Electron beam welding

Optimum vacuum solutions for electron beam welding

PFEIFFER VACUUM

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The electron beam as a heat source in thermal material processing has become indispensable in many industrial applications such as drilling, milling, perforating, melting or welding. Electron beam welding, in particular, has long since established itself in applications where high-precision, deep and distortion-free welds are required (see section „Applications“) and is used in a wide variety of industrial sectors. But what exactly is this joining process and why does vacuum play an important role?

What is electron beam welding?

In electron beam welding, a beam of strongly accelerated electrons is focused on a workpiece via adjustable magnetic fields. On the surface of the workpiece, the electrons release energy precisely at the point of impact, where they heat, melt and vaporize material. Generating the beam in the electron beam gun and the actual welding process in the welding chamber take place almost exclusively under vacuum at pressures in the high vacuum range (10^{-3} to 10^{-6} hPa). This is to prevent the electrons from being scattered by air molecules and enable trouble-free and loss-free focusing of the beam on the workpiece.

Figure 1: Electron beam welding machine with welding chamber and electron beam generator (courtesy of Steigerwald Strahltechnik)

Contents

Figure 2: Aircraft engine

Electron beam welding

Fundamentals

Advantages

Electron beam welding offers many advantages over traditional welding processes. It allows high welding speeds of up to 10 mm/s and welding depths of up to 300 mm to be achieved. And that's not all. The ability to adjust beam parameters electrically also ensures precise real-time control and highly reproducible welding results.

Thanks to the high local energy density in electron beam welding, a wide variety of material combinations can be welded that are either impossible or extremely difficult to weld using conventional welding methods. Low heat input into the material surrounding the weld ensures minimal deformation of welded workpieces during electron beam welding and enables metals with high thermal conductivity to be welded. In addition, vacuum prevents unwanted oxidation of the welded workpieces.

Applications

Electron beam welding is used in high-tech branches of industry where toughest demands are made on the design and quality of welds, and the processing time must be as short as possible. Important areas of application include mass produced products in the automotive supplier industry, and in electrical, medical and precision engineering, as well as sophisticated special designs in the aerospace, energy and nuclear industries. While large companies usually operate their own application-specific electron beam welding systems, contract manufacturing companies use all-purpose machines to cover a wide range of applications and customers.

Figure 3: Energy technology

Figure 4: Wind turbine

Vacuum technology requirements

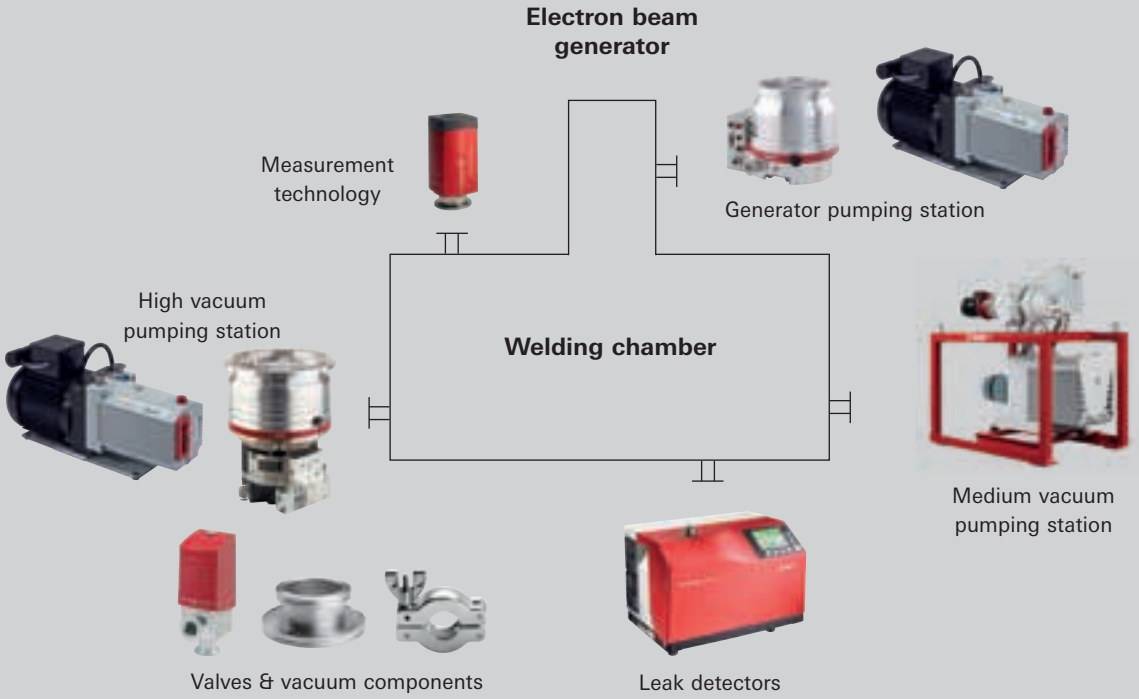
Vacuum pumps for an electron beam generator need to maintain a permanent background pressure in the high vacuum range following an initial, usually not time-critical, pump-down process.

In comparison, the pump configuration for the welding chamber has to meet considerably higher requirements. Evacuating volumes of common welding chambers can vary between a few liters and several hundred cubic meters. It is essential that all these chamber sizes achieve very rapid pump-down times to a defined operating pressure, which is usually located in the upper high-vacuum range. One of the most important criteria for the selection of the vacuum pumps at the welding chamber is therefore a very high pumping speed in the entire relevant pressure range from atmospheric to operating pressure.

In order to minimize downtimes, long maintenance intervals combined with high reliability are of the utmost importance for all pumps used.

Comprehensive portfolio for electron beam welding

Pfeiffer Vacuum offers a comprehensive portfolio for electron beam welding. This includes high and medium vacuum pumps for evacuating the welding chamber and the electron beam generator, pressure gauges for atmospheric to high vacuum pressure, valves and flange components for connecting vacuum components and leak detectors for locating leaks.



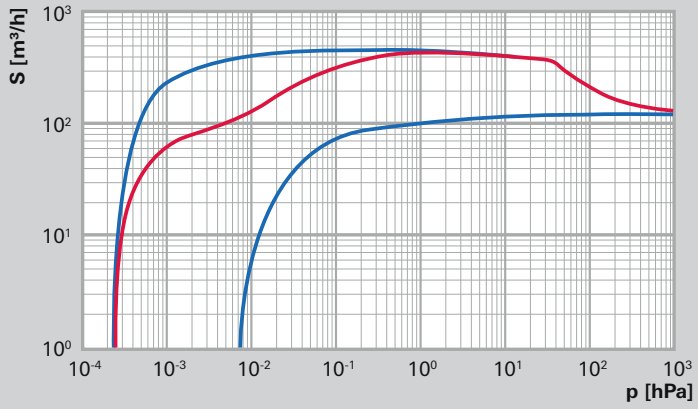
Electron beam welding

Evacuation

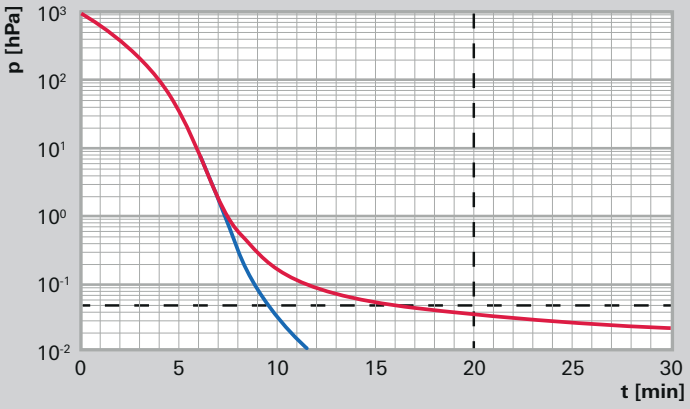
Design

Pfeiffer Vacuum supports you in designing the complete vacuum system for an electron beam welding system. This includes dimensioning of all medium and high vacuum pumps including recommendations for any additional components required. The design takes into account the individual pump characteristics, losses in tube lines, and leaks and desorption effects from inner chamber surfaces. Modern calculation programs developed specially for this purpose are used in the design process.

Pumping speed characteristic



Evacuation time curve



Evacuating the welding chamber

A combination of medium and high vacuum pumps is used to evacuate the welding chamber. The task of the medium vacuum pumps is to achieve a suitable fore-vacuum pressure in the welding chamber for switching on the high vacuum pumps within the required time. This is usually in the range of 10^{-1} to 10^{-2} hPa, depending on the type of high-vacuum pump used. These pressures can be reliably achieved with compatible and suitably dimensioned multi-stage combinations of Roots and rotary vane pumps. With the CombiLine series of Roots pumping stations, Pfeiffer Vacuum offers a complete standard series of Roots pumping stations that covers a wide range of achievable pumping speeds and ultimate pressures. In addition, customer-specific pumping stations can also be designed and manufactured to meet the most demanding requirements. In cases where a completely hydrocarbon-free vacuum is needed, Roots pumping stations can also use dry screw vacuum pumps as an alternative to rotary vane pumps.

High-vacuum pumps used for the welding chamber should generate and maintain the working pressure required for welding, which is usually in the range between 10^{-3} and 10^{-6} hPa.

Pfeiffer Vacuum turbopumps are available for pumping speeds of between 10 and 2,700 liters per second. These pumps will win you over with their high cost-efficiency and flexibility. With their optimized reliability, Pfeiffer Vacuum turbopumps use proven bearing systems which are available in two different bearing system options - a hybrid bearing system with a combination of a ceramic ball bearing on the fore-vacuum side and a permanently magnetic radial bearing on the high vacuum side, and a full and active magnetic bearing in which the rotor is levitated with no contact or wear at all. The sophisticated rotor design makes it possible to achieve extremely high pumping speeds, critical backing pressures and gas throughput values as well as very good compression values for light gases.

Oil diffusion pumps and cryopumps from our cooperation partners can be purchased in appropriate dimensions directly from Pfeiffer Vacuum. Pfeiffer Vacuum can thus offer a complete, ideally matched vacuum solution from a single source to meet the requirements of the electron beam welding chamber.

Medium vacuum			High vacuum		
CombiLine Roots pumping stations	**HiLobe Roots pumps**	**DuoLine rotary vane pumps**	**HiPace turbo-molecular pumps**	**Oil diffusion pumps**	**Cryopumps**
					
■ CombiLine stands for a large variety of Roots pumping stations with different backing pumps, graduations and accessories ■ Modular concept with DuoLine (WD series), HeptaLine (WH series) and HenaLine (WU series) ■ In addition to the standard range, customer-specific pumping stations can also be designed to meet individual requirements	■ Pumping speed range, depending on version, from 520 – 2,100 m^3/h because of variable speed control ■ Extremely short pump-down times due to superior, next-generation drive concept ■ Intelligent interface technology allows process adjustment and condition monitoring (Industry 4.0) ■ Reduced installation costs due to flexible mounting orientation	■ High operational safety thanks to integrated high-vacuum safety valve ■ Complete series from 1.25 to 300 m^3/h ■ Optionally available with wear-free magnetic coupling. As a result, extended maintenance intervals and no unplanned outages due to oil leaks	■ High pumping speeds for light and heavy gases ■ High process suitability, resilient against particle accumulation ■ Maximum operating reliability by monitoring all operating data ■ Extensive range of accessories	■ Very high pumping speed for air ■ Optionally with integrated baffle cap or, if necessary, with upstream baffle to minimize oil return flow	■ Very high pumping speed for air and water vapor ■ Hydrocarbon-free vacuum

Electron beam welding

Evacuation

Evacuating the electron beam generator

For the electron beam generator, turbomolecular pumps are normally used to generate and maintain pressure in the high vacuum range. Since the pump-down process on the electron beam generator is generally not time-critical, medium-sized turbomolecular pumps (HiPace 300 or HiPace 700, with a DN 100 or DN 160 inlet flange) are normally used. Single rotary vane pumps are used as backing pumps or, if hydrocarbon-free vacuum is required, small dry backing pumps such as multi-stage Roots pumps or scroll pumps are used.

Figure 5: HiPace turbomolecular pump on the electron beam generator
Courtesy of Steigerwald Strahltechnik

Electron beam welding

Pressure measurement

Pressure measurement

For pressure measurement on the welding chamber and electron beam generator, combination vacuum gauges of type PKR (Pirani/ cold cathode transmitter) from the Pfeiffer Vacuum ActiveLine range have proven themselves in practice.

Compact Pirani transmitters (Pfeiffer Vacuum TPR, Active Line) are typically used to measure the backing pressure of the high-vacuum pumps used.

As an alternative to transmitters from the ActiveLine series, DigiLine gauges with digital signal transmission can also be used for interference-free communication with a PLC.

Product overview

PKR 251 / 261 / 360 / 361	TPR 270 / 271 / 280 / 281
	
■ FullRange® gauges with two sensors in one housing ■ Measurement range 10^{-9} to 1,000 hPa ■ Robust and reliable ■ Insensitive to air infiltration	■ Pirani transmitter ■ Measurement range 10^{-4} to 1,000 hPa ■ Compact and robust

Electron beam welding

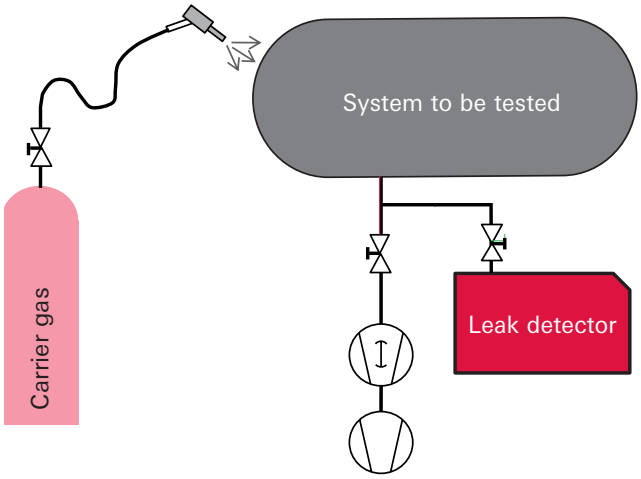
Leak detection

Leak detection

A good tightness of the electron beam welding system is indispensable for achieving the necessary working pressure. The integral leak test is carried out, typically using the pressure rise method. In doing so, the system is evacuated to a defined pressure value. After that, all valves are closed. The pressure rise as a function of time then yields the integral leakage rate. It should be noted that internal leaks, desorption from surfaces and evaporation or sublimation can also cause a pressure increase and may falsify the result. Therefore, an empty, clean and dry chamber is a requirement for accurately detecting the leakage rate.

If the leakage rate exceeds the desired threshold, it is important to locate and correct any leaks. Their high detection sensitivity, short test time and easy operation make helium leak detectors ideal for localizing leaks. The system is first of all evacuated. From the outside, helium is sprayed locally on sealing points, welds and other potential leaks using a spray gun. In the event of a leak, the helium flows into the evacuated vacuum chamber and is sucked in and detected by the leak detector. In order to realize short response times, the leak detector is used in large systems in partial flow to the existing vacuum system.

Figure 6: Aluminum rims



With the ASM 340, Pfeiffer Vacuum offers a powerful leak detector for universal use. The compact and portable ASM 310 is the first choice for mobile use, such as for service engineers.

Product overview

ASM 340	ASM 310
	
■ Fastest response time thanks to high helium pumping speed ■ Easy handling, intuitive menu navigation and large color touchscreen ■ Fastest operational readiness in its class	■ Dry pumping system, fore-vacuum pumping speed 1.7 m^3/h ■ Ultralight, only 21 kg and portable ■ Smart design with retractable handle ■ Removable control panel ■ SD card for data storage

Pfeiffer Vacuum Service

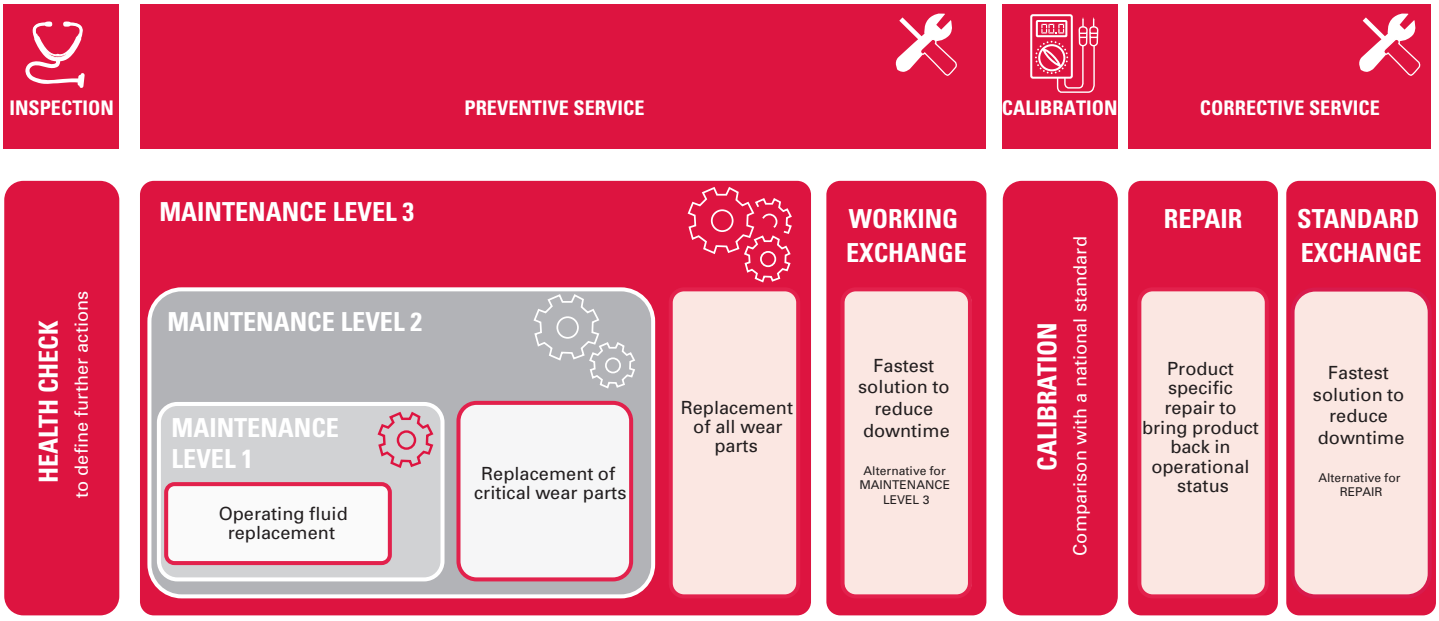
Our services – your advantages

Each customer places its own particular demands on its products, and these may also be influenced by application-specific parameters. Our flexible service concept, with a focus on preventive services, offers just the right solution for you.

Preventive maintenance – avoid downtimes

With our preventive service concept, we can recommend service intervals tailored to each product. The aim is to avoid failures and to carry out planned and predictable servicing.

Maintenance level 1 includes fluid changes and contributes significantly to the good working order of the product. **Maintenance level 2** also includes replacement of all wear and tear parts. In **maintenance level 3**, all wear and tear parts of the product are replaced and the product is overhauled. In order to keep downtimes to a minimum, we offer temporary replacements for many of our products for the duration of maintenance. We provide an equivalent **replacement product** that our customers can start using immediately.



Services at a glance

- User training and product training
- Pfeiffer Vacuum original spare parts and tools
- Troubleshooting and advice from our technical support team
- Comprehensive on-site service by our service technicians
- Maintenance and repair in our service centers worldwide
- Individual service agreements
- Replacement products
- Calibration service for measuring devices and helium test leaks

Spare parts – original parts increase life expectancy

Pfeiffer Vacuum's spare parts and tools are defined as early as at the product development stage. This ensures their tailor-made fit and quality.

Every improvement to our serial products is also transferred to our spare parts. This means products are brought up to state of the art status after undergoing maintenance level 3 or a repair.

Advice – to assist you with any questions you may have

In addition to our individual concepts and the quality of our replacement parts, it is our employees and personal contact that give our service its special touch.

Technical support – competent advice from the experts

Since not everything about our products is self-explanatory and questions can arise both before and after purchase, Pfeiffer Vacuum's Technical Support is available to assist our customers.

Each member of our team specializes in a specific area of our portfolio to enable them to assist our customers competently with technical questions relating to our products. Our team also works closely with our developers and application experts.

Field service technicians on site

From commissioning new vacuum components and systems to troubleshooting, and from maintenance to repairs, we offer our customers a comprehensive range of on-site services. Our service locations ensure customer proximity and short-term assistance in emergencies.

Service agreements – individually tailored to your project

We offer project-specific service agreements so that our customers can plan maintenance or service interventions over a long term. These agreements can be made at a later date or as early as during the project planning stage. In order to take our customers' differing needs into account, agreements may include all or just some of the services we offer.

Components and valves

The connection in your vacuum system

A vacuum system is made up of a variety of individual parts which are combined to form a single unit. Pfeiffer Vacuum also offers more than standard solutions. Components can be modified to meet your requirements or a customized solution can be produced to fit your needs perfectly.

Your advantages and benefits

- A direct contact for you and your projects
- Proactive support and competent advice
- Make ordering more convenient

- Short delivery times
- High delivery reliability
- High security of supply

- More than half a million parts in stock
- High uptime
- Cost saving - no own stock keeping necessary

- Vacuum components available in online shop
- Convenient online ordering at any time

www.vacuum-shop.com

- Information about your prices, delivery times and terms

Components

Valves

Feedthroughs

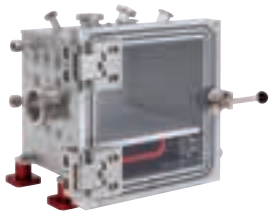
Manipulators

Custom vacuum chambers

Individually designed chambers for your vacuum applications

Due to our many years of experience we are familiar with almost all possible tasks and can provide professional guidance for system specifications, design and engineering.

Our physicists, designers, project managers and production specialists have extensive experience in many applications from all market segments. The tasks are based on your requirements: our starting point on the path to a finished product can range from a rough sketch to a complete set of blueprints.

High vacuum chambers	Advantages	Benefits
	■ Preconfigured design	■ Cost and time savings due to lower design expenses
	■ Proven, tough design	■ Reliable and safe
	■ Customized ports	■ Individual adaptation to your processes

Medium vacuum chambers	Advantages	Benefits
	■ Preconfigured design	■ Cost and time savings due to lower design expenses
	■ Proven, tough design	■ Reliable and safe
	■ Customized ports	■ Individual adaptation to your processes

Modular vacuum chambers	Advantages	Benefits
	■ Preconfigured design	■ Cost and time savings due to lower design expenses
	■ Modularly expandable	■ Maximum flexibility at all times
	■ Customized ports	■ Adaptable individually to your application

Custom vacuum chambers	Advantages	Benefits
	■ Individual design	■ Can be adapted optimally to your process
	■ High quality materials	■ Best quality and long life
	■ Robust design	■ Reliable and safe
	■ Project engineering and construction by qualified and experienced project managers	■ Time saving

VACUUM SOLUTIONS FROM A SINGLE SOURCE

Pfeiffer Vacuum stands for innovative and custom vacuum solutions worldwide, technological perfection, competent advice and reliable service.

COMPLETE RANGE OF PRODUCTS

From a single component to complex systems:
We are the only supplier of vacuum technology that provides a complete product portfolio.

COMPETENCE IN THEORY AND PRACTICE

Benefit from our know-how and our portfolio of training opportunities!
We support you with your plant layout and provide first-class on-site service worldwide.

Are you looking for a perfect vacuum solution? Please contact us:

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