



# Heat Exchangers

Part 2 - THERMAL PERFORMANCE





## IMPROVING THERMAL PERFORMANCE

Vehicle manufacturers all over the world are realising that it is crucial to improve the thermal performance of their heat exchangers. Many original equipment manufacturers feel that today's aluminium designs have reached a performance limit and cannot fulfill future demands.

If you are concerned about the following issues, then you too should look for better heat exchangers:

- You want to improve the thermal performance of your heat exchangers.
- The new engine in your offering requires heat rejection capability, which your existing heat exchangers cannot offer.
- You wish to maximise thermal performance without compromising the size of the heat exchanger.
- As your existing heat exchangers are unable to provide the desired heat rejection, they are causing failures and in turn giving rise to warranty problems.
- You are concerned that new design solutions to comply with the upcoming stringent emission standards may require greater heat rejection capability in heat exchangers.
- The thermal performance of your heat exchangers has reached its limit, hindering the development or implementation of more powerful engines.

## MEASURING THERMAL PERFORMANCE

In a finned tube heat exchanger, the process of heat transfer is driven by the difference in temperature between the coolant flowing inside the tubes and the air that blows over the fins outside the tubes.

The measurement of the heat exchanger's thermal performance is the rate of heat transfer between the coolant and the air. The relationship between the rate of heat transfer and the factors influencing it is reflected in the following equation:

$$Q = U A \Delta T, \text{ where}$$

$Q$  = Amount of Heat Transferred Over Time (W)

$U$  = Heat Transfer Coefficient (W / m<sup>2</sup>-K)

$A$  = Area Available for Heat Transfer (m<sup>2</sup>)

$\Delta T$  = Temperature Difference (K)

The higher the value of  $U$ ,  $A$  or  $\Delta T$ , the greater the rate of heat transfer and the better the thermal performance of heat exchanger. To achieve the latter requires improvements in the design and/or material to increase one or more factors influencing thermal performance:  $U$  (overall heat transfer coefficient);  $A$  (area of heat transfer); and  $\Delta T$  (temperature difference between the coolant and ambient air).

[ A revolutionary technology for manufacturing new generations of high-performance heat exchangers, *CuproBraz*, uses brass tubes and copper fins ]

## THERMAL PERFORMANCE TECHNOLOGY

A revolutionary technology for manufacturing new generations of high-performance heat exchangers, *CuproBraz* uses brass tubes and copper fins. The technology employs a special brazing alloy for the copper/brass joints.

*CuproBraz* was developed by the International Copper Association (ICA). Besides producing high-performance heat exchangers, *CuproBraz* is cost-effective, environmentally friendly, and low in investment cost. It can be used to produce a wide variety of heat exchangers, such as heat exchangers for passenger cars, trucks and off-road equipment; oil coolers; charge air coolers; condensers; and evaporators.



### BENEFITS OF HIGHER THERMAL PERFORMANCE

CuproBrazed uses a unique combination of copper and brass, along with a new process, thus offering several key advantages over the conventional aluminium heat exchanger technology. These advantages combine to result in superior thermal performance. The advantages include:

#### HIGHER THERMAL CONDUCTIVITY

The use of copper in CuproBrazed heat exchangers benefits from its greater thermal conductivity over aluminium (Table 1), which contributes to a greater value of U, the overall heat transfer coefficient.

Table 1: Comparison of Thermal Conductivities

Thermal Conductivity (W/m K)	ALUMINIUM	COPPER
	222	377

Table 1



#### THINNER TUBES AND FINS

CuproBrazed, which uses copper fins, results in a slightly thinner fin and tube material than aluminium technology (Table 2). This improves the value of U (overall heat transfer coefficient) and creates a somewhat lower air pressure drop.

Table 2: Comparison of Tubes and Fins

Same basic design:

- Tube inside height (1.2mm)
- Fin width
- Louver shape, angle
- Tube centre-to-centre (C-C)

	ALUMINIUM	COPPER
Tube wall thickness (µm)	300	125
Fin thickness (µm)	90	35
Tube height (mm)	1.8	1.45
Fin height (mm)	7.2	7.55

Table 2

[ The use of copper in CuproBrazed heat exchangers

results in greater thermal conductivity over aluminium ]

#### LARGER FREE FRONTAL AREA

Thanks to thinner tubes and fins, CuproBrazed heat exchangers have larger free frontal area (Fig 1).

Figure 1: Comparison of Frontal Areas

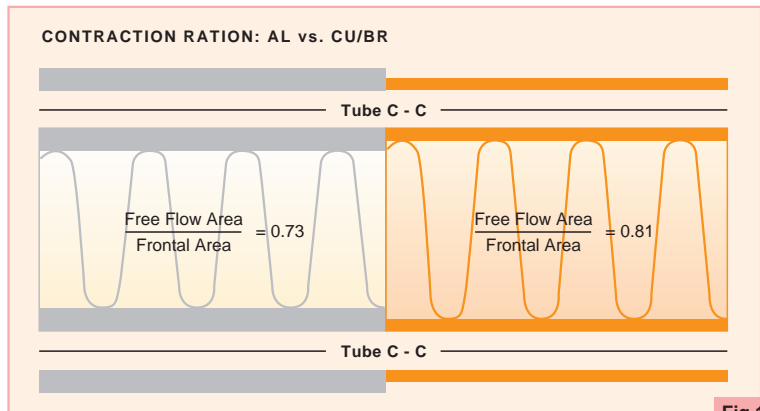


Fig 1



**LOWER VELOCITY AND PRESSURE DROP**

Larger free frontal area leads to a lower velocity advantage in CuproBrazed heat exchangers. Aluminium heat exchangers have 11% higher velocity but also therefore a larger pressure drop compared to CuproBrazed heat exchangers (Fig 2).

Figure 2: Comparison Air Velocities



Fig 2

[ As you can see, CuproBrazed clearly outperforms aluminium heat exchangers when it comes to thermal performance ]

When comparing airside heat resistance for heat exchangers, aluminium has a small advantage in lower heat resistance (Fig 3).

However, when comparing the air side pressure drop, CuproBrazed has a great advantage. It has as much as 24% lower air side pressure drop (Fig 4).

The pressure drop advantage can be used in different ways (Fig 5).

Figure 3: Comparison of Airside Heat Resistance

HEAT RESISTANCE ON AIR SIDE			
Property	Al	Cu/Br	Why?
Heat Transfer coeff. ( $\alpha$ )	+5%		Core velocity 11% higher for Al and $\alpha \propto \sqrt{\text{Vel}}$
Heat Transfer Area		+5%	Fin height 5% higher for Cu/Br
Fin Efficiency	+4%		Fin height, thickness, conductivity, and $\alpha$
Heat Resistance Diff.	4%		Only 70% of total heat resistance on air side
Heat Rejection Diff.	< 3%		

Fig 3

Figure 4: Comparison of Airside Pressure Drop

PRESSURE DROP ON AIR SIDE			
Property	Al	Cu/Br	Why?
Friction Factor	-5%		Core velocity 11% higher for Al and $f \propto \text{Vel}^{-0.5}$
Heat Transfer Area	-5%		Fin height 5% higher for Cu/Br
Contraction Ratio Effects on Entry and Exit Losses	+20%		
Core Velocity	+22%		$P \propto \text{Velocity in square}$
<b>Pressure Drop Diff.</b>	<b>+32%</b>	<b>-24%</b>	

Fig 4

Figure 5: Thermal Advantages of CuproBrazed Heat Exchangers

HOW TO USE THE PRESSURE DROP ADVANTAGE			
	Heat Rejection	Pressure Drop	Core Area
<b>Keep Same</b>			
Fin Count	-3%	-24%	Same
Heat Rejection	Same	-18%	Same
Air Pressure Drop	+6%	Same	Same
Heat Rejection and Pressure Drop	Same	Same	-6%

Fig 5

Overall, if the core area and airside pressure drop are kept the same, CuproBrazed offers about 6% greater heat rejection as compared to aluminium heat exchangers.

As can be seen, CuproBrazed clearly outperforms aluminium in heat exchangers when it comes to thermal performance.



### HIGHER TENSILE STRENGTH

Whereas aluminium has limitations at high temperatures, the tensile strength for tube brass is more than 300 MPa at 200°C and that is still well above 250 MPa even at 300°C.

Figure 6 shows the inherent difference between the tensile strengths of the two materials. With aluminium, serious problems occur at temperatures above 200°C, at which point the strength of aluminium drops 40% to 60% compared to its strength at 150°C.

CuproBrazing's ability to withstand higher temperature allows designs where the coolant can be at a higher temperature, providing bigger  $\Delta T$ , the difference between the temperature of the coolant and ambient air. This results in better thermal performance.

Figure 6: Effects of temperature on the strength of aluminium and brass tubes

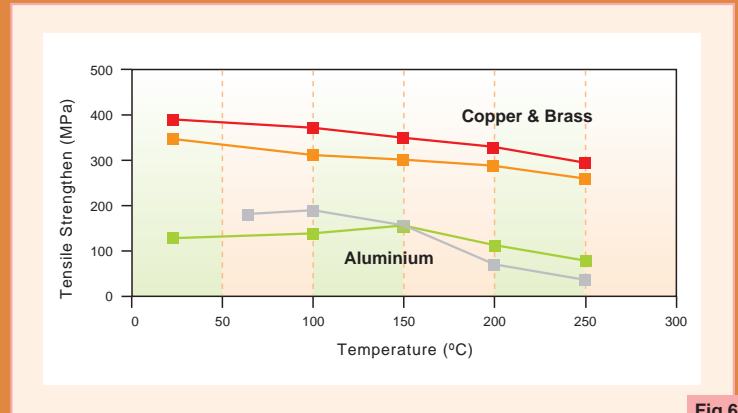
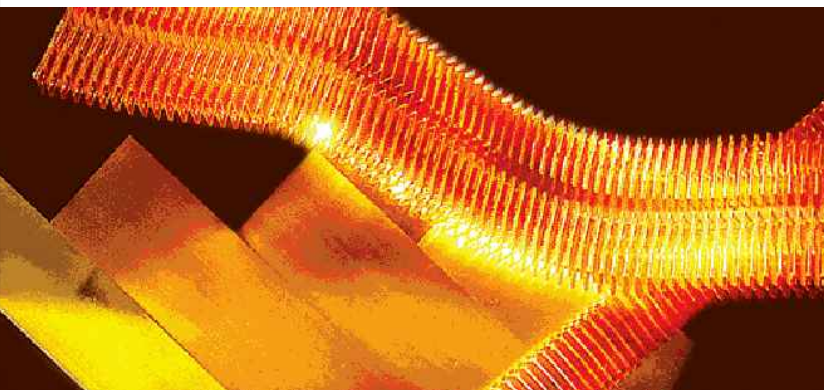


Fig 6

### FLEXIBILITY IN DESIGNS

Due to its material structure and manufacturing process, CuproBrazing provides a greater potential for using innovative fin and tube designs that can deliver better thermal performance.

[ Commercial production has been done in batches and installation in vehicles has been carried out since 1999. No heat exchanger failures have been reported so far ]



### WHO'S USING CUPROBRAZE?

The first manufacturing line for CuproBrazing production was built in Pittsburgh, PA, USA, in 1998. Commercial production has been done in batches and installation in vehicles has been carried out since 1999. No heat exchanger failures have been reported so far.

In 2000, Najico started CuproBrazing production in Japan and the company built a new factory dedicated to its production. A year later, Astro Air also started using CuproBrazing in the US.

In France, Berry Radiateur started production in early 2002. In 2003, Shaaz, a Russian company in Shadrinsk, will be the first company to mass produce CuproBrazing heat exchangers. Several additional decisions to start production have been taken around the world and they will be made public during 2003.



# CuproBraze<sup>®</sup> a new, better process to make heat exchangers



## CONCLUSION

Greater thermal performance in heat exchangers is an issue confronting vehicle manufacturers worldwide. Aluminium heat exchangers are unable to fulfil the demands for greater thermal performance due to aluminium's inherent limitations.

With superior material and design characteristics, CuproBraze is the answer to higher thermal performance. It has proved to be reliable and has already been implemented by vehicle manufacturers in the US, Europe, Russia and Japan.



### Useful References:

#### [www.dieselnet.com](http://www.dieselnet.com)

An online information service on diesel emissions, emission control, diesel engines, fuels, and more...

#### [www.sae.org](http://www.sae.org)

Website of The Engineering Society for Advanced Mobility in Land, Sea, Air and Space.

#### [www.behrgroup.com](http://www.behrgroup.com)

Website of Behr GmbH & Co, a specialist in environmentally compatible vehicle air-conditioning and engine cooling. Behr is one of the leading original equipment manufacturers for passenger cars, commercial vehicles.

#### [www.narsa.com/acj/](http://www.narsa.com/acj/)

Automotive Cooling Journal of the U.S. National Automotive Radiator Service Association

#### [www.copper.org](http://www.copper.org)

A service of the U.S. Copper Development Association

### Resources:

For more information about CuproBraze, free literature and technical tips, you can look up the website of the CuproBraze Alliance at:

## [www.CuproBraze.com](http://www.CuproBraze.com)

If you have any questions or requests for information, you can email to: [Info.cuprobrazec@cuprobrazec.com](mailto:Info.cuprobrazec@cuprobrazec.com)

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