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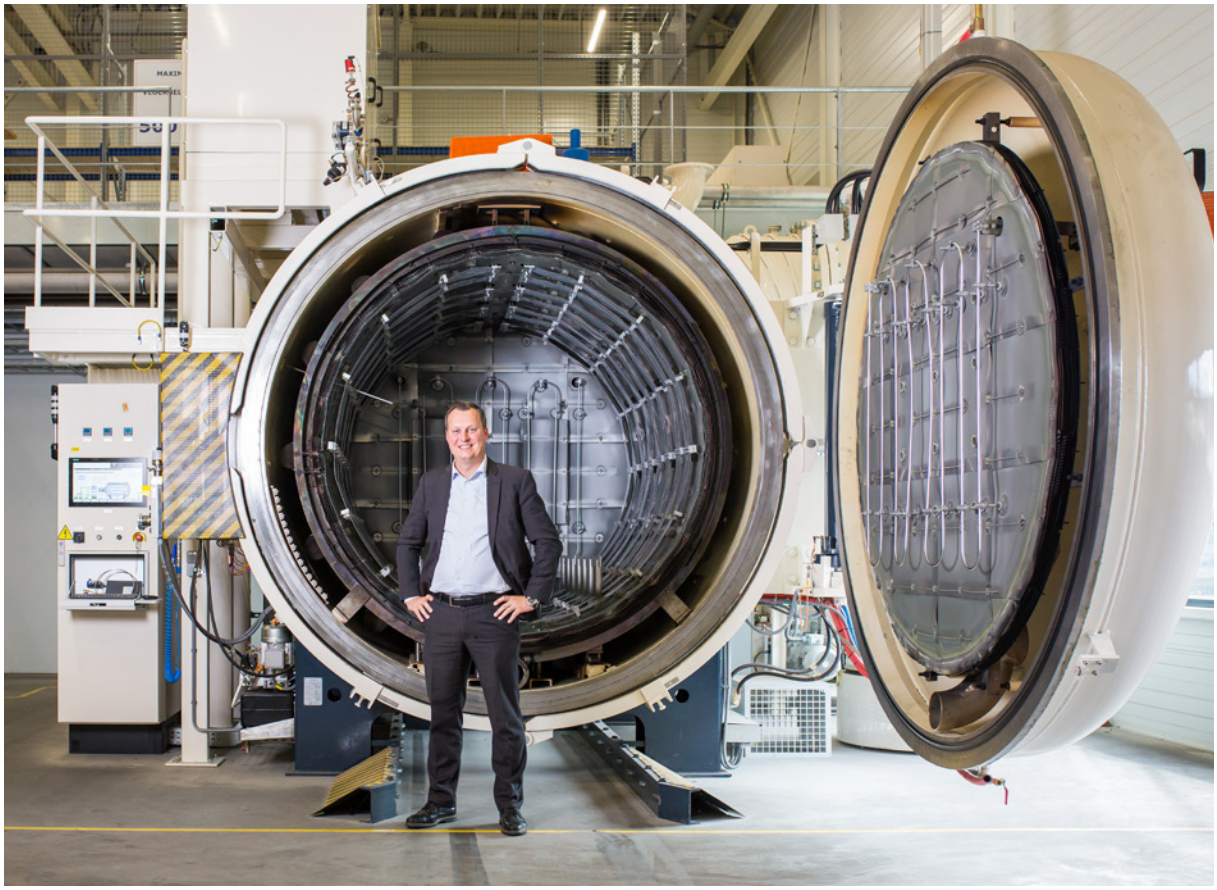
vacuum brazing

whitepaper

WHAT IS VACUUM BRAZING?

Vacuum brazing is a joining technique in which the brazing material is heated to the melting point and is thereby formed into one product in combination with diffusion in the base material. Vacuum-brazed joints are very clean, even and strong. This makes vacuum-brazed products very suitable for creating joints that meet the highest possible technical requirements. In addition, vacuum brazing can be used to create joints that cannot be created in any other way.



The largest vacuum oven in the Benelux is located in Eindhoven.

In this whitepaper, we will discuss the technical aspects and advantages of vacuum brazing and offer a glimpse behind the scenes in the largest independent vacuum brazing site in Europe.

Vacuum brazing: markets and applications

Vacuum brazing can be used in a vast variety of markets and offers a number of unique advantages. The reliability of vacuum-brazed joints is an important factor for almost every market. Examples include aviation and the semiconductor industry, markets in which the highest demands are placed on the reliability of joints and components. The possibility to create complex geometries and work with very high vacuum values in the semiconductor industry is another important reason for selecting vacuum brazing. Vacuum brazing is frequently used in the following markets:

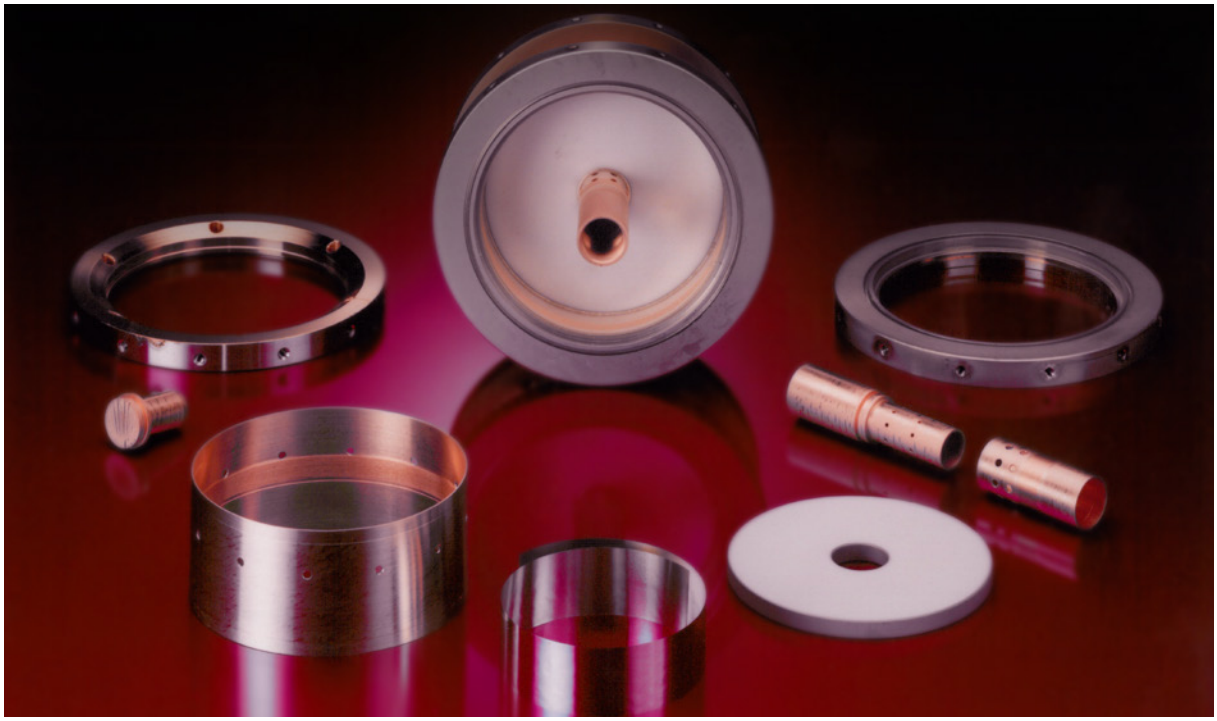
- Medical device construction
- Food industry
- Semiconductor industry
- Mold construction
- Automotive
- Aviation
- Power generation
- Scientific applications

“ In the mold making market, the creation of complex geometries is the main reason to opt for vacuum brazing, while, in the automotive industry, parts with relatively simple shapes are created with vacuum brazing. In this market, vacuum brazing is preferred to produce high-quality, wear-resistant parts in larger batches in a price-efficient manner. Other markets where vacuum brazing is increasingly used in the production process include power generation, scientific applications and medical device construction.”
- Steffen Schneiders, Plant Manager Aalberts Surface Technologies Eindhoven B.V.

A broad and diverse furnace range offers flexibility and shows ambition
Aalberts Surface Technologies Eindhoven has the ambition and expertise to continue to apply vacuum brazing at the highest level. This ambition is also reflected in the wide furnace range, with a diversity of dimensions, geometries and technologies. In addition, Aalberts Surface Technologies Eindhoven has a very large number of furnaces available in order to offer flexibility and speed in the production process in combination with their diversity.

“ At our site in Eindhoven, we currently have the largest furnace in the Benelux which is suitable for vacuum brazing. It is 2 metres deep and 1.2 meters wide and high. In addition, we have recently invested in metallic furnaces. With two of these furnaces, we offer the option of brazing with hydrogen, thereby achieving an even higher degree of surface cleanliness. The levels of cleanliness and the vacuum values with which we can vacuum braze in these furnaces and the use of hydrogen in a vacuum furnace are unique factors.”
- Steffen Schneiders, Plant Manager Aalberts Surface Technologies Eindhoven

The furnace range consists entirely of class 2 furnaces in accordance with AMS2750, with a very high temperature uniformity of 5 degrees Celsius within the set value. The critical accuracy of these furnaces is essential in the various certifications and standards of Aalberts Surface Technologies. Aalberts Surface Technologies will continue to invest in its processes and production capabilities in the future.



Technical possibilities and advantages of vacuum brazing

The application of vacuum brazing as a joining technique creates new products and production capabilities in various markets. And this is just the beginning: the full possibilities and advantages of vacuum brazing are not yet as well-known in all markets. The main features and benefits:

- Homogeneous product with an exceptionally clean and even joint
- Resistant to deformation and corrosion
- Brazing and hardening in one efficient process
- Construction of complex forms
- Joining unique material combinations
- Suitable for very high vacuum values
- Unparalleled temperature resistance
- A multi-layer, phased construction is possible
- Efficient in small batches

Homogeneous product with a very clean and even joint
Products are heated to very high temperatures (> 800°) in a vacuum furnace that heats both the product and the brazing material very evenly. The consistent heating ensures that the brazing material melts and joins the parts into one product. This creates an unprecedented tight joint without welds, splatters or grooves. This is also known as a sanitary or aseptic joint because dirt does not adhere to this joint, nor can it get stuck on it.

In addition, there is a reducing environment in the furnace, which, in combination with the very high temperature, results in very clean products. Because the material can oxidise during heating due to contamination (the presence of undesirable substances), the workpieces are always cleaned and assembly takes place in clean rooms as far as possible. The result is a literally spotless product, a workpiece that comes out of the furnace cleaner than it has ever been.

Optimal material structure, resistant to deformation and corrosion
The uniform heating of the product ensures that the furnace material does not feature any locally influenced zones – as is often the case with other joining techniques. Where heat is applied locally, areas arise that are prone to deformation or even microscopic cracks that affect corrosion resistance and fracture resistance. Vacuum brazing is a very stable and reproducible process that is applied evenly across the entire material, where the prevention of deformation and the creation of the optimal material structure is considered right from the start.

Vacuum brazing and other treatments in once process

The products can optionally be hardened or undergo a different heat treatment in the same furnace, as part of the same treatment. After brazing, the furnace is brought to the temperature at which the joint material can subsequently mold to the desired structure. For example, hardness, corrosion resistance or permeability of the products are immediately optimal, without any additional process steps being required. Vacuum brazing facilitates the construction and combination of complex shapes or materials. Vacuum brazing is a joining technique that makes very complex shapes, geometries and constructions possible, which cannot be achieved with any other joining technique. For example, it is normally not possible to braze the interior of a part. With vacuum brazing, however, we can join inaccessible parts of a product. An example is the creation of internal cooling channels that must not be in a straight line. It is impossible to position these channels in any other way. However, vacuum brazing makes it possible to join several partial products, whereby products with complex cooling channels can be achieved.

Also, different materials can be reliably joined only by using vacuum brazing. An example is the combination of copper and various stainless steel alloys or the joining of ceramics and metal. This is possible with vacuum brazing.

“ For a wide variety of materials, joints can only be made at temperatures above 800 or 1000 degrees. In addition, the material has to be completely clean and oxide-free, as the presence of dirt or oxide can result in a weak joint, no joint or a joint with a critical fracture surface. In a very high vacuum, we can exclude oxidation on the one hand, and braze at very high temperatures on the other hand. This makes it the only practical joining technique for many materials. ” – Rick Bruggeman, Sales Aalberts Surface Technologies

Very tight joints, suitable for very high vacuum values

A brazing joint is very dense and compact due to the complete fusion of the various layers. As a result, the joint does not leak at an atmospheric level, nor does it leak under positive pressure or negative pressure. This also makes the joints very compatible with a high to ultra-high vacuum. Vacuum requirements of 10-9, 10-10 or mbar.l.s-1 are not uncommon nowadays.

Aalberts Surface Technologies uses vacuum brazing to connect various parts of turbines used in the aerospace and power generation.

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"The vacuum-brazed construction can be easily and reliably pumped vacuum because there are no hidden corners, edges or crevices.
Vacuum brazing enables us to achieve a homogeneously closed joint, without cavities or pores. It is a beautiful, clean construction that is very suitable for vacuum applications."

– Rick Bruggeman, Sales Aalberts Surface Technologies

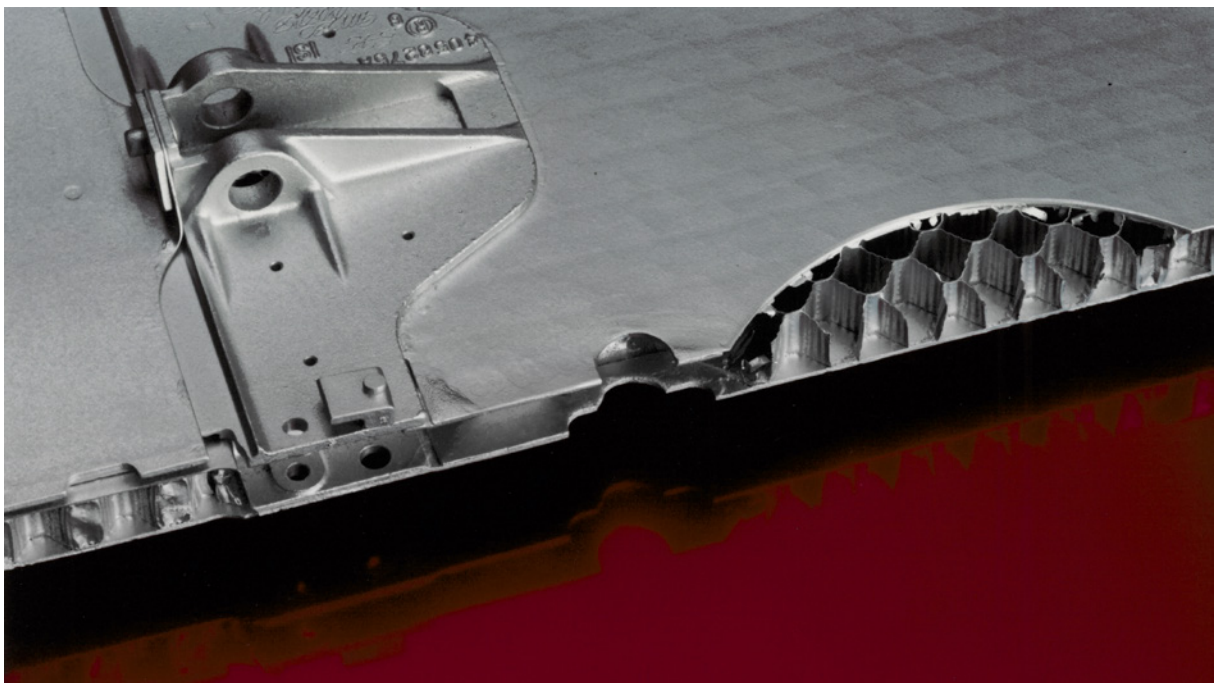
Unparalleled temperature resistance
Compared to other joining techniques, but also to other brazing forms, vacuum brazing offers a unique temperature resistance. The vacuum-brazed part or product offers a temperature resistance up to the temperature at which it is brazed and, depending on the selected brazing material, the temperature could even be far higher.
This point is around 450° C for soft soldering and up to 800° C for brazing. However, it could exceed 1200° C with vacuum brazing. Conversely, the material is able to resist extremely low temperatures and is therefore suitable for cryogenic applications even down to the absolute zero point of -273K.

Suitable for multi-layer construction
The temperature resistance above the previous melting point of vacuum-brazed products offers a very practical and unique advantage, not only in terms of use but also in terms of the production process. Because the parts and products can withstand temperatures above the original melting point from a previous cycle, it is possible to rejoin parts to other products in a subsequent brazing cycle without the previously brazed parts becoming disconnected. This makes it possible to join one product or part from products that are vacuum brazed in several cycles.

“We can build a product in several steps and furnace cycles, which means we can achieve larger, complex and composite constructions that cannot be achieved with any other technology. First of all, we vacuum braze the components in an initial vacuum brazing cycle. In the next cycle, we vacuum braze new components on the product that was created in the first step. Depending on the brazing material, this can be done at the same temperature, but it can also be done by selecting a different brazing material that can be vacuum brazed at a lower temperature. This process can be repeated several times, which can further increase the complexity of the product and create a unique composite product.”

Vacuum brazing also offers efficiency benefits in small batches
Vacuum brazing is ideally suited as a joining technique that is widely used for the production of parts and products with very high technical requirements. Less well-known are the efficiency benefits in the production chain. On the one hand, vacuum brazing is a technique that is suitable for joining larger batches in one cycle. On the other hand, it is a process in which many pre- and post-treatments can be carried out in one cycle. “Depending on the dimensions, technical requirements and batch size, we assess which furnaces are suitable and how the space in the furnace can be used as effectively as possible. We can achieve a whole batch of products in one go. It is also possible to harden the product at the same time, which, in turn, benefits efficiency.

In addition, various pre- and post-treatments such as cleaning, pickling or annealing can be carried out in one production cycle. We therefore offer a faster and very cost-efficient production process compared to other – often manual – joining techniques. And this generally also applies to smaller production batches.”



The so-called honeycomb structures, often used in aviation, are vacuum brazed to obtain rigidity in combination with a relatively low weight.

VACUUM BRAZING: A SPECIALTY OF AALBERTS SURFACE TECHNOLOGIES

As a client, you know which product or part you need, which requirements it must meet and what it should look like. You want to innovate, produce in a cost-efficient manner, meet a specific market demand or meet changing expectations in your industry. Vacuum brazing is a high-quality and cost-efficient way of joining the various components. But how does this work?
What happens once your drawing is delivered to the engineers of Aalberts Surface Technologies? Our engineers will guide you from start to finish, and together we will arrive at the best possible end product. We are happy to explain how.

The vacuum brazing process in a nutshell

Do you know exactly which opportunities vacuum brazing offers? Then we will discuss your drawing, ask the necessary questions for clarification and subsequently set up the production process to your specifications at the required quality level. Our employees have a unique knowledge of the possibilities of vacuum brazing and experience with the widest possible variety of materials, constructions and treatments. This means that we can always get started quickly, which means that you will receive your composite product before too long.

Cooperation
But what if there are opportunities for improvement or design changes that would benefit the cost-efficiency of your production process? This generally offers great opportunities for improvement, especially in the case of batch production. In this case, you will work closely with our engineers to ensure that all aspects of your production process are in line with the optimal end product. This means that we will discuss material selection, construction, pre-, post- and surface treatment as well as the final production process. This way, you can be sure that you use all the possibilities of vacuum brazing.

A solder assembly in which a heating wire is vacuum soldered to a product.

OVERVIEW OF THE PROCESS:

Studying the drawing
When you come to us with a product requirement and drawing, the first step is to have this drawing assessed by our engineers. They will try to establish a picture of as many design variables as possible which have an impact on the vacuum brazing process. An example is the manufacturing of the material, is it hot or cold rolled? And in which direction has it been rolled? Our experts use their knowledge and experience with materials and vacuum brazing to achieve the best possible design and production process.

“This is why we would ideally prefer to meet with the customer as early as possible in the design process. This enables us to contribute ideas in terms of construction and material. It also enables us to advise on the possibilities. Clients often adjust the drawing based on our input before we proceed with the initial tests.”

Methodical design
Methodical design is a methodical approach to the design process, in which the designer lists a number of alternatives and gradually discovers the most suitable technology and materials for this design. This approach enables a designer to take every aspect of the design into consideration. This avoids a situation where a particular solution is immediately selected, with a more effective choice or new solution possibly being skipped.

Process design
Our engineers design a process that describes exactly which steps the materials go through from the moment they arrive at Aalberts Surface Technologies until the moment they are delivered. This process can be divided into four phases:

- Pre-treatment
- Brazing material and assembly
- Furnace process / heat treatment
- Testing and quality control

Material and the necessity of pre-treatment
The process design starts with the starting position of the material. Our engineers not only consider which material you use, but also the quality, manufacturing method and other parameters. They will determine how the material is brought to the correct starting position for vacuum brazing. It is possible that the product has to be cleaned, for example.

Some materials or material combinations require a surface treatment to make them suitable for brazing. The composition of, for example, titanium or the combination of stainless steel and silver-based brazing material generally requires the material to be copper-plated or nickel-plated, which makes the surface suitable for brazing. Depending on the selected brazing material, the base material will not wet well and the brazing will not properly flow without this surface treatment.

Brazing material and assembly
The brazing material could be a powder, a paste, a wire, a coating or a foil. Depending on the components and the application, the engineer will determine which brazing material is used. In addition to the brazing material that is ‘melted’ during vacuum brazing to join the various parts, the products have to be positioned very precisely in relation to each other.

We use our own tools for this or special positioning tools. Alternatively, it could be decided to join the materials by tack welding so that they remain in the right place during the brazing process without using a positioning tool. The engineer will determine the parameters for tack welding in advance, so that it does not affect the desired end result.

Determining the furnace process
On the one hand, the furnace process consists of the controlled heating of the materials so that they 'fuse together'. On the other hand, it features the controlled cooling of the materials in order to bring them back to room temperature without unwanted side effects. Both heating and cooling as well as the way in which these processes are carried out have an effect on the material and the final result. Based on their many years of experience and knowledge, our engineers will determine in advance how these processes will proceed, focusing on every detail.

Four factors are decisive in both processes:

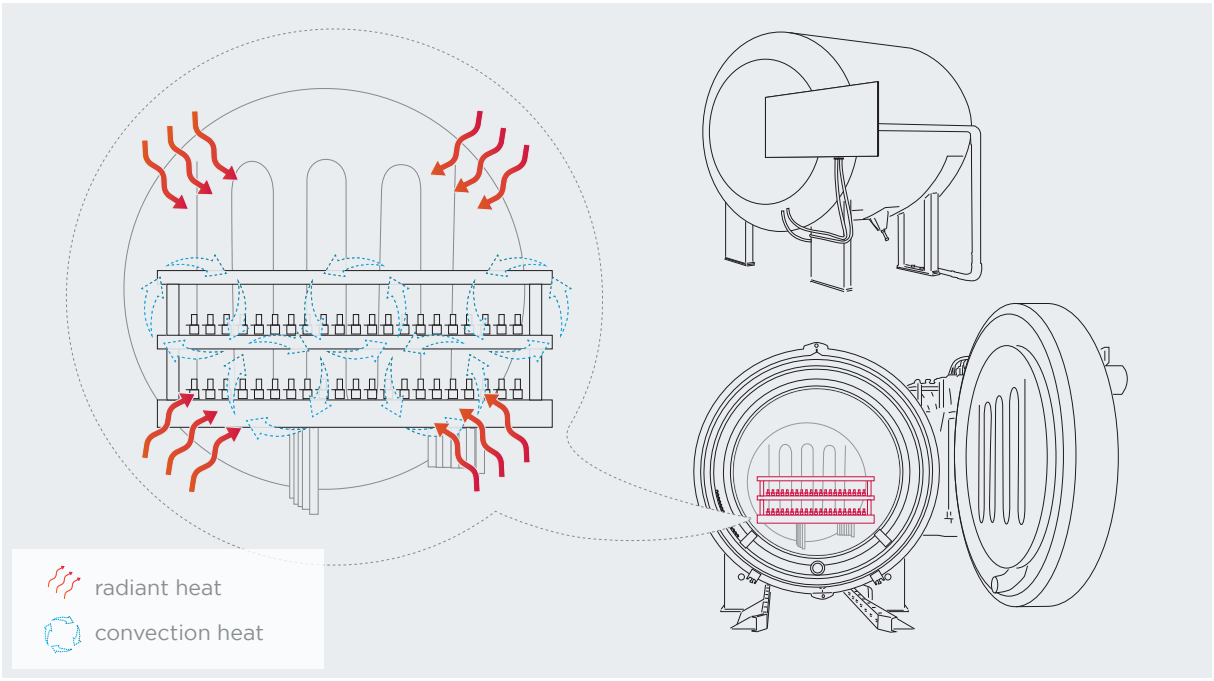
- Atmosphere
- Temperature
- Positioning of the workpiece in the furnace
- Cooling method

Atmosphere
The atmosphere in which parts are treated affects the surface condition of the parts. We work with two types of atmospheres, each with its own properties, in a vacuum or under partial pressure. Vacuum atmosphere is a very high negative pressure where nearly all oxygen is pumped out of the furnace chamber. Partial pressure is very precisely controlled negative pressure, a controlled oxygen-poor atmosphere with a controlled flow of argon, nitrogen or hydrogen. By brazing at a high temperature in a vacuum or under partial pressure, a reducing atmosphere is created in which the brazing material reacts with the material without the use of fluxes (the reaction is therefore very clean). This way, very strong joints can be created. Vacuum brazing under partial pressure offers better control of the vapour pressure of some brazing materials.

Temperature
There are three types of heat transfer that affect the products: convection, radiation and conduction. In a furnace, the heat is never the set temperature for 100%, as there is temperature distribution. The furnaces of Aalberts Surface Technologies offer very high accuracy, whereby the deviation from the set value is a maximum of 5 degrees Celsius. In the furnace process, we take into account cold and hot spots as well as the type of heat transfer.

Positioning of the workpiece in the furnace
Positioning in the furnace is essential for uniform heating and cooling of the parts, and is determined by the geometry of the parts in combination with the geometry of the furnace taking into account the heat transfer method. The number of parts and the cooling method also influence the positioning in the furnace.

Cooling method
After the products have been at the desired temperature for the desired time, the cooling process starts. This can be done in vacuum (very slowly), with a cooling medium or with a combination of both. The cooling medium is nitrogen or argon. The type of gas, the quantity, the pressure and the speed at which cooling takes place are factors that influence the product and any tension in the material.



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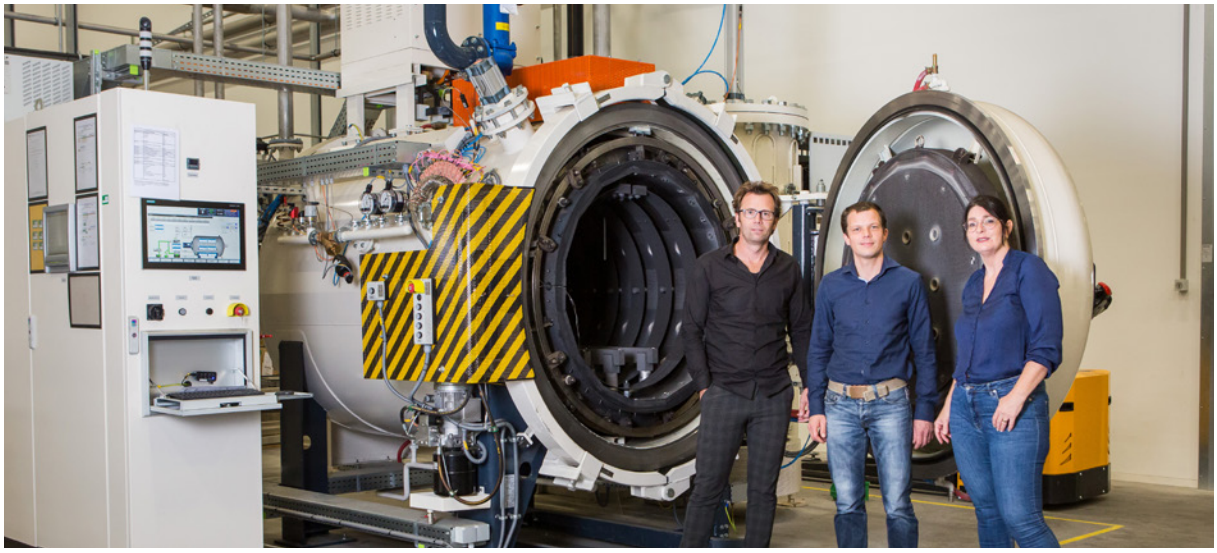
"Setting up the furnace process partly comes down to expertise. However, experience also plays an important role. We combine our metallic background with the knowledge and experience of all our projects. There are some variables that we cannot retrieve or model. For example, the placement of products, pressure weights or tools. This is expertise that we as Aalberts Surface Technologies Eindhoven add to the design and production process."

– Monique van de Put, Process Engineer Vacuum Brazing Aalberts Surface Technologies



Engineers Monique, Bjorn and Eric guide customers and put together the production process to achieve an optimal final product.

Testing and validation minimises risks in the production process
What do you do if not all variables are visible or clear? You test! Before we implement the optimal process determined by our engineers, we want to know the impact of any invisible variables to the greatest possible extent. An example includes the manufacturing method of the base material or the influence of the different materials and how they impact the construction. This is especially crucial in preparations for batch production. Testing enables us to minimise the risks in the production process to the greatest possible extent.

This is why we prefer to make a trial product. We will treat this exactly as described in the process, from pre-treatment to assembly, vacuum brazing and post-treatment, if applicable.

Subsequently, we will extensively test whether the process has resulted in the desired outcome. Depending on the product and the requirements of the client, a number of tests are conceivable and available:

- Helium leakage test
- Positive pressure test
- Flow test
- Destructive test
- X-ray test
- Functional test

We use the tests to map out the effects of invisible variables as far as possible. This allows us to adjust the production process – from starting material to end product – to achieve the desired result. We will review the results together with the client. Does the product meet all the expectations, or do we still have to change something? When the client is satisfied with the test result, the project is ready for production.

The process is frozen (end of engineering)
When the test results are completely to your liking, our engineers will freeze the process. From that moment on, changes will no longer be made, and the engineers will prepare the instructions and processes for transfer to the production team. From that moment on, all variables in the process will stay the same, from pre-treatment to vacuum brazing process and post-treatment, if applicable. This way, you are assured of the best possible end product. It is also important that the manufacturing process of the parts is not changed prior to the brazing process as any change here could also affect the brazing process.

Vacuum brazing vs (Laser) welding
Where, on the one hand, vacuum brazing is a joining technique with which otherwise impossible joints can be made, it is also a good alternative to other joining techniques such as (laser) welding. Vacuum brazing offers the following advantages compared to (laser) welding:

- A very clean joint, without seams and grooves
- The parts are joined over a (soldering) surface, not just locally
- The material structure is not affected locally
- Any other furnace treatments are possible in the same production cycle
- The technology, implementation and the results are very consistent
- Batch production is very efficient both in terms of time and in terms of costs
- The joined products will be annealed after brazing

Our in-house engineers will continue to ensure that the production team knows exactly how the process should proceed. Using instructions and workbooks, they transfer the design and process to our production team so that this team knows exactly which pre-treatment is required, where which amount of brazing material has to be applied, how the furnace is to be brought up to temperature and what role any post-treatments have in the production cycle.

Production starts
Production will kick off once our engineers have transferred the full knowledge of the design and the process to the production team. From that moment on, our highly skilled and experienced professionals will be involved in the process and create your product with the best possible care and attention.

Cleaning and surface treatment: the starting condition of the material
A clean product is essential in vacuum brazing because contamination during the heating process will affect the base material. This is why the material is always thoroughly cleaned first. Depending on the quantity and size of the material, this is done in the cleaning installation or manually. Additions here could be cathodic or galvanic degreasing and the pickling of copper parts.

After cleaning, the required intermediate layer is separately applied to the component – if necessary – to make it suitable for brazing.

Assembly
Completely clean material is the starting condition for the assembly. In a clean room, the brazing material is usually manually applied to the components and the whole is optionally placed in a mold.

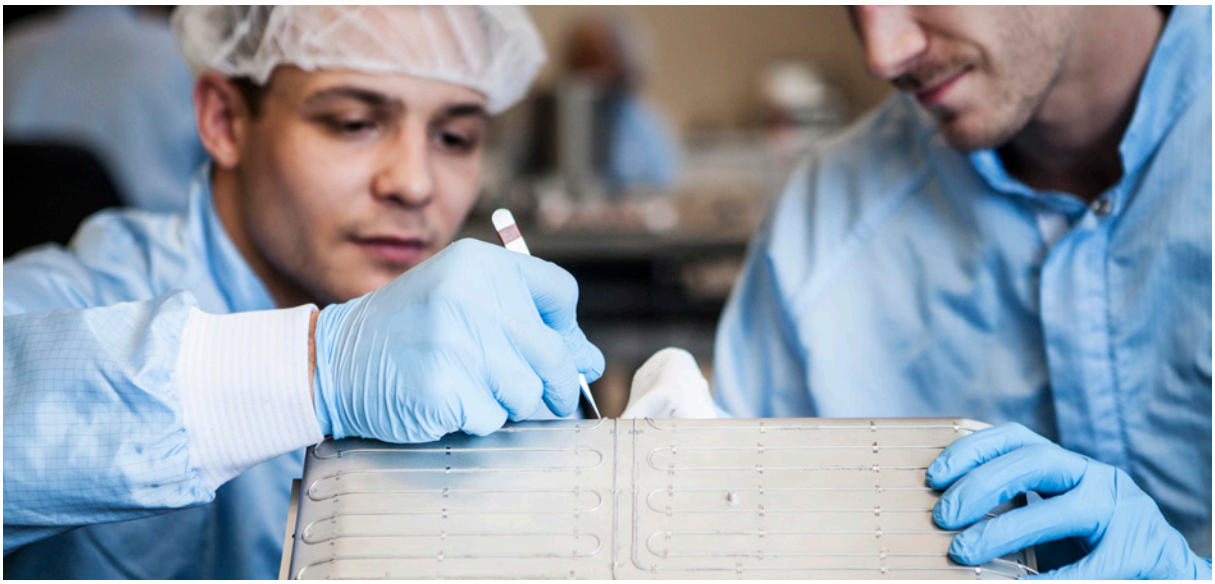
If necessary, materials are joined together where applicable. A small spot weld is applied with laser welding or spot welding. After vacuum brazing, the weld is often no longer visible.

It is a conscious choice to carry out the assembly in a clean room, and this significantly distinguishes our production process from the competition. We always work with gloves, sterile clothing and hair nets in dust-free areas to rule out contamination in order to exclude brazing imperfections as far as possible.

Certification and documentation
Documentation is becoming increasingly important in our processes. On the one hand, we use various documentation tools to limit any risks as far as possible in the initial stages. On the other hand, traceability is becoming increasingly important to our clients. They still want to be able to find out how a product was created a decade or more later.

Aalberts Surface Technologies Eindhoven works with three quality classes, which each have their own documentation requirements. During each process, furnace graphs are written and work orders are documented and issued for each production step. Only the highest quality classes are used in vacuum brazing processes.

The second highest quality class is supplemented with a full description of processes and work orders with internal regulations and dedicated equipment if applicable. The highest quality class meets the most extensive requirements of aviation and automotive standards. The process is fully documented and 100% traceable. In consultation with the client, risks are limited by using FMEAs, control plans and PPAPs. In addition, release tests are performed in according with the requirements of the client.



A solder assembly in which a heating wire is vacuum soldered to a product.

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