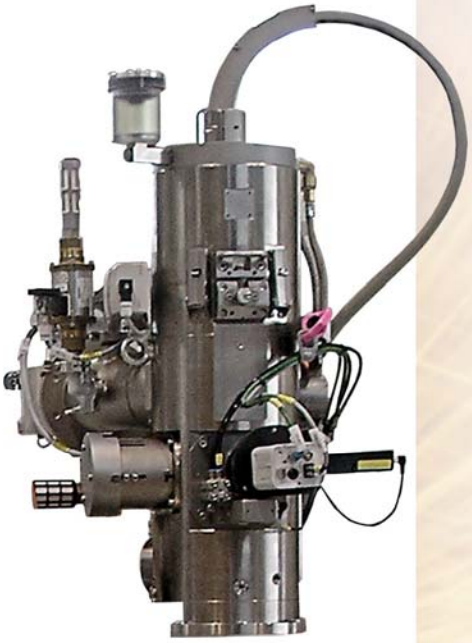
EBOGEN

GLOBAL Beam Technologies AG



PTR PRÄZISIONSTECHNIK GMBH

SST STEIGERWALD STRAHLTECHNIK GMBH

PTR PRECISION TECHNOLOGIES, INC.

Electron Beam Technique

Precise tools for material processing

BEAM TECHNOLOGY *WORLDWIDE*

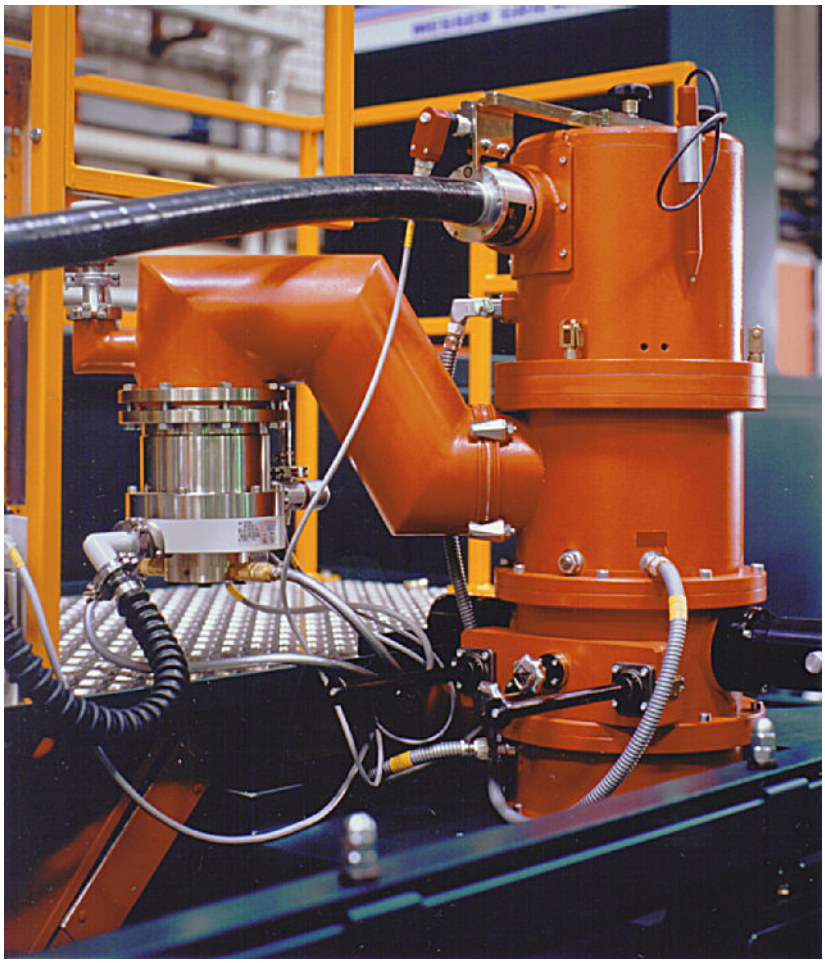
Quality produced by means of electron beam

EB-generators by
Steigerwald Strahltechnik
tradition and innovation

In material processings Steigerwald Strahltechnik has been well known for its production and application of electron beam installations (EB-installations) for more than 40 years. Among experts, the so-called "Steigerwald gun" has become a traditional hallmark of quality.

As a series of products with a power range from 3 to 60 kW the EB-generators by Steigerwald Strahltechnik offer the following advantages:

- fast exchange of cathodes including evacuation within a max. period of 10 minutes without realignment
- spot position accuracy better than ± 0,1 mm even after the exchange of cathodes
- separate high-vacuum system (better than 10^{-4} mbar) for the beam generation section
- pressure throttle between beam generation system and working chamber column valve for sealing off the beam generation section against the
- working chamber while venting the chamber
- high-resolution telescope eyepiece, axis of vision nearly parallel to the beam axis
- high-voltage connector without oil isolation
- precise control of high-voltage, beam current and lens current (focal position) through modern semiconductor technology
- beam deflection into two axes, in addition to many standard functions
- CNC-controllability, e. g. of high-voltage, beam current, lens current and all beam deflection parameters
- beam modulation and pulse mode
- easy maintenance

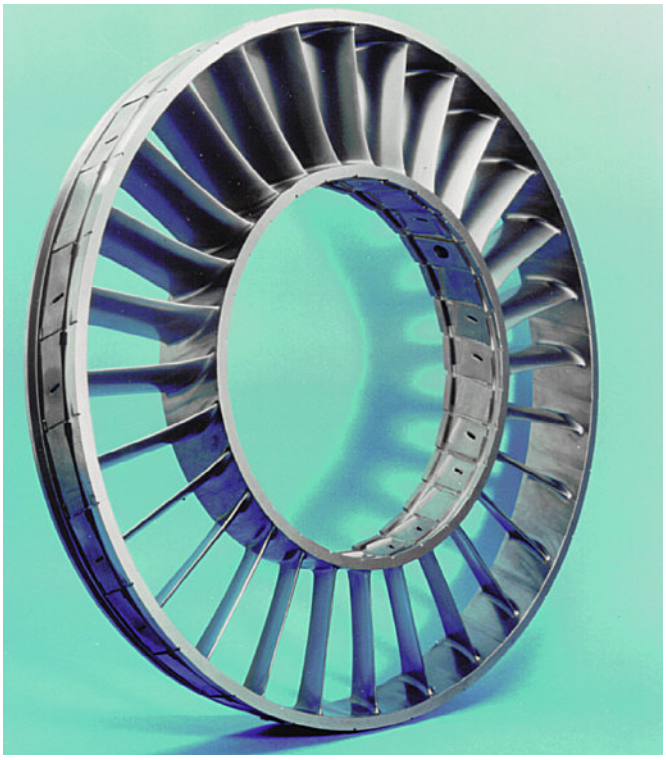


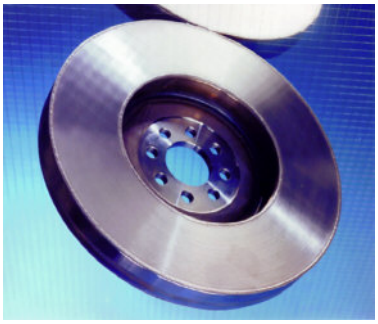
EB high-voltage generator (P47.10.16i/16)

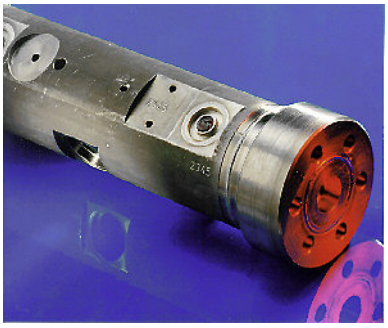
Steigerwald Strahltechnik -
high performance
through experience and success

Electron beam technology is a modern tool. We certainly base the decisions concerning the application of electron beam technology on economic analyses.
Due to its advantages electron beam technology allows special technical solutions, especially as regards material combinations and constructive design, but also with respect to the order of processing and mounting steps.

For the industrial application of welding, surface treatment (hardening, surface remelt and alloying techniques) and drilling Steigerwald Strahltechnik offers beam powers from 3 to 60 kW.







Welding examples (47.10.07b) (47.43.16a/12) (47.20.06a)

Criteria for evaluating the EB-quality

Beam quality:

The symmetrical power density distribution with high peak power in the beam centre, a low-tolerance stability of the electrical supply system and the proven mechanical construction play a decisive factor for the beam quality.

Spot position accuracy:

The position of the focused beam relative to the machine co-ordinates must be independent of the operating conditions.

Economical background:

Through its great reliability and easy operation the solid but precise mechanical construction is to ensure lower operating costs at optimum processing conditions.

Low-voltage generators up to 70 kV

Acceleration voltages of 70 kV are characteristics for the so-called low-voltage generators.

The fact whether certain production methods can be applied for specific weldments and economic advantages, such as for example low-priced high-voltage supplies and x-ray protection without lead screenings, determine the use of low-voltage generators.

Here, the maximum usable working distance is up to 800 mm according to the type of generator.

High-voltage generators up to 150 kV

Generators using acceleration voltages up to 150 kV are called high-voltage generators. They offer the following technical and economic advantages for the user:

- higher power density in the focus, which means a lower beam diameter in the focus. This results in narrower welds and a greater penetration depth
- greater working distance up to 1,500 mm. Due to the higher speed of electrons the power density even for greater working distances is higher than for low-voltage generators, as the focus diameter is smaller
- reduced magnetic deflection. Resident magnetic fields, residual magnetism in workpieces or in clamping devices deflect the electron beam from its planned direction.
  The beam deflection through magnetic fields of interference at an acceleration voltage of 150 kV amounts to only halve the value of that of 70 kV.

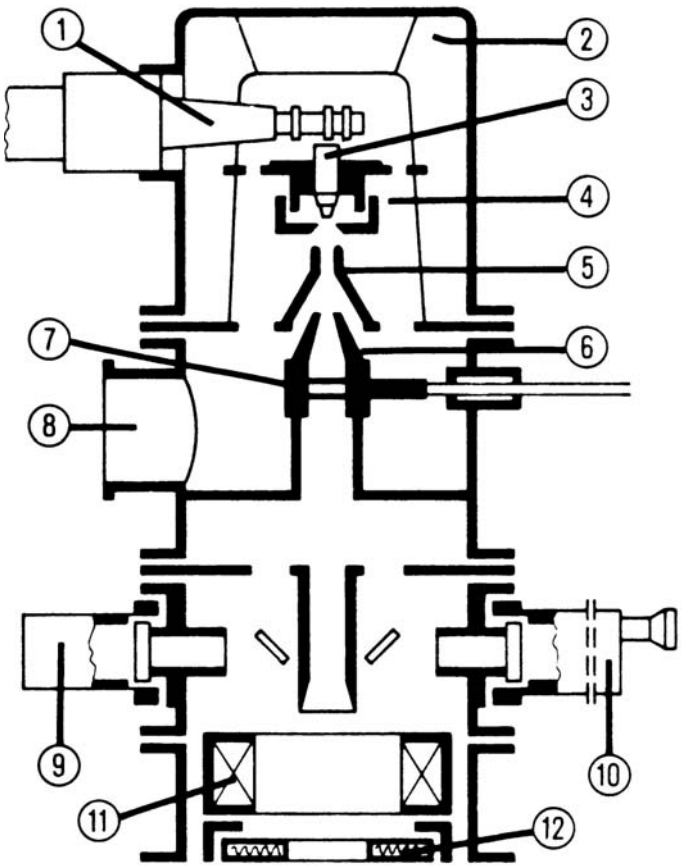
Electron beam generation - the high-tech heart in the EB-generator

The principle, focusing and directing the electrons

The beam is produced and controlled by the EB-generator within the triode system (see illustration). The electrons emerge from the cathode consisting of a Tungsten filament which has been heated to approx. 2,500 °C. The direct heating of the Tungsten filament ensures trouble-free operation.

Voltages of up to 150 kV between cathode and anode accelerate the electrons towards the workpiece. They move at up to 2/3 the light velocity through a bore in the anode. The electrons "hit" the workpiece with a certain energy that corresponds to their speed.

A Wehnelt cylinder is arranged between anode and cathode, which is used as control electrode. By means of a voltage of up to 2,000 V with reference to the cathode potential the beam current is varied from its maximum value to zero, while the acceleration voltage applied is not altered.
An electromagnetic lens focuses the diverging electron beam.

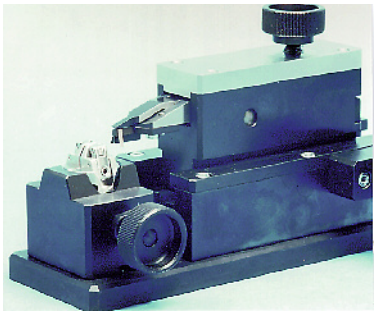


Schematic drawing of an EB-generator

AE① *High-Voltage plug-in connection*
② *High-voltage isolator*
③ *Quick-change filament cartridge*
④ *Bias (Wehnelt) electrode* ⑤ *Anode*
⑥ *Vacuum throttle* ⑦ *Column valve*
⑧ *Vacuum flange* ⑨ *Illumination*
⑩ *Telescope* ⑪ *electromagnetic lens*
⑫ *Deflection system*

Focal point

By changing the lens current the distance of the focal point from the lens may be altered to a great extent. In practice the working distance from the generator to the workpiece is determined by the lens current. By means of an electromagnetic deflection system with 2 independent coil systems the electron beam can be deflected in any direction in the x/y-plane.



Loading device for filament (47.10.07g)

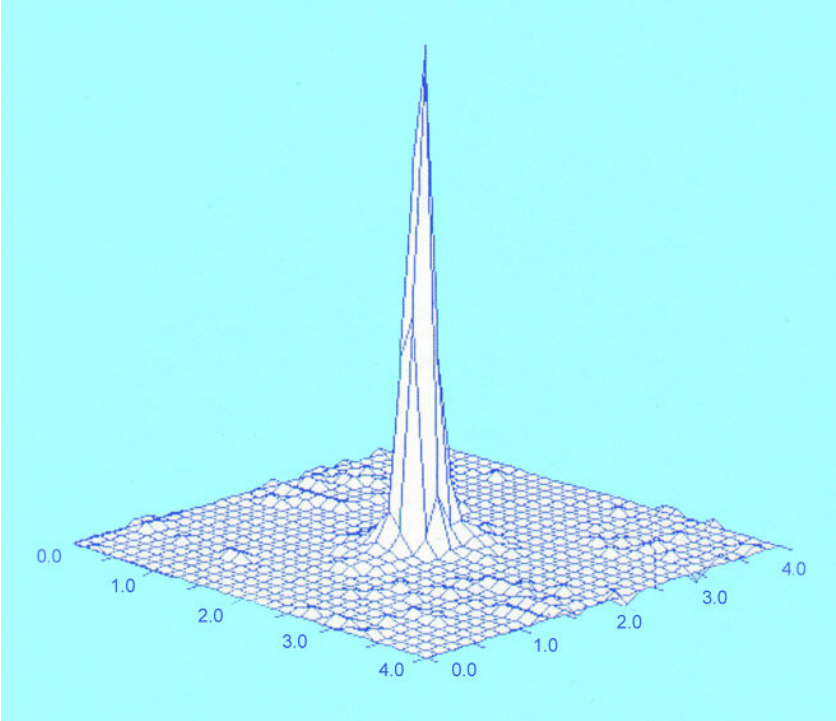
Mounting tool for filament cartridge (47.10.07f)

The structure of an EB-generator and its technology

EB-generators of Steigerwald Strahltechnik are made up of modular units. The modular concept enables standard sub-assemblies to be exchanged for specialized ones. This may, for instance, be the case for generators for very fine weldments of bimetallic sawband material.

Beam generating system:
The beam generating system itself consists of a triode system and is accommodated in the upper portion of the generator column. The metallic support for cathode system and Wehnelt cylinder is sealed into an insulating case made of high-voltage proof and temperature insensitive material.

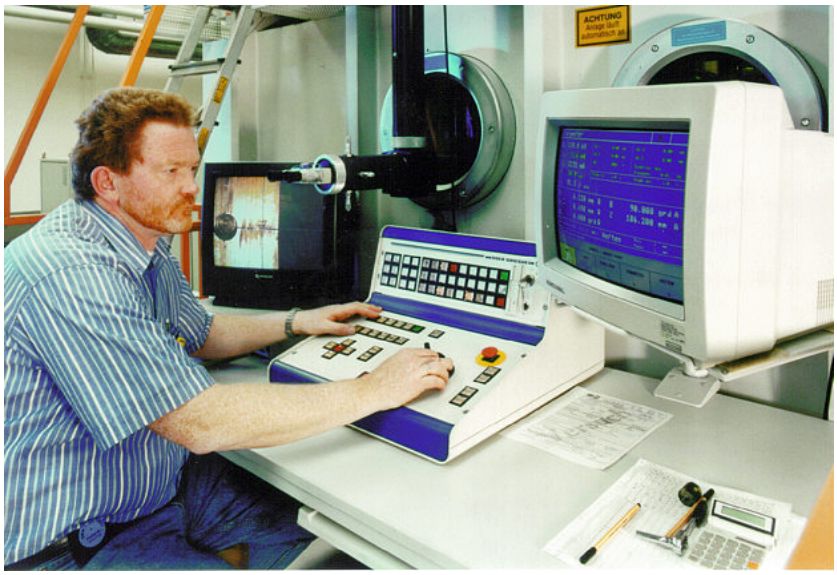
Selecting materials with optimized thermal expansion coefficients as beam source components ensures the accuracy of geometrical allocation, especially as regards cathode and Wehnelt cylinder.



Accelerating voltage U_B = 150 kV
Effective beam current I_A = 100 mA
Lens current I_L = 2,260 mA
Focus distance A_F = 500 mm

Density of beam power
L = 2.20 x 10^7 W/cm^2
Equivalent of beam diameter at 90%
beam Power d_{90} = 0.43 mm

Energy distribution of the beam of an Steigerwald Strahltechnik EB-generator



Binocular view coupled with TV-system (P47.10.18b/5)

Through fitting systems produced with high accuracy cathode, Wehnelt cylinder and anode are mounted in fixed positions with reference to each other.

Even after an exchange of the cathode or after cleaning individual components the exact position can be reached again without any realignment. The performed Tungsten filament is installed in the filament cartridge in a way, which allows an easy replacement.

With the aid of a loading device the filament exchange is a matter of few seconds only. The filament cartridge may also be replaced within one minute by means of a special tool.

Vacuum unit:

Below the beam generating system is the vacuum section of the generator column. This unit comprises the pressure throttle, the column valve and the pumping unit.
The column valve is automatically closed before the chamber is vented and opened after the predetermined vacuum in the chamber has been reached. The pressure throttle prevents complete pressure compensation between the beam generating section and the chamber.

The high-vacuum is thus maintained in the beam generating section independent of the pressure in the working chamber (soft-vacuum of approx. 5 x 10^{-2} mbar or high-vacuum of approx. 7 x 10^{-4} mbar). It is this principle that guarantees the excellent flash-over resistance of EB-generators of Steigerwald Strahltechnik.

Viewing system:

According to the generator type there are various types of viewing systems in order to be able to watch the workpiece during the welding process immediately at the welding spot. A telescope with binocular eyepiece offers a resolution of 0.05 mm at the workpiece. As an alternative or in addition to the telescope a video system can be installed (optional). The monitor will then display the welding spot.
EB-machines with low-voltage generators, which are used for welding mass products only, require an optical window, i. e. a so-called auxiliary eyepiece for the installation of the workpiece.

Protective glasses protect the system from vapour deposits and spatter formed during the welding process. Soiled protective glasses can be exchanged by remote control.

EB - a flexible tool for special welding duties

Beam focusing and deflection:

The electromagnetic lens and the deflection system form another section within the generator column.

A very important parameter for the welding result is the lens current of the focusing lens. It determines the focal position and controls it with a tolerance of ± 0.1 % only. Even with large working distance the focal position differs insignificantly from the set value caused by this accuracy.

Magnet coils within the deflection system are fed by the deflection amplifier, which in turn is controlled manually or by means of CNC by a function generator. Thus, contours may be welded by means of beam deflection only.

By coupling the deflected signals with the mechanical axes of motion even complicated workpiece contours can be welded at a constant speed.

This is due to the fact that the inertia-free beam compensates by beam deflection for the inertia of the mechanical workpiece movement whenever sharp corners or narrow radii are involved.

For this purpose Steigerwald Strahltechnik offers a patented CNC control as an option.

Control device of a tri-metal band saw line (47.10.12g/6)

Electrical supply and control system:

The fact that the electron beam can be controlled electrically is the ideal prerequisite for adaptation to complex processing duties.

The following parameters can be controlled electronically with high precision:

- acceleration voltage
- beam current
- slope-in and slope-out
- lens current and thus, focal position and working distance
- beam deflection in x- and y-direction, static and dynamic

The acceleration voltage, the heating current for the cathode and the Wehnelt voltage are produced by the medium frequency high voltage supply structured in modern IGBT (Insulated Gate Bipolar Transistor) Technology. They are supplied by means of a three-wire line and oil-free connectors from the high voltage tank to the generator column.

The medium frequency technique (20 kHz) distinguishes by a fast high voltage and beam current regulation (< 200 µs) as well as by small stored energy and a high efficiency.

The highly stable DC system modules are easily exchangeable and permit an emergency operation with reduced performance.

Both, beginning and end of weldment may be critical and require a special beam current control. Slope-in and slope-out can be adjusted to workpieces and materials, which are difficult to be welded by the excellent controllability of the electron beam.

The basic supply of an EB-generator comprises time-controlled regulating elements which adjust the beam current linearly from zero to the set value (slope-in) at the start of the welding while reducing it to zero (slope-out) at the end of the weldment. Slope-in and slope-out may be adjusted independently each other.

The available beam power is a product of beam current and acceleration voltage, which is at the same time an important criterion for the selection of generator type in relation to the welding duty. It is the beam power, which determines the beam welding speed and its penetration depth into the workpiece.

For welding with vertical beam the material thickness is limited in dependence of the material. Otherwise the molten material would run out of the weld.

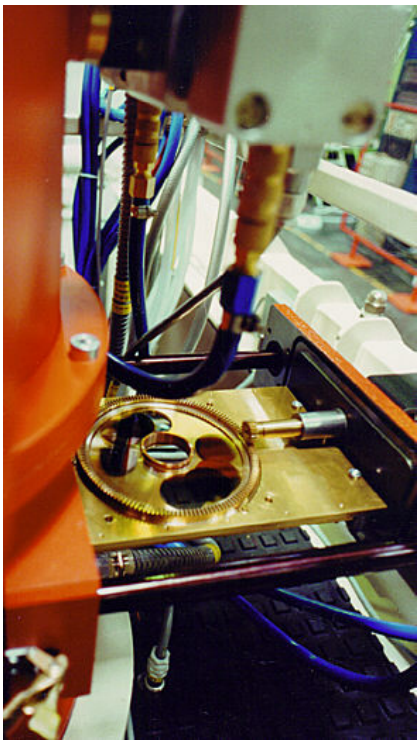
The same applies to the welding speed, as the liquefied material must merge and solidify behind the vapour capillary formed by the electron beam.

Optional equipment for electron beam generators

Function generator:

Metallurgical features or workpiece tolerances may require wider welding seams. A "sweeped" i. e., dynamically deflected beam helps to vary the seam forms of weldments. The function of the curve, amplitude and frequency of deflection may be adjusted by the function generator or be predetermined by CNC.

The function generator produces the periodic deflection function for the beam. Standard curve outlines may be sinusoidal, rectangular, triangular, circular and elliptical functions. The amplitudes of AC-deflection range up to ± 2 ° for 1 kHz.



Protective device of the viewing system (47.10.13i/19)

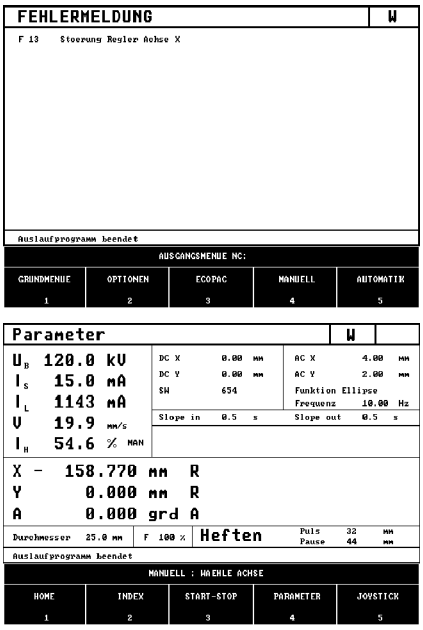
A deflection frequency range of up to 10 kHz can be used.
For particular applications the periodical deflection can be brought into a perpendicular position with reference to the welding contour by vectorization.

Heating current control system:

The optimum heating current of the cathode depends on both, the value of the beam current and the time the cathode has been in operation. By means of this system the heating current is automatically adjusted to the operating conditions after every filament exchange and during the complete filament lifetime.
For that reason an overheating, which would reduce the cathode lifetime considerably, can be avoided. At the same time underheating is avoided, which would lower the emission of electrons and thereby reduce the welding quality.

Pulse generator:

A pulsed electron beam may improve the welding result considerably. This is the case for very narrow, deep penetration welding for special welding seam geometries, or if the heat input must be restricted.
The optional pulse generator can directly be integrated into the EB-installation. Pulse form and pulse frequency may be adjusted independently of each other. In principle, a distinction is drawn between two modes of operation; i. e. pulsed mode and modulated mode.
For pulsing application frequencies up to 1000 Hz and pulse times from 400 µs to DC have to be reached. For modulation purposes a modulation of either triangular, rectangular or saw tooth form for frequencies up to 1000 Hz is available. The modulation amplitude reaches from 0 to 100 % of the medium value of the beam current.



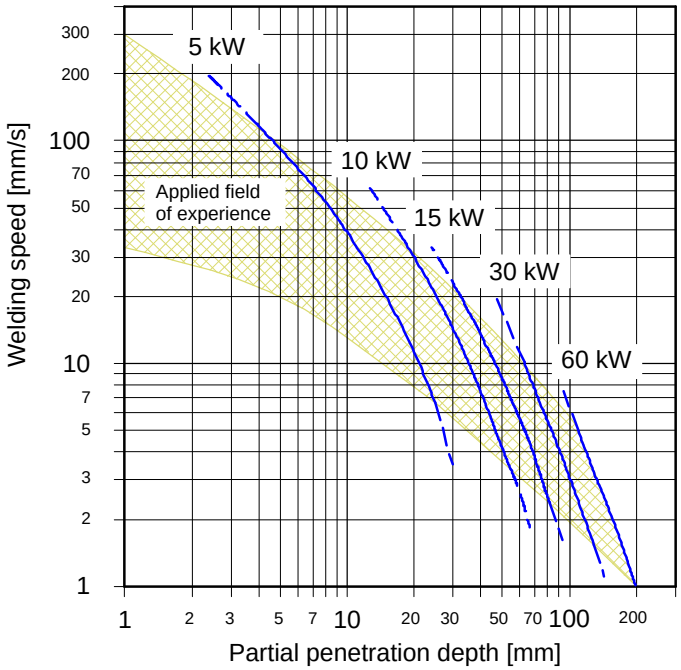
Displays at the VDU

Irrespective of the type of application there are various options available: e. g. video camera, devices for a horizontal use of the generator, wobble-system and CNC with all supplements for quality control.

Technical data

		Type of EB generator							
		GN 50 TM/KM	GN 100 TM/KM	GN 150 TM/KM	G 50 BM	G 100 KM	G 150 KM	G 300 KM/KML	G 600 KM/KML
Acceleration voltage	kV	70			70 to 150				
Max. permanent beam power	kW	5	10	15	5	10	15	30	60
Max. beam current	mA	72	143	215	30 [1]	66 [1]	100 [1]	200 [1]	400 [1]
Max. working distance [2]	mm	800	800	800	fix	1500	1500	1200	1200
Beam diameter [3]									
at 200 mm working distance	mm	0.4	0.45	0.5	0.1 [4]	0.2	0.25	0.4	0.6
at 500 mm working distance	mm	0.6	0.7	0.8		0.3	0.4	0.6	0.9
Max. angle of beam deflection [5]									
static	°	± 3			± 1.5	± 5			
dynamic	°	± 2			± 1.5	± 2			
Repeatability of beam position after change of the filament at 200 mm working distance	mm	± 0.1			± 0.05				

1) For $U_B \geq 80$ kV
2) Measured from chamber ceiling or wall to focal point. The values are only valid for standard mounting (lower edge chamber ceiling to middle of lens = 204 mm). Another wall thickness and generator movements change the maximum working distance. Larger working distance is possible depending on the requirement to the joint quality
3) At max. beam current
4) At 150 mm working distance
5) Mechanical components and type of amplifier can reduce maximum deflecting angle



Guide values for electron beam welding with 150 kV in steel. Due to different material properties, beam modulations and oscillations precise statements can only be determined by experiments. Full penetration welds need additional power to create the underbead.

Know how and after-sales support - committed to the customer on an international level

Steigerwald Strahltechnik does not only supply EB-installations but also engages in studies concerning specifically defined user applications. We also make the know-how of our decades of experience in the field of EB-technology available to our customers.

Extensive training of customers' personnel is just as well part of our services as the world-wide supply with spare parts and qualified after-sales support.

STEIGERWALD STRAHLTECHNIK GMBH

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