NOCOLOK® Flux Brazed Aluminum Heat Exchangers
For the Refrigeration and Air Conditioning Industry
Refrigeration and air-conditioning markets have been evolving dramatically over the past decades. The most important factors on system design and alternative technologies are:

- Legislation and phase-out schedules for ozone depleting refrigerants
- Increased demand for comfort cooling
- Rising energy costs
- Regulations on energy efficiency

The phase-out of ozone depleting refrigerants was and continues to be one of the most radical changes for the HVAC&R industry. Moving from CFC’s to HCFC’s and then to HFC’s has not been easy, but it is a success story of global magnitude.

15% of all the electricity produced in the developed world is used to run refrigeration or air conditioning systems. With ever increasing oil-prices and energy costs alongside environmental concerns, increasing energy efficiency is currently the biggest challenge to the industry.

Up to 90% of the climate impact of the refrigeration and air conditioning industry is due to indirect emissions (CO₂ emissions due to electricity consumption), while only 10% is due to the direct emission of refrigerants.

Consequently, containment of refrigerants and above all improving energy efficiency are the key elements for a sustainable technology.

According to IIR [1], it is possible to halve the impact of greenhouse gas emissions, using 2000 as baseline, through:

- Containment of refrigerants in all phases of product life, from fluid production to system waste management
- Recycling, reclaiming and destruction of refrigerants
- Effective energy labelling
- Increasing the use of heat pumps

Improving by 30–50% the unitary energy consumption of systems. “Making use of high performance technology and improving component efficiency” [3]

Energy efficiency regulations and labeling initiatives are being introduced or – where already in place – tightened in order to minimize the energy consumption of a given society. In January 2006, the minimum efficiency level for all new central air conditioners manufactured in the U.S. was raised from 10 SEER to 13 SEER [2].

There are multiple ways to improve the efficiency of a given air-conditioning or refrigeration system. Analysis of the real refrigerant cycle and comparison with an ideal Carnot cycle reveals a number of optimization potentials in virtually every component of the unit. Improved and more efficient compressor designs with modulated capacities, more efficient expansion (refrigerant flow) controls, improved design and energy management of the fans are only some of the means that can contribute to improved efficiency. One of the largest potentials to increase efficiency lies within the heat-transfers: reducing the condensing temperature by 3 °K will improve the overall system efficiency by approx. 10% for a standard R410A air conditioning cycle. A minimization of the temperature difference between the airflows and the phase change temperatures of the refrigerants can be achieved by increasing the heat transfer surface area or by improving the heat transfer efficiency of the heat exchangers.

Brazed microchannel heat exchangers have already proven that they are able to provide an elegant and cost effective solution for the utilization of this optimization potential – while also providing a number of other benefits.

Brazed microchannel heat exchangers have been the technology of choice for the automotive industry for the past 10 to 15 years. This brochure illustrates...
2. Why Brazed Heat Exchangers?

**Improved Heat Transfer Performance**

Approximately 5–10% of the heat transfer resistance in a standard heat exchanger is due to lack of contacts between fins and tubes. The traditional way of manufacturing finned tube heat exchangers by mechanical or hydraulic expansion of the round tubes will always leave imperfect connections between the parts. The microscopic image on the left shows an example of the small gaps between fins and tubes. These gaps are responsible for a contact resistance that reduces the heat transfer performance.

A brazed connection metallurgically bonds fins and tubes in a single conductive material eliminating all potential sources of contact resistance.

Brazing also offers the chance to change the design of heat exchangers, substituting round tubes with flat channels, also named microchannels.

Flat channels offer improved heat transfer on both refrigerant and air sides. The first reason is the more favourable section/surface ratio, which affects the efficiency of heat exchange on the air side and on the refrigerant side. On the air side, flat tubes reduce the surface in the shadow of the air stream, where the flow becomes turbulent. The shade of the tubes not only causes inefficient heat-transfer, it is also the cause of a lot of noise.

**Pressure Drop Reduction**

If the heat exchange is more efficient, a lower air flow is necessary to exchange the desired heat. On the other hand, the microchannel technology is already advantageous because it offers a lower resistance to the air flow. Comparing the two designs it is evident that flat is beneficial: the reduction in resistance is up to 3-fold under typical operating conditions!
Refrigerant Charge Reduction

This increase in efficiency means the same refrigerant capacity can be produced with smaller exchange surfaces at the condenser and at the evaporator, which leads to a reduced piping volume of the system itself.

In other words, a higher heat exchange efficiency means smaller systems and lower refrigerant charge. Third generation HFC refrigerant blends such as R410A are significantly more expensive than R22 which they are now replacing.

Reliability in Performance

Aluminum alloys offer high heat conductivity but also high resistance to corrosion. The $\text{Al}_2\text{O}_3$ protective layer is a guarantee against time-aging. Coupling two different metals is often synonymous with galvanic corrosion. This is particularly true for the connection of aluminum and copper and such joints are common in current HVAC designs. One should however be aware that galvanic corrosion appears only in electro-conductive liquid environments, such that proper protection against contact with water by painting or thermally shrunk plastics applied on the joint eliminates the problem.

Brazed heat exchangers also offer a higher mechanical resistance, especially in the fin connection, so that even incorrect handling or accidental collisions cause less deterioration with time.

Recycling Advantages

Microchannel heat exchangers are single-alloy system components. This allows for easy and efficient recycling: Aluminum has a well established market for recycled material which helps in reducing the complexity of end-of-life management of air conditioning systems.

Noise Reduction

As already discussed, flat channels that make up brazed heat exchangers have a smaller air stream shadow. This limits the turbulence with consequent noise reduction. Moreover, the brazed connections between fins and tubes are rigid structures, reducing mechanical noise in the presence of air turbulence. Brazed microchannel heat exchangers are the silent solution!

Lower Weight

The specific gravity of copper is more than 3 times higher than that of aluminum alloys used in heat exchangers. Heat conductivity of copper is higher than that of aluminum. However, for a heat exchanger, the boundary conditions between the metal and surrounding environment are the determining factor for the overall performance. Those conditions as mentioned above are much more favourable for brazed heat exchangers. As a result, an aluminum brazed heat exchanger will have a similar performance to an all copper unit of similar size. In this way we have an exchanger offering the same performance but which is about three times lighter. Furthermore, it is important to consider the cost of the raw materials for an exchanger.
3. How to Braze Heat Exchangers

What is Brazing?
Aluminum brazing involves joining of components with a brazing alloy, which is an aluminum-silicon alloy (Al-Si) whose melting point is appreciably lower than that of the components. This brazing alloy is usually placed adjacent to or in between the components to be joined and the assembly is then heated to a temperature above the brazing alloy melting point, but below that of the components. Upon cooling, the alloy forms a metallurgical bond between the joining surfaces of the components.

Role of the Flux
Aluminum owes its excellent corrosion resistance properties to a tough, very thin, but tenacious oxide film. This oxide melts at a much higher temperature than aluminum and therefore must be removed before brazing can occur. A flux is then used to displace, or more specifically, dissolve the oxide film barrier coating the aluminum. At brazing temperature, the flux melts and spreads over the aluminum surfaces, dissolving the oxide film and preventing further oxidation during the brazing process. The molten flux then wets the surfaces to be joined allowing the filler metal to be drawn freely into the joint by capillary forces. Upon cooling, the flux residue remains on the surface as a thin, strongly adherent film. NOCOLOK® Flux is a potassium aluminum fluoride salt of the general formula K$_{1.3}$AlF$_{4.6}$.

Brazing Process
The following section briefly describes the typical production process stream for manufacturing brazed aluminum heat exchangers.

Core Assembly
The individual components are assembled and fixed in place in a core builder. The fixture is designed to maintain dimensional stability during the brazing process.

Cleaning
Also known as degreasing or de-oiling, this step is to remove residual lubricants and forming oils. A popular cleaning method today is a technique known as thermal degreasing whereby the coils are simply heated to a specified temperature and specialty lubricants are flashed off.

Fluxing
Flux is then applied to the coil as an aqueous suspension by flooding, dipping or spraying. The slurry concentration, typically in the range of 5% to 25%, regulates flux loading. An air
NOCOLOK® Flux Brazed Aluminum Heat Exchangers

Furnace Atmosphere

Temperature (°C)

0 100 200 300 400 500 600 700

Brazing Time (min)

0 2 4 6 8 10 12 14 16 18 20 22

Cooling
Joint solidifies
Flux solidifies and remains on part as residue.

565–570 °C
1049–1058 °F

NOCOLOK® flux melts and displaces the oxide on Al.

°C
°F

Reaction

Driving off moisture from fluxing step.

N 2 Gas Flow

N 2 gas: 30 m³/h
Belt speed: 1000 mm/min

Aqueous Fluxing Unit

Air Blow Off

Dry Off Section

≤ 110 °C
≤ 230 °F

Heating Section

110–565 °C
230–1049 °F

565–570 °C
1049–1058 °F

NOCOLOK® flux melts and displaces the oxide on Al.
Dry-Fluxing: This technique makes use of powder painting equipment modified to work with the flux properties. As the flux is applied dry, there is no need to mix flux slurries, to measure flux slurry concentration and there is no wastewater. NOCOLOK® Dry-static flux, with a unique particle size characteristic, was specially developed for this application. Some care is required with the handling of dry-fluxed components as the pre-braze flux adhesion is less that that of wet fluxing.

Pre-Fluxing, also known as binder fluxing: The concept here is to pre-flux certain heat exchanger components such as microchannel tubes, headers and manifolds in a paint-line like fashion. The flux is mixed with a suitable binder/carrier and the components are cleaned, sprayed with the flux mixture and dried/cured. The components can then be sent directly to the core-assembly machine or packaged for future use. This technique results in a defined flux load on the components and the components can be handled without the risk of removing the flux.

NOCOLOK® Sil Flux: Particularly suitable for condenser manufacturing, this technique uses a mixture of flux and elemental silicon powder, sprayed on the microchannel tubes using a binder/carrier. Similar to pre-fluxing, spraying or coating the tubes is carried out prior to assembly. After core assembly and during brazing, the silicon powder reacts with the aluminum surface to create the brazing alloy in-situ, thereby eliminating the need for clad fins.

Flux Residue
After cooling, the flux residue remains on the surface as a very thin, adherent film with a thickness of 1-2 µm. It does not need to be removed. The layer of flux residue is non-hygroscopic, non-corrosive in all standard applications and only very slightly soluble in aqueous media. Since it is possible that the flux residue can come in contact with the refrigerant or cooling media, numerous studies were undertaken to prove compatibility. In all the studies conducted, there is no evidence that the flux residue accelerates, contributes to or catalyzes the decomposition of the lubricant, refrigerant components or damages any other component of the system.
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