Brazing
Technical handbook
Why brazing?
Do you need to securely join components being resistant to high temperature and corrosion? If so, brazing could be the right process for you. Virtually any metallic material can be combined while the base metal of the joint is not melted. The process allows for much tighter tolerance control and results in a clean joint which does not require secondary finishing. Thanks to these unique process advantages, brazing is often used for demanding applications in industries such as automotive, heating, ventilation, air conditioning and refrigeration (HVACR), power generation and aviation. Typical examples include exhaust gas recirculation (EGR) coolers, heat exchangers, oil coolers, catalytic converters or turbine applications.

Why use Höganäs for brazing?
Here at Höganäs, we support you throughout the entire brazing process so that you can achieve the best possible results. We offer you our full-service expertise and materials that meet your exact requirements. By working closely with you, we can shorten your time to market, efficiently automate paste application solutions and also improve your quality, yield and productivity in order to offer the lowest total costs for your solutions.

Are you looking for a material supplier that can support you throughout your entire brazing process? Welcome to Höganäs! We’ll help you achieve your goals by guiding you from material selection all the way through to the processing phase.

Höganäs
Your preferred brazing partner
How Höganäs can support you in achieving the best brazing result

**Application development**

We support you in defining the brazing filler metal and braze joint properties

By working closely with our customers' applications, we have gained extensive knowledge, experience with application requirements and insights into the latest industry trends. This includes the required properties for brazed joints, such as mechanical strength and corrosion resistance, as well as in-depth knowledge of industry requirements and end-user specifications for the components. Besides optimizing brazed joints, our material specialists can also assist you with the correct selection and specification of your application's base materials.

**Filler metal selection**

Choose from our broad portfolio of BrazeLet® filler metals

Here at Höganäs, we offer a full range of nickel (Ni) and iron (Fe)-based BrazeLet filler metals for high temperature brazing, including powders and pastes. As the global leader in metal powders, we have in-depth knowledge about high-temperature brazing filler metals and we know how to fine-tune their properties in order to meet your exact requirements. Development of new and customized filler metals is achieved by our state-of-the art equipment in our pilot centres, our application centres and our metallographic and analytic labs. Our filler metal production meets the highest quality standards and is certified according to ISO9001, ISO14001 and IATF16949, following automotive standards. All filler metals produced by Höganäs ensure high-quality and consistent brazing results.
Paste application method
Helping you find the best application method for your brazed components
Our state of the art tech centres enable pilot scale production tests using your components. This opens for the possibility to use different application techniques, such as dispensing, screen-printing, roller coating and spraying, all with your components and with Höganäs’ application specific brazing pastes. Our experienced brazing team members will assist you in every way possible, based on your specific needs and requirements. This covers everything from part cleaning and calculation of the optimal amount of brazing paste, to recommending suitable brazing alloys and brazing profiles. Why not benefit from our global network of equipment suppliers?

Brazing process
Making your process as efficient as possible
Whether you want to evaluate your brazing results or find the root cause of poor components or low brazing performance, Höganäs’ brazing experts are available to help you improve your process and increase your value. We have all the necessary equipment needed to perform extensive and in-depth analysis of your brazing results. Our customer service investigation includes, but is not limited to microstructure evaluation, microhardness measurements, gap thickness and porosity evaluation. Here at Höganäs, we have substantial experience when it comes to furnace atmospheres thanks to our market leadership in powder metallurgy, which gives us a unique understanding of brazing atmospheres and profiles. We use this pool of experience to help our customers in achieving a brazing process that runs as smooth and efficient as possible.

Continuous improvements
Lifetime consultancy for your total quality management
Here at Höganäs, our support does not end once the project is in production. We provide continuous production improvements to our customers, in order to maximize their value. Examples of this include optimizing the brazing cycle for improved quality and productivity, minimizing the applied brazing paste amount to reduce costs and diminishing waste through smarter packaging.
Ni-based brazing filler metals are well-established in the brazing industry. New brazing filler materials have been developed continuously since their first introduction in the 1950s. Höganäs’ experience with manufacturing high-quality Ni-based brazing filler metals benefits from our extensive production of powders for surface coating which share many similarities with the brazing filler metals. Höganäs’ Fe-based brazing filler metals were developed as an alternative to the Ni-based brazing filler metals, while retaining similar material properties such as strength and corrosion resistance. The Fe-based brazing filler metals are a cost-effective alternative to the Ni-based brazing filler materials which are sensitive to Ni price fluctuations.

**Pastes**
Are you looking for an efficient paste solution? You should try Höganäs’ pastes, which have a higher metal content and a minimized polymer content compared to conventional pastes, resulting in more brazed joints per kilogram of paste. Ultimately, you will reduce the maintenance needs for your furnace. Additionally, you will ensure that your brazed parts maintain a high quality.

Our brazing pastes consist of a homogenous mixture of the brazing filler metal powder (normally 85–93 wt%) and a water or oil-based flux-free binder which is removed during brazing. Here at Höganäs, we adapt the paste formula to factors such as the paste application method and furnace conditions. This ensures that you can achieve the best possible brazing results for your application. Our binders have been developed in a way that minimizes their polymer content.

The rheological behaviour of our brazing pastes has been designed to suit the different application methods used. In general, thin layer application methods like roller coating, thin printing or spraying require more liquid formulations, whereas dispensing or thick layer printing require a higher viscosity. Höganäs’ high-quality brazing pastes are based on our broad filler metal selection. Moreover, we offer customized brazing pastes as well as several types of paste packaging to fulfill your exact requirements.
<table>
<thead>
<tr>
<th>Product name</th>
<th>Chemistry (wt %)</th>
<th>Speciation</th>
<th>Melting range</th>
</tr>
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<tbody>
<tr>
<td><strong>Ni-based alloys</strong></td>
<td></td>
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<tr>
<td>BrazeLet®</td>
<td>Ni Cr Si Fe B C P Cu Nb Mo</td>
<td>EN ISO 17672 AMS AWS A5.8 °F</td>
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<tr>
<td>BNi1</td>
<td>Bal. 14 4.5 4.5 3.2 0.75 - - - - Ni 600</td>
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<td>BNi1A</td>
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<td>4776 BNi-1a</td>
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<tr>
<td>BNi2</td>
<td>Bal. 7 4.5 3 3 - - - - - Ni 620</td>
<td>4777 BNi-2</td>
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<td>4778 BNi-3</td>
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<td>BNi7</td>
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<td>Ni623</td>
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<td>BrazeLet®</td>
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<td>EN ISO 17672 AMS AWS A5.8 °F</td>
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<td>F300-10</td>
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<td>n/a n/a</td>
<td>1877–1967</td>
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<td>F300-20</td>
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<td>F86</td>
<td>18 29 6.5 Bal. - - 6 - 0.5 - n/a</td>
<td>n/a n/a</td>
<td>1922–2012</td>
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Please see the specific product datasheets at www.hoganas.com for further information.
<table>
<thead>
<tr>
<th>Product name</th>
<th>Melting range</th>
<th>Rec. brazing temperature (min.)</th>
<th>Typical properties</th>
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<tbody>
<tr>
<td>Ni-based alloys</td>
<td></td>
<td></td>
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</tbody>
</table>
| BNi1 | 980–1060 °C | 2102 °F | 1150 °C | • Good corrosion resistance  
• Good gap filling ability of narrow joints |
| | 977–1077 °C | 2147 °F | 1175 °C | • Similar to BNi-1, with low carbon content |
| | 970–1000 °C | 1922 °F | 1050 °C | • Excellent joint strength  
• High oxidation resistance  
• Sensitive to corrosion in acidic environments  
• Recommended gap clearance max. 50 μm |
| | 980–1040 °C | 2012 °F | 1100 °C | • Excellent joint strength  
• Sensitive to corrosion in acidic environments |
| | 980–1065 °C | 2048 °F | 1120 °C | • Excellent gap filling ability  
• Sensitive to corrosion in acidic environments |
| | 1080–1135 °C | 2102 °F | 1150 °C | • Excellent joint strength  
• High oxidation resistance  
• Good corrosion resistance  
• High elevated temperature strength  
• Recommended gap clearance max. 50 μm |
| | 875 °C | 1742 °F | 950 °C | • Low recommended brazing temperature  
• Good gap filling ability of narrow joints |
| | 890 °C | 1796 °F | 980 °C | • Good corrosion resistance  
• High oxidation resistance  
• Low recommended brazing temperature  
• Recommended gap clearance max. 30 μm |
| | 1055 °C | 2012 °F | 1100 °C | • Excellent joint strength  
• High oxidation resistance  
• Sensitive to corrosion in acidic environments |
| | 880–950 °C | 1922 °F | 1050 °C | • Excellent corrosion resistance  
• High oxidation resistance |
| | 970–1030 °C | 1994 °F | 1090 °C | • Excellent corrosion resistance  
• Excellent gap filling ability  
• Recommended gap clearance max. 150 μm |
| | 1160–1200 °C | 2264 °F | 1240 °C | • Excellent corrosion resistance  
• Excellent gap filling ability  
• Recommended gap clearance max. 150 μm |
| Fe-based alloys | | | |
| F300-10 | 880–950 °C | 2012 °F | 1100 °C | • Excellent corrosion resistance  
• Suitable for vacuum brazing  
• Recommended gap clearance max. 150 μm |
| | 875 °C | 1742 °F | 950 °C | • Excellent corrosion resistance  
• Excellent gap filling ability  
• Recommended gap clearance max. 150 μm  
• Recommended gap clearance max. 150 μm |
| | 890 °C | 1796 °F | 980 °C | • Excellent corrosion resistance  
• Suitable for belt furnace brazing  
• Recommended gap clearance max. 150 μm |
| | 1055 °C | 2012 °F | 1100 °C | • Excellent corrosion resistance  
• Suitable for vacuum brazing  
• Recommended gap clearance max. 150 μm |
| | 1025–1075 °C | 2012 °F | 1100 °C | • Excellent corrosion resistance  
• Suitable for vacuum brazing  
• Recommended gap clearance max. 150 μm |
| | 1025–1060 °C | 2012 °F | 1100 °C | • Excellent corrosion resistance  
• Suitable for belt furnace brazing  
• Recommended gap clearance max. 150 μm |
| | 1050–1100 °C | 2012 °F | 1150 °C | • Excellent joint strength  
• Excellent corrosion resistance  
• Recommended gap clearance max. 150 μm |
Höganäs brazing pastes

<table>
<thead>
<tr>
<th>Product name</th>
<th>Particle size (µm)</th>
<th>Solvent type</th>
<th>Recommended drying °F</th>
<th>Evaporation temp. of binder °F</th>
<th>Viscosity* (Pa.s)</th>
<th>Density* (g/cm³)</th>
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<td>Dispensing</td>
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<td>D-9302</td>
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<td>250–340</td>
<td>660–840</td>
<td>300 (T-spindle D)</td>
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<td>D-9004</td>
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<td>oil</td>
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<td>660–840</td>
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<tr>
<td>DW-9201</td>
<td>&lt;106</td>
<td>water born</td>
<td>250–300</td>
<td>570–750</td>
<td>1000 (T-spindle E)</td>
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<tr>
<td>DW-9003</td>
<td>&lt;106</td>
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<td>DW-9013</td>
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<td>DW-9007</td>
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<td>RT–300</td>
<td>482–572</td>
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<tr>
<td>DW-9017</td>
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<td>RT–300</td>
<td>482–572</td>
<td>1200 (T-spindle E)</td>
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<td>Screen printing</td>
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<td>P-9011</td>
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<td>660–840</td>
<td>230 (T-spindle D)</td>
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<td>P-9002</td>
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<td>660–840</td>
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<td>P-9012</td>
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<td>oil</td>
<td>250–340</td>
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<td>300 (T-spindle D)</td>
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<td>P-9003</td>
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<td>Spraying</td>
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<tr>
<td>Roller coating</td>
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<td>R-8501</td>
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<td>250–340</td>
<td>660–840</td>
<td>90 (T-spindle C)</td>
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<tr>
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<td>250–340</td>
<td>660–840</td>
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<td>CRW-8502</td>
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<td>570–750</td>
<td>70 (T-spindle C)</td>
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<tr>
<td>R-9003</td>
<td>&lt;63</td>
<td>oil</td>
<td>250–340</td>
<td>660–840</td>
<td>95 (T-spindle C)</td>
<td>4.0</td>
</tr>
</tbody>
</table>

*Viscosity values measured with Brookfield Helipath spindles with speed of 2.5 rpm at 20 °C
Values for viscosity and density are typical values

Example: DW-9201

Example: DW-9201

D = Dispensing, R = Roller coating
W = Water based / water born, S = Spraying
C = Customized, P = Printing
92 = Metal content in %, i.e. 92% metal content
01 = Internal serial number
Water based pastes
can be dried in ambient temperature whereas oil-based pastes require elevated temperatures to evaporate all solvent from the paste. All pastes can be dried with the standard drying process (using hot air) at ~100–170 °C. The drying time depends on thermal mass, part design and the furnace used, and must therefore be established on a case by case basis.

Oil based pastes
require proper ventilation during the drying process. A drying chamber/furnace with an exhaust system and sufficient air circulation should be used. This avoids fume emissions and keeps the volatile organic concentrations at a low level.

For paste adhesion
the paste needs to be dried to achieve the best possible adhesion to the component. For product specific properties and drying recommendations, please refer to the product’s technical datasheet.

We offer different packaging solutions for our products
Microhardness
Alloying elements such as phosphorus (P), silicon (Si) or boron (B) is a prerequisite in Ni- and stainless brazing filler materials to lower the melting range to an adequate temperature for brazing. The brittle phases given by such elements increase the microhardness within the joint area. Lower levels of microhardness can improve the dynamic stress lifetime on brazed components.

Most conventional Ni- and Fe- based brazing filler metals contain a significant amount of melting point depressant elements such as P, Si and B, which can lead to the formation of brittle intermetallic phases in the brazed joint. These intermetallic phases in the microstructure have a much higher hardness compared to the base material, and will have an adverse effect on the joint ductility.

Höganäs' BrazeLet® F300 and Ni613 have a significantly different microstructure with substantially lower microhardness, compared to standard Ni- filler metals. Components brazed with BrazeLet F300 and Ni613 will therefore benefit from improved dynamic mechanical and thermal stress reliability.
Wetting

The ability of the brazing filler metal to wet and spread out over the base materials to be joined is an important feature to achieve good brazing results. For best possible wetting results, the base material surfaces needs to be clean and free from oxides. Wetting is dependent on both the filler metal and the base material. It is important that the filler metal can alloy with the base material, and also that the base material’s composition is of high quality. Some base materials contain strong oxide forming elements such as titanium or aluminium, which cannot be reduced during the brazing cycle. This leads to titanium (Ti) or aluminium (Al) oxides being present on the base material surface, limiting the wetting results.

By performing spreading ratio tests, Höganäs has tested the BrazeLet® filler metals performance in combination with many different base metals. In these tests a defined amount of brazing paste is applied in a circle with a defined diameter on a plate. The plate is then subjected to a brazing cycle and the spreading ratio is calculated as the ratio between the wetted area and the initial area. The most common base materials are austenitic stainless steels and ferritic stainless steels. Spreading ratios for the different filler metals on AISI 304 austenitic stainless steel and AISI 444 ferritic stainless steel are shown in the graph below.

Some brazing filler metals will not spread out significantly over the base material but may have other desirable properties. In such cases, using the appropriate brazing paste application technique is key for good results. Höganäs has extensive experience with brazing paste application and the facilities to work together with our customers in demonstrating the different techniques in our tech centres.

Spreading ratio of BrazeLet filler materials on typical base materials
The designer of brazed components needs to factor in the strength value in the gap design. Most Ni brazing filler metals are sensitive to gap sizes, requiring <50 µm, whereas BrazeLet® Ni613 and BrazeLet® F300 maintain their good strength even at larger gap clearances. Strength evaluation of brazing filler metals and brazing joints is more complex than just measuring the strength of the bulk material. The loading conditions will also affect the strength of the brazed joint. Höganäs uses shear strength testing and tensile testing to measure the joint strength of brazed joints. Shear strength testing is done in accordance with the requirements and guidelines outlined in AWS C3.2/C3.2M.

In many cases, for example in brazed plate heat exchangers, the brazed joints are loaded in tension rather than shear. To provide the best advice for the individual application, Höganäs performs extensive tensile testing of all BrazeLet brazing filler metals. Tensile testing is performed in accordance with SS-EN 12797 and EN ISO 6892-1 (as shown below).

The method of choice is the butt joint method which requires two separate machining steps with a brazing process in between. Finally, the geometry is tested in a traditional tensile testing machine. As the testing shows, Ni- and Fe- based filler metals form vastly different microstructures depending on gap clearance, brazing temperature and time spent etc.

Due to the differences in microstructure, the gap clearance greatly affects the joint strength for some of the brazing alloys. The common Ni-base alloys such as BNi-2, BNi-5 and BNi-7 experience significant increases in joint strength at low gap clearances. On the other hand, Höganäs BrazeLet F300 and Ni613 have shown not to be sensitive to the gap clearance, since they do not have the same brittle centreline eutectic phase at large gaps as the BNi alloys.

(a) Assembly of test specimen halves with stainless steel wires aligned along the two edges.
(b) Sample prepared for brazing with brazing paste applied outside the joint.
(c) Sample after brazing.
(d) Tensile test brazing specimen geometry.
**Gap clearance effect on microstructure and fracture propagation**

<table>
<thead>
<tr>
<th>Material</th>
<th>&gt; 50 µm gap</th>
<th>&lt;50 µm gap</th>
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Corrosion
Testing is normally done on finished components during service. But here at Höganäs we can give the best advice to you – as our customer – on which BrazeLet® brazing filler material you should use for your application. When evaluating corrosion in brazed joints, three main factors are evaluated:

- **Base material corrosion**
- **Brazing filler metal corrosion**
- **Diffusion zone corrosion**

Höganäs has extensively tested the corrosion resistance of AISI 316L austenitic stainless steel joints brazed with the different BrazeLet brazing filler metals. In addition to this, corrosion testing has also been performed for the most commonly used ferritic stainless steel grades, such as AISI 430, AISI 441 and AISI 444. As a supplement to the standard-ized corrosion testing methods for brazed joints – such as salt spray testing and VDA 230-214 testing – Höganäs has developed an internal method for testing the corrosion resistance of brazed joints in acidic environments. The corrosion resistance is evaluated both qualitatively (metallographic evaluation after testing) and quantitatively (high-precision weight measurements with set time intervals during testing). Several factors such as the base material, brazing filler metal combination or the brazing process and atmosphere, influence the corrosion resistance of brazed joints. Based on extensive testing, Höganäs’ brazing experts can recommend the best alloys for specific corrosive environments.

**Corrosion of brazed joints can occur in different forms, such as**

- Preferential corrosion of certain phases in the microstructure with lower corrosion resistance than the surrounding matrix
- Corrosion along the base material – filler metal interface where the alloyed mixture of base material and filler metal may have lower corrosion resistance than the surrounding material
- Intergranular corrosion in the base material due to chromium (Cr) depletion from the formation of Cr carbides, Cr borides, Cr nitrides etc.
- Galvanic corrosion between the filler metal and base material can occur in cases where there are significant differences between the corrosion resistance of the filler metal and base material, such as for copper brazing
- Stress corrosion cracking (SCC) can occur for stressed braze joints exposed to high temperatures and corrosive environments

Höganäs experts can help you find the right materials for your needs!
The brazed joint is an integral part of the brazed component and is important for the overall component performance in a corrosive environment.
Here at Höganäs, we have developed BrazeLet® brazing pastes for the specific requirements of different application methods such as spraying, dispensing and roller coating to ensure consistent high-quality brazing results.

Dispensing

Feeding paste out of a needle is the most common paste application. This can be done by hand, by using small air pressure driven dispenser units or with automated dispenser systems for high volume mass production. Dispensing is suitable for heat exchanger plates of different types, or housing components and add-on elements, such as inlet and outlet tubes. It is easy to achieve application speeds of up to 6–12 m/min by using the correct dispenser type, size, needle geometry and diameter. By using precise screw dispensers (±1%) instead of air pressure dispensers (±5%) additional cost savings can be achieved.

Höganäs’ dispensing unit features a motor driven precise screw dispenser and a robot, allowing for automated and fast paste application on complex parts that other application techniques are not capable of reaching.

Jet dispensing

The technology fills a gap for classical paste application methods where part geometry is a barrier, such as beading of inlet and outlet holes on plates with dimples. Neither screen printing nor roller coating can be used for this type of plates. The jet-dispenser shoots small amounts of paste to the substrate out of a print head. It consists of a small head with an attached syringe containing paste. The head can be mounted on a xy-table as well as on any robot.
Screen and stencil printing

Screen and stencil printing are suitable for flat components such as different types of frames or hole plates where efficiency, production rate and quality are of highest importance. The application method is effective, flexible in automation and mass production scale.

Screen printing is a paste application technique where a mesh is used to transfer paste onto the component. A blade or squeegee pushes the paste through the open mesh area of the screen which has been designed specifically for the component. Stencil printing is a paste application technique where a laser cut steel plate is used to transfer paste onto the component. A blade or squeegee pushes the paste through the laser cut open area of the stencil which has been designed specifically for the component.

It is possible to print thin paste layers down to 50 µm and structures as narrow as 0.3 mm, but also thick layers up to 0.8 mm.

Höganäs’ screen printer, located in our tech centre, is suitable for prototyping customer parts by screen or stencil printing with appropriate paste thickness.
Roller coating

Roller coating is suitable for flat components where production rate and quality are of highest importance. Brazing paste alloys can be manufactured without any boron (B), making it a great alternative to B-containing brazing foils. B has been found to negatively affect brazed joint corrosion resistance and base material mechanical properties such as strength and ductility. At the same time, it is possible to make savings on material costs, since less material is used with roller coating compared to foil. During the roller coating process, the components are fed on a conveyor belt underneath a paste-covered roll. A layer of paste with homogenous thickness is then sheared onto the components. The unique properties of Höganäs’ roller coating pastes guarantee low variation in applied paste amount at coating speeds up to 20 m/min.

Some applications do not tolerate additional thickness by brazing filler during assembly. This is especially the case when the fins are inserted into welded tubes or when multiple components should be stacked and tolerance issues occur during assembly. Höganäs has addressed this preposition by developing the roller coating process forward, in order to achieve “zero gap” paste application. During so-called side-coating, paste is applied on the sides of the component’s elevated parts.

Achievable coatings with roller coating:

**Top coating**

![Top coating diagram]

**Side coating**

![Side coating diagram]
Spraying

Spraying is a flexible application technique where a layer of paste is applied evenly across the surface of the components. It is suitable for many different component types and geometries. Applying the brazing paste as a thin, even layer provides better binder elimination, improved part assembly and reduced risk of erosion. Brazing paste application by spraying can be done both manually and with automated systems. Choosing the correct equipment is key for the best spraying results and equipment lifetime.
The brazing process

Furnace brazing

For optimal results, the different brazing processes and atmospheres require special considerations and the correct selection of brazing paste. Here at Höganäs, we give you the support you need to make your process as efficient as possible.

Successful furnace brazing

Höganäs’ BrazeLet® filler metals are mainly applied for furnace brazing processes such as vacuum brazing, controlled atmosphere brazing and induction brazing. One of the many advantages of furnace brazing is the possibility to monitor and control all stages of the brazing cycle. This results in improved repeatability, increased quality and maximum yield. To achieve good brazing results, the base material needs to be free from oil, dirt, grease and oxides which will prevent flow of the brazing filler metal on the surface. This is achieved by properly cleaning the components prior to brazing. During the process, the component should be kept clean and free from oxidation by working in a sufficiently dry atmosphere. The Metal-Metal Oxide Equilibrium Curve provides a guideline for how dry the atmosphere must be and how high the temperature should be to reduce common metal oxides. Over the years, it has been shown that the curve does not only apply for hydrogen atmospheres, but also for other atmospheres such as nitrogen, argon and vacuum. For successful brazing results, the brazing furnace needs to be operated at conditions to the right of the relevant Metal-Metal Oxide Equilibrium Curves.
**Tip**

Review the base material composition to find the element that has the most difficulty to reduce metal oxide, and then ensure the brazing conditions are sufficient to reduce these oxides. Typically, only elements present in the base material in concentrations over 0.5 wt% need to be considered. Some elements — such as Ti or Al — are such strong oxide formers that it is not possible to reduce these oxides in a brazing furnace. In cases where the Ti or Al concentration exceeds 0.5 wt%, you may need to electroplate the base material with a layer of Ni prior to brazing.

Achieve good and consistent results by acquiring proper knowledge, gaining experience with your brazing furnace, monitoring your process parameters and brazing results and following a suitable maintenance schedule.


Based on N. Bredzs and C. Tennenhouse, 1970, Metal-Metal Oxide Equilibria in Pure Hydrogen Atmosphere (Welding Journal)
Vacuum brazing

Why vacuum brazing?
Vacuum brazing produces clean brazed joints which are free from porosity. It is especially suitable for large or complex components where other brazing atmospheres will not reach all areas effectively. During the brazing process, gases — and thereby also oxygen — are removed from the brazing furnace. This is done by pumping down to a sufficiently low pressure to avoid oxidation of the base material and brazing filler material. Vacuum furnaces are most commonly batch-type furnaces, but semi-continuous vacuum furnaces are also available.

What needs to be considered for successful results?
There is a common misconception that the stronger the vacuum in the brazing furnace, the better the brazing process will be. This is not true, as metals will start to outgas at sufficiently low pressures and high temperatures, causing problems such as joint porosity and increased need for furnace maintenance. As shown in the vapour pressure curves below, the vacuum level in the brazing furnace should be sufficiently strong to reduce the metal oxides, but weak enough to prevent outgassing of the base materials or brazing filler metal. It is also possible to reduce the outgassing by introducing a partial pressure of a dry inert gas such as argon or nitrogen into the furnace. Many vacuum furnaces can operate under a partial pressure.

Vapour pressure curves
Controlled atmosphere brazing

Why controlled atmosphere brazing?
Although vacuum is also defined as a controlled atmosphere, the term “controlled atmosphere brazing” is used here for brazing in other gaseous protective or reducing atmospheres. There are many different atmospheres that can be used for brazing Höganäs BrazeLet® products. The most commonly used atmospheres for brazing Ni- and Fe-based brazing filler metals are:

- Deoxygenated and dried hydrogen
- Cryogenic or purified nitrogen + hydrogen
- Purified inert gas (e.g. argon)
- Dissociated ammonia (75% N₂ + 25% H₂)

Controlled atmosphere brazing furnaces can be continuous belt-type furnaces, semi-continuous furnaces or batch type furnaces. Continuous belt-type furnaces are typically employed for high production quantities, for components that are not overly sensitive to oxidation.

What to consider for successful results?
The different brazing atmospheres require special considerations when it comes to selecting the optimal brazing paste and the correct brazing filler metal. Please take notice of the safety considerations for operating the furnace equipment.

When brazing in a controlled atmosphere under ambient pressure, the brazed joints typically contain somewhat more porosity compared to vacuum brazed joints. This is the case as the driving force for removing gas from the filler material is lower.

For brazing with paste in a continuous or semi-continuous furnace, it is important to have a furnace capable of including a dedicated de-binding step at the recommended temperature (typically 450 °C) to avoid sooting of the parts or oxidation of the brazing filler metal. Moreover, it is critical to have a smooth belt movement in the furnace to avoid the brazing filler metal shifting or falling off the part after the de-binding step.

High production rates for high-quality parts can be produced with belt furnace brazing, as long as the correct process parameters are used. Höganäs’ brazing experts can recommend the optimal BrazeLet brazing paste for your process.
The brazing process
Optimize your brazing cycle

During the brazing process, our Höganäs BrazeLet® pastes go through a series of stages. Learn how to optimize your results by using the recommended standard cycle.

The recommended brazing cycle
In the recommended brazing cycle, as shown on the right side, the paste starts off as wet, containing metal powder, polymer and solvent. As the temperature increases, the solvent evaporates leaving a dry paste. Next, the polymer burns off and leaves only the metal particles, which then start to sinter. Lastly, the melt initiates and the filler metal starts flowing and fills any gaps by capillary action.

When the different stages occur depends on the paste and brazing filler metal. In the Höganäs BrazeLet® F300 example, the following is used:

- **Drying:** 20–170 °C depending on the binder
- **Debinding:** 300–450 °C depending on the binder
- **Melt initiation:** 1000–1030 °C
- **Metallic residue:** 1040–1060 °C
- **Full braze:** 1100 °C

Enhance your process
In order to optimize your brazing process, it is important to understand the purpose of the brazing profile. Some of the steps are not always necessary, while others may require additional complexity to yield the best possible brazing results. Typically, all brazing profiles should contain a controlled binder burn-off hold at 450 °C which is long enough to guarantee that the entire batch has reached the required temperature. It is also common to include a homogenization step before the melt initiates. This is essential to ensure that the entire batch has the same temperature before passing the solidus temperature of the brazing alloy. The need for a homogenization step can be avoided by reducing the furnace’s heating rate. A hold time at brazing temperature is also recommended. However, it should be shorter in duration than the previous steps since the temperature should be relatively even in the furnace at this stage. Accelerated cooling is recommended to speed up the overall process time and
minimize any negative impact on the base materials such as grain boundary segregation or grain growth.

If the recommendations for an optimal brazing profile are not followed, there is a risk of poor brazing results, even with high quality brazing filler metals and brazing pastes. The two main factors that should be considered carefully is using the correct binder burn-off temperature and heating the whole batch to the correct brazing temperature.

Ensure a proper drying cycle for the applied paste!
Binder removal

Some brazing filler metals are more sensitive to oxidation than others, and this can occur at any stage in the brazing profile as long as the temperature is high enough. Examples of oxidation sensitive brazing filler materials are the high Cr filler metals Ni613 and BNi-12. The oxides that are formed vary in colour, from a light gray to dark green depending on the oxidation temperature and oxygen content in the atmosphere.

Binder burn-off oxidation is one common issue which can occur if the component’s temperature is too high when the polymer in the binder decomposes. It starts becoming critical at temperatures around 550 °C and higher.

Höganäs BrazeLet® pastes normally contain 85–93% metal powder, with the remainder being binder.

Water or oil — the main constituent of the binder — can be dried off before the component is put in the furnace. 0.2-2.7% of the brazing paste (depending on paste type) is polymers which will decompose in the furnace in the temperature interval 300–450 °C. During the decomposition of the processes, gas by-products such as N₂, O₂ and CO are formed.

The binder burn-off products form a semi-atmosphere around the parts, which can oxidize if the temperature is too high. Therefore, they need to be removed from the furnace before the temperature is increased. The vacuum pumps are generally sufficient enough to remove the semi-atmosphere, but the process can be sped up by introducing a sufficient flow of dry process gas, such as N₂.

Even if the temperature is not deliberately increased to over 550 °C during binder burn-off, there is still the possibility of oxidation. Due to the inherent low heat transfer at low temperatures in a vacuum furnace, the middle of the batch may be trailing in temperature. Because of the lack of atmosphere inside the furnace, radiation is the primary way of heat transfer. The inherent issue with radiation is that the middle of the batch will be in the “shade”, which usually has the same effect on the temperature ramp that is shown in the diagram above.

The effect may be binder burn-off oxidation of the outer batch, since once the inner batch reaches the burn-off temperature (300–400 °C) the outer batch may already have reached a critical temperature of 550 °C or higher.
Still brazing problems?

With our brazing experience, we can help you find the source of your problems and support you in improving your processes.

Discolouration of the base material or filler metal is a common problem in brazing which can be easily avoided. It stems from oxygen being present in the furnace during the high temperature portion of the brazing cycle. To overcome this problem, the source of oxygen needs to be located. The tables on the right side show some of the common causes for base material and brazing filler metal oxidation.

As a quality control measure, it is also possible to include one or several reference samples of known and consistent quality with each furnace batch. This way, it is possible to pinpoint whether the issue comes from the brazing furnace itself, or whether it is a problem with the base material or brazing filler metal.
### Vacuum furnace brazing

<table>
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<tr>
<th>BM* oxidized</th>
<th>BFM** unmelted (no joint)</th>
<th>BFM melted but oxidized (complete joint)</th>
<th>BFM partly melted with oxidized residues (complete joint)</th>
<th>Potential causes</th>
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<td>Incorrect selection of brazing paste type for the process</td>
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<td>Marginal brazing atmosphere</td>
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** BM = Base material  ** BFM = Brazing filler metal

### Belt furnace brazing

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** BM = Base material  ** BFM = Brazing filler metal
Application support

Industry examples

We will help you find better solutions for your needs, to keep you one step ahead of future challenges.

By using our experience and the test capabilities in our tech centres, we consult you in running your brazing process as efficiently as possible, so that you can find the lowest total cost solution. Here are a few examples of our industry success stories that will show how we can help our customers grow in their respective markets.

**EGR coolers**
Höganäs is working together with several EGR cooler manufacturers, providing not only the brazing filler material but in some cases also the application of brazing paste. EGR coolers can be brazed with Höganäs’ licensed product BrazeLet® Ni613, which is a brazing alloy with excellent corrosion and oxidation resistance that is capable of withstanding the high temperatures in an EGR cooler. Together with Höganäs’ unique binder formulations, it is possible to produce high quality brazing paste coatings and leak-tight joints.

**Stainless steel brazed plate heat exchangers**
Savings in space, energy and maintenance are all crucial to manufacturers of brazed plate heat exchangers for gaining a competitive edge in the HVAC market. Strict environmental requirements in drinking water applications supersede the use of copper as brazing filler.

Höganäs is working closely together with several manufacturers to transit production to use Fe-based brazing filler metals to go along with use of cost effective paste application methods. The stainless steel filler offers the best sustainable solution as it is fully recyclable.
Cu-free oil coolers with a brazing solution from Höganäs

Höganäs BrazeLet® F300, a patented stainless steel brazing filler material, makes it possible to braze oil coolers completely without copper. Zero ppm copper leaching to the engine oil results in increased oil lifetime and minimises wear on the engine. Better yet, it produces a product made entirely from stainless steel, which is easier to recycle and promotes sustainability in every step of the way. Oil cooler turbulators can be efficiently coated with paste using roller coating. This produces even coating layers with up to 20 m/min belt speeds using Höganäs’ own developed paste, which has been specially formulated for the roller coating process.

Let us find solutions for your needs! We are looking forward to collaborating with you and helping you growing in the market!
Catalytic converters

A catalytic converter is a device used to reduce the toxicity of emissions from an internal combustion engine. It works by using a catalyst to stimulate a chemical reaction in which toxic by-products of combustion are converted to less-toxic substances. Catalytic converters are also used on generator sets, forklifts, mining equipment, trucks, buses, trains, airplanes and other machines using engines. By using Höganäs’ BrazeLet® BNi5 paste the process can be optimized, improving process security as well as product quality.
We walk the sustainable path!

Höganäs strives to be a catalyst for change and become a truly sustainable business. For us, environmental and social care, and business success are intertwined. Our sustainability strategy, Mount Sustainability, sets the direction.

A great and meaningful place to work means respect, equal treatment, competence and leadership development. For us, people that prosper are the foundation for the timely and efficient delivery of quality products and services to our customers.

Building communities and responsible partnerships includes amongst other things our extensive work with responsible sourcing, working together with our suppliers to develop and secure high standards concerning human rights, labor rights, anti-corruption and environmental protection.

Sustainable products and long-term profitability describes our efforts to develop products that benefit both our customers and society. Our products not only enable our customers to reduce their material and energy consumption, but also improve the efficiency of their final products. Future-proof business means ensuring high quality in our products through effective work methods, a clean work environment, responsible use of resources, Zero Waste and Zero Accidents. Climate neutral operations is the guiding vision for our work with careful monitoring of our emissions, efficient use of energy and resources in production and transport, and gradually changing to renewable resources.

Höganäs aims to be the partner that enables sustainability and seeks cooperation with suppliers, end users, academia and communities to meet the expectations and requirements of society.
We are looking forward to collaborating with you.
Inspire industry to make more with less

Höganäs vision is to inspire industry to make more with less. Metal powder technology provides endless opportunities; not only does it enable our customers to reduce their material and energy consumption, but it also helps them use new and better techniques that make final products more efficient and less expensive. In short, metal powders are a resource-efficient alternative, suitable for many industries – that’s one of our contributions to a sustainable world.

Contact your nearest Höganäs office today.