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NOCOLOK® Flux Brazed Aluminum Heat Exchangers

For the Refrigeration and Air Conditioning Industry

1. Introduction

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 (CO_2 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" [1]

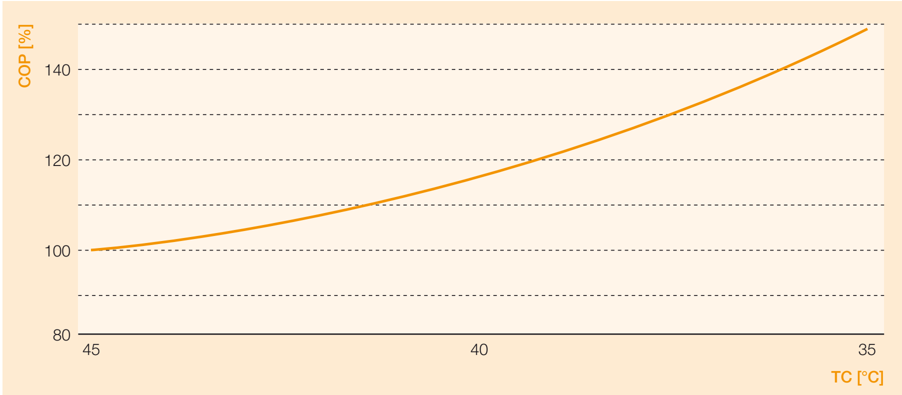
Energy efficiency regulations and labelling initiatives are being introduced or – where already in place – tightened in order to minimize the energy consumption of a given society. In January 2006, the minimum efficiency level for all new central air conditioners manufactured in the U.S. was raised from 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 why the paradigm shift will penetrate the stationary HVAC&R industry as well.

[1] Energy efficiency and refrigerant emissions reduction are the key elements of sustainable refrigeration. www.fluorocarbons.org

[2] SEER (Seasonal Energy Efficiency Ratio) measures how efficiently a residential central cooling system (air conditioner or heat pump) will operate over an entire cooling season, as opposed to a single outdoor temperature. As with EER, a higher SEER reflects a more efficient cooling system. SEER is calculated based on the total amount of cooling (in Btu) the system will provide over the entire season divided by the total number of watt-hours it will consume



2. Why Brazed Heat Exchangers?

Improved Heat Transfer performance

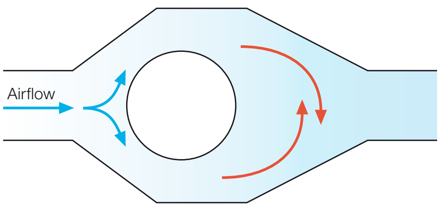
Approximately 5–10% of the heat transfer resistance in a standard heat exchanger is due to lack of contacts between fins and tubes. The traditional way of manufacturing finned tube heat exchangers by mechanical or hydraulic expansion of the round tubes will always leave imperfect connections between 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.

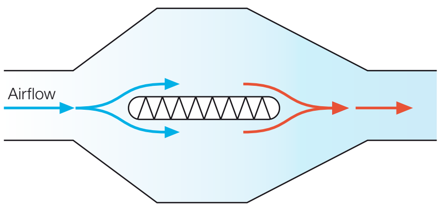
Brazing also offers the chance to change the design of heat exchangers, substituting round tubes with flat channels, also named microchannels.

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

Flat Tubes – Air-Side Effects



Back side of a round tube has low heat transfer, causes pressure drag, and is a source of noise.

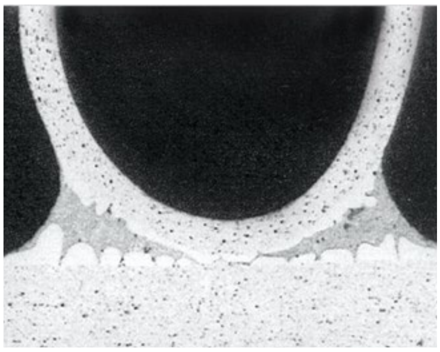


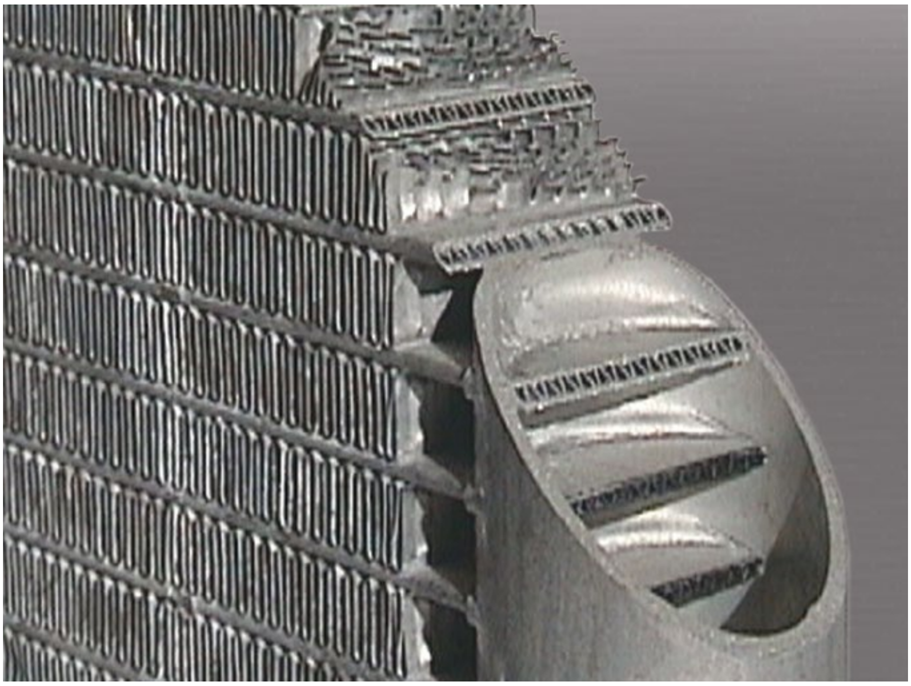
Back side of flat tube has improved heat transfer, reduced pressure drop with lower noise.

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!





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.

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 Al_2O_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.

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!

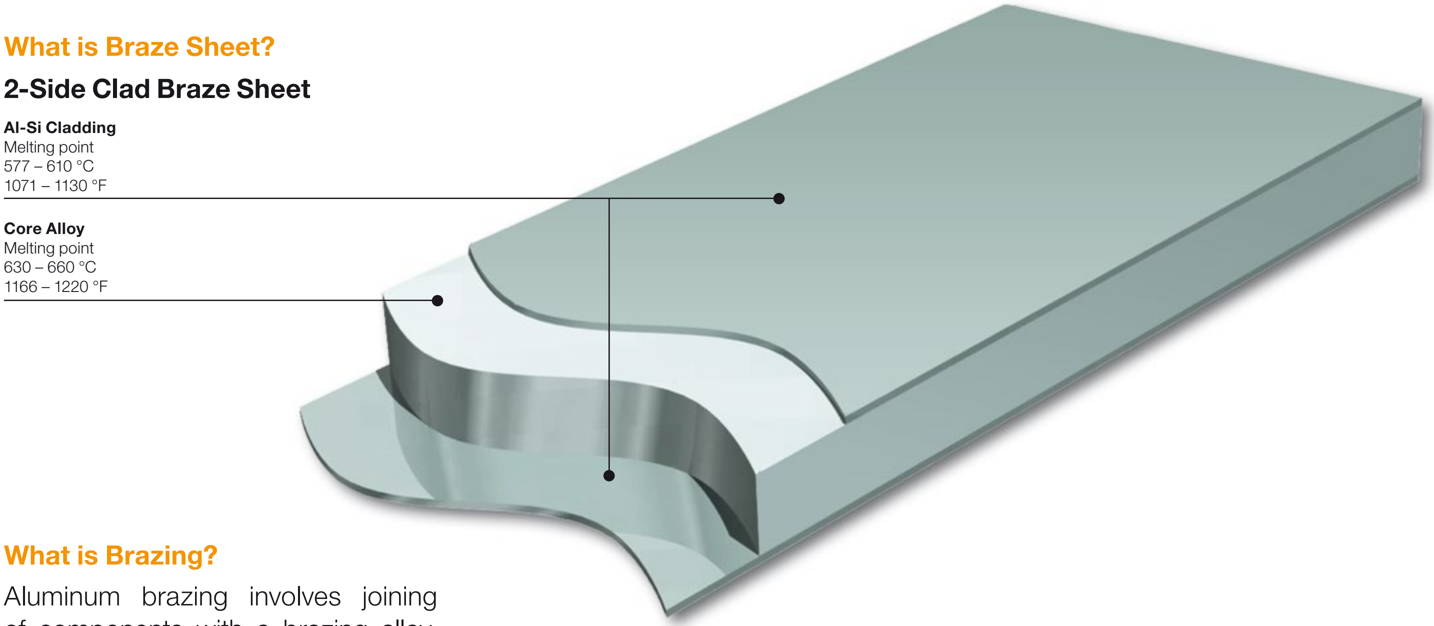
Lower Weight

The specific gravity of copper is more then 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, is important to consider the cost of the raw materials for an exchanger.

3. How to Braze Heat Exchangers

What is Braze Sheet?

2-Side Clad Braze Sheet



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

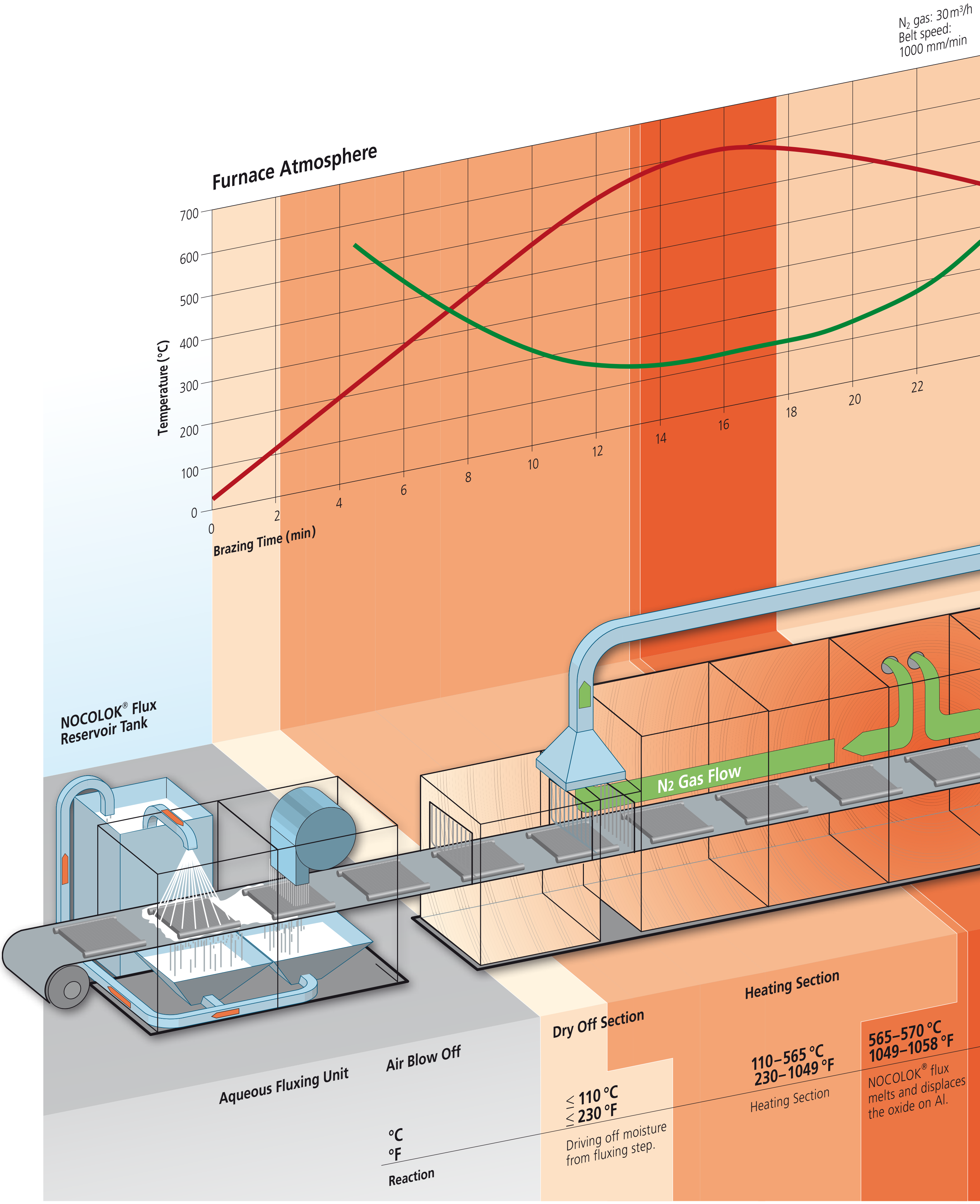
The individual components are assembled and fixed in place in a core builder. The fixture is designed to maintain dimensional stability during the brazing process.

Cleaning

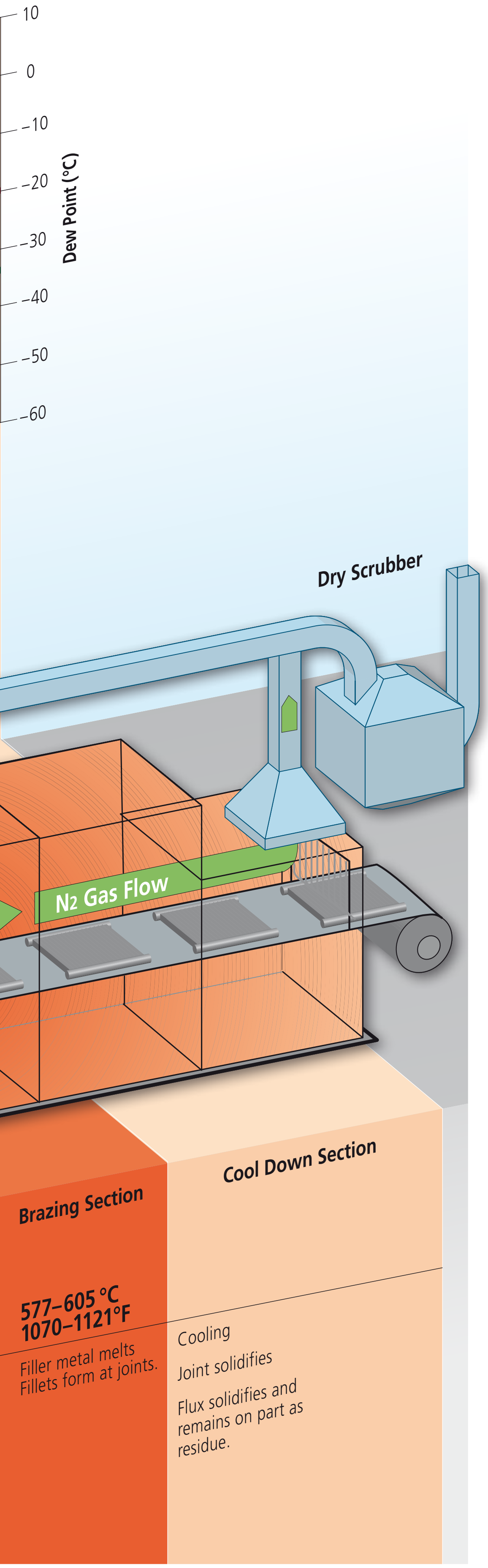
Also known as degreasing or de-oiling, this step is to remove residual lubricants and forming oils. A popular cleaning method today is a technique known as thermal degreasing whereby the coils are simply heated to a specified temperature and specialty lubricants are flashed off.

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



Furnace Atmosphere
N_2 gas: 30 m³/h
Belt speed:
1000 mm/min
Temperature (°C)
700
600
500
400
300
200
100
0
0
2
4
6
8
10
12
14
16
18
20
22
Brazing Time (min)
NOCOLOK® Flux
Reservoir Tank
N2 Gas Flow
Aqueous Fluxing Unit
Air Blow Off
Dry Off Section
Heating Section
°C
°F
Reaction
≤ 110 °C
≤ 230 °F
Driving off moisture
from fluxing step.
110–565 °C
230–1049 °F
Heating Section
565–570 °C
1049–1058 °F
NOCOLOK® flux
melts and displaces
the oxide on Al.



blow-off is also used to remove excess flux slurry from the coil and distribute the flux evenly throughout the coil.

The most common method still today is to apply the flux slurry using a low pressure spray over the entire heat exchanger. In recent years however, other techniques have evolved which are suitable for certain applications

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.

Drying

Water is used as a vehicle to bring flux on the coil. The aim here is to simply remove the water from the fluxing stage so that the coil is dry before entering the brazing furnace. Drying is usually carried out at around 200 °C coil temperature and should not exceed 250 °C.

Brazing

NOCOLOK® Flux brazing, also known as Controlled Atmosphere Brazing or CAB for short, is carried out in an inert atmosphere such as nitrogen in continuous tunnel furnaces such as the one shown in the schematic. Low volume brazing can also be done in batch-type furnaces.

The coil's temperature increases as it travels through the furnace. At approximately 565 °C the flux will melt, followed by the onset of melting of the brazing alloy at 577 °C. In the critical brazing zone, where the moisture and oxygen are at the lowest concentrations, the filler metal flows into the joints by capillary action. Solidification of the filler metal takes place in the cooling zone whereby a metallurgical bond is formed between all components. At the exit end of the furnace, the coils are cool enough to be handled with gloves.

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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