

A close-up photograph of several metal tubes, likely stainless steel, arranged in a cluster. The tubes are joined at their ends using a brazing process, creating a complex, multi-jointed structure. The lighting highlights the metallic surfaces and the texture of the brazed joints.

Brazing

Technical handbook

Filler metals | Processing | Application development

Höganäs 
POWDER THAT EMPOWERS®

Höganäs

Your preferred brazing partner



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.

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?

Höganäs supports 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.



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Höganäs will support you in achieving the best brazing result



Application development

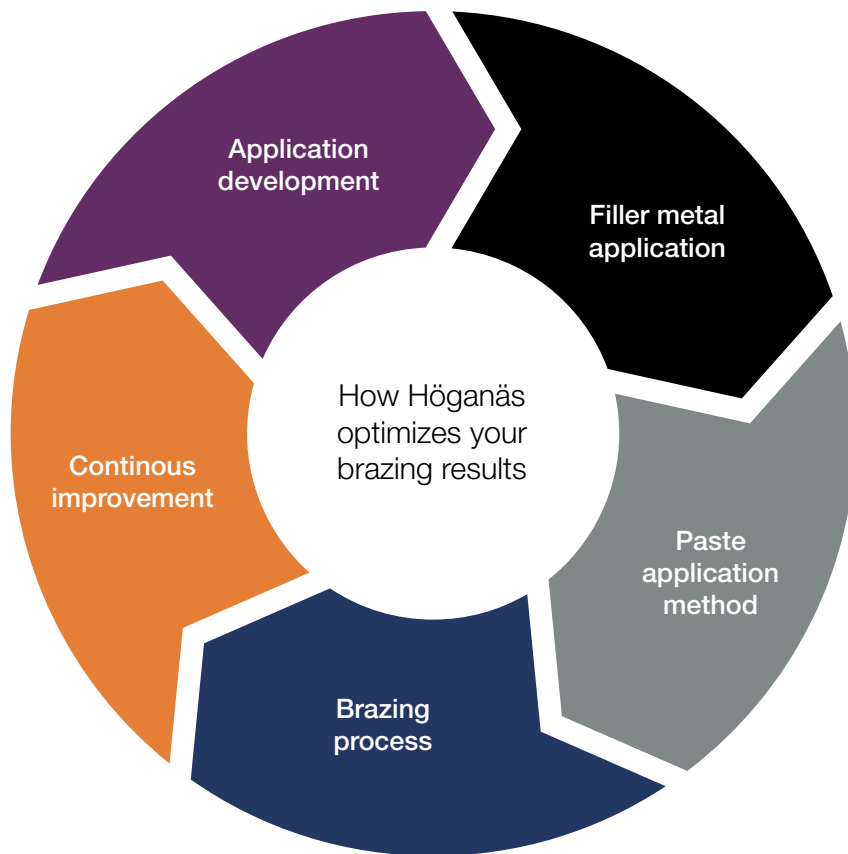
We support you in defining the brazing filler metal and braze joint properties

By working closely with our customers' applications, we have gained extensive knowledge and 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 optimising 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

Höganäs offers 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. Our highly qualified employees in our pilot centres, application centres and metallographic and analytic labs utilise state-of-the-art equipment to develop new and customised filler metals. Our filler metal production meets the highest quality standards and is certified according to standards such as ISO 9001, ISO 14001 and IATF 16949, as well as relevant OEM specifications for the industries we serve. 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. Höganäs has 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

Höganäs 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.



Höganäs filler metals

Powders & Pastes



Discover Höganäs' broad portfolio of Ni and Fe-based powders and pastes being produced in Höganäs' state-of-the-art production facilities.

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. Further to the cost-benefit, the Fe-based brazing filler metals offer reduced metal ion leaching compared to most conventional Ni-base brazing filler metals, making them advantageous for many heat exchanger applications.

Pastes

Are you looking for an efficient paste solution? Pastes from Höganäs has 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. Höganäs adapts 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 fulfil your exact requirements.

Höganäs filler metals

Product name	Chemistry (wt %)										Specification			Melting range	
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Ni-based alloys

BrazeLet	Ni	Cr	Si	Fe	B	C	P	Cu	Nb	Mo	EN ISO 17672	AMS	AWS A5.8	°F	°C
BNi1	Bal.	14	4.5	4.5	3.2	0.75	-	-	-	-	Ni 600	4775	BNi-1	1796-1940	980-1060
BNi1A	Bal.	14	4.5	4.5	3.2	-	-	-	-	-	Ni 610	4776	BNi-1a	1790-1970	977-1077
BNi2	Bal.	7	4.5	3	3	-	-	-	-	-	Ni 620	4777	BNi-2	1778-1832	970-1000
BNi3	Bal.	-	4.5	-	3.2	-	-	-	-	-	Ni 630	4778	BNi-3	1800-1900	980-1040
BNi4	Bal.	-	3.5	-	2	-	-	-	-	-	Ni 631	4779	BNi-4	1800-1950	980-1065
BNi5	Bal.	19	10.1	-	-	-	-	-	-	-	Ni 650	4782	BNi-5	1976-2075	1080-1135
BNi6	Bal.	-	-	-	-	-	11	-	-	-	Ni 700	n/a	BNi-6	1607	875
BNi7	Bal.	14	-	-	-	-	10.1	-	-	-	Ni 710	n/a	BNi-7	1634	890
BNi9	Bal.	15	-	-	3.6	-	-	-	-	-	Ni 612	n/a	BNi-9	1931	1055
BNi12	Bal.	25	-	-	-	-	10	-	-	-	Ni 720	n/a	BNi-12	1616-1742	880-950
Ni613	Bal.	29	4	-	-	-	6	-	-	-	n/a	n/a	BNi-15	1778-1886	970-1030
Ni623	Bal.	29	7	11	-	-	-	-	-	7.5	n/a	n/a	n/a	2120-2192	1160-1200

Fe-based alloys

BrazeLet	Ni	Cr	Si	Fe	B	C	P	Cu	Nb	Mo	EN ISO 17672	AMS	AWS A5.8	°F	°C
F300-20	20	20	4	Bal.	-	-	7	6.5	-	-	n/a	n/a	n/a	1877-1940	1025-1060
F86	18	29	6.5	Bal.	-	-	6	-	0.5	-	n/a	n/a	n/a	1922-2012	1050-1100



Please see the specific product datasheets at www.hoganas.com for further information

Höganäs also produces a range of customer specific and OEM specific alloy compositions and can support you in all stages from initial alloy development to large scale production. Please contact us to discuss your specific requirements

Rec. brazing temperature (min.)	Rec. gap clearance	Typical properties
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°F	°C	µm	
2102	1150	50-120	<ul style="list-style-type: none"> • Excellent joint strength • Excellent oxidation resistance • Medium fluidity • The first developed Ni-based brazing filler metal composition
2147	1175	50-150	<ul style="list-style-type: none"> • Similar to BNi1, with low carbon content
1922	1050	30-100	<ul style="list-style-type: none"> • Excellent joint strength • Excellent oxidation resistance • Good fluidity • Low brazing temperature and narrow melting range makes it a versatile brazing filler metal
2012	1100	0-50	<ul style="list-style-type: none"> • Good joint strength • Good oxidation resistance • Good fluidity • Less sensitive to marginal atmosphere conditions as it is Cr-free
2048	1120	50-100	<ul style="list-style-type: none"> • Similar to BNi3, but with better gap filling ability and better ductility • Good oxidation resistance • Medium fluidity • Forms relatively large fillets
2102	1150	30-100	<ul style="list-style-type: none"> • Excellent joint strength • Excellent oxidation resistance • Good fluidity • Low erosivity of most base metals
1742	950	0-30	<ul style="list-style-type: none"> • Medium joint strength • Medium oxidation resistance • Excellent fluidity (free-flowing) • Less sensitive to marginal atmosphere conditions as it is Cr-free
1796	980	0-30	<ul style="list-style-type: none"> • Medium joint strength • Medium oxidation resistance • Excellent fluidity (free-flowing) • Suitable for thin-walled components
2012	1100	30-100	<ul style="list-style-type: none"> • Excellent joint strength • Excellent oxidation resistance • Good fluidity • Particularly suitable for diffusion brazing applications as B diffuses rapidly
1922	1050	10-50	<ul style="list-style-type: none"> • Similar to BNi7, but with slightly higher strength and corrosion resistance • Medium oxidation resistance • Good fluidity
1994	1090	25-150	<ul style="list-style-type: none"> • Good joint strength • Excellent oxidation resistance • Excellent fluidity (free-flowing) • Excellent gap filling ability
2264	1240	25-150	<ul style="list-style-type: none"> • Good joint strength • Excellent oxidation resistance • Excellent fluidity (free-flowing) • Particularly suitable for brazing high-strength joints in super-austenitic stainless steels

°F	°C	µm	
2012	1100	25-150	<ul style="list-style-type: none"> • Good joint strength • Good oxidation resistance • Excellent fluidity (free-flowing) • Excellent gap filling ability • Excellent metal ion leaching characteristics
2102	1150	25-150	<ul style="list-style-type: none"> • Excellent joint strength • Good oxidation resistance • Good fluidity • Excellent gap filling ability • Excellent metal ion leaching characteristics

Höganäs brazing pastes

			Typical properties					
Product name	Particle size (µm)	Solvent type	Recommended drying		Evaporation temp. of binder		Viscosity* (Pa.s)	Density* (g/cm³)
			°F	°C	°F	°C		

Dispensing

D-9302	<106	oil	250-340	120-170	660-840	350-450	400 (T-spindle D)	4.6
D-9004	<106	oil	250-340	120-170	570-750	300-400	250 (T-spindle D)	4.0
DW-9201	<106	water born	250-300	120-150	570-750	300-400	1000 (T-spindle E)	4.6
DW-9003	<106	water	210-340	100-170	570-750	300-400	300 (T-spindle D)	4.2
DW-9013	<63	water	210-340	100-170	570-750	300-400	300 (T-spindle D)	4.3
DW-9005	<106	water	210-340	100-170	570-750	300-400	400 (T-spindle D)	4.0
DW-9007	<106	water	RT-300	RT-150	480-570	250-300	1000 (T-spindle E)	4.5
DW-9017	<63	water	RT-300	RT-150	480-570	250-300	1000 (T-spindle E)	4.5

Screen printing

P-9002	<63	oil	250-340	120-170	660-840	350-450	300 (T-spindle D)	4.0
P-9012	<106	oil	250-340	120-170	660-840	350-450	300 (T-spindle D)	4.0
P-9003	<63	oil	250-340	120-170	570-750	300-400	300 (T-spindle D)	4.0
P-9013	<106	oil	250-340	120-170	570-750	300-400	250 (T-spindle D)	4.0

Spraying

S-8701	<63	oil	250-340	120-170	660-840	350-450	25 (T-spindle B)	3.6
SW-8603	<63	water	210-340	100-170	570-750	300-400	80 (T-spindle C)	3.7

Roller coating

R-8501	<63	oil	250-340	120-170	660-840	350-450	90 (T-spindle C)	3.3
R-8511	<45	oil	250-340	120-170	660-840	350-450	90 (T-spindle C)	3.3
CRW-8502	<63	water	210-340	100-170	570-750	300-400	70 (T-spindle C)	3.8
R-9003	<63	oil	250-340	120-170	660-840	350-450	100 (T-spindle C)	4.0

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

Name explanation:

D = Dispensing
W = Water based / water born
C = Customized
P = Printing
R = Roller coating
S = Spraying

Example: DW-9201

DW = Dispensing, water based / water born
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.



BrazeLet packed in syringes.



BrazeLet packed in cartridges.



Interested in a more sustainable packaging choice?

We offer different packaging solutions for our products



BrazeLet packed in cans and buckets.

BrazeLet Stop-off

Höganäs BrazeLet Stop-off solutions act as a barrier to the flow of molten brazing filler metals. They should be used when the flow of the molten brazing filler metal must be contained or redirected due to tolerances, following assembly steps, and even to prevent brazed parts from bonding to their furnace fixtures.

To avoid contamination, care must be taken with the parts that will be brazed since the stop-offs are very effective and should not be applied where brazing will take place. It is not possible to completely remove the stop-off once applied.

BrazeLet Stop-off 10

- Recommended for general brazing applications.
- Due to its superior adhesion to the applied surfaces, it is specially recommended for application on fixtures.
- Can be applied by different methods, such as brushing, dispensing and spraying.

Available in 1 kg and 5 kg containers

BrazeLet Stop-off 11

- Recommended for general brazing applications.
- Specially designed for application with a marker pen.
How to use the pen: Shake it, then press the tip down until stop-off starts flowing. Keep the pen slightly pressed against the surface to ensure an even flow of stop-off while drawing the wanted markings.
- The pen can be reused and coupled with the stop-off refill, which allows for decrease waste in both packaging and stop-off material.

Available in pens and 1 kg refill container

BrazeLet Stop-off 20

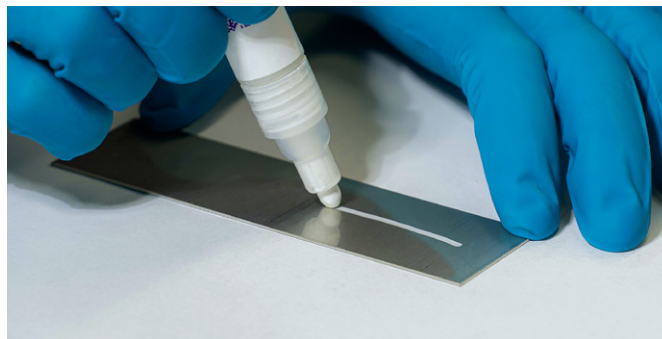
- Recommended when best surface finish after brazing is needed.
- Due to its easiness of removal, it is specially recommended for application on the brazed parts.
- Can be applied by different methods, such as brushing, dispensing and spraying.

Available in 1 kg and 5 kg containers



Directions for use

Drying temperature	RT – 200 °C (RT–329 °F)
Working temperature	Up to 1,320 °C (2,408 °F)
Recommended storage	5–30 °C (41–86 °F) in closed container and well-ventilated space
Recommended uses	<ul style="list-style-type: none"> • All base materials (except reactive metals such as Ti and Zr and their alloys) • Any of Höganäs brazing filler metals • Vacuum and controlled atmosphere brazing
Post-brazing cleaning	The residual stop-off is easily removed by using a dry or damp cloth



Applying BrazeLet Stop-off 11 with a pen

Water-based and
without odour

Sinter Braze 21

Combining our knowledge and experience as the market leader in powders for pressed and sintered metal components with our brazing capabilities, Höganäs developed an improved solution for sinter brazing that was launched to the market in 2022.

Sinter brazing allows you to save time and reduce costs when producing complex parts through simultaneously sintering and bonding components.

Sinter Braze 21 is an easy solution that facilitates a better brazed joint which is generally as strong, or stronger, than the base materials being joined.

This sinter braze material offers more efficient brazing compared to conventional sinter braze materials. In addition to less sinter braze material needed, Sinter Braze 21 delivers stable mass production of components with improved joint quality and consequently fewer rejected components. In mass production trials the braze amount could be reduced by up to 20% compared to the previously existing solutions on the market.

Sinter Braze 21 was developed to give optimal flow characteristics in the gap with limited infiltration into the base material, making it less sensitive to density variations in the compacted component. Compared to conventional sinter braze materials the amount of flux can be significantly reduced or in some cases completely removed, which is good for the working environment as well as for compacting and braze quality.



Main product benefits

- » Uniform braze quality
- » Improved brazing efficiency
- » Less sinter braze consumption
- » Less residue
- » Robust

Basic product characteristics

Sinter Braze 21 press ready mix for tablet usage.

Nominal Chemistry

	Ni	Cu	Mn	Si	B	Fe	Others
Content (wt-%)	38.6	37.6	14.1	1.7	1.4	6.0	<1

Apparent density

2.05 g/cm³

Size distribution

-425/+75 micron

Operating temperature

Solidus: 925 °C

Liquidus: 1,045 °C

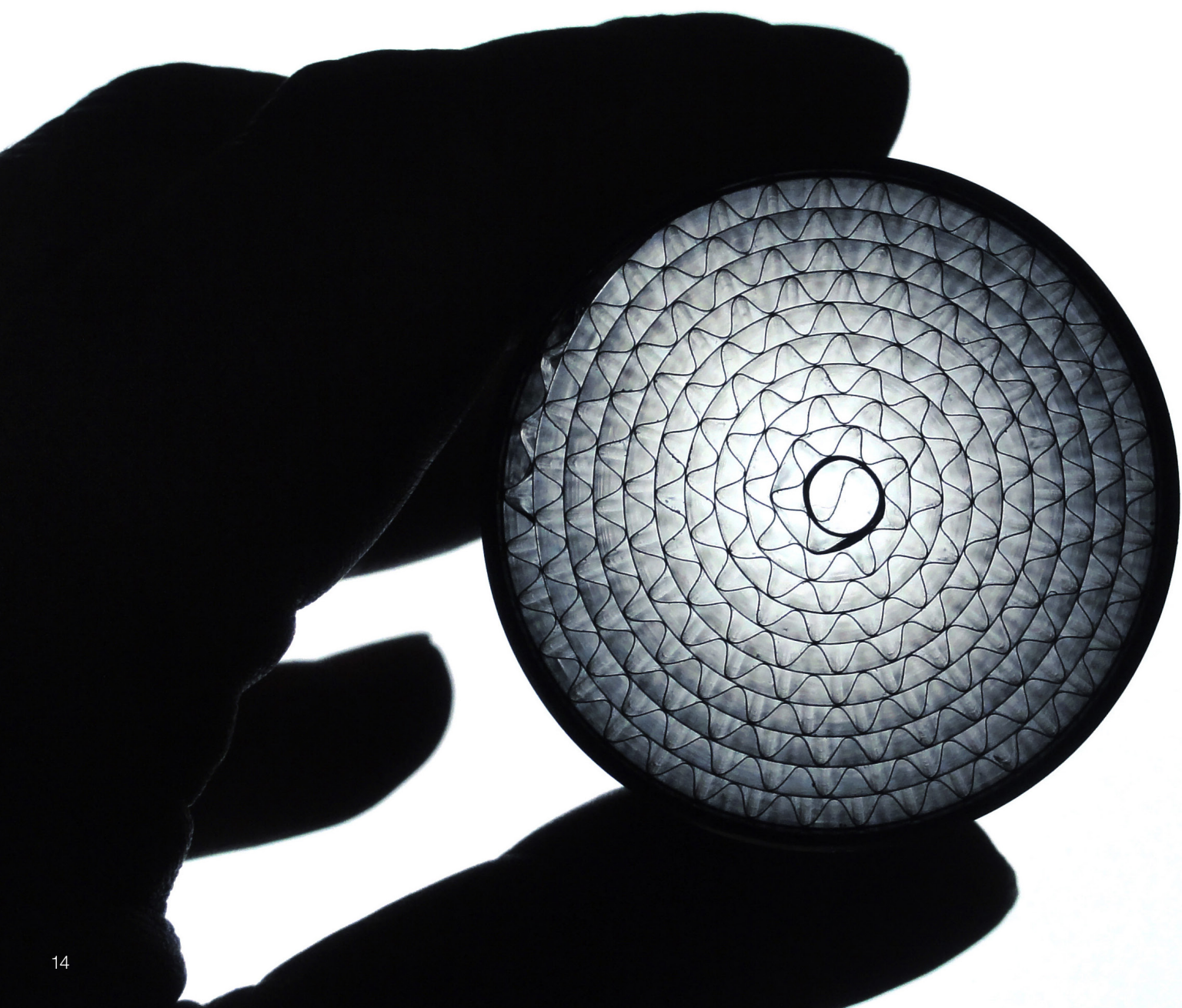
Process recommendation

Gap clearance: 0.05-0.15 mm

Minimum sinter brazing temperature: 1,100 °C



For a uniform and robust brazing result



Höganäs filler metals

Properties

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.

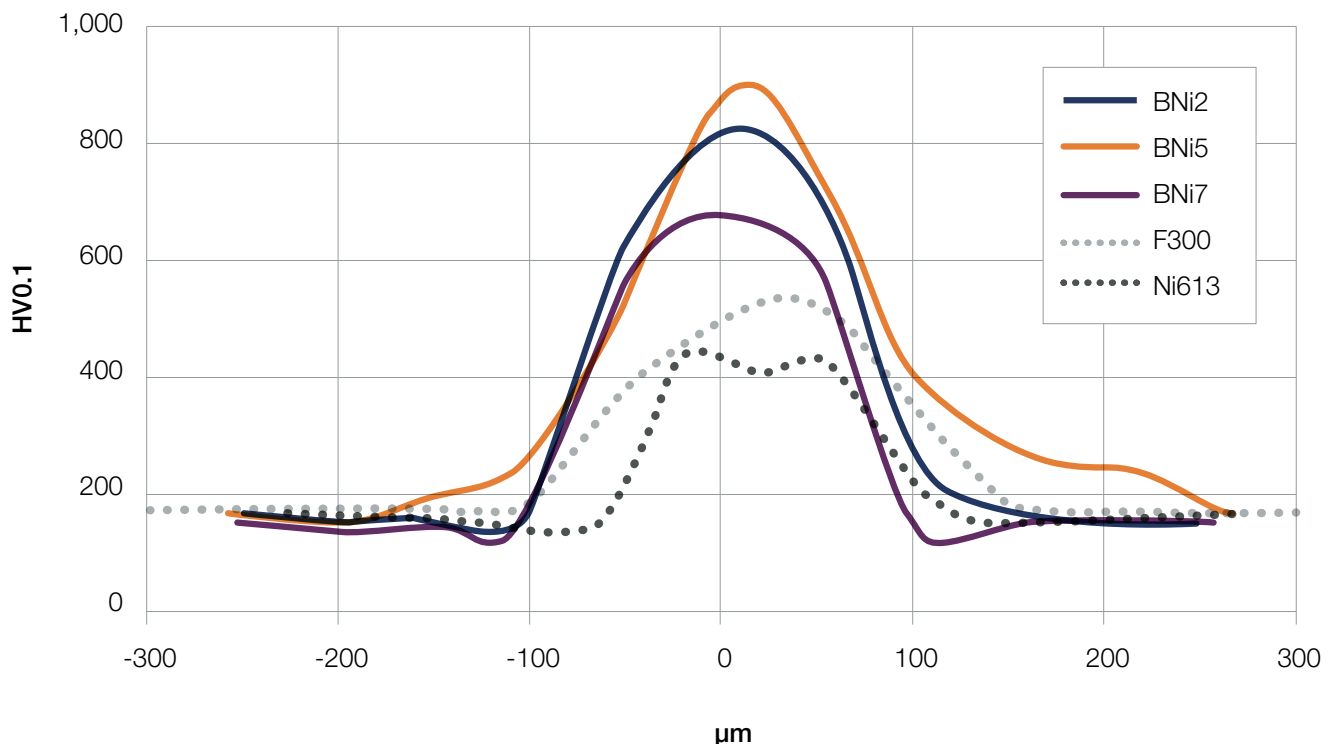
Most conventional Ni- and Fe-based brazing filler metals contain a significant amount of melting point depressant elements such as P, Si and B, which can lead to the formation

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 for joints wider than 50-100 µm.

Microhardness profile of BrazeLet filler metals



Wetting

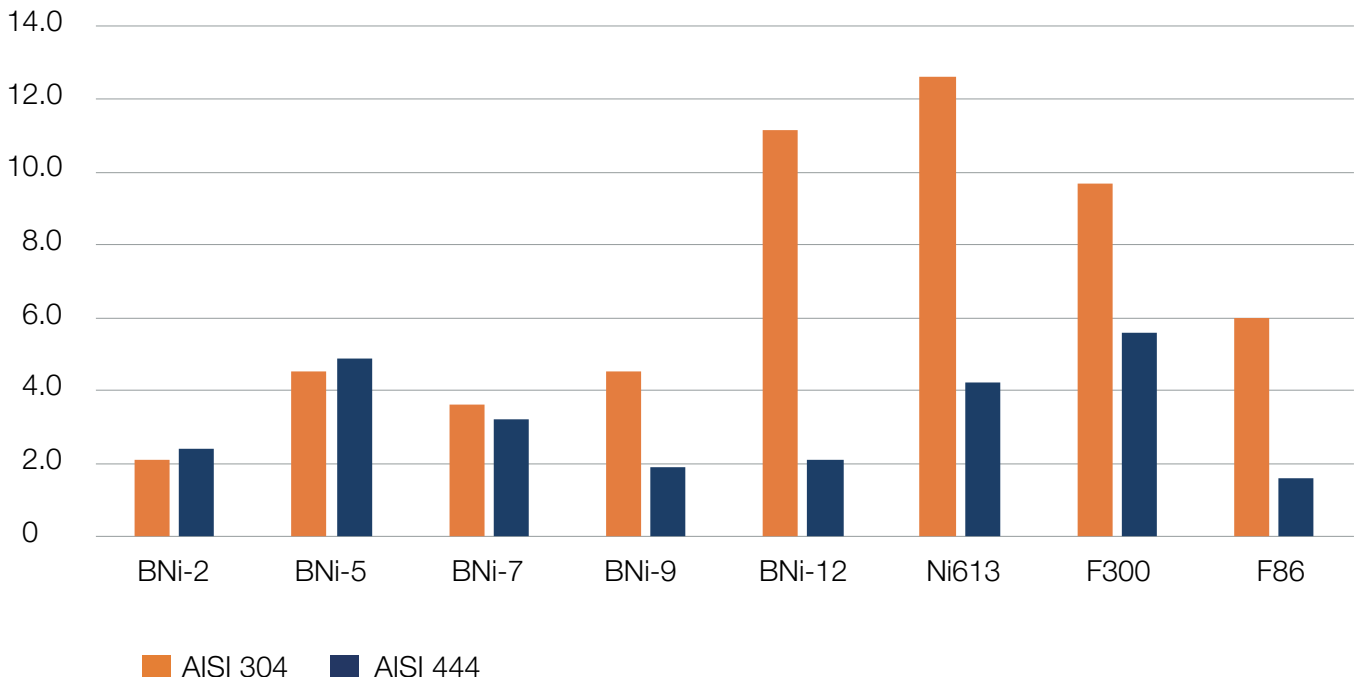
The ability of the brazing filler metal to wet and spread out over the base materials to be joined is an important feature to achieve good brazing results. For best possible wetting results, the base material surfaces need to be clean and free from oxides. Wetting is dependent on both the filler metal 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





Strength

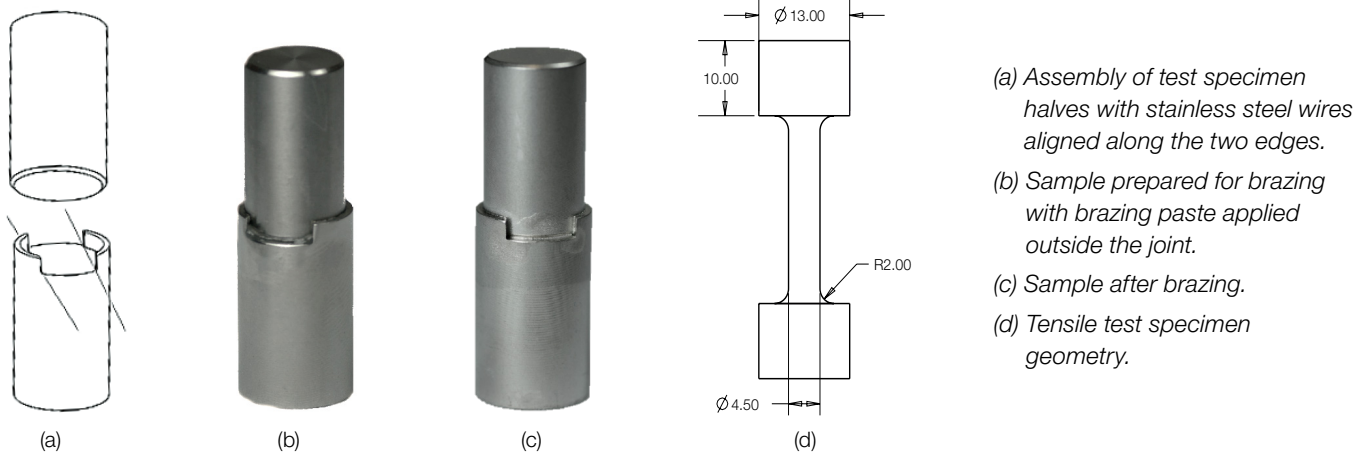
The designer of brazed components needs to factor in the strength value in the gap design. Most Ni brazing filler metals are sensitive to gap sizes, requiring $<50\text{ }\mu\text{m}$, whereas BrazeLet Ni613 and BrazeLet F300 maintain their good strength even at larger gap clearances. Strength evaluation 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 both single-lap joint tensile testing and butt-joint tensile testing to measure the joint strength of brazed joints. Single-lap joint tensile testing is done in accordance with the requirements and guidelines in AWS C3.2/C3.2M with the specimen configuration shown below. As the overlap / thickness ratio greatly influences the complex stress state in the brazed joint for single-lap joints, testing is typically performed at a range of different overlaps.

In many cases, for example in brazed plate heat exchangers, the brazed joints are loaded in tension transverse to the joint. To provide the best advice for the individual application, Höganäs performs extensive tensile testing of all BrazeLet brazing filler metals.

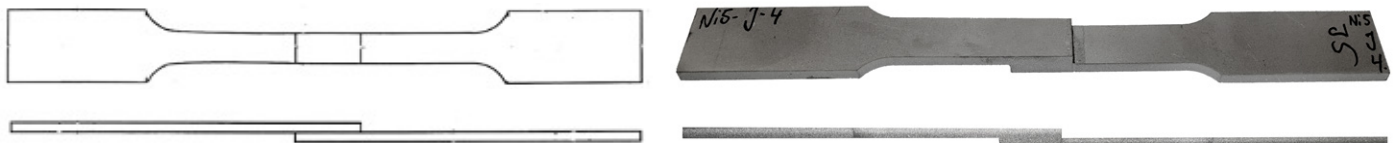
Butt-joint tensile testing is performed in accordance with SS-EN 12797 and EN ISO 6892-1 (as shown below).

Preparation of the butt-joint tensile testing specimens 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.

For any of the test methods, the gap clearance greatly affects the joint strength for some of the brazing alloys, due to the differences in microstructure of the brazed joint. 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 BrazeLet 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.

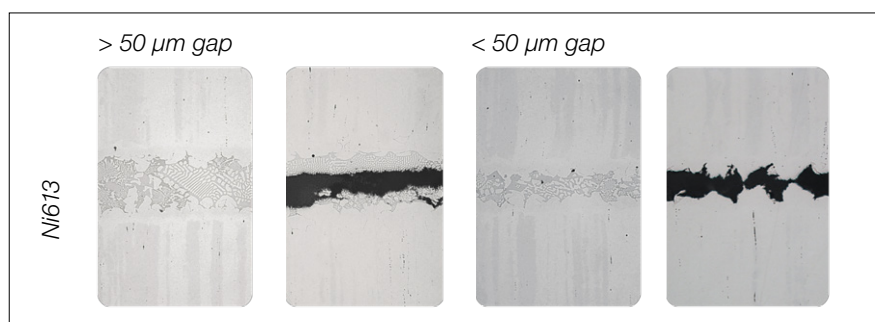
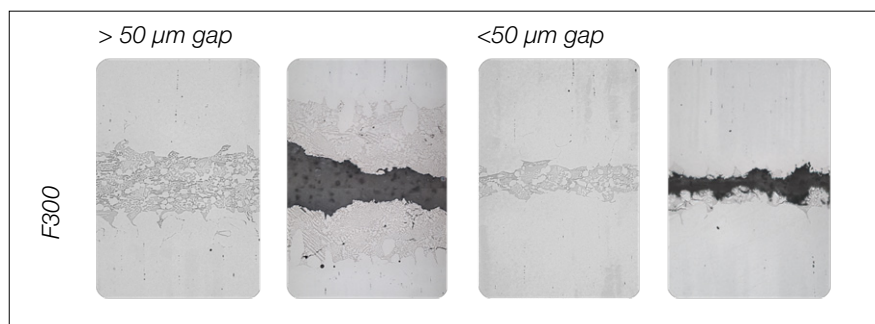
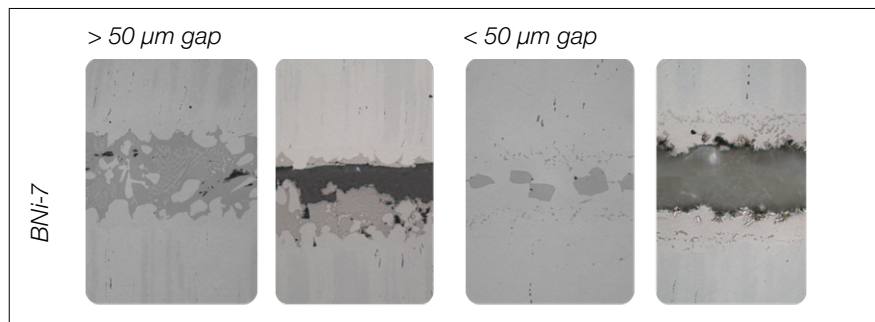
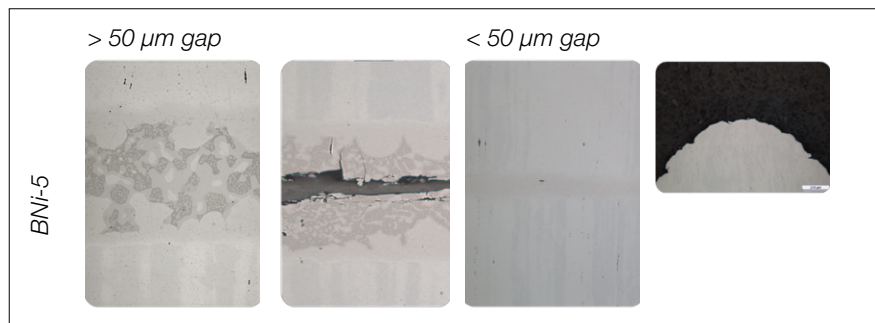
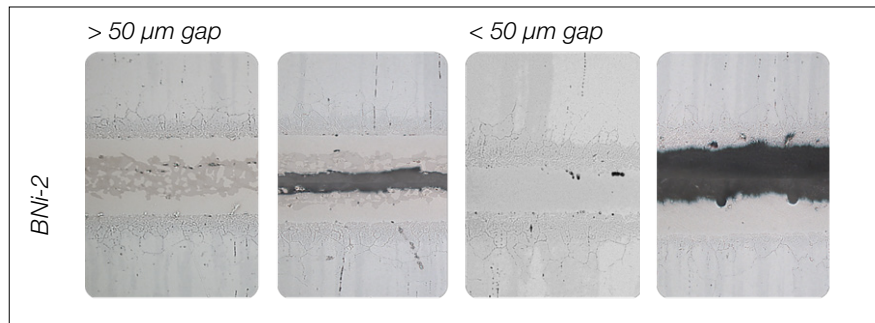


Butt-joint tensile test specimen preparation according to SS-EN 12797



Single-lap joint tensile test specimen preparation according to AWS C3.2/C3.2M

Gap clearance effect on microstructure and fracture propagation





Corrosion

Testing is normally done on finished components during service. Höganäs will 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 standardized 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). All Höganäs' BrazeLet filler metals offer good corrosion resistance in a range of different corrosive media. Several factors such as the base material, brazing filler metal combination or the brazing process and atmosphere influence the corrosion resistance of brazed joints. Testing is therefore required for the specific application. Based on extensive

testing, Höganäs' brazing experts will recommend the best alloys for specific corrosive environments.

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

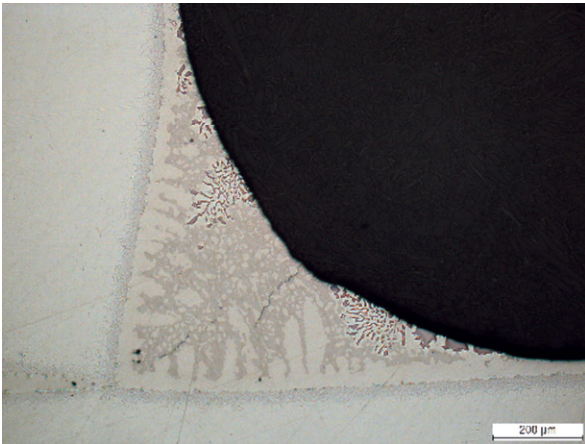
- Preferential corrosion of certain phases in the microstructure with lower corrosion resistance than the surrounding matrix
- Corrosion along the base material – filler metal interface where the alloyed mixture of base material and filler metal may have lower corrosion resistance than the surrounding 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 will help you find the right materials for your needs!

Examples of corrosion testing of filler metals in corrosive environments

BrazeLet Ni2

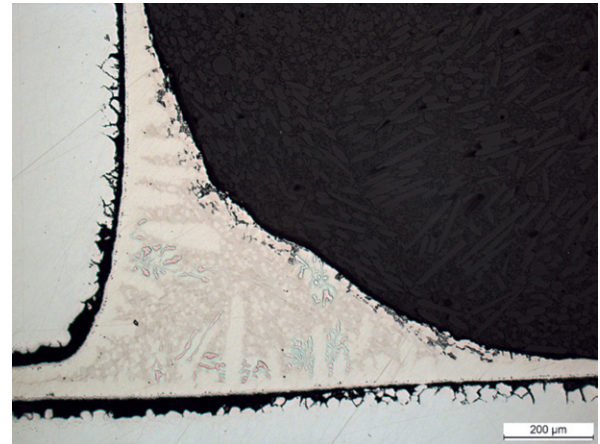
Reference sample – not subjected to corrosive media



Week 1

BrazeLet Ni2

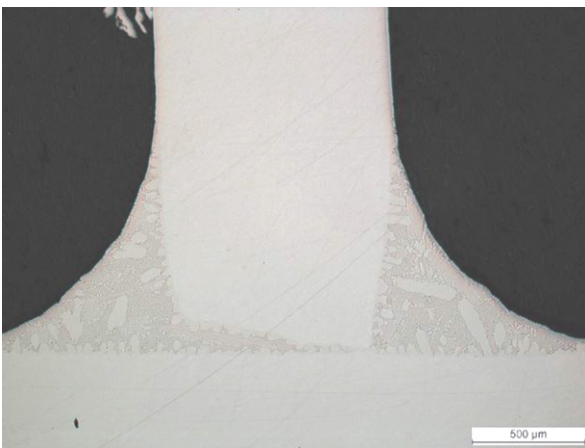
After 4 weeks in Höganäs' pH1 sulphuric acid condensate mix – interface line corrosion due to Cr-boride precipitation



Week 4

BrazeLet Ni613

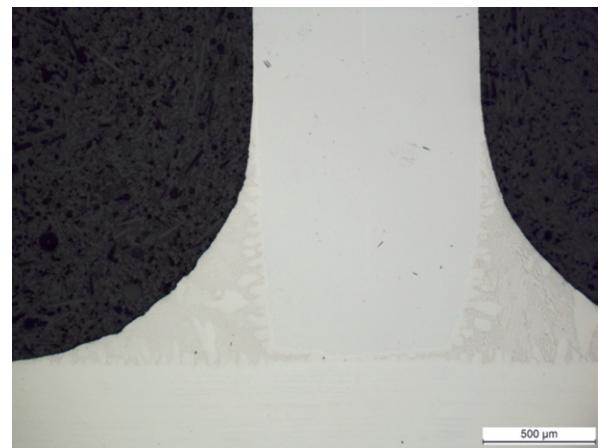
Sample – not subjected to corrosive media



Week 1

BrazeLet Ni613

After 8 weeks in Höganäs' pH1 hydrochloric acid condensate mix – no significant corrosive attack



Week 8



The brazed joint is an integral part of the brazed component and is important for the overall component performance in a corrosive environment.



Paste application methods

Höganäs has developed BrazeLet brazing pastes for the specific requirements of different application methods such as spraying, dispensing, roller coating and screen printing 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 ($\pm 1\%$) instead of air pressure dispensers ($\pm 5\%$) additional cost savings can be achieved.

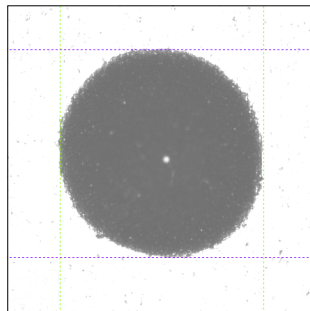
Höganäs' dispensing unit features a motor driven precise screw dispenser and a robot, allowing for automated and fast paste application on complex parts that other application techniques are not capable of reaching.

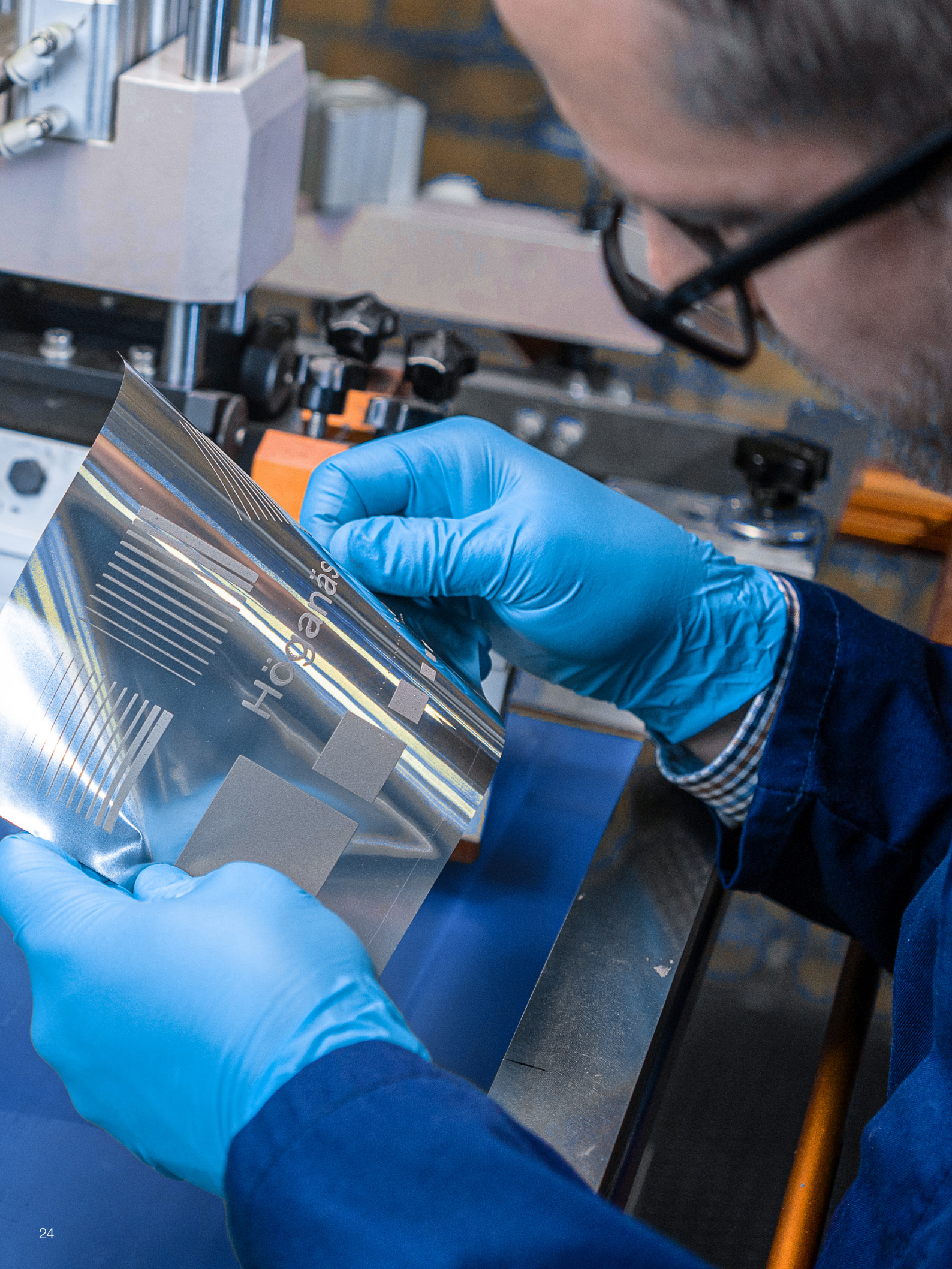
Jet dispensing

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.

$dx = 1.053 \text{ mm}$
 $dy = 1.068 \text{ mm}$

Micrograph picture and picture of a jet dispensing equipment (courtesy of Musashi Engineering, Inc.)





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

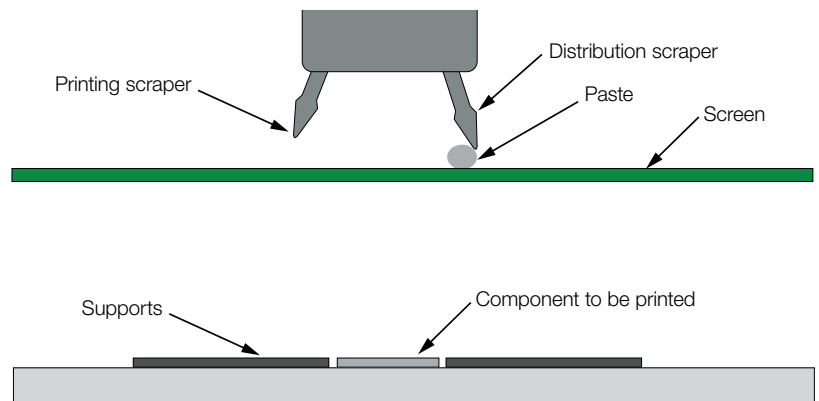
component. A blade or squeegee pushes the paste through the laser cut open area of the stencil which has been designed specifically for the component.

It is possible to print thin paste layers down to $50\text{ }\mu\text{m}$ and structures as narrow as 0.3 mm , but also thick layers up to 0.8 mm .

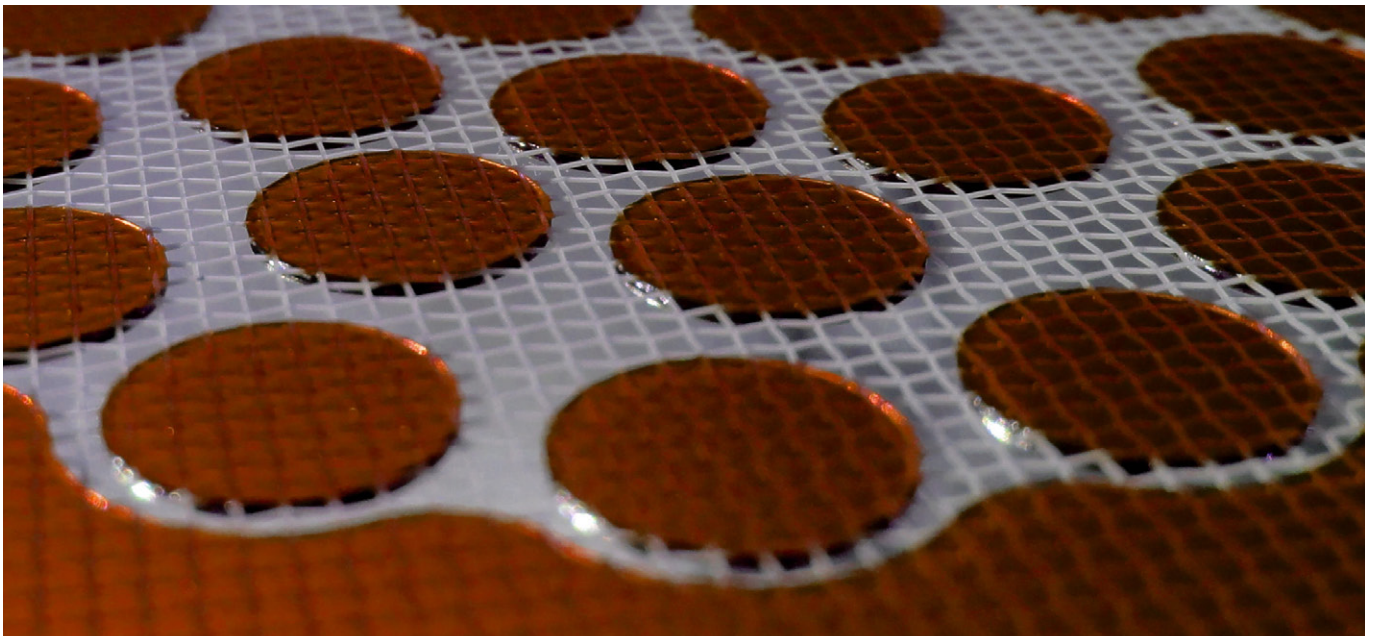
Höganäs' screen printer, located in our tech centre, is suitable for prototyping customer parts by screen or stencil printing with appropriate paste thickness.

Printing operation

- Paste applied on top of the stencil/screen, outside printing area
- Distribution scraper is distributing the paste over the printing area
- Printing scraper pushing the paste through the mesh to the component



Printing setup





Roller coating

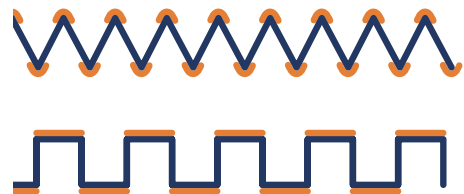
Roller coating is suitable for flat components where production rate and quality are of highest importance. At the same time, it is possible to make savings on material costs, since less material is used with roller coating compared to foil. During the roller coating process, the components are fed on 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.

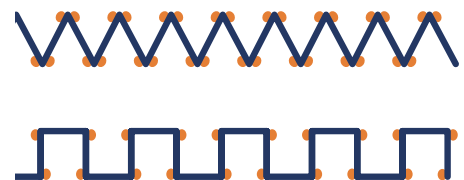
Brazing paste alloys can be manufactured without any boron (B), making it a great alternative to B-containing brazing foils. B has been found to negatively affect brazed joint corrosion resistance and base material mechanical properties such as strength and ductility.

Achievable coatings with roller coating:

Top coating



Side coating



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 for high volume production. Spraying as application method is very flexible. No need for fixtures or other clamping devices. On components like plates for heat exchangers spraying can eliminate additional dispensing application, reducing the overall investment cost.

Choosing the correct equipment is key for the best spraying results and equipment lifetime.



With Höganäs BrazeLet brazing pastes you can recycle and recondition the overspray



*Automated spraying machine
(Courtesy of Robert Bürkle GmbH)*



The brazing process

Furnace brazing

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

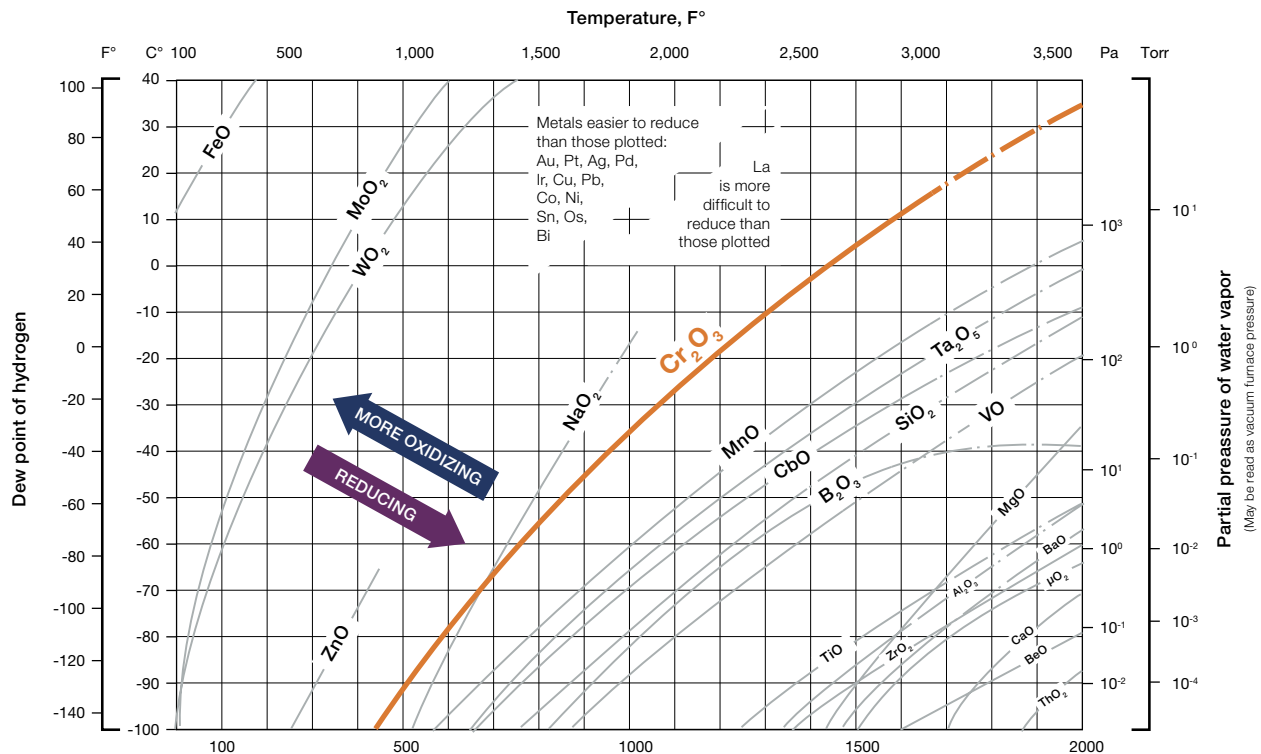
Successful furnace brazing

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 compo-

nents 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.



Metal-Metal Oxide Equilibrium Curve



Based on N. Bredz and C. Tennenhouse, 1970,
Metal-Metal oxide equilibria in pure hydrogen atmosphere (Welding Journal)



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, but issues with improper wetting and flow of the brazing filler metal can often be seen at even lower concentrations depending on the brazing process conditions.

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.

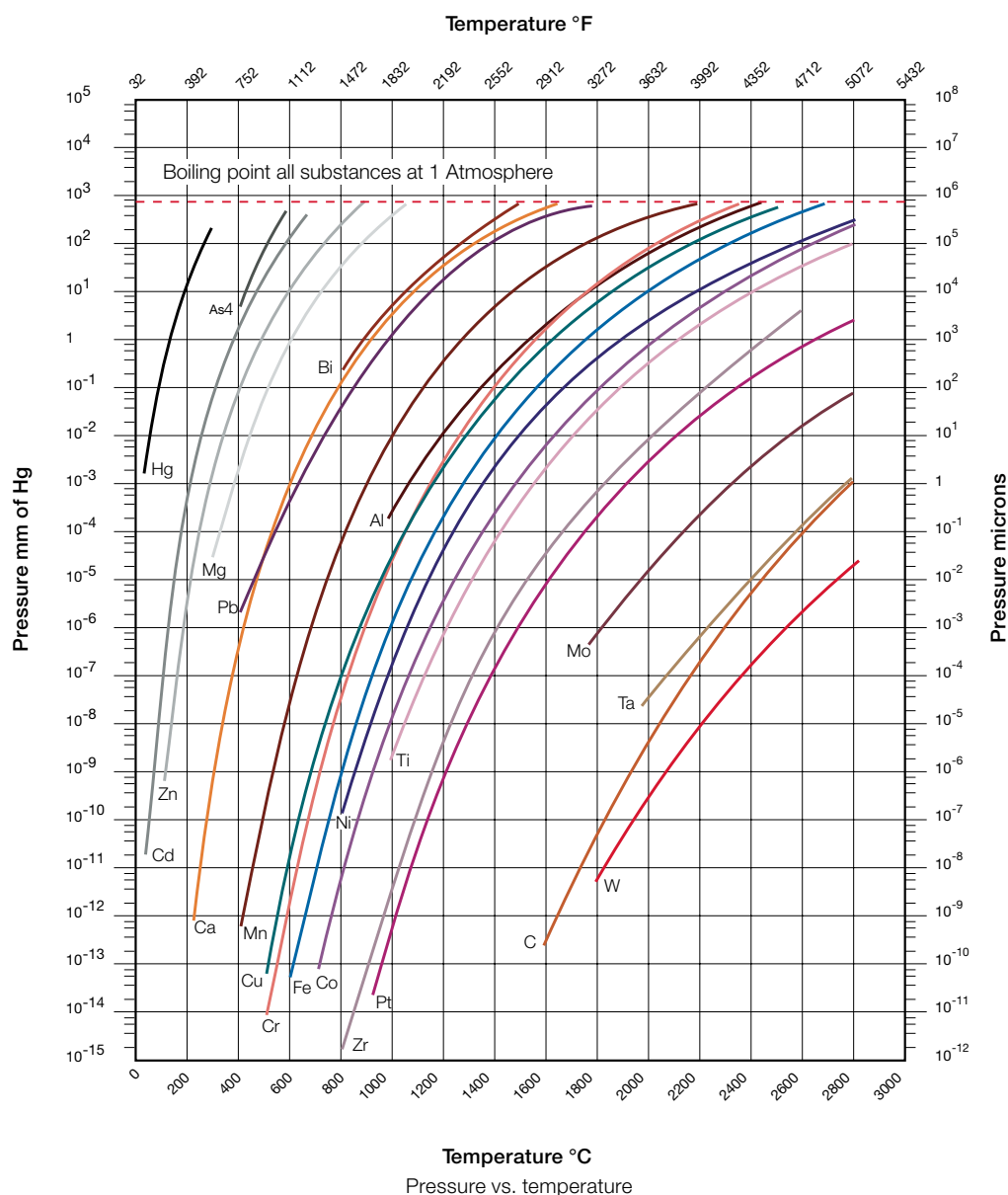
Vacuum brazing

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

Based on R.G. Aspdub and W. Feduska, 1958, *Fatigue Characteristics of Single-Lap Joints of AISI 347 Brazed with Ni-Cr-Si-B-C Alloy* (Welding Journal)



Do you want to learn more about brazing processes? Please visit our website: www.hoganas.com/brazing



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% H₂ + 25% N₂)

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, the heating rates are typically much higher compared to vacuum brazing. This makes selection of the correct brazing paste formulation, filler metal placement and setting the optimal temperature profile more important to achieve good brazing results. 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

Optimise your brazing cycle



During the brazing process, Höganäs BrazeLet pastes go through a series of stages. Learn how to optimise 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:	1,000-1,030 °C
Metallic residue:	1,040-1,060 °C
Full braze:	1,100 °C

Enhance your process

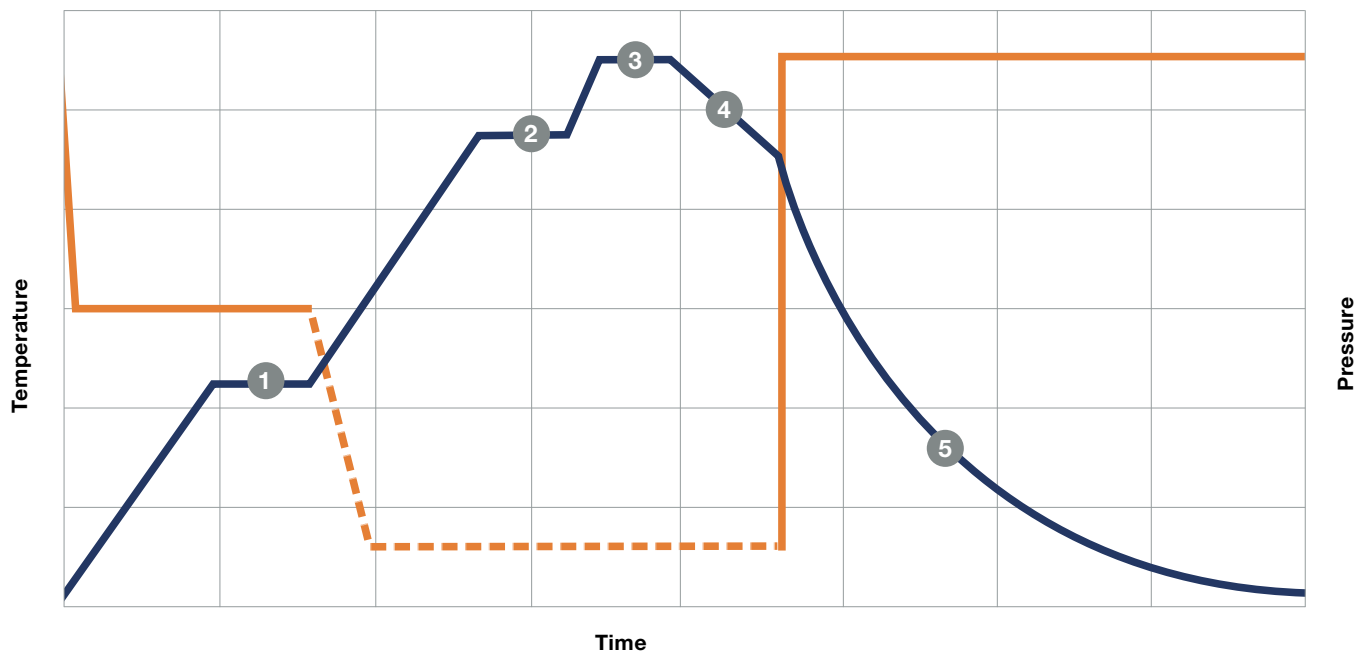
In order to optimise your brazing process, it is important to understand the purpose of the brazing profile. Some of the steps are not always necessary, while others may require additional complexity to yield the best possible brazing results. Typically, all brazing profiles should contain a controlled 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 in a uniform manner.

Ensure a proper drying cycle for the applied paste!

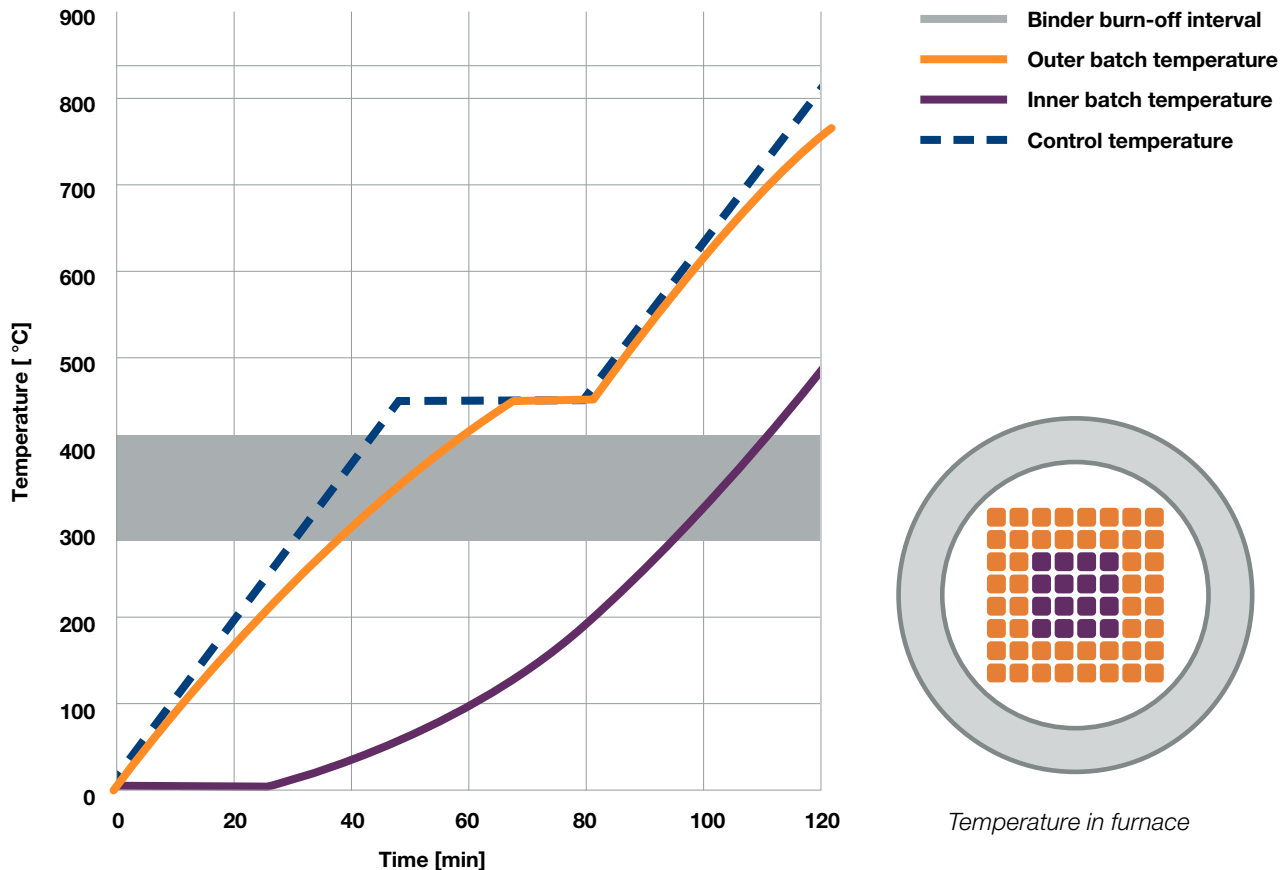
Recommended temperature and pressure profile for vacuum furnace brazing with partial pressure



- 1. Controlled binder burn-off
- 2. Temperature homogenization

- 1. Controlled binder burn-off
- 2. Temperature homogenization
- 3. Brazing
- 4. Controlled cooling
- 5. Accelerated cooling

Heat transfer during temperature ramp up and its effect on binder burn-off



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 — should be dried off before the component is put in the furnace. 0.2-2.6 % 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, the burn-off products need to be removed from the furnace before the temperature is increased. The vacuum pumps are generally sufficient to remove the semi-atmosphere, but the process can be sped up by introducing a sufficient flow of dry process gas, such as N₂ or Ar. The use of partial pressure will aid as a carrier gas in transporting the burn-off products out of the furnace chamber.

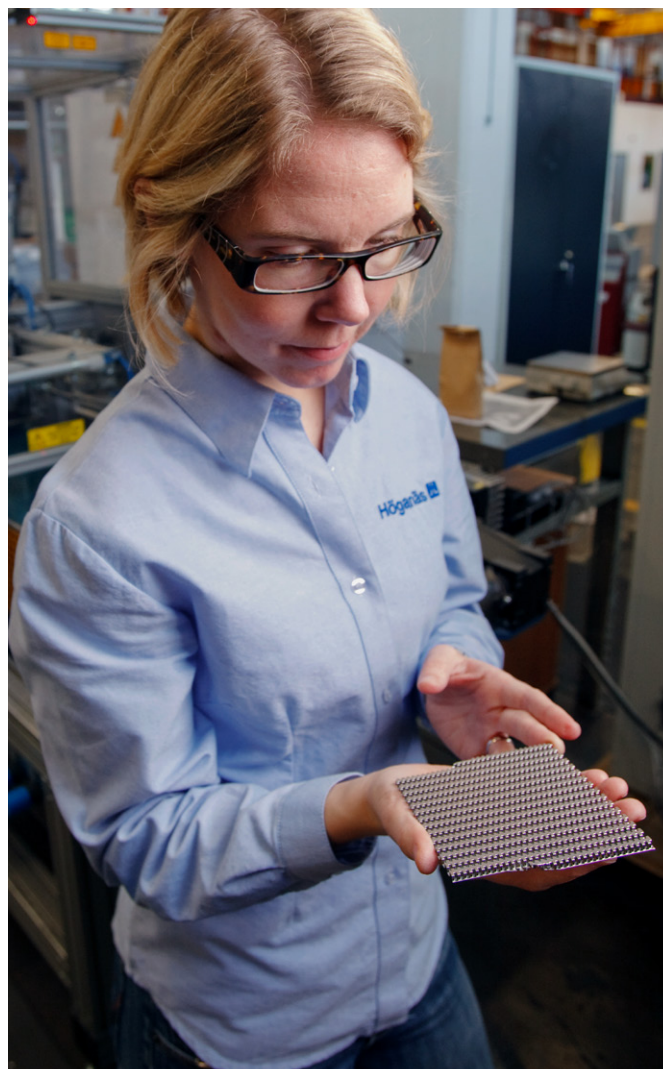
Even if the temperature is not deliberately increased to over 550 °C during binder burn-off, there is still the possibility of oxidation. Due to the inherent low heat transfer at low temperatures in a vacuum furnace, the middle of the batch may be trailing in temperature. Because of the lack of atmosphere 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, Höganäs will 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

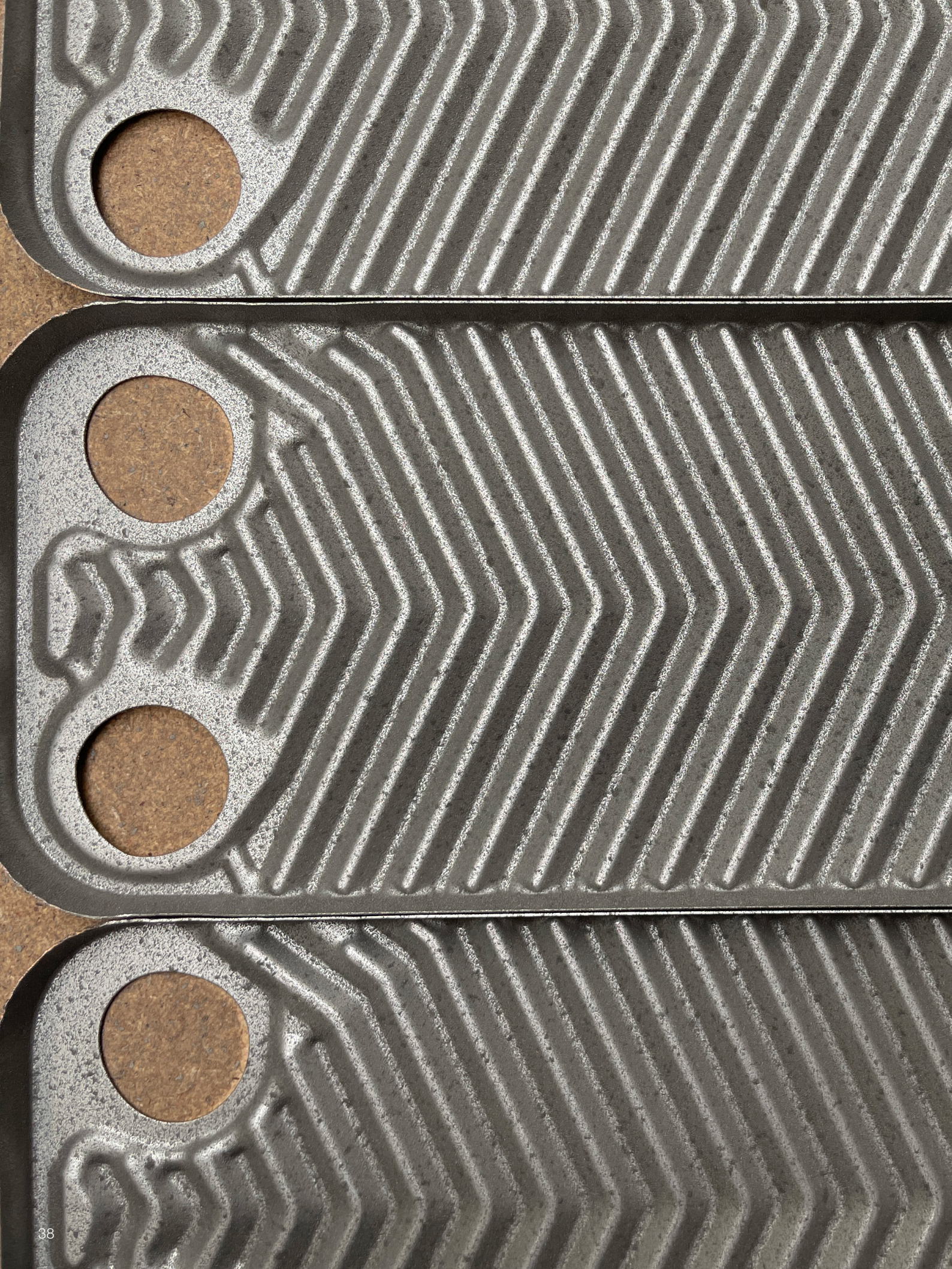
BM* oxidised	BFM** unmelted (no joint)	BFM melted but oxidised (complete joint)	BFM partly melted with oxidised residues (complete joint)	Potential causes
–	X	–	–	<ul style="list-style-type: none"> • Suboptimal binder burn-off • Brazing temperature not reached
–	–	–	X	<ul style="list-style-type: none"> • Suboptimal binder burn-off • Incorrect selection of brazing paste type for the process • Marginal brazing atmosphere
X	X	–	–	<ul style="list-style-type: none"> • High leak-up rate in the furnace • Brazing temperature not reached
X	–	–	X	
X	–	X	–	<ul style="list-style-type: none"> • Leak in the cooling gas system • Cooling gas introduced at too high temperature

Belt furnace brazing

BM* oxidised	BFM** unmelted (no joint)	BFM melted but oxidised (complete joint)	BFM partly melted with oxidised residues (complete joint)	Potential causes
–	X	–	–	<ul style="list-style-type: none"> • Suboptimal binder burn-off • Brazing temperature not reached • Incompatible brazing atmosphere with brazing filler metal
–	–	–	X	<ul style="list-style-type: none"> • Suboptimal binder burn-off • Incorrect selection of brazing paste type for the process • Marginal brazing atmosphere
X	X	–	–	<ul style="list-style-type: none"> • Insufficiently dry process gas/leak in process gas system • Air entering the furnace – Improper low flow rate of protective gas
X	–	X	–	<ul style="list-style-type: none"> • Air entering the cooling zone of the furnace

* BM = Base material

** BFM = Brazing filler metal



Application support

Industry examples

Höganäs 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.

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 for drinking water applications such as the EU Drinking Water Directive 2020/2184, NSF/ANSI 61 or country-specific regulations supersede the use of copper as brazing filler for many of its current applications.

Höganäs is working closely together with several manufactures to transit production to use Fe-based brazing filler metals to go along with the use of cost effective paste application methods. The Fe-based brazing filler metals offer reduced metal ion leaching compared to many of the conventional Ni-based brazing filler metals, making them an ideal choice for applications where the water quality is important. The Fe-based stainless brazing filler metals offers the best sustainable solution as it is fully recyclable.

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' 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.



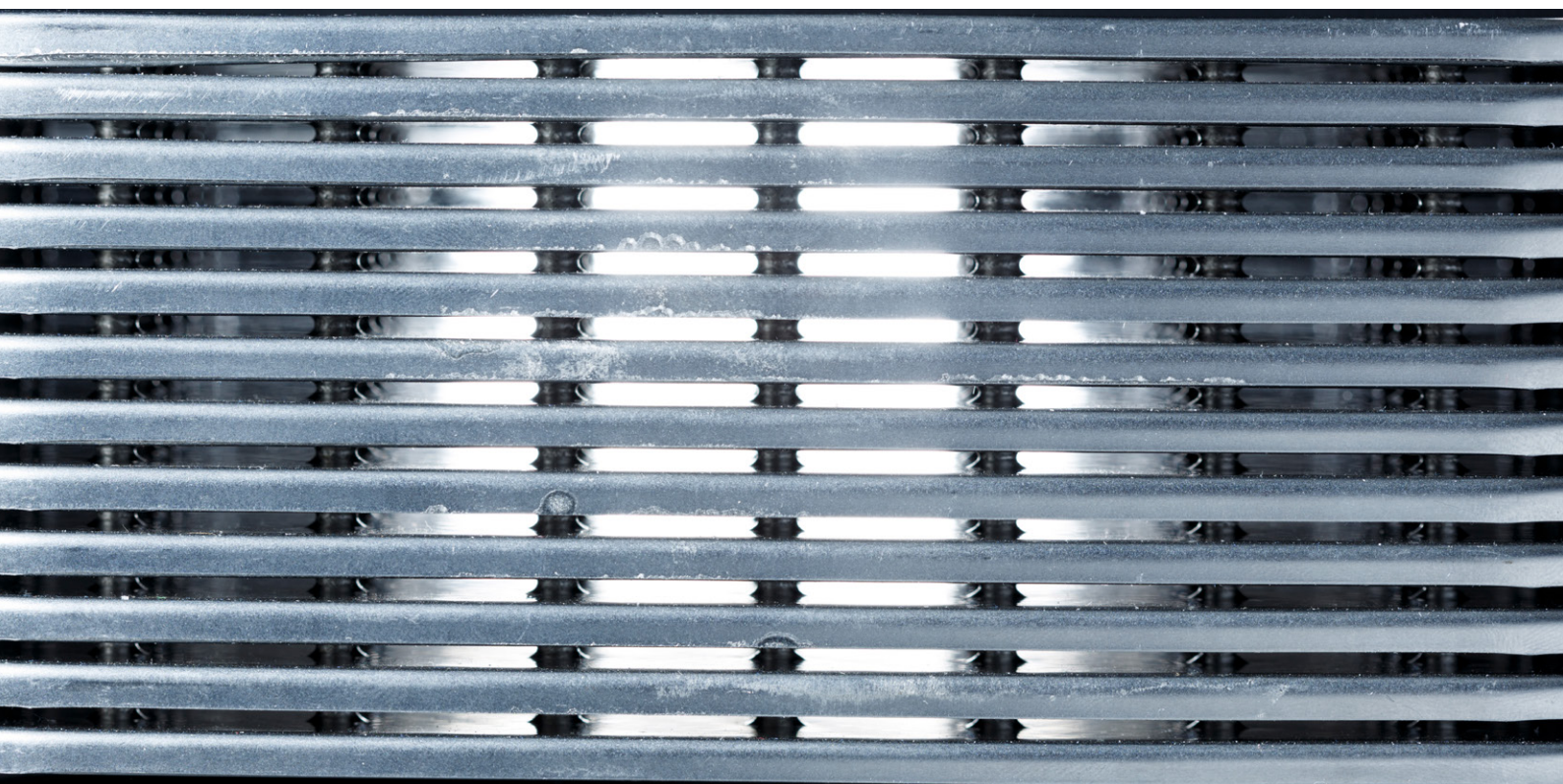
Cu-free oil coolers with a brazing solution from Höganäs

Höganäs BrazeLet F300, a patented stainless steel brazing filler metal, makes it possible to braze oil coolers which give no significant copper ion leaching to the engine oil. Avoidance of copper leaching to the engine oil results in increased oil lifetime and minimizes 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!

Keep lubricants clean, cool and dry with Cu-free oil coolers, made possible by Höganäs.



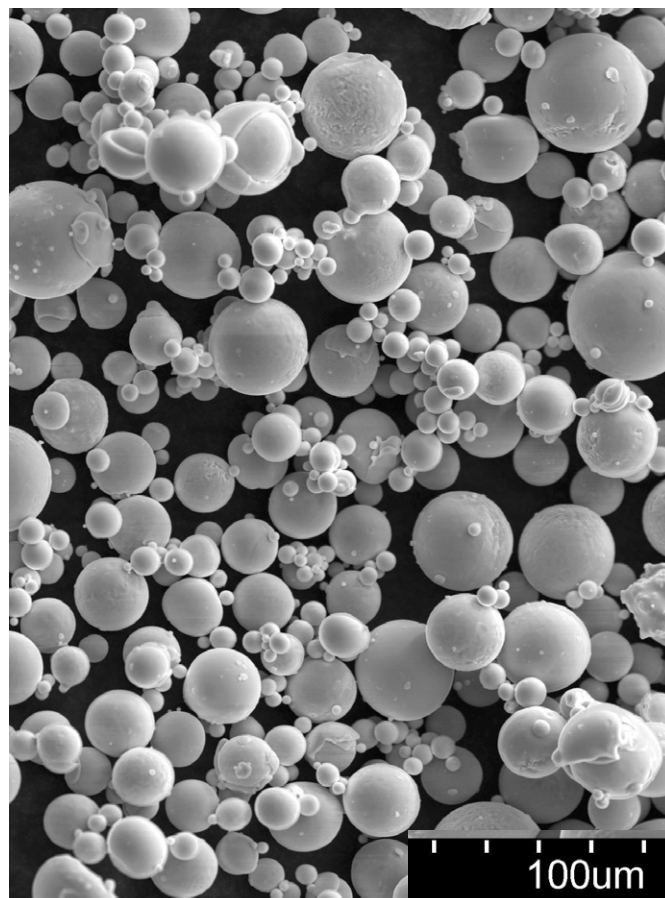


Turbine components

Brazing is an essential technique for Original Equipment Manufacture (OEM) and Maintenance Repair and Overhaul (MRO) of a range of components in aerospace and industrial gas turbines. The parts need to withstand extreme environments with increasing operating temperatures, oxidation, corrosion, wear and friction. Many of the super-alloys used for the turbine components have poor weldability, whereas brazing allows reliable joining of components as well as crack repair or restoration of worn surfaces. Höganäs offers a range of OEM or customer-specific brazing filler metals, as well as relevant super-alloy powders which are often used in blends with brazing filler metals for repair brazing.



Höganäs offers producible and reliable brazing materials upon OEM specifications.



The Höganäs sustainability agenda

Our ambition is to become the most sustainable metal powder producer in the world.

Combining optimal powder performance with improved sustainability is a priority for Höganäs, being at the forefront of innovations and setting the benchmark in our industry. In addition to our material innovations, we have committed to Science Based Targets initiative and demonstrating our ongoing commitment to leading sustainable transformation in our industry.

Our five sustainability areas – Climate, Environment, Products, Workplace and Society.

Climate

To counter climate change, Höganäs works proactively to minimise carbon emissions generated in our operations and throughout the value chain, accelerating towards our long-term net zero target.

Environment

Höganäs is working to promote healthy ecosystems by minimising the environmental impacts from our production and from the materials and chemicals we use. We proactively promote biodiversity, as well as clean water, air, and soil.

Products

By lowering our products' carbon footprint, becoming more circular, and using resources and energy more efficiently, we help our customers do the same and contribute towards a more sustainable society.

Workplace

By creating good and safe working conditions, and by promoting gender equality, Höganäs aims to set an industry example and continue to be an employer that attracts and retains the right competence and skills.

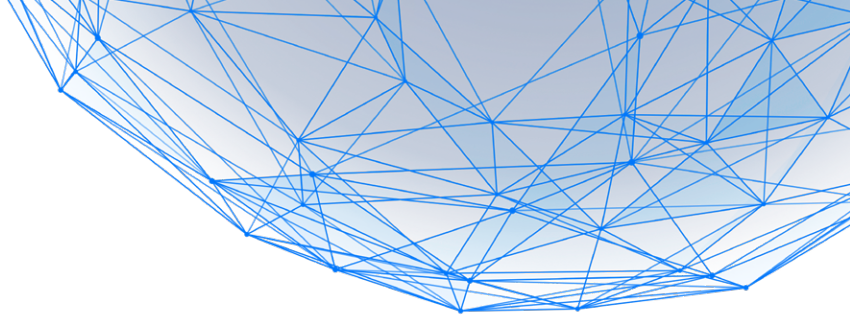
Society

By being committed to high ethical standards in everything we do, including our sourcing, financial reporting, tax payments, and our responsibility towards external stakeholders and the local community, we contribute to building a better society for all.





We are looking forward
to collaborating with you.



Driving positive change through material innovation

Höganäs' vision is to drive positive change through material innovation, which in turn will help us in our ambition to become the globally preferred partner for sustainable powder materials. Powder technology provides endless opportunities; not only does it empower 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, powders are a resource-efficient alternative that are optimal for a range of industries.

World leader in powders

Höganäs is a global company with local presents all over the world. We are a global leader in advanced ceramic and metal powders. Contact your nearest Höganäs office today, click or scan the QR-code:

