SOLVAY

asking more from chemistry®

NOCOLOK®

The NOCOLOK® Flux Brazing Process

1. Introduction

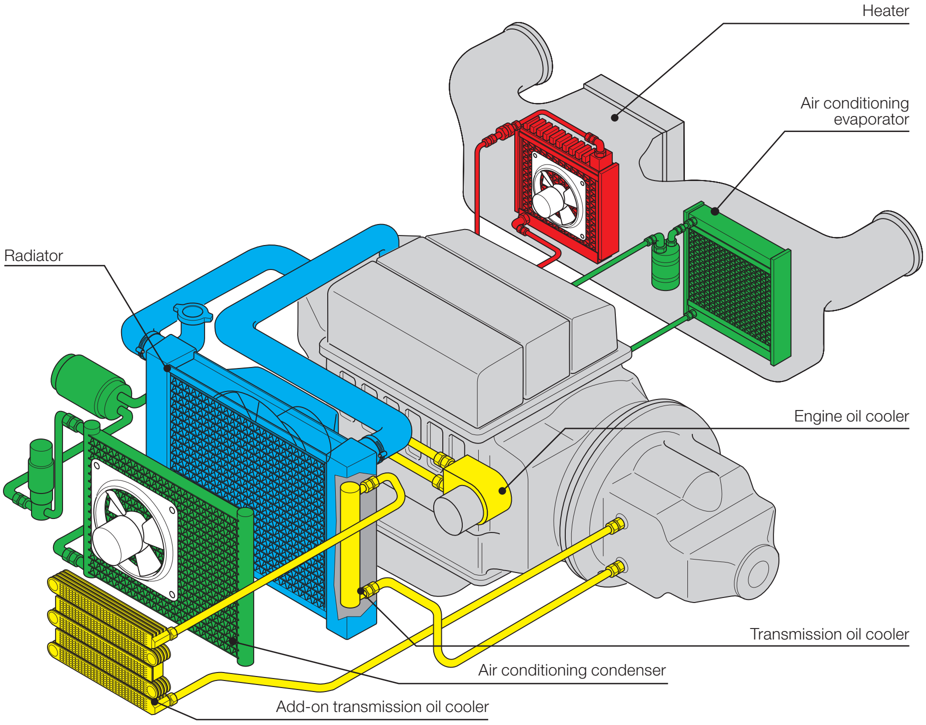
Aluminum brazing is now the preferred process for the production of automotive heat exchangers such as radiators, condensers, evaporators and heater cores. Good corrosion resistance, formability and high thermal conductivity make aluminum an ideal material for the construction of these heat exchangers.

Aluminum brazing involves joining of components with a brazing alloy, that is an aluminum 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 where the brazing alloy melts but not the components. Upon cooling, the brazing alloy forms a metallurgical bond between the joining surfaces of the components.

In automotive heat exchanger applications, this filler metal is supplied via a thin sheet or clad on a core alloy. The core provides structural integrity while the low melting point Al-Si cladding alloy melts and flows during the brazing process, to provide upon cooling a metallic bond between the components.

It is usually necessary to employ a flux in brazing aluminum to remove the native oxide film present on all aluminum surfaces. The flux must be capable of displacing the oxide film barrier during brazing to allow the filler metal to flow freely and must prevent the surfaces from reoxidizing. Many fluxes and brazing techniques have evolved over the years, but one process that is now recognized worldwide is the NOCOLOK® flux brazing process.

There are many automotive applications for aluminum heat-exchangers



Chronology of Brazing Processes

Chloride flux brazing

The earliest brazed aluminum heat exchangers employed a chloride flux, a mixture of chloride salts with minor additives of fluorides. The units were immersed in a molten salt bath where the salt acted as a flux and a means of raising the unit to brazing temperature. However, this technique left a hygroscopic corrosive residue on the heat exchanger.

The brazed unit required extensive post braze treatment in the form of water washing, pickling and passivation of the pickled surface to prevent further corrosive action.

Furnace brazing techniques were also employed using chloride flux loadings in the range of 150 g/m^2 – 300 g/m^2. To reduce the extent of post braze treatments, stringent furnace atmosphere requirements were imposed (eg. dew point ≤ –40 °C) to reduce the flux loadings.

Post braze treatments however were still required to remove the corrosive residue. The cost and pollution of post braze treatments presented a barrier to a wider application of brazed aluminum products.

Vacuum brazing

The industry's attention was then directed to fluxless brazing processes i.e. vacuum brazing. This technique indeed eliminated the need for post braze treatments but presented much tighter tolerances with respect to furnace atmosphere (≤–60 °C dew point), surface cleanliness and fit-up. In this process, the maintenance of atmosphere purity was difficult and expensive and attention was soon redirected to processes employing a flux.

NOCOLOK® flux brazing

The objective was to develop a process which would offer the benefits of a flux while avoiding the disadvantages of post braze treatments and corrosion susceptibility. A brazing method was thus developed using a non-hygroscopic and in standard applications non-corrosive potassium fluoroaluminate flux which successfully removes the oxide film on aluminum, does not react with aluminum in the molten or solid state and whose residue is only very slightly soluble in water. This flux and the process for using it is called the NOCOLOK® flux brazing process.

Production

NOCOLOK® flux is produced in the liquid phase using $Al(OH)_3$, HF and KOH as raw materials as indicated in the process flow diagram.

Stringent process tolerances and a variety of quality control procedures produces a flux of the highest quality and consistency.

The result is a fine white powder consisting primarily of a mixture of the potassium fluoroaluminate salts of the general formula $K_{1\text{-}3}\,Al\,F_{4\text{-}6}$ where a water of hydration may be present. At brazing temperature, this corresponds to the KF-AlF_3 phase diagram.

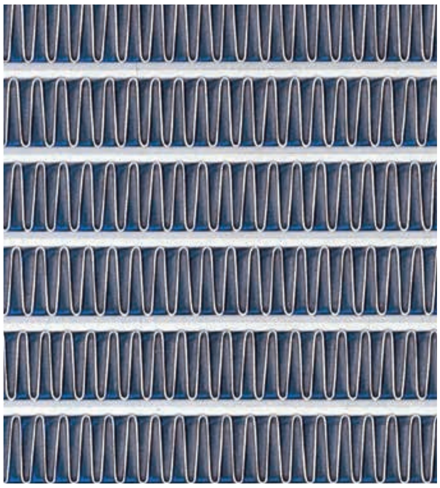
Characteristics

The resulting eutetic flux composition has a clearly defined melting point range of 565 °C to 572 °C, below the melting temperature of 577 °C of the Al-Si brazing alloy. The particle size lies in the range of 2 µm to 50 µm. A larger fraction of fine particles is deliberately avoided. This feature reduces dust levels during powder handling and still maintains good slurry characteristics.

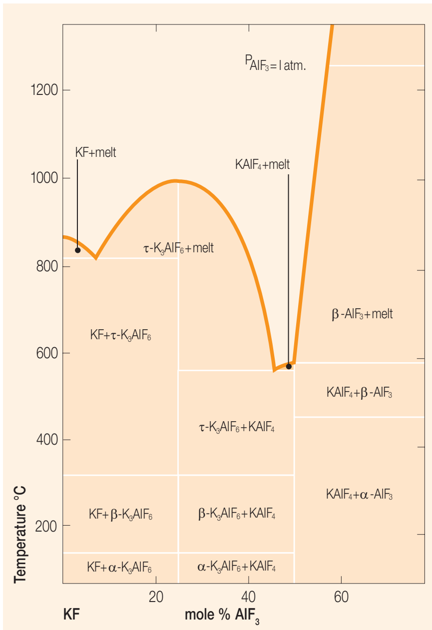
NOCOLOK® flux is non-hygroscopic and only very slightly soluble in water (0.2 % to 0.4 %). The shelf and pot life of the flux is therefore indefinite. The flux does not react with aluminum at room temperature or at brazing temperature and only becomes reactive when molten (at least partially molten). The flux leaves a mainly water insoluble residue which need not be removed.

Role of the flux

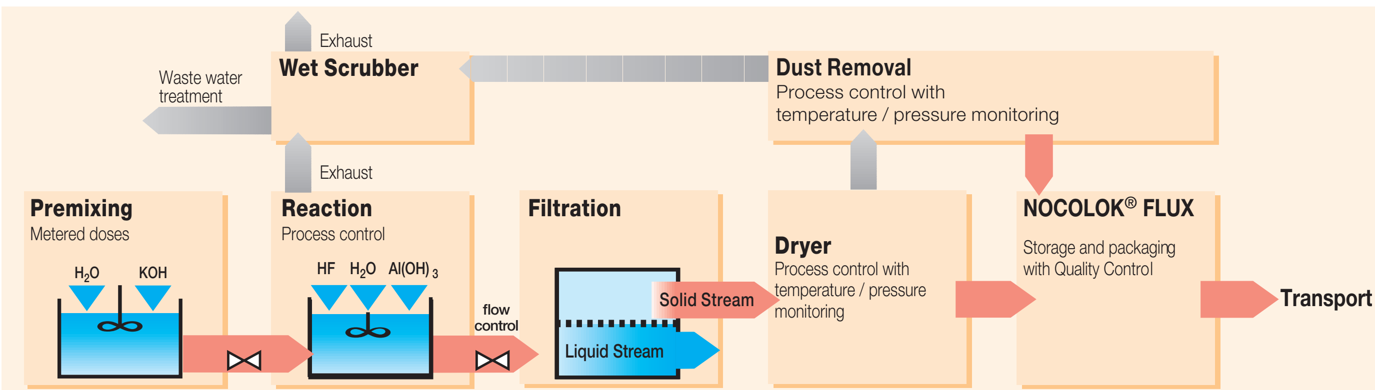
Once molten, the flux works by dissolving the tenacious oxide present on aluminum, and prevents further oxidation. The flux wets the faying surface of the components to be joined allowing the filler metal to be drawn freely into the joint by capillary action. Upon cooling, the flux remains on the surface as a thin, strongly adherent film.



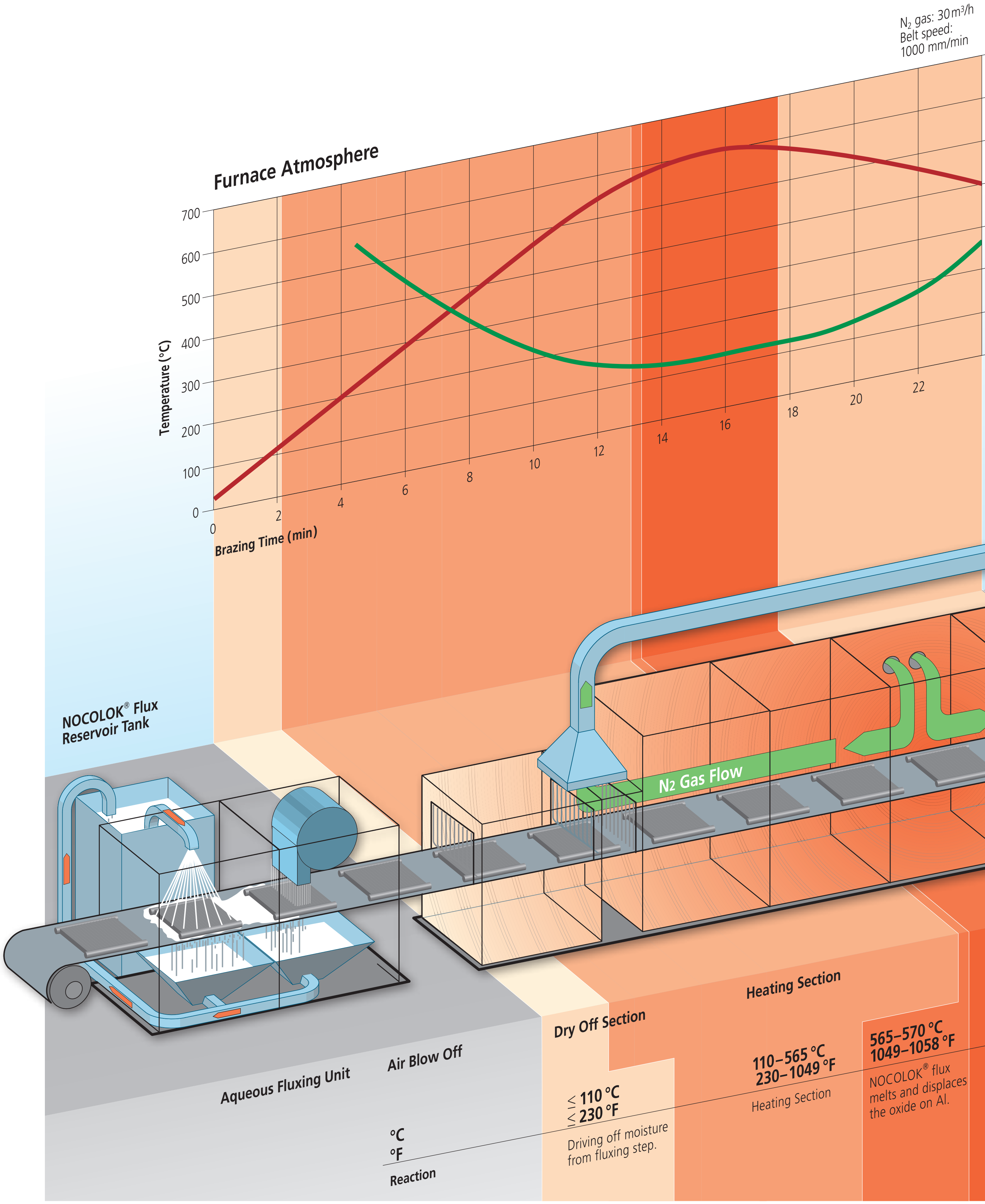
NOCOLOK® Flux Brazed Condenser

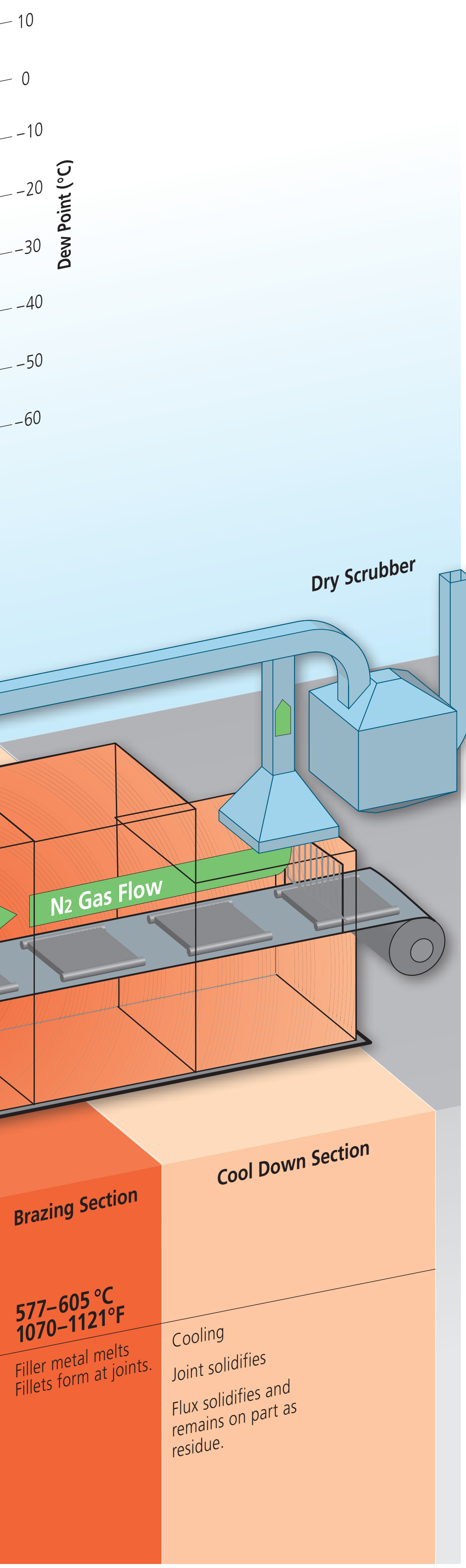


KF-AlF_3 Phase Diagram



NOCOLOK® Flux Process Flow Diagram


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.



Brazing Process

Flux application

Prior to fluxing, the assembled heat exchanger typically goes through a cleaning step to remove residual lubricants and forming oils.

NOCOLOK® flux is then applied to individual parts or assembled units as an aqueous slurry by flooding, spraying or dipping. A surfactant is commonly added to the slurry to aid in wetting and uniformity of flux deposition. Agitation is required to prevent the flux from settling. The slurry concentration, typically in the range of 5 % to 25 %, regulates flux loading. An air "blow-off" step is also typical to remove excess slurry accumulated at the downside of the fluxed part. The goal is to achieve a uniform coating of flux without significant accumulation in any one place.

The coating can also be applied using electrostatic fluxing.

In recent years, there is an increasing trend to using sophisticated flux formulations for selective pre-fluxing of components and/or localized fluxing of complicated geometries. The driving force behind this trend is multi-faceted: heat exchanger manufacturers are seeking to out-source flux application, to partially or completely eliminate certain process elements (fluxer, degreaser) and the movement away from seam-welded and extruded tubes to folded tube technology

Drying

After fluxing, the part is then dried, usually at about 200 °C. Care is taken not to overheat the heat exchanger as excess heat (i.e. > 250 °C) may cause high temperature oxides to form on aluminum surfaces. These oxides are more difficult to remove with NOCOLOK® flux. The aim here is simply to remove water from the fluxing stage so that the component is completely free of adsorbed water prior to entering the brazing furnace. Since only a light flux loading is required (~ 5 g/m^2) the resultant flux adhesion is quite sufficient.

Brazing

NOCOLOK® flux brazing is carried out in an inert atmosphere such as nitrogen in either batch type furnaces or more commonly in continuous tunnel furnaces such as the one shown in the schematic.

Nitrogen is introduced in the critical brazing section of the furnace and flows towards the entrance and exit. This prevents the ingress of contaminants from outside the furnace. As the component enters the critical brazing zone, furnace atmosphere becomes established, i.e. the dew point is ≤ –40 °C and the O_2 concentration is < 100 ppm. These conditions are necessary for optimum brazing results.

In the temperature range of 530 to 560 °C, traces of $KAlF_4$ evaporate and in presence of moisture can react to form traces of HF. Therefore, the dewpoint is tightly controlled, not only to provide a good atmosphere for brazing, but to minimize HF generation.

Flux residue

After cooling, the flux residue remains on the surface as a very thin adherent film with a thickness in the range of 1 – 2 µm. The layer of flux residue is non-hygroscopic, in standard applications non-corrosive and only very slightly soluble in aqueous media. No further surface treatment is required if painting or conversion coatings are desired. The flux residue is known to provide enhanced corrosion resistance. The residue is not subject to spalling during thermal cycling.

Core alloys

Aluminum alloys are classified according to their alloying elements. The Aluminum Association designations are listed in the table below:

Designation System for wrought aluminum alloys

Alloyseries	Description or major alloying element
1xxx	99.00% minimum Aluminum
2xxx	Copper
3xxx	Manganese
4xxx	Silicon
5xxx	Magnesium
6xxx	Magnesium and Silicon
7xxx	Zinc
8xxx	Other Element
9xxx	Unused Series

The chemical composition of each AA alloy is registered by the Aluminum Association and a few examples are listed:

Example of aluminum alloy composition limits in weight percent*

Alloy-Number	Si	Fe	Cu	Mn	Mg	Zn	Cr	Others each	Others total
1100	0.95	(Si + Fe)	0.05 – 0.20	0.05	–	0.10	–	0.05	0.15
1435	0.15	0.30 – 0.50	0.02	0.05	0.05	0.10	–	0.03	0.03
3003	0.60	0.70	0.05 – 0.20	1.00 – 1.50	–	0.10	–	0.05	0.15
3005	0.60	0.70	0.30	1.00 – 1.50	0.20 – 0.60	0.25	0.10	0.05	0.15
6063	0.20 – 0.60	0.35	0.10	0.10	0.45 – 0.90	0.10	0.10	0.05	0.15

* Maximum, unless shown as a range

Many of these core alloys are compatible with NOCOLOK® flux brazing. Alloys such as AA-3003 and AA-3005 are commonly used as core materials for NOCOLOK® flux brazing heat exchangers.

Magnesium

For added strength and machinability, certain alloys contain Mg as an alloying element. However, there is a limit to the amount of Mg that can be tolerated for NOCOLOK® flux brazing. There is reduced furnace brazeability of aluminum alloys containing greater than 0.5 % Mg. NOCOLOK® flux has a limited solubility for the magnesium oxides that form on the surface of Mg bearing alloys.

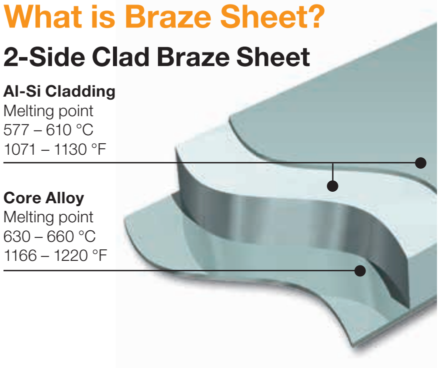
Furthermore, Mg can diffuse to the surface of the alloy during brazing and react with the flux, thereby changing its composition, and therefore its effectiveness. Rapid heat-up rates and heavier flux loadings such as used in torch brazing applications will tolerate slightly greater Mg concentrations.

Cladding alloys

As described earlier, brazing sheet comprises of a core alloy clad on 1 or 2 sides with a lower melting aluminum-silicon (Al-Si) alloy. This thin layer, usually makes up 5 % to 10 % of the total thickness of the brazing sheet.

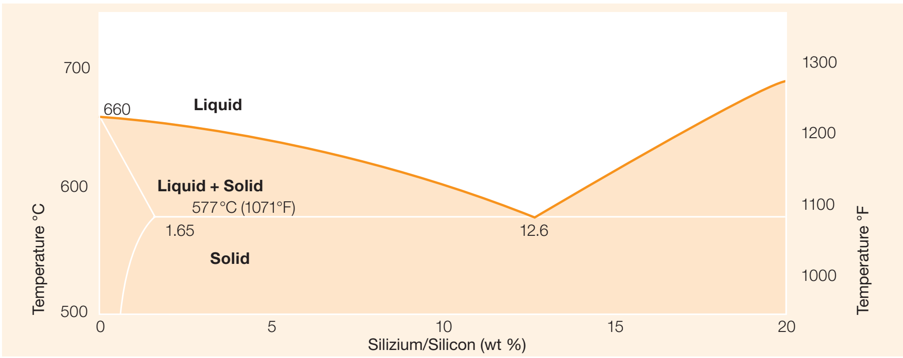
What is Braze Sheet?

2-Side Clad Braze Sheet



Phase diagramm

The addition of Si lowers the melting point of aluminum. This phenomena is illustrated with the Al-Si Phase diagram.



Aluminum End of Al-Si Phase Diagram

The eutectic composition, i.e. the amount of Si required to produce the lowest melting point is 12.6 %. The melting point at this composition is 577 °C. At lower Si levels the solidus or the point at which melting begins is also 577 °C. However, melting occurs in a range and the temperature above which the filler is completely molten is called the liquidus. In between the solidus and liquidus, the filler is partially molten, existing as both solid and liquid. The difference between the solidus and liquidus forms the basis for various filler metal alloys. Commercial filler metals may contain from 6.8 % to 13 % Si.

Brazing alloys

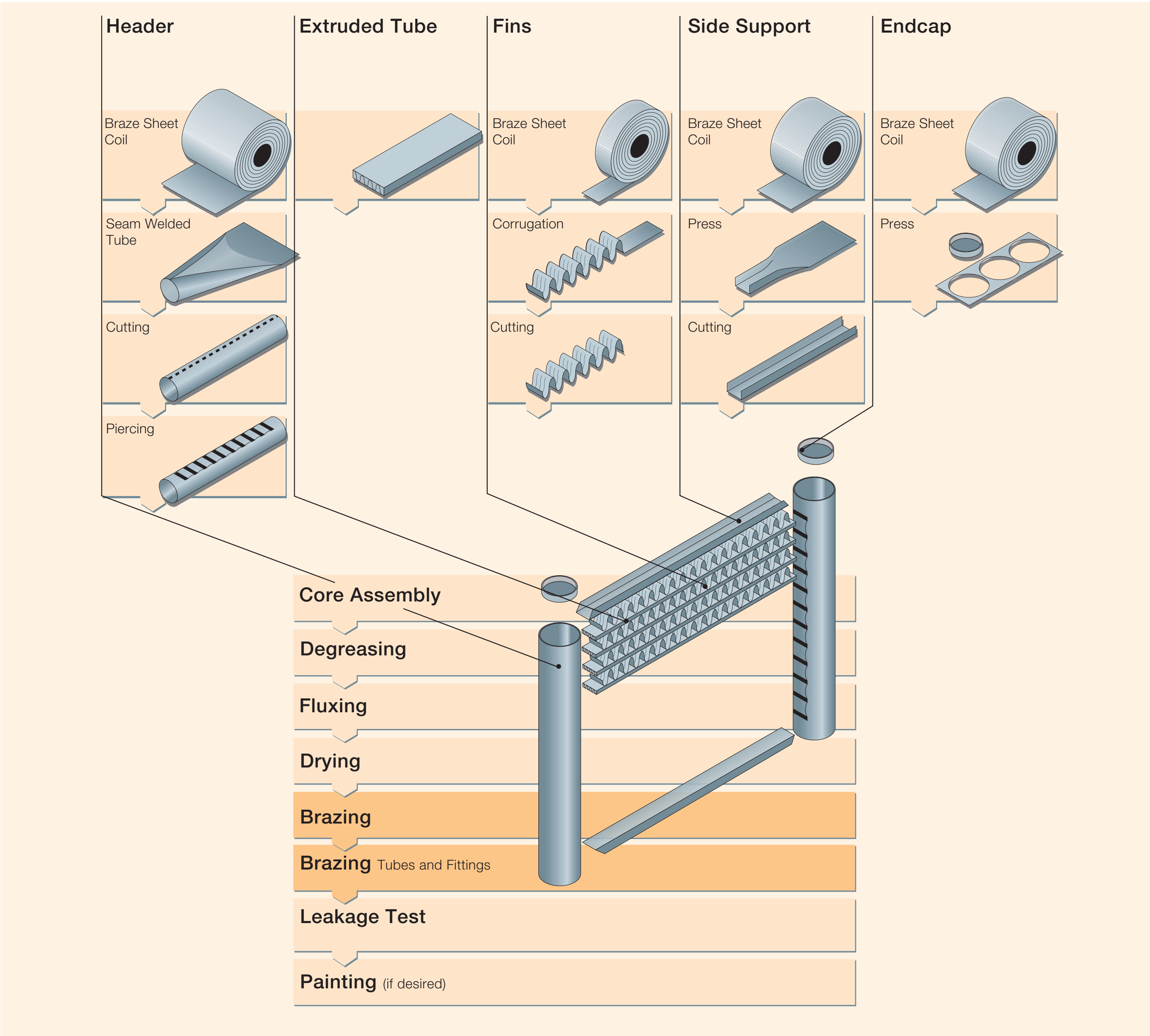
AA-4343 is a common filler metal brazing alloy. However, if larger fillets are desirable, or if in a situation where brazing is likely to occur at lower temperatures, AA-4045 is the preferred choice. The choice, of course, is dependent on the specific application.

Alloy	AA-4343	AA-4045	AA-4047
% Si Nominal	7.5	10.0	12.0
Start Melting (°C)	577	577	577
Start Melting (°F)	1,071	1,071	1,071
Fully Molten (°C)	613	591	582
Fully Molten (°F)	1135	1095	1080
Recommended Braze Range (°C)	593 – 621	588 – 604	582 – 604
Recommended Braze Range (°F)	1,100 – 1,150	1,090 – 1,120	1,080 – 1,120

Aluminum Brazing Clad Alloys

Production

The main elements of a typical production process stream are depicted here for a condenser.



NOCOLOK® CREATING INNOVATIVE FLUXES

FOR JOINING ALUMINIUM

SOLVAY
asking more from chemistry®

Europe
Solvay Fluor GmbH
Postfach 220
30002 Hannover, Germany
Tel.: +49 511 857-0
Fax: +49 511 857-2146

North America
Solvay Fluorides, LLC
3737 Buffalo Speedway,
Suite 800,
Houston, TX 77098, USA
Tel.: +1 713 525-6000
Fax: +1 713 525-7805

Asia/Pacific
Solvay Korea CO., LTD
EWAH-Solvay R&I Center
150, Bukahyun-ro
Seodaemun-gu
Seoul 120-140, South Korea
Tel.: + 82 2 2125 5300
Fax: + 82 2 2125 5380

31/327/02.18/007/pdf

www.solvay.com
www.nocolok.com