



***Metglas***<sup>®</sup>

# High Performance Brazing Foil

Understanding Amorphous  
Brazing Material

**Metglas<sup>®</sup> Amorphous  
Brazing Filler Metals**

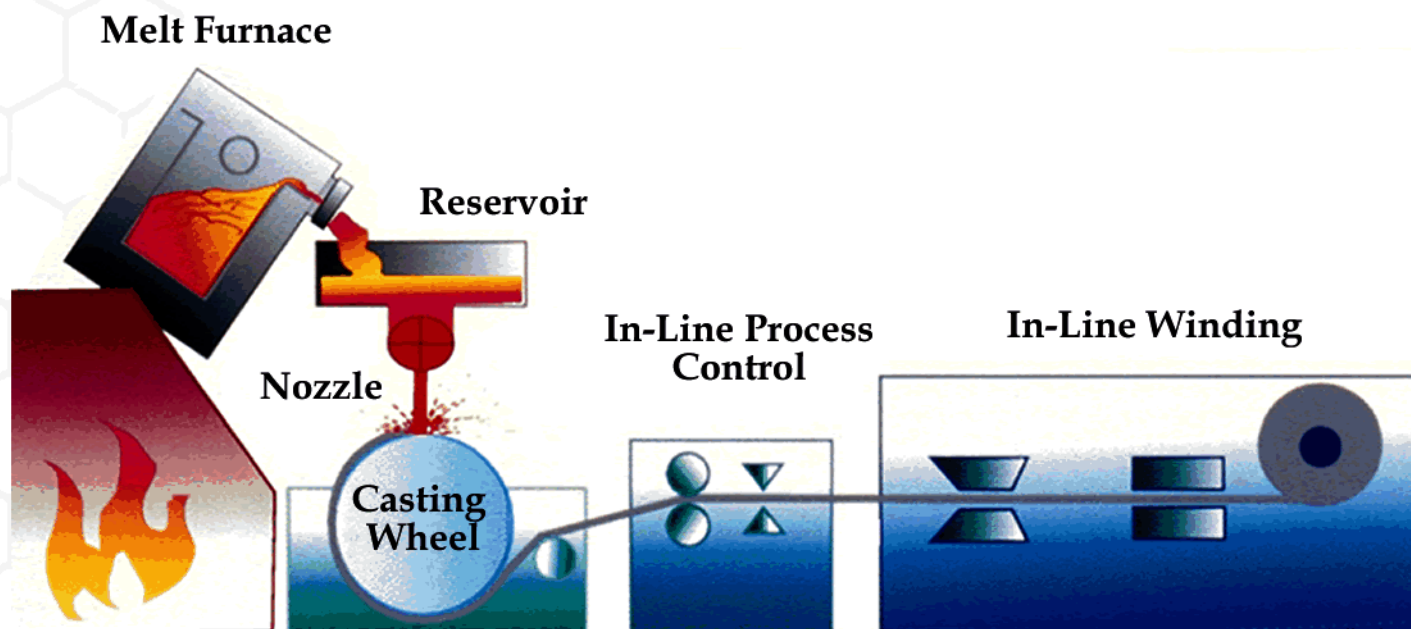
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***[www.metglas.com](http://www.metglas.com)***

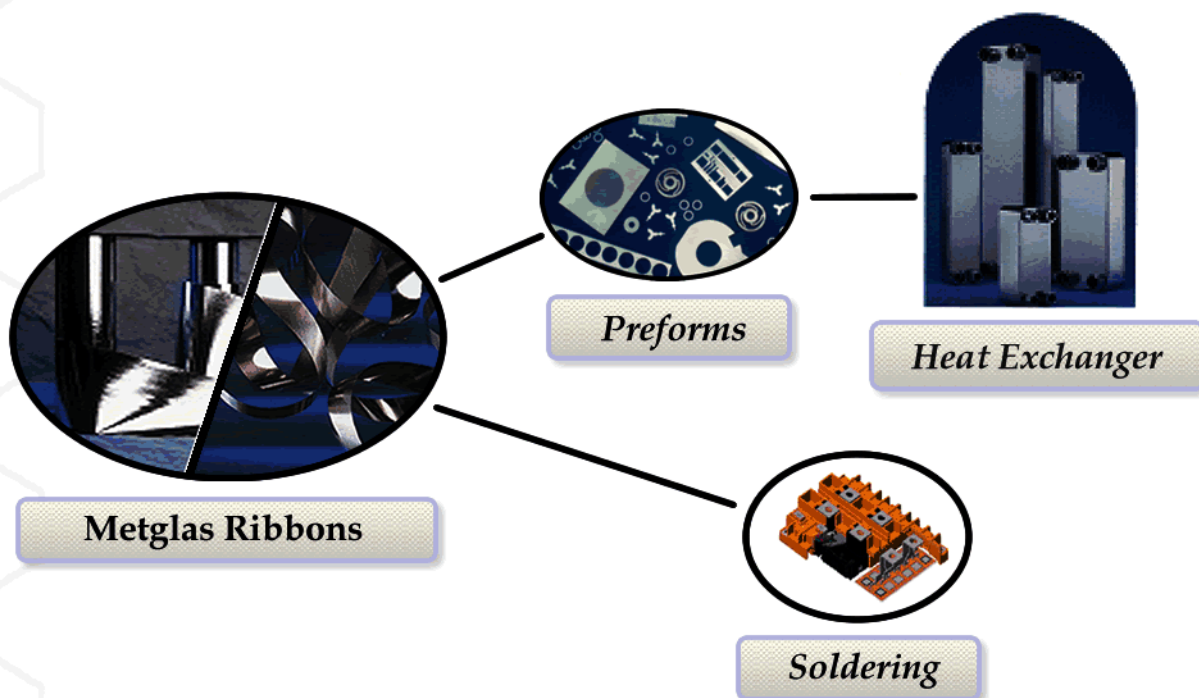
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## How Do We Make It?

### Melt Spinning Process

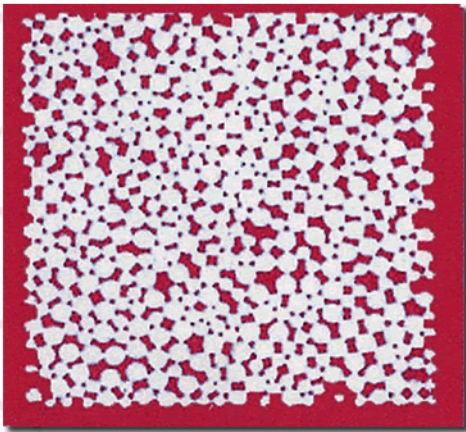


Unique Process Allows For Enhanced Properties



## What Makes Metglas<sup>®</sup> Amorphous Brazing Foil (MBF) Unique?

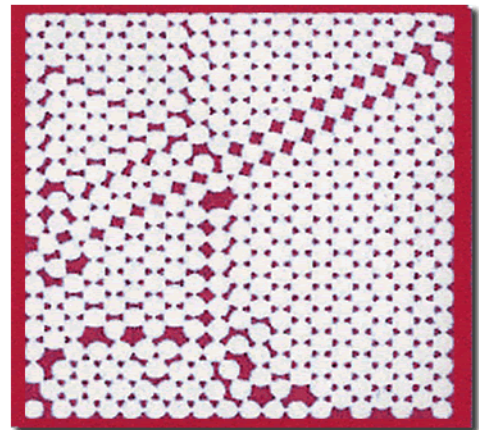
Our manufacturing process gives Metglas<sup>®</sup> filler metals the ultimately uniform atomic structure



### Metglas<sup>®</sup> Brazing Foil

- Ductile, Flexible, 100% Metallic Foil
- Melts Quickly within a Narrow Temperature Range
- Creates Strong and Non-porous Joints
- Can Be Placed with Precision Between Parts
- Very Economical and Effective Vs. Powder Metal Fillers
- Reduces Set Up & Assembly Process Time
- Does not Harm the Environment and Vacuum Brazing Furnaces

Conventional brazing filler metals of the same composition have a crystalline structure with different segregated phases



### Conventional Braze Fillers

- Generally Brittle Powders
- Melts Slower than MBF within a Wider Temperature Range
- Excessive Amount of Detrimental Oxides
- Larger Quantities Required per Joint than MBF
- Prone to Form Porous Joints with Large Crystal Grains
- Messy and Difficult Assembly Processing
- Contaminates the Environment and Degrades Vacuum Brazing Furnaces

**MBF Properties Make it a Better Solution than Powders**



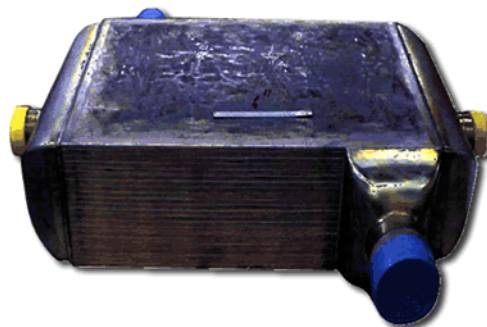
## Amorphous Brazing Filler Metals

### *Advantageous Properties for Metal Joining*

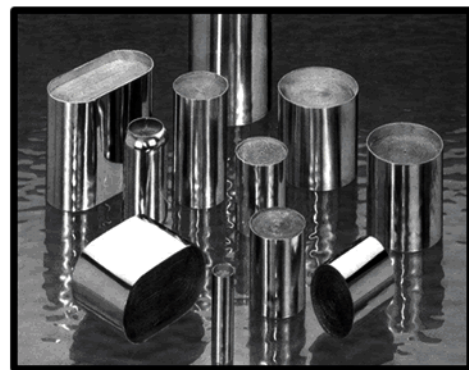
- **Unique 100% Metallic Foil With Outstanding Ductility**
- **Contaminant-Free**
- **Wide Range of Base Metals Successfully Brazed**
- **Wide Range of Widths**
- **Multiple Thickness Available**
- **Ease of Assembling Automation**



**Stamped and Photo-etched Preforms**



**Heat Exchanger**



**Automotive Catalytic Converter Support**

	Metglas <sup>®</sup> Foil	Adhesive Bonding	Welding	Power Paste & Tapes
Strength	+++		+	+++
Process Efficiency	+	+		
Contamination	+++			
Range of Temperature	+++		++	
Ease of Use	++	+++	+++	
Furnace Life	+++	N/A	N/A	

**Metglas<sup>®</sup> Brazing Foil Outperforms The Alternative Filler Metals**

## Amorphous Brazing Filler Metals

Metglas<sup>®</sup> Brazing Foils (MBF) are produced by rapidly quenching molten metal at rates of over 1,000,000°C per second. This process creates very uniform, ductile, and homogeneous brazing foils that can be used to create consistent, void-free, and optimum strength joints. Environmentally-friendly MBF also allows you to reduce your operating costs by reducing wastage, improving yield, improving furnace performance, and by lending itself to automation.

### Nickel-Based Brazing Foils

Alloy	Nominal Chemical Composition, Weight %								Temperatures						Density	
									Solidus		Liquidus		Brazing (Approx.)			
	Cr	Fe	Si	C*	B	P	Mo	Ni	°C	°F	°C	°F	°C	°F	g/cm <sup>3</sup>	lb/in <sup>3</sup>
MBF-15 <sup>1</sup>	13.0	4.2	4.5	0.06	2.8	--	--	Bal	965	1769	1103	2017	1135	2075	7.82	0.283
MBF-20 <sup>2</sup>	7.0	4.5	4.5	0.06	3.2	--	--	Bal	969	1776	1024	1875	1055	1931	7.88	0.285
MBF-30 <sup>3</sup>	--	--	4.5	0.06	3.2	--	--	Bal	984	1803	1054	1929	1085	1985	8.07	0.292
MBF-50 <sup>4</sup>	19.0	--	7.3	0.08	1.5	--	--	Bal	1052	1926	1144	2091	1170	2138	7.70	0.278
MBF-51 <sup>5</sup>	15.0	--	7.25	0.06	1.4	--	--	Bal	1030	1886	1126	2059	1195	2183	7.71	0.279
MBF-53	15.0	--	7.25	0.06	1.4	--	5.0	Bal	1045	1900	1127	2060	1195	2183	7.75	0.280
MBF-60 <sup>6</sup>	--	--	--	0.10	--	11.0	--	Bal	883	1621	921	1690	950	1742	8.14	0.294
MBF-80 <sup>7</sup>	15.2	--	--	0.06	4.0	--	--	Bal	1048	1918	1091	1996	1120	2048	7.94	0.287

### Cobalt-Based Brazing Foils

Alloy	Nominal Chemical Composition, Weight %								Temperatures						Density*	
									Solidus		Liquidus		Brazing (Approx.)			
	Co	Cr	Ni	W	B	Si	Pd	Oth	°C	°F	°C	°F	°C	°F	g/cm <sup>3</sup>	lb/in <sup>3</sup>
MBF-100	Bal	21.0	--	4.5	2.15	1.6	--	<0.5	1136	2077	1163	2125	1180	2156	8.13	0.294
MBF-102**	Bal	21.0	15.0	4.5	1.50	4.2	--	<0.5	1078	1972	1139	2082	1160	2120	8.10	0.293
MBF-103**	Bal	21.0	15.0	4.5	1.60	4.4	3.0	<0.5	1068	1954	1156	2113	1180	2156	8.15	0.294
MBF-104**	Bal	21.0	15.0	4.5	1.60	4.4	5.0	<0.5	1018	1864	1152	2106	1180	2156	8.18	0.296

Notes:

\* Designates calculated value

\*\* Commercial availability pending for MBF-102, MBF-103, and MBF-104

### Nickel-Palladium Brazing Foils

Alloy	Nominal Chemical Composition, Weight %								Temperatures						Density*	
									Solidus		Liquidus		Brazing (Approx.)			
	Ni	Fe	Cr	Pd	Si	B	Co	Mo	°C	°F	°C	°F	°C	°F	g/cm <sup>3</sup>	lb/in <sup>3</sup>
MBF-1005	Bal	--	--	46.7	6.1	--	--	--	810	1490	851	1564	870	1598	9.93	0.359
MBF-1011	Bal	--	--	45.5	5.0	--	5.0	4.5	847	1557	895	1643	920	1688	9.11	0.329
MBF-1012	Bal	--	10.5	36.0	0.5	3.0	--	--	820	1508	960	1760	990	1814	8.80	0.318

Notes:

\* Designates calculated value

### Cross Reference Chart of MBF Designations and Specifications

MBF	AWS	AMS	Pratt & Whitney	General Electric	Garrett Engine Division EMS 54752	Rolls Royce MSRR 9500	Snecma DMR 35	Textron Lycoming
15			PWA996 CPW494		-XIII	-705		M3876
20	BNi-2	4777		B50TF204	-II	-97	.302	
30	BNi-3	4778		B50TF205	-I	-114	.304	
50	BNi-5a*			B50TF217*		-722		
51	BNi-5b							
60	BNi-6		WA3610		-XI			
80				B50TF207	VIII	-719	.307	

\* Alternative to GEB50TF81 powder and AMS 4782

## Available Foil Geometry

### Maximum Width

Alloy	Standard Foil Thickness				
	0.0010 inches (25.4 $\mu\text{m}$ )	0.0015 inches (38.1 $\mu\text{m}$ )	0.0020 inches (50.8 $\mu\text{m}$ )	0.0025 inches (63.5 $\mu\text{m}$ )	0.0030 inches (76.2 $\mu\text{m}$ )
MBF-15	4.0 inches (101.6 mm)	4.0 inches (101.6 mm)			
MBF-20	8.5 inches (215.9 mm)	8.5 inches (215.9 mm)	8.5 inches (215.9 mm)	8.5 inches (215.9 mm)	8.5 inches (215.9 mm)
MBF-30	8.5 inches (215.9 mm)	8.5 inches (215.9 mm)	8.5 inches (215.9 mm)	8.5 inches (215.9 mm)	8.5 inches (215.9 mm)
MBF-50	2.0 inches (50.8 mm)	2.0 inches (50.8 mm)			
MBF-51	8.5 inches (215.9 mm)	8.5 inches (215.9 mm)	8.5 inches (215.9 mm)		
MBF-53	4.0 inches (101.6 mm)	4.0 inches (101.6 mm)			
MBF-60	3.0 inches (76.2 mm)	2.0 inches (50.8 mm)			
MBF-80		2.0 inches (50.8 mm)			
MBF-100	4.0 inches (101.6 mm)	4.0 inches (101.6 mm)	2.0 inches (50.8 mm)		
MBF-102	4.0 inches (101.6 mm)	4.0 inches (101.6 mm)	2.0 inches (50.8 mm)		
MBF-103	2.0 inches (50.8 mm)	2.0 inches (50.8 mm)	2.0 inches (50.8 mm)		
MBF-104	2.0 inches (50.8 mm)	2.0 inches (50.8 mm)	2.0 inches (50.8 mm)		
MBF-1005	2.0 inches (50.8 mm)	2.0 inches (50.8 mm)	1.0 inches (25.4 mm)		
MBF-1011	2.0 inches (50.8 mm)	2.0 inches (50.8 mm)	1.0 inches (25.4 mm)		
MBF-1012	2.0 inches (50.8 mm)	2.0 inches (50.8 mm)	1.0 inches (25.4 mm)		

### Mechanical Properties Of The As-Cast MBF-51 Brazing Foil

Foil Thickness $\mu\text{m}$ (mil)	Stress at Maximum Load MPa(ksi)	Strain at Peak %	Young's Modulus GPa(psi)
28.2 (1.11)	1660 (241)	$\approx 2.0$	125 (18 x10 <sup>6</sup> )
46.5 (1.83)	1900 (276)	$\approx 2.0$	125 (18 x10 <sup>6</sup> )

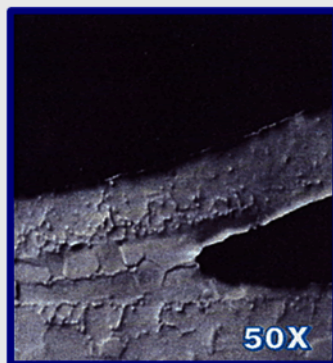
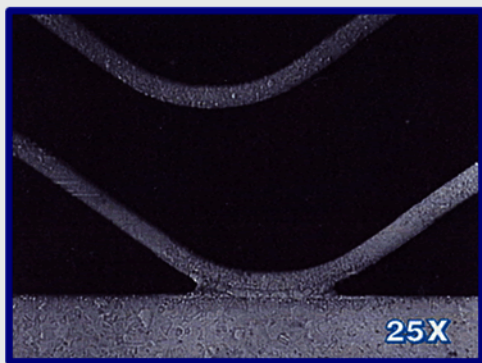
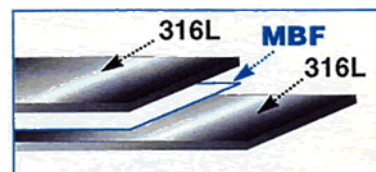


## MBF Alloy Joints and Properties

### Properties of 316L/MBF-51/316L Joints Brazed Under Optimal Conditions

**Base Metal** 316L(SC1603 UNS)0.317 cm (1/8") thick plate

**Filler Metal** MBF-51 (Ni-15Cr-7.25-Si-1.4B) amorphous foil with 25  $\mu\text{m}$  (1 mil) and 50  $\mu\text{m}$  (2 mil) thickness.  
Solidus 1030°C (1886°F); Liquidus 1126°C (2058°F);  
Density 7.71 g/cm<sup>3</sup>



Shown here at 25X and 50X magnification, a strong and ductile single phase microstructure is formed in 316L stainless steel joints of an industrial heat exchanger brazed with Metglas MBF-51 amorphous brazing foil.

### Joint Mechanical Strength

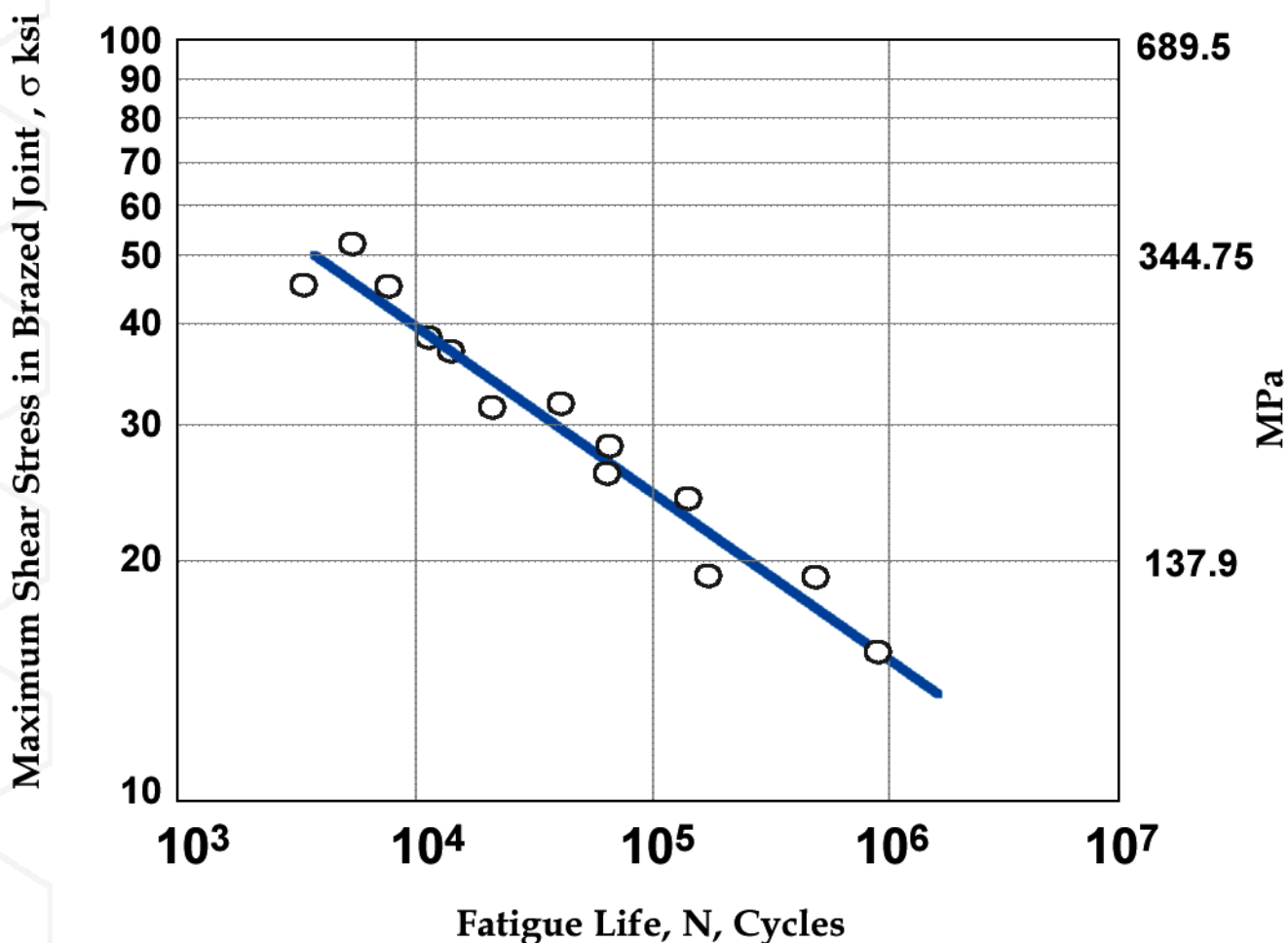
Thickness of brazing foil, $\mu\text{m}$ (mil)	Joint stress at max. load, MPa	Base metal stress at max. load in joint vicinity, MPa	Failure location
25 (1)	364	546	Base metal (lap joint with 1:1 overlap)
50 (2)	351	416	Base metal/joint (lap joint with 1:1 overlap)
316L virgin sample subjected to annealing together with samples during brazing		Tensile/shear strength: 590 Yield strength: 199 i.e., below joint stress at max load	

\*Joint tensile/shear testing is made using procedure similar to that recommended in American Welding Society AWS C3.2 Specifications for the lap-type joint configuration

## MBF Alloy Joints and Properties

### Fatigue Resistance

S/N Fatigue Curve for 316L/MBF-51/316L Brazed Joints\*



Room Temperature  
25 Hz, R=0.1  
Axial Loading

○ Experimental results  
— Curve Fit

$$\log \sigma = 2.4167 - 0.2067 \log N$$

$$\text{RMS}(\sigma) = 2.36$$

\* Fatigue testing is made using samples in a lap shear configuration similar to that of AWS C3.2 Specifications. A sine wave loading cycle was used with the stress ratio, R, ( $R_{\min}/R_{\max}$ ) of 0.1 and a frequency of 25 Hz



## MBF Alloy Joints and Properties

### Corrosion Resistance

**Total Weight Loss and Appearance of 316L/MBF-51/316L Joints  
Subjected to Corrosion Testing**

Corrosion medium	Percent weight losses after 864 hr exposure	Visual corrosion of joint
Standard sea water solution  ASTM-D114 Standard Procedure	0.21	minor pitting
30% NH <sub>4</sub> OH water solution	none	none
25% H <sub>3</sub> PO <sub>4</sub> water solution	0.62	minor pitting
0.5% NaCl&O .3% (NH <sub>4</sub> ) <sub>2</sub> S water solution	none	none

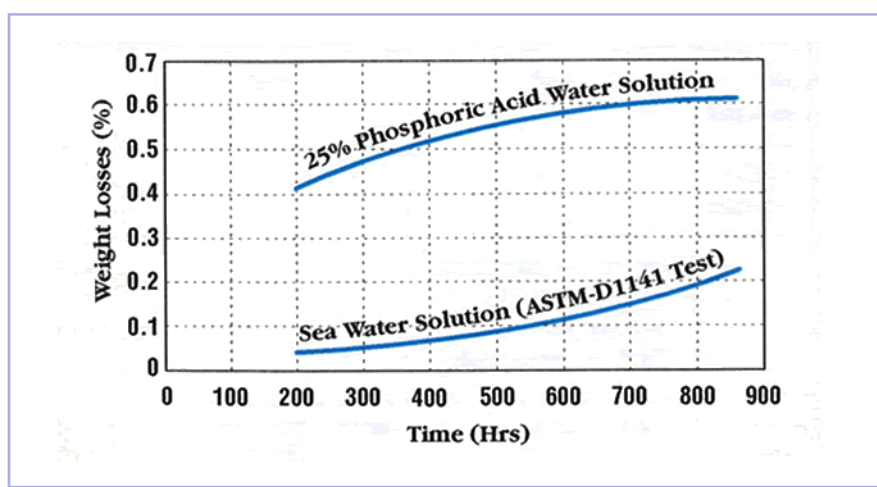
Tested samples were comprised of two overlapping 2.5 x 3.75 x 0.317 cm 316L plates brazed with MBF-51 brazing foil with 50 µm (2mil) thickness. The brazed overlap is 1.25 cm. Samples were completely immersed in corrosive solutions at 50°C (120°F) under 1 atm for up to 864 hours.

**Corrosion weight losses of some brazed samples in a solution\*  
simulating the environment in car exhaust pipes**

Brazing filler metals used in tested samples	Weight change, %, after 258 hr exposure		Weight change, %, relative to the initial weight after 524 hr exposure		Weight change, %, relative to the initial weight after 781 hr exposure	
	316SS	321SS	316SS	321SS	316SS	321SS
MBF-51 (Ni-15Cr-7.3Si-1.4B)	2.748	21.375	-4.89	-22.3	-6.14	-22.3
MBF-51+5% Mo (Ni-15Cr-7.3Si-1.4B-5Mo)	0.4888	11.132	-1.13	-11.23	-1.74	-11.23
MBF-101 (Co-21Cr-4.5W-4.4Si-1.55B)	-0.5912	-0.1025	-0.59	-0.1	-0.59	-0.1
Unbrazed base metal 316SS and 321SS coupons having the same weight as the tested samples and used for comparison	-0.314	-0.0505	-0.31	-0.05	-0.31	-0.05

\* Water Solution of HNO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>, HCl, NH<sub>4</sub>OH

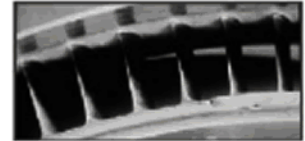
## Total Weight Loss (%) of 316L/MBF-51/316L Lap Joints During Exposure



## Metglas<sup>®</sup> Brazing Foil Aerospace Applications

### *Compressor Vane and Shroud Assemblies (Stators)*

These stationary components are set between rotating blade assemblies in the compressor section of jet turbine engines. They guide airflow between blade stages, critical to increased engine efficiency.



#### Brazing Application

12 to 15 stators may be used in an engine, with each stator requiring attachment of 100+ airfoil vanes to a shroud ring. High strength, corrosion resistant, economical joints with uniform gap are required.

#### Solution

Brazing powder and powder-binder composites may be used, but these leave contaminating residues and promote joint shrinkage and brazing rejects. MBF is simply tack welded into place on the shroud ring and the vanes are assembled and fixtured with an expansion ring for brazing. Clean, nonporous and strong joints are formed upon brazing.

### *Rotating Blade Porous Metal (Feltmetal) Seals*

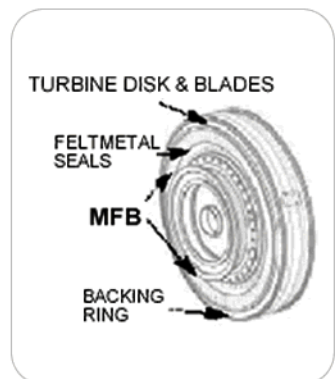
These seals are used in the rotating blade assemblies of jet turbine engines. They are designed to wear down from abrasion by rotating blades and then be periodically replaced.

#### Brazing Application

20 or more of these seals may be used in an engine. Each seal is brazed to the backing ring and requires uniform joint gap and minimum wicking. If excessive wicking occurs, when the powder brazing filler metals are used then the feltmetal will damage the more complex and costly blade assembly.

#### Solution

MBF is sandwiched between the backing ring and feltmetal, fixtured with an expansion ring, and brazed. Ultra-thin custom-designed MBF meets the specified dimensional tolerance to avoid excessive wicking, simplifies the process, and eliminates rejects.



## Metglas<sup>®</sup> Brazing Foil Aerospace Applications

( continued )

### ***Brazed Honeycombs***

Sandwich-Like Structures Contain Perforated Face Sheets

Honeycomb structural panels are widely used in aerospace applications since they offer exceptional strength/stiffness-to-weight ratio. Acoustic turbine tailpipes, exhaust plugs, cones, nozzles, and fan ducts are often brazed as honeycombs.

Honeycomb brazed at edges to perforated face sheets. The perforations are free of braze alloy or other contaminants, so the structure's noise reduction qualities are retained and the mechanical bond is unimpaired. Tailpipes for the McDonnell Douglas 80, Boeing 727, and the Rolls Royce TAY engines, etc. and hushkits for the Pratt & Whitney JT8D engine are brazed by "wallpapering" the skin surfaces with MBF or by using Brazcor.

### **Brazing Application**

For acoustic or sound attenuation structures, the brazing filler alloy must flow off the honeycomb surfaces to form fillets at all the junctions without clogging the perforations, which are needed for sound absorption. Residues left by other conventional powder containing brazing filler metal clog the perforations due to inferior flow, leading to joint rejects.

### **Solution**

By tack welding the MBF to the face sheets or using Brazcor<sup>™</sup> honeycomb core\*, capillary action draws the melted brazing alloy to the thin edges of the honeycomb structure, while keeping it out of the perforations. Joint strength is improved because the foil acts as a spacer to maintain an optimum joint gap. Filler metal flows only in necessary contact area.

\* Brazcor by Alloy Spot Welders is the world's first ready-to-braze metallic honeycomb core. It is manufactured through a patented process which places precisely metered amounts of MBF between the cell nodes during fabrication for clean, precise brazed joints. Brazcor can be manufactured using heat resistant alloys (Inconel and Hastelloys), titanium-based alloys and stainless steels.



## Metglas<sup>®</sup> Brazing Foil Heat Exchanger Applications

### *Heat Recycler*

Waste heat recovery systems are gaining popularity because of rising energy costs. This finned tube heat exchanger recovers the waste heat in steam for a Rankine cycle turbine.

#### Brazing Application

Fins must be brazed onto single-piece sections of tube up to 6 m long. Approximately 22 km of tubing may be used in a single heat exchanger. High flexibility and the ability to resist tension and crushing during assembly are crucial. High strength, corrosion resistant joints with a uniform thickness are essential. Brazing filler metals in powder and powder-binder composite forms are poor candidates because of contaminating residues and possible joint shrinkage.

#### Solution

MBF offers the advantages of purity and consistent thickness allowing a fully automated process. Each tube is rotated to wrap it with foil and fin. The machine tensions brazing foil and fin stock as it turns the tube. The fins are crimped at one edge which is pressed tightly against the brazing foil. The assembly is then brazed in a pure argon continuous furnace at 1065°C for 10 minutes. High automation and low manufacturing cost are provided.

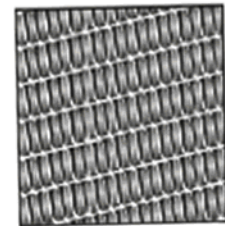
### *Plate-Fin Heat Exchangers*

#### Design Requirements

High efficiency use in demanding installations where light weight and high performance are necessary, such as in aerospace applications.

#### Solution

MBF foil thickness can be controlled to provide at least a 15% weight savings over comparable powder alloys. Without the binders or adhesives, the MBF joint is typically stronger than comparable powder, paste or tape joints by insuring clean and complete joint coverage.



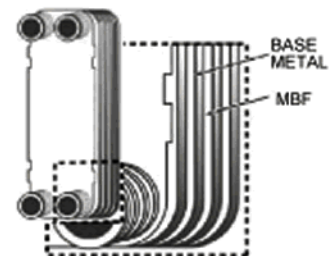
### *Plate-Plate Heat Exchangers*

#### Braze Application

The ability to resist corrosion in deionized water, ammonia, and other harsh chemical systems while sustaining design pressures up to 1760 psi (120 bar).

#### Solution

MBF series alloys are corrosion resistant to ammonia and other corrosive environments. High resistance to sulfuric, phosphoric, and nitric acids make MBF foil an ideal brazing filler metal for joining austenitic stainless steels or nickel/cobalt-based superalloys.



## Metglas<sup>®</sup> Brazing Foil Metallic Catalyst Support Applications

In recent years, metallic catalyst supports have begun to replace the ceramic substrates used to support precious metal catalyst. In addition to being sturdier and resilient to vibrations, as well as enabling the unit to be mounted closer to the engine, the metallic supports heat up faster to reduce harmful emissions.

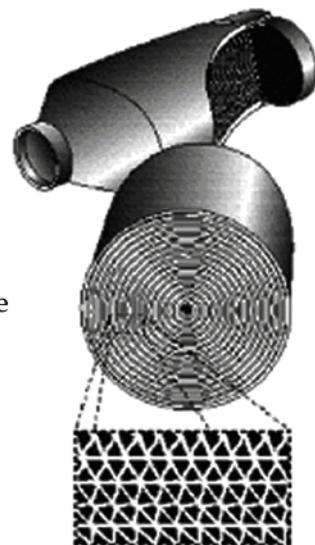
### Brazing Application

The cells of these units are formed from approximately 50 - 100  $\mu\text{m}$  (2.0 - 4.0 mil) thick corrugated and flat sheet stock. The concentrically wrapped corrugated and uncorrugated metal sheets must be securely fastened to each other forming an integrated core to prevent vibration and potential release of catalyst during engine operation (which would result in unit failure). Brazing is an important technique for manufacturing the advanced metallic catalytic converters, because it achieves fastening of core components and core to the case in one operation.

### Solution

When using MBF versus powder, smaller, high-quality fillets are formed. As a result, cells become more open, thereby reducing exhaust back-pressure. MBF foil leaves more effective surface area for the catalyst. Finally, process automation is easily achieved with ductile MBF foil.

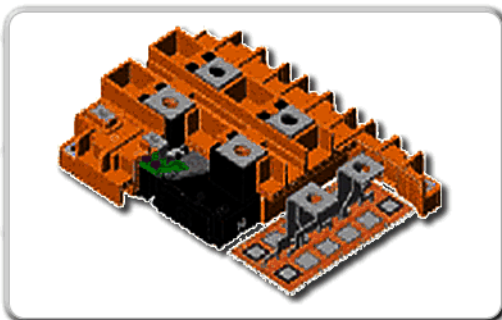
**Note:** For a typical FeCrAl base metal, MBF-50 with its low boron content provides superior high temperature strength and corrosion resistance with virtually no base metal erosion.



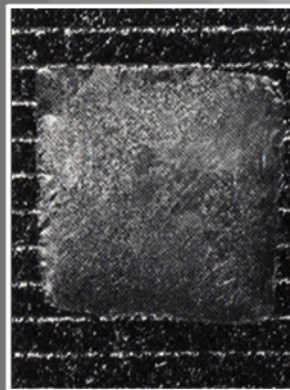
## Metglas<sup>®</sup> Solders

### *Superior Solder Joining*

- Lead Free
- High Purity (>99.99% by weight)
- No Contaminants - Improved Soldering Cycle Time
- Melts & Flows - Wetting and Bonding - Improved Yield
- Better Non-Porous Joints with High Strength and Ductility
- Fine Joint Microcrystalline Structure Prevents Joint Cracking & Extends Product Life Throughout Service Fatigue Thermal Cycling



Metglas<sup>®</sup> Solder



Ordinary Solder

