Technical Guide

Microchannel Heat Exchangers • Quality made in Europe • Go for Aluminium!

CONDENSERS • EVAPORATORS • HEATERS
Contents of the Technical Guide

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Important Notice

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PED CERTIFICATE
Aluminium Microchannel Heat Exchangers

CERTIFICATE OF COMPLIANCE WITH PED Nº 97/23/EC

PRODUCT TYPE: T14XXX

CLIMETAL, S.A. certifies, under its sole responsibility, that:

- All the air cooled condensers are heat exchanger made of pipes, intended for group I and II cooling fluid condensation. They are compared to a set of pipes [in accordance with the definition given in article 1st § 2.1.2 «pipes» PED 97/23/EC].
- All these equipments are excluded from the area of application of PED 97/23/EC. At the most, they fall under category I in compliance with PED article Nº 9 and they are in conformity with the requirements of the machine directive Nº 98/37/CE (article 1st § 3.6 PED 97/23/EC).

<table>
<thead>
<tr>
<th>Classified for:</th>
<th>Condensation of fluids: Groups I &amp; II</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS1:</td>
<td>≤ 50 bars</td>
</tr>
<tr>
<td>Burst pressure 1:</td>
<td>&gt; 150 bars</td>
</tr>
<tr>
<td>TS min/max 1:</td>
<td>-30 ºC / +140 ºC</td>
</tr>
<tr>
<td>Conformity and assessment procedure followed:</td>
<td>Not subjected to PED requirements</td>
</tr>
<tr>
<td>Risk class:</td>
<td>Classified «article § 3.3»</td>
</tr>
</tbody>
</table>

Agustín Maiz
CEO
03/04/2014

1 The above mentioned values should not be considered as nominal value of running. They are the limits from which the pressure and temperature resistance is no more guaranteed.
ALLOYS
ALLOYS

Brazing Al alloys for All-Aluminium Heat Exchanger

Heavy metal brazing alloys cannot be used for brazing aluminium due to the melting point of aluminium and its alloys and due to the required corrosion resistance of the brazed joint. As a result, brazing alloys based on aluminium, containing no or very small quantities of heavy metals and at least 70% aluminium, are employed. There are hence alloys which themselves have to be regarded as aluminium alloys and which often have melting point intervals in the range of the aluminium brazing alloys which are used.

Brazeable tubes and profiles from Al alloys are composed of a clad brazing material, the core material which determines the properties of the tube or profile, and a thin diffusion barrier of pure Al between the clad brazing and the core material. The mechanical properties achieved with this multi-layer composite are really excellent!

Brazing alloys in the aluminium-silicon system with silicon contents between 7% and 13% have proven successful from strength and corrosion-chemical points of view. These alloys have melting temperatures in the range between 575 °C and 615 °C. A standard product here is brazing alloy AL104 having a melting interval from 575 – 585 °C. The working temperature of this brazing alloy is 585 °C. Joints made with this brazing alloy show good corrosion resistance. As the base material may not be melted during brazing, only materials having melting intervals above the processing temperature of the brazing alloy (minimum temperature which is required for brazing) can be brazed with this brazing alloy. As a result, it is predominantly pure aluminium and aluminium alloys with melting intervals above 640 °C which are brazed. In practice this means that chiefly pure aluminium and AlMn 1 materials are brazed. An overview of aluminium alloys which are suitable for brazing and those which are not is given in Table 1.

Table 1: Overview of the suitability of aluminium and aluminium alloys for brazing (from the Aluminium Pocket Book).

<table>
<thead>
<tr>
<th>Material type</th>
<th>Brazing</th>
<th>Soldering</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forged material: pure and super-pure aluminium</td>
<td>Suitable</td>
<td>Suitable</td>
<td></td>
</tr>
<tr>
<td>AlMn</td>
<td>Suitable</td>
<td>Suitable</td>
<td>Mg concentrations &lt; 0.6% make wetting more difficult.</td>
</tr>
<tr>
<td>AlMg</td>
<td>Conditional</td>
<td>Suitable</td>
<td></td>
</tr>
<tr>
<td>AlMgSi</td>
<td>Suitable</td>
<td>Suitable</td>
<td>Remember strength decrease! After brazing, hardening is possible.</td>
</tr>
<tr>
<td>AlCuMg</td>
<td>Not suitable</td>
<td>Possible</td>
<td>Brazing causes irreversible damage to material, soldering causes a considerable strength decrease.</td>
</tr>
<tr>
<td>AlZnMg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AlZnMgCu</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cast alloys</td>
<td>See comment</td>
<td>Conditional</td>
<td></td>
</tr>
</tbody>
</table>

In the USA, brazing alloys of the type AlSi10Cu (4145) and AlSi10Zn10Cu4 (4245) are available, with solidus temperatures of 520 °C and 515 °C respectively.
Heat Exchanger components for HVAC & R

CAPS AND BAFFLES
AW-3xxx

HEADER
AW-3xxx
AW-3xxx LONG LIVE

MPE tubes AW-3102
AW-3102 mod.

FIN
AW-3xxx
BRAZING PROCESS
Brazing Process All-Aluminium Heat Exchanger

Basics about brazing
Aluminium brazing is a thermal process for joining two pieces 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.

Brazing techniques
The most common brazing methods for aluminium heat exchangers are:

- Controlled atmosphere brazing (CAB) with non-corrosive flux.
- Vacuum brazing (VB).

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 K1-3AlF4-6.

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

- The time-temperature cycle has to be carefully adjusted, because of its direct influence on the final products.
- The temperature in the furnace must be homogeneous to ensure that melting of the braze filler metal starts everywhere at the same time.

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.
BRAZING PROCESS

Cleaning/degreasing
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 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.

Source: 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.

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 than 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.

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. 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.
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.
BRAZING PROCESS

Component Assembly → Thermal Degreasing → Cleaning → Fluxing → Drying → Brazing → Cooling

STEP 1 SELECT THE RIGHT ALLOY
STEP 2 CLEAN DE SURFACES
STEP 3 REMOVE THE OXIDE LAYER
STEP 4 CHOOSE THE RIGHT FILLER A
STEP 5 SELECT THE SUITABLE GAP SIZE
STEP 6 APPLY SUFFICIENT FLUX AMOUNT
STEP 7 HEAT METAL COMPONENTS EVENLY

Source: Solvay

7 Steps to Successful Aluminum Brazing
SUPPLIERS
**SUPPLIERS**

*Climetal Suppliers*

The first class suppliers collaborate with us, including main row materials as headers, manifolds, fins, MP-tubes, welding alloys and fluxes.

Suppliers such as:

<table>
<thead>
<tr>
<th>Sapa</th>
<th>Erbslöh</th>
<th>WWW automotive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro</td>
<td>Sika</td>
<td></td>
</tr>
<tr>
<td>Castolin</td>
<td>Trumony</td>
<td></td>
</tr>
<tr>
<td>Flux</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
GEOMETRIES & MAXIMUM DIMENSIONS
GEOMETRIES & MAXIMUM DIMENSIONS

MICROCHANNELS

Dry Cooler 1 Phase

Condenser 2 Phases

MANIFOLD

MAXIMUM DIMENSIONS

FINS

LOUVERED

NO LOUVERED


**Vibration and environmental test**

Climetal’s products has been tested to guarantee mechanical and climatic resistance. Here are some of the most common test:

<table>
<thead>
<tr>
<th>EXTERNAL EFFECTS</th>
<th>TESTS</th>
<th>STANDARD – EXAMPLES</th>
</tr>
</thead>
</table>
| CHEMICAL         | Corrosion Tests  
Acidified Synthetic Sea Water resistance test (swaat, etc.).  
Different samples of coils had successfully reached more than 2200 of exposure without leaks. | ASTM G85  
[Annex 2; Annex 3] |
|                  | Burst pressure  
The heat exchanger is designer for operation at 35 bar with burst pressure above 135 bar as a single unit. Several tested performed show this results. | DIN EN 779:2002 |
|                  | Clogging Test  
Determination of dust holding capacity of separators and heat exchangers. | |
|                  | Pressure Cycle testing  
Pressure temperature cyclic test of soldered joints.  
Test of solder joints by Dynamic and Static Pressure. | |

All the reports are available for our customers. If you want further information contact with our quality department.
CHARACTERISATION OF CLIMETAL BRAZED CONDENSERS AFTER SWAAT TESTING
SWAAT TEST

INTRODUCTION

The experience of Climetal in the MCHEx manufacturing has taught us the importance of the epoxy coating on condensers against the galvanic corrosion.

The main objective of the inclusion of this process in our condensers is to avoid the corrosion in the coils. This product have been tested by Climetal, and we have only got positive results from the test done. For your review, herewith you can find some basics about epoxy coating.

We want the name Climetal to be synonymous in your mind with quality. We are committed to your satisfaction.

If you have questions about this process, our personnel will contact you shortly in order to describe the product in details as well as answer your questions, in case you have any.
EXPERIMENTAL

Material:
4 heat exchangers with current standard Climetal material combination:
- MPE Long life alloy (25 mm).
- FIN with clad in both sides (25 mm).
- HEADER with clad (32 mm).

- 2 heat exchangers without coating and without protection in the joint.
- 2 heat exchangers protected with epoxy and adhesive sleeve in the joint.

Conditions in Salt Spray Chamber:
The conditions in salt spray chamber are according to ASTM G85 Annex 2 "Cyclic acidified salt spray test".

Definition of 1 cycle:
- 45 minutes of saltwater spray at 49 ± 2 °C.
- 120 minutes of drying at 49 ± 2 °C.
- 195 minutes (soak period) at 49 ± 2 °C and 98% ± 2% relative humidity.

Test dates: From 20th June to 04th November 2013 (2200 hours).

Test Equipments:
- Salt Spray Chamber CCI.
- Pressure measuring made at Climetal installations (Leak test machine).

Note: During the salt spraying test, the inlet tubes of the samples are covered with a plastic tap in order to protect them from the spray.
SWAAT TEST

**Samples Evaluation: Visual inspection**
Visual inspection of the samples with photographs has been performed:
1. The first visual inspection has been performed before the beginning of the test.
2. The following visual inspection takes place after every 300 hours.

**Samples Evaluation: Pressure leak checking test**
Leak of samples is evaluated at the beginning of the test and during the test every 150 hours. In this evaluation, each sample has been tested by compressed air (35 bar) in CLIMETAL’s leak testing machine.

**TEST RESULTS:**

<table>
<thead>
<tr>
<th>IDENTIFICATION</th>
<th>AIR PRESSURE VALUE (BAR)</th>
<th>Salt spray test duration (hours) until pressure leak is detected</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONDENSER 1</td>
<td>35 BAR</td>
<td>No leaks after 2200 hours</td>
</tr>
<tr>
<td>CONDENSER 2</td>
<td></td>
<td>No leaks after 2200 hours</td>
</tr>
<tr>
<td>PAINTED CONDENSER 1</td>
<td></td>
<td>No leaks after 2200 hours</td>
</tr>
<tr>
<td>PAINTED CONDENSER 2</td>
<td></td>
<td>No leaks after 2200 hours</td>
</tr>
</tbody>
</table>
RESULTS. Unpainted condenser 1200 hours salt spray test
SWAAT TEST

RESULTS. Unpainted condenser 2200 hours salt spray test

Presence of corrosion. The upper and lower elements (plates and fin) are detached from the coil. The Copper/Aluminum joint shows presence of corrosion.

Nevertheless, no leaks after 2200 hours of exposure. End of the test.
SWAAT TEST

RESULTS. Painted condenser 1200 hours salt spray test
SWAAT TEST

RESULTS. Painted condenser 2200 hours salt spray test

The coating has fallen off in several areas. However, the general aspect of the fins, multiport tubes, manifolds and Cu/Al joints has been preserved almost intact.

After 2200 hours of exposure, leakage is not detected. End of test.
CHARACTERISATION OF CLIMETAL CU/AL BRAZED JOINTS AFTER SWAAT TESTING
SWAAT TEST

INTRODUCTION

The experience of Climetal in the MCHEx manufacturing has taught us the importance of the protection of the Cu/Al joints against the galvanic corrosion. As result of this experience and after a deep and thorough analysis of all of the connection protectors available in the market, we have introduced the latest improvement, the adhesive sleeve + Sikaflex joints protector.

The main objective of the inclusion of this new product in our condensers, is to avoid the corrosion in the brazed connections. This product have been tested by Climetal, and we have only got positive results from the test done. For your review, herewith you can find some basics about adhesive sleeve + Sikaflex features.

In addition to this, we would like highlight the 2200 h SWAAT test we made of the different protections against galvanic corrosion of the Cu/Al connections that are applied in the market by the different manufacturers:

• No sleeve.
• Non adhesive sleeve.
• Adhesive sleeve.
• Adhesive sleeve + Sikaflex.

As you can read on the last page of this report, the metallographic analysis of the cross sections of the tested samples shows that the best protection is provided by the adhesive sleeve together with Sikaflex, as no evidence of corrosion is to be seen in the cross section of that sample. In conclusion, Climetal applies to the Cu/Al connections of their condensers the best protection according to the SWAAT tests: adhesive sleeve and Sikaflex.

Take note from now on, all condensers manufactured by Climetal will include this new component, unless stated otherwise.

We want the name Climetal to be synonymous in your mind with quality. We are committed to your satisfaction.

If you have questions about this new component, our personnel will contact you shortly in order to describe the product in details as well as answer your questions, in case you have any.
PERFORMED TEST: CYCLIC ACIDIFIED SALT SPRAY TEST

Conditions in Salt Spray Chamber:
The conditions in salt spray chamber are according to ASTM G85 Annex 2 “Cyclic acidified salt spray test”.

Definition of 1 cycle:
- 45 minutes of saltwater spray at 49 ± 2 °C.
- 120 minutes of drying at 49 ± 2 °C.
- 195 minutes [soak period] at 49 ± 2 °C and 98% ± 2% relative humidity.

Test dates: From 20th June to 04th November 2013 (2200 hours).

Note: Two stops of chamber.

Total test duration: 2200 hours.

Test Equipments:
- Salt Spray Chamber CCI.
- Pressure measuring made in Climetal installations (Leak test machine).

Note: During the salt spraying test, the inlet tubes of the samples are covered with a plastic tap in order to protect the interior from the spray.

Samples Evaluation: Visual inspection
Visual inspection of the samples with photographs has been performed:
1. The first visual inspection has been performed prior to the beginning of the test.
2. The following visual inspection after every 300 hours or when any leak has been detected.
## SWAAT TEST

<table>
<thead>
<tr>
<th>TYPE SAMPLE</th>
<th>N°</th>
<th>PICTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without sleeve (using current filler material 2% Aluminum &amp; 98% Zn)</td>
<td>6</td>
<td><img src="image1.jpg" alt="Picture" /></td>
</tr>
<tr>
<td>Without sleeve (using filler material 22% Aluminum &amp; 88% Zn)</td>
<td>6</td>
<td><img src="image2.jpg" alt="Picture" /></td>
</tr>
<tr>
<td>With non-adhesive sleeve</td>
<td>8</td>
<td><img src="image3.jpg" alt="Picture" /></td>
</tr>
<tr>
<td>TYPE SAMPLE</td>
<td>Nº</td>
<td>PICTURE</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>----</td>
<td>---------</td>
</tr>
<tr>
<td>With adhesive sleeve</td>
<td>9</td>
<td><img src="image1.png" alt="Picture 1" /></td>
</tr>
<tr>
<td>With adhesive sleeve and SIKAFLEX</td>
<td>9</td>
<td><img src="image2.png" alt="Picture 2" /></td>
</tr>
<tr>
<td>Epoxy coated</td>
<td>9</td>
<td><img src="image3.png" alt="Picture 3" /></td>
</tr>
</tbody>
</table>
SWAAT TEST

Samples Evaluation: Pressure leak checking test
Leak of samples is evaluated at the beginning of the test and during the test every 150 hours. In this evaluation, each sample has been tested by compressed air (35 bar) in CLIMETAL’s leak testing machine.

TEST RESULTS:

<table>
<thead>
<tr>
<th>IDENTIFICATION</th>
<th>AIR PRESSURE VALUE (BAR)</th>
<th>Salt spray test duration (hours) until pressure leak is detected</th>
</tr>
</thead>
<tbody>
<tr>
<td>JOINT 2%</td>
<td></td>
<td>No leaks after 2200 hours</td>
</tr>
<tr>
<td>JOINT 22%</td>
<td></td>
<td>No leaks after 2200 hours</td>
</tr>
<tr>
<td>JOINT WITH NON ADHESIVE SLEEVE</td>
<td>35 BAR</td>
<td>No leaks after 2200 hours</td>
</tr>
<tr>
<td>JOINT WITH ADHESIVE SLEEVE</td>
<td></td>
<td>No leaks after 2200 hours</td>
</tr>
<tr>
<td>JOINT WITH ADH. SLEEVE AND SIKAFLEX</td>
<td></td>
<td>No leaks after 2200 hours</td>
</tr>
<tr>
<td>PAINTED JOINT</td>
<td></td>
<td>No leaks after 2200 hours</td>
</tr>
</tbody>
</table>

Next Step: Visual and Metallurgical inspection of joints in external Laboratory.
RESULTS. SAMPLES WITHOUT PROTECTION

Presence of corrosion is observed all over the sample.

Nevertheless no leaks after 2200 hours of exposure. End of test.

Metallographic analysis:

Cross-section. The samples show evidence of severe corrosion.
SWAAT TEST

RESULTS. EPOXY PAINTED SAMPLES

Presence of corrosion is observed all over the Cu/Al joint. No leaks after 2200 hours of exposure.

Metallographic analysis:

Cross-section. The sample show almost no evidence of corrosion.
SWAAT TEST

RESULTS. JOINTS WITH NON-ADHESIVE SLEEVE

Presence of corrosion is observed all over the sample. After removing the sleeve, there is almost no evidence of corrosion on the joint.

Metallographic analysis:

Cross-section. The sample show minor corrosion.
SWAAT TEST

RESULTS. JOINTS WITH ADHESIVE SLEEVE

Presence of corrosion is observed all over the sample.

After removing the sleeve, there is almost no evidence of corrosion on the joint. No leaks after 2200 hours of exposure.

Metallographic analysis:

Cross-section. The sample show some minor corrosion.
RESULTS. JOINTS WITH ADHESIVE SLEEVE + SIKAFLEX

Presence of corrosion is observed all over the sample.

After removing the sleeve, there is almost no evidence of corrosion on the joint.
No leaks after 2200 hours of exposure.

Metallographic analysis:

Cross-section. The sample show no corrosion at all. This is the best among the three cross-sections samples.
CLOGGING TESTS
## CLOGGING TESTS

<table>
<thead>
<tr>
<th>SAMPLE Nº</th>
<th>MATERIAL</th>
<th>THICKNESS</th>
<th>FIN TYPE</th>
<th>COMMENTS</th>
<th>PICTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Copper</td>
<td>2T 25 mm</td>
<td>P 1.6 mm</td>
<td></td>
<td><img src="image1.png" alt="Picture" /></td>
</tr>
<tr>
<td>2</td>
<td>Aluminum</td>
<td>16 mm</td>
<td>P 2.5 mm</td>
<td></td>
<td><img src="image2.png" alt="Picture" /></td>
</tr>
<tr>
<td>3</td>
<td>Aluminum</td>
<td>25 mm</td>
<td>P 2.5 mm</td>
<td></td>
<td><img src="image3.png" alt="Picture" /></td>
</tr>
<tr>
<td>4</td>
<td>Aluminum</td>
<td>5T 62.5 mm</td>
<td>P 2.4 mm</td>
<td></td>
<td><img src="image4.png" alt="Picture" /></td>
</tr>
</tbody>
</table>
# Clogging Tests

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Material</th>
<th>Thickness</th>
<th>Fin Type</th>
<th>Comments</th>
<th>Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Aluminum</td>
<td>2 x 25 mm</td>
<td>P 2.5 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Copper</td>
<td>5T 110 mm</td>
<td>P 2.1 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Aluminum</td>
<td>25 mm</td>
<td>P 4 s/ventana</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Copper</td>
<td>6T 130 mm</td>
<td>P 3.15 mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CLOGGING TESTS

Maineux, October 27, 2011

TEST REPORT CLI 110782
DETERMINATION OF DUST HOLDING CAPACITY OF SEPARATORS AND HEAT EXCHANGERS

1. Scope and Test Bench Setup
   a. Test Program

On eight heat exchanger units the pressure drop and the dust holding capacity had to be determined according to the test plan below. All tests were done at the same face velocity of 2.5 m/s. The airflows had to be adjusted due to the differing face areas of the devices.

The test bench complies with the requirements defined in DIN EN 779:2002 „Air filters for general ventilation applications“. The test parameters have been chosen as listed below:

Test Parameters:
- Test Dust: ASHRAE 52.76, batch 73681
- Temperature: 24°C ± 5°C
- Relative Humidity: 50% ± 10%
- Face Velocity: 2.5 m/s
- Loading Test Dust Concentration (Target): 300 mg/m²

Test Plan:

<table>
<thead>
<tr>
<th>Test</th>
<th>Filter weight</th>
<th>Pressure Drop</th>
<th>Dust Loading</th>
<th>Filter weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>2</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>3</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>4</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

The accuracy of the airflow control is 2% relative to the set point. For the pressure drop measurement three sensors with the ranges 0 - 100, 0 - 500 and 0 - 10000 Pa are used. The accuracy of the sensors is 1% of the range maximum.

The test dusts A4 and ASHRAE 52.76 were dispersed using an ASHRAE type Venturi generator (fiatec GmbH). The dusts were not neutralized.
CLOGGING TESTS

b. Test Procedure

In an initial pre-trial the sample number 5 was loaded with dust according to ISO 12 103-1 A4 for 1.5 hours. The loading did not show any increase or changes in pressure drop. Therefore the tests were performed using dust according to ASHRAE 52.76 instead as it was expected that with this aerosol the loading effects would become more clearly visible.

2. Results

The detailed results are shown in the attachments 1 through 8 in tables and graphs. The table below shows an overview over the detailed test conditions of each sample.

<table>
<thead>
<tr>
<th>Atom</th>
<th>Filler</th>
<th>Face velocity [m/s]</th>
<th>Airflow [m³/s]</th>
<th>Dust injected [g]</th>
<th>Concentration in dust [mg/m³]</th>
<th>Sedimentation in duct [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A01</td>
<td>1</td>
<td>2.5</td>
<td>1513</td>
<td>611</td>
<td>288</td>
<td>119.0</td>
</tr>
<tr>
<td>A02</td>
<td>2</td>
<td>2.5</td>
<td>874</td>
<td>255</td>
<td>138.0</td>
<td></td>
</tr>
<tr>
<td>A03</td>
<td>3</td>
<td>2.5</td>
<td>662</td>
<td>158</td>
<td>142.0</td>
<td></td>
</tr>
<tr>
<td>A04</td>
<td>4</td>
<td>2.5</td>
<td>748</td>
<td>220</td>
<td>137.0</td>
<td></td>
</tr>
<tr>
<td>A05</td>
<td>5</td>
<td>2.5</td>
<td>462</td>
<td>150</td>
<td>130.0</td>
<td></td>
</tr>
<tr>
<td>A06</td>
<td>6</td>
<td>2.5</td>
<td>659</td>
<td>220</td>
<td>120.0</td>
<td></td>
</tr>
<tr>
<td>A07</td>
<td>7</td>
<td>2.5</td>
<td>210</td>
<td>220</td>
<td>131.0</td>
<td></td>
</tr>
<tr>
<td>A08</td>
<td>8</td>
<td>2.5</td>
<td>1094</td>
<td>241</td>
<td>118.0</td>
<td></td>
</tr>
</tbody>
</table>

Comment: It was difficult to control and achieve the loading concentration of 300 mg/m³ as due to varying airflows the sedimentation effects differed very much and led to different concentrations in the tests. However, for the result we consider this concentration influence as completely uncritical. It can be seen from the results that under the applied test conditions no significant increases in pressure drops could be observed anyway.

It is not clear if this behaviour changes when the surfaces of the heat exchangers become sticky (e.g. when coated with an oil film or something similar).

Heinz Bittigehaus

Attachments 1 through 8
CLOGGING TESTS

Attachment 1 to Test Report CLU 110701
Summary of Test Results for Sample 1
fiatec-No.: CLU 110701_S1

1. Pressure Drop

<table>
<thead>
<tr>
<th>Air Flow</th>
<th>[m³/h]</th>
<th>1.0</th>
<th>2.0</th>
<th>3.0</th>
<th>3.5</th>
<th>4.0</th>
<th>4.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>[m³/h]</td>
<td>30</td>
<td>625</td>
<td>975</td>
<td>1375</td>
<td>1875</td>
<td>3000</td>
<td>6000</td>
</tr>
</tbody>
</table>

| Water Flow | [m³/h] | 9 | 19 | 39 | 57 | 83 | 116 |

- New Device

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CLOGGING TESTS

Attachment 2 to Test Report CLU 110701
Summary of Test Results for Sample
fiatec-No.: CLU 110701_S2

1. Pressure Drop

<table>
<thead>
<tr>
<th>Air Flow (l/min)</th>
<th>0</th>
<th>1.0</th>
<th>2.0</th>
<th>2.5</th>
<th>3.0</th>
<th>5.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Drop (Pa)</td>
<td>91</td>
<td>193</td>
<td>195</td>
<td>197</td>
<td>232</td>
<td>350</td>
</tr>
</tbody>
</table>

![Graph showing pressure drop vs. air flow]

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CLOGGING TESTS

![Clogging Test Image]

Attachment 2 to Test Report CLU 110701
Summary of Test Results for Sample 2
fiatec-No.: CLU 110701_52

2. Dust Loading  

<table>
<thead>
<tr>
<th>Air Flow</th>
<th>Test Date</th>
<th>Dust Injec. [g]</th>
<th>Dust Holding Capacity [g]</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 ml/s</td>
<td>2014-01-24</td>
<td>500</td>
<td>100</td>
</tr>
</tbody>
</table>

**Pressure Drop vs. Dust Challenge**

<table>
<thead>
<tr>
<th>Dust Injected [g]</th>
<th>Pressure Drop [Pa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>500</td>
<td>22</td>
</tr>
<tr>
<td>1000</td>
<td>24</td>
</tr>
<tr>
<td>1500</td>
<td>26</td>
</tr>
</tbody>
</table>

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CLOGGING TESTS

Attachment 3 to Test Report CLU 110701
Summary of Test Results for Sample 3
fiatec-No.: CLU 110701_53

1. Pressure Drop

<table>
<thead>
<tr>
<th>Air Flow (l/min)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Drop (Pa)</td>
<td>0</td>
<td>13</td>
<td>37</td>
<td>60</td>
<td>66</td>
<td>130</td>
</tr>
</tbody>
</table>

![Graph showing pressure drop vs. air flow]
CLOGGING TESTS

Attachment 3 to Test Report CLU 110701
Summary of Test Results for Sample 3
fiat-No.: CLU 110701_53

<table>
<thead>
<tr>
<th>Dust Loading</th>
<th>All Dust</th>
<th>Test Dust</th>
<th>Mean velocity</th>
<th>Mean pressure drop</th>
<th>Dust Holding Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

Pressure Drop vs. Dust Challenge

<table>
<thead>
<tr>
<th>Dust injected [g]</th>
<th>Pressure Drop [Pa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>55</td>
<td>60</td>
</tr>
</tbody>
</table>

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CLOGGING TESTS
CLOGGING TESTS
CLOGGING TESTS
CLOGGING TESTS
CLOGGING TESTS
CLOGGING TESTS

[Image of a chart showing pressure drop vs. dust challenge]
# Clogging Tests

## Attachment B to Test Report CLU 110701

Summary of Test Results for Sample 7

fiatec-No.: CLU 110701_SR

### 1. Pressure Drop

<table>
<thead>
<tr>
<th>Gas Flow</th>
<th>Test-1</th>
<th>Test-2</th>
<th>Test-3</th>
<th>Test-4</th>
<th>Test-5</th>
<th>Test-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>m³/h</td>
<td>0.00</td>
<td>1.00</td>
<td>2.00</td>
<td>3.00</td>
<td>4.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Pressure</td>
<td>4 psi</td>
<td>9 psi</td>
<td>13 psi</td>
<td>16 psi</td>
<td>20 psi</td>
<td></td>
</tr>
<tr>
<td>Test-1</td>
<td>4 psi</td>
<td>9 psi</td>
<td>13 psi</td>
<td>16 psi</td>
<td>20 psi</td>
<td></td>
</tr>
<tr>
<td>Test-2</td>
<td>4 psi</td>
<td>9 psi</td>
<td>13 psi</td>
<td>16 psi</td>
<td>20 psi</td>
<td></td>
</tr>
<tr>
<td>Test-3</td>
<td>4 psi</td>
<td>9 psi</td>
<td>13 psi</td>
<td>16 psi</td>
<td>20 psi</td>
<td></td>
</tr>
</tbody>
</table>

![Graph showing pressure drop vs. air flow](image-url)

- **New Device**

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CLOGGING TESTS

![Graph showing Pressure Drop vs. Dust Challenge](image_url)
CLOGGING TESTS

Attachment 7 to Test Report CLU 110701
Summary of Test Results for Sample
fiatec-No.: CLU 110701_S7

1. Pressure Drop

<table>
<thead>
<tr>
<th>Air Flow [m³/h]</th>
<th>0</th>
<th>1.5</th>
<th>2.0</th>
<th>2.5</th>
<th>3.0</th>
<th>3.5</th>
<th>4.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Drop</td>
<td>0</td>
<td>493</td>
<td>998</td>
<td>1995</td>
<td>2992</td>
<td>3990</td>
<td>4996</td>
</tr>
</tbody>
</table>

![Graph showing pressure drop vs. air flow](image-url)
CLOGGING TESTS
HOW TO CLEAN A MICROCHANNEL COIL
HOW TO CLEAN A MICROCHANNEL COIL

How to clean a microchannel coil

Many customers ask us what procedure they should follow to wash and clean microchannel condensers. Their main concern is that, as they see how light and thin these condensers are, they are afraid they can get damaged with high pressure water or by brushing them. Not at all! MICROCHANNEL CONDENSERS ARE EXTREMELY ROBUST. And as an image is worth more than one thousand words... a video is worth more than one million words...

This cleaning was done with a 120 bar Karcher machine.
HOW TO CLEAN A MICROCHANNEL COIL

As you can see in the video, one of the great advantages of microchannel technology is that, because being so thin, water goes very easily through the coil, cleaning every little corner between fins.

General recommendations for cleaning:
1. You can use high pressure air or water, up to 120 bars (hot or cold).
2. You can also use a soft brush to remove debris or persistent dirt.
3. You can use some NEUTRAL soap or detergent. VERY IMPORTANT: it has to be neutral. The reason is extreme pH chemicals can affect the natural protective aluminum oxide layer.

Despite these easy and simple recommendations, we at CLIMETAL are always ready to help. Send us your questions and doubts and we will be happy to give you our best advice.
WATER PRESCRIPTIONS FOR MCHEx APPLICATIONS
IDEAL QUALITIES OF COOLING WATER

Water is used in cooling systems as a heat transfer medium and frequently also as the final point to reject heat into the atmosphere by evaporating inside cooling towers. Depending on the quality of available fresh water supply, waterside problems develop in cooling water systems from:

1. Scaling.
2. Corrosion.
3. Dirt and dust accumulation.
4. Biological growth.

Any of these problems – or more usually a combination of them – result in costly unscheduled downtime, reduced capacity, increased water usage, high maintenance costs.

There is no single method of treating cooling water. Selection of water treatment program for a specific system depends on:

1. System design.
2. Water.
3. Contaminants.
4. Wastewater discharge restrictions.
5. Surrounding environment and air quality.

Critical Parameters

The critical parameters for cooling water are conductivity, total dissolved solids (TDS), hardness, pH, alkalinity and saturation index.

Conductivity and Total Dissolved Solids (TDS)

Conductivity is a measure of the ability of water to conduct electrical current and it indicates the amount of the dissolved solids (TDS) in water.

The problem with dissolved solids is that many of the chemical compounds and elements in the water will combine to form high insoluble mineral deposits on the heat transfer surfaces generally referred to as “scale”.

Hardness

The amount of dissolved calcium and magnesium in water determines its hardness that is broken down into two categories:

1. The carbonate or temporary hardness.
2. The non-carbonate or permanent hardness.

Hardness particularly the temporary hardness is the most common and is responsible for the deposition of calcium carbonate scale in pipes and equipment.

pH

Control of pH is critical for the majority of cooling water treatment programs. In general, when pH points to acidic environment, the chances for corrosion increase and when pH points to alkaline environment, the chances for scale formation increase.
WATER PRESCRIPTIONS
FOR MCHEx APPLICATIONS

Alkalinity
When the pH rises above 8.3, the alkalinity converts from the bicarbonate to the carbonate and the scale will start to form.

Saturation Index
The saturation index of a water (LSI) is a measure of the stability of the water with respect to scale formation. When LSI readings are positive they tend to be scale forming, and when they are negative they tend to be corrosive. Normally readings within 1.0 units from zero are considered stable.

SCALE INHIBITION
Scale is a hard deposit of predominantly inorganic material on heating transfer surfaces caused by the precipitation of mineral particles in water that can cause blockage of piping and also reduces heat transfer and increases the energy use. The principle factors responsible for scale formation are:

1. As alkalinity increases, calcium carbonate – scale constituent – decreases in solubility and deposits.
2. The crystallization of sparingly soluble salts as the result of elevated temperatures and/or low flow velocity. Some salts, such as calcium carbonate, become less soluble as temperature increases. Therefore, they often cause deposits at higher temperatures.
3. High TDS water will have greater potential for scale formation.

Control
Scale can be controlled or eliminated by application of one or more proven techniques:

1. Water softening equipment – Water softener, dealkalizer, ion exchange to remove scale-forming minerals from make-up water.
2. Adjusting pH to lower values – Scale forming potential is minimized in acidic environment i.e. lower pH.
3. Controlling cycles of concentration – Limit the concentration of scale forming minerals by controlling cycles of concentration. This is achieved by intermittent or continuous blow down process, where a part of water is purposely drained off to prevent minerals built up.
4. Chemical dosage – Apply scale inhibitors and conditioners in circulating water.
5. Physical water treatment methods – Filtration, magnetic and de-scaling devices.

CORROSION INHIBITION
Pure aluminum is corrosion-resistant due to its natural tendency to form a very thin, protective, hydrated aluminum oxide film on surfaces exposed to air.
When unoxidized aluminum is immersed in pure water, it will form a white hydroxide film, which remains more or less constant in thickness once equilibrium is reached. The equilibrium thickness of the layer depends on temperature. The film is stable in natural water with a pH in the neutral range from 4.5 to 8.5. However, water with a lower pH (more acidic) may attack some aluminum alloys, and water with higher pH (more basic) will attack all aluminum alloys.

The limits of range, however, vary somewhat:
1. With temperature.
2. The specific form of oxide film present.
3. Presence of substances that can form soluble complexes or insoluble salts with aluminium.

In general, there are four types of inhibitors: 1) anodic, 2) cathodic, 3) mixed and 4) adsorption, commonly adopted in cooling water treatment. In addition, passivation technique is used for galvanized components.

To protect against corrosion, most commercial grade ethylene and propylene glycols contain a blend of corrosion inhibitors (typically six to twelve depending on the supplier). These additives protect metal surfaces by applying a combination of physical and electrochemical barriers that reduce the effects of corrosion.

**BACTERIAL & MICROBIOLOGICAL CONTROL**

There are many species of microorganisms (algae, protozoa, and bacteria) that can thrive in cooling systems under certain circumstances; their growth is helped by favourable water temperature and pH, the oxygen picked up by the spray water, sunlight, and organics that provide food. Generally microbial organisms form colonies at points of low water velocity that leads to uncontrolled microbiological accumulations. The deposits are transferred throughout the piping system, which interfere with heat transfer surfaces and restrict flow through piping, strainers, spray nozzles, and control valves. The deposits are also concern for threatening infectious agents like the bacteria Legionella pneumophillus. Possible types of microorganisms that exist in cooling water.

**Algae**
- Provide a nutrient source for bacterial growth.
- Deposit on surface contributes to localized corrosion process.
- Loosened deposits can block and foul pipe work and other heat exchange surfaces.

**Fungi**
- Proliferate to high number and foul heat exchanger surfaces.
WATER PRESCRIPTIONS FOR MCHEx APPLICATIONS

Bacteria
- Some types of pathogenic bacteria such as Legionella may cause health hazards.
- Sulphate reducing bacteria can reduce sulphate to corrosive hydrogen sulphide.
- Cathodic depolarization by removal of hydrogen from the cathodic portion of corrosion cell.
- Acid producing bacteria produce organic acids, which cause localized corrosion of deposit laden distribution piping and also provide the potential for severe pitting corrosion of heat exchanger surface.

Treatment Methods
Chemical biocides are the most common products to control the growth of micro-organisms.

Three general classes of chemicals are used in microbial control 1) Oxidizing biocides, 2) Non-oxidizing biocides and 3) Bio-dispersants.

WATER TREATMENT SYSTEM EQUIPMENT, CONTROLS AND MONITORING

Chemical Feed Equipment
The purpose of most chemical treatment control programs (other than certain biocides) is to maintain a constant concentration in the recirculating water at all times.

There are two types of cooling water systems:
1. Closed-loop systems and
2. Open systems; both requiring different approach.

In a closed system, there is very little or no loss of water into a known volume as system water remains in the piping. Little, if any, makeup water is required to maintain a filled system as little or none is lost through evaporation or steaming as in an open system where the water content of the system is open, at some point, to the atmosphere. In addition, the closed loop systems are pressurized at all times so that excess air can be eliminated through simple automatic air venting devices.

The water treatment in closed system is thus not very critical. Once the initial volume is chemically treated, the quality of the circulating fluid needs to be monitored on a regular basis and additional chemicals added as required to maintain recommended residual concentrations of treatment chemicals. Pot feeders are used to add chemicals to systems that do not require frequent chemical treatment.

In an open loop system such as cooling tower, there is constant loss of water due to evaporation and a constant addition of makeup water into the system, which constantly changes the quality of the recirculating stream.
WATER PRESCRIPTIONS
FOR MCHE\textsubscript{e}X APPLICATIONS

The oxygenated water is primary cause of corrosion and the debris can accumulate and cause flow restrictions; as well as aggravate corrosion. In addition, after the water evaporates, dissolved minerals are left behind and accumulate rapidly. For these reasons, the water quality in open systems must be regularly monitored and treated to control the following conditions:

1. Lime scale and other water mineral deposits.
2. Corrosion of all types.
3. Microbiological growth, such as algae, bacteria, fungus and molds.
4. Suspended solids accumulations, such as airborne dirt and debris that is washed into the cooling tower water.

The water treatment options for open loop systems can be manual or automatic.
Application Notes

- Present information is intended exclusively as a kit of information designed to provide a preliminary support to our Present and Future Customers that start the introduction of micro-channel for water applications.

- The above information is a general indication, which must be verified case by case by the owner of the installation, because quality of water can depend from many aspects that are not indicated in the above list and quality of water can change during life cycle of the installation. For these reasons, the above information does not represent any sort of direct or indirect responsibility for CLIMETAL S.A.

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CLIMETAL, S.A.
@climetal
CLIMETAL, S.A.
Climetal Aluminium Heat Exchangers