

Test Procedure for Evaluating Corrosion Behavior of MAC Condensers

RATIONALE

The purpose of this standard is to provide a common methodology that all suppliers of aluminum-brazed MAC condensers and OEMs can utilize to assess the robustness of MAC condensers derived from real-life corrosive climate conditions.

Included in this standard are general corrosion test procedures utilized for assessing aluminum-brazed MAC condensers. This standard is valid for both horizontal and vertical tubes for aluminum-brazed MAC condensers and outside heat exchangers.

These test procedures do not necessarily replicate the failure morphology found in the field for a MAC condenser (for cyclic condenser corrosion test).

MAC condensers are exposed from moderate to severe corrosives from the field. These corrosives cover all the pH range, from exhaust gases (acid media) to car cleaning products (alkaline media), including deicing salts, other pollutions from the vehicle, etc.

Two tests are proposed to evaluate the corrosion resistance of a condenser:

- The first test represents the pollution in an acid media with copper, sodium chloride and acetic acid as pollutants and with a temperature and humidity cycle. This test is called cyclic condenser corrosion test (CCCT).
- The second test represents the pollution in a neutral media including graphite and sodium chloride with another temperature and humidity cycle. This test is called DeCa test.

Both tests come from the work of a reliability test development for condensers.

Multiple test configurations have been performed in order to reproduce as close as possible the field conditions in which the condenser is submitted. In these configurations, the most efficient test was the one that includes carbon as pollutant. Corrosion profiles were well reproduced, corrosion depths were consistent with the field on every type of condenser.

1. SCOPE

This test procedure describes the corrosion test of brazed aluminum condensers as well as the subsequent assessment of the tested components and the applicable assessment criteria.

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Documents

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2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D1193-2006 Standard Specification for Reagent Water

2.1.2 Other Publications

DIN EN ISO 9227 Corrosion Tests in Artificial Atmospheres - Salt Spray Tests

TRGS 220 (91/155/EEC) Technical Rules for Hazardous Substances

3. DEFINITIONS

CAS: Chemical abstract service.

CASS: Copper-accelerated acetic acid salt spray test.

DE-MINERALIZED OR DE-IONIZED WATER: Demineralized water can be achieved via ion exchange or reverse osmosis. Electrical conductivity level for de-mineralized water must be lower than 5 µs/cm in accordance with ASTM D1193-2006.

FIN DEBONDING: Complete detachment of fins from tubes due to the high corrosion level of tube/fin brazed joints.

PPE: Personal protective equipment.

RH%: Relative humidity, in percent (%).

T: Temperature, in degrees Celcius (°C).

4. OCCUPATIONAL SAFETY AND HEALTH, ENVIRONMENTAL PROTECTION

4.1 Occupational Safety and Health

4.1.1 Safety Precautions

A face shield and rubber gloves shall be worn when working with nitric acid. The work shall be carried out under a fume hood to extract any build-up of nitrous gases in a targeted manner. Further PPE such as gown, mask, and safety footwear may be required depending on the work being done in accordance with the MSDS for the appropriate substances and other workplace job standards.

Additionally, the applicable national statutory provisions must be followed.

4.1.2 Technical Safety Data

Refer to the corresponding safety specifications as per TRGS 220 (91/155/EEC) for the safety-relevant characteristics of nitric acid.

4.2 Environmental Protection

4.2.1 General

The national regulations applicable to the individual areas of environmental protection shall be observed at all times.

4.2.2 Waste Disposal

Refer to the safety specifications for material-specific information for the disposal of nitric acid.

4.2.3 Waste Water

The accumulated flushing water and concentrated substances shall be disposed of in compliance with the limit values listed in the approval notice via the central waste water treatment system.

5. CYCLIC CONDENSER CORROSION TEST

5.1 Description of the Corrosion Test

5.1.1 Equipment and Chemicals

- Plastic pan with dimensions 900 x 550 x 150 mm should be used, but sizes may vary slightly as long as the entire condenser is completely submerged in the solution as defined in [5.1.3.1](#). (Alternatively: Corrosion chamber for CASS test as described in DIN EN ISO 9227, referred to in [5.1.3.2](#).)
- Chemicals: CASS test solution (prepared in accordance with DIN EN ISO 9227).
 - pH value: 3.1 to 3.3.
 - Compliance with the purity required in accordance with DIN EN ISO 9227 for the raw materials required for preparation of the CASS solution, as well as monitoring of the density and pH value of the solution is mandatory.
- Programmable cyclic climate test chamber.

5.1.2 Number and Type of Components to be Tested

Please note that the corrosion test must always be carried out on unpainted condensers (even if they may be painted later for design reasons for series use) and that the condensers must pass this test. The test applies to the condenser assembly, connection plumbing is excluded from this test. However, if the condenser contains an integrated receiver/dryer, this can be evaluated as well.

The connections of the condensers must be plugged by appropriate means prior to the test to prevent entry of the CASS solution into the condenser during immersion or during flusing.

5.1.3 Sequence of the Corrosion Test

5.1.3.1 Initiation Phase: Immersion in the CASS Solution

The corrosion test is a combined corrosion test consisting of a single initiation phase using a CASS solution in accordance with DIN EN ISO 9227 and a subsequent cyclic climate change test repeated at weekly intervals. The total duration of the test is 6 weeks

Immersion into the CASS solution allows the entire component surface to be wetted in an even, repeatable manner. This method should therefore preferably be used for initiation.

- Immersion of the condenser in CASS solution in accordance with DIN EN ISO 9227 (CASS).
- Temperature of the solution: 22 °C ± 3 °C.

- Immersion container: Plastic pan.
- Immersion time: 10 minutes.
- Quantity of CASS solution: 15 L $\pm$ 2.5 L. It must be ensured that the level of the liquid is approximately 10 to 20 mm above the condenser to make sure the core area of the condenser surface is immersed completely. If the required height is not met, there are two recommendations:
 - Add containers or other objects into the pan to displace the solution to the specified height while maintaining the same volume.
 - Add additional solution to achieve the specified height and document the deviation.
- The condensers must be immersed individually.
- After the condenser has been immersed, it is lifted out of the solution, the condenser surface is held horizontally over the plastic pan and the CASS solution adhering to the core area is shaken off in five abrupt downward movements.

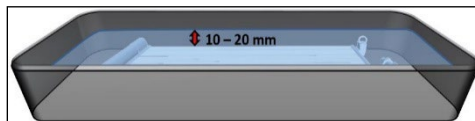


Figure 1 - Plastic pan for immersion load test

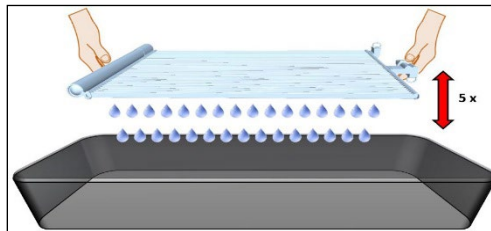


Figure 2 - Illustration of shaking off the solution after the immersion test

- The plastic pan must be filled with new CASS solution for each condenser to be tested.
- The condensers shall not be in direct contact with the bottom of the pan during immersion. The required clearance can be created by inserting thin plastic or glass tubes.

When handling the CASS solution and the components wetted with it, the operators shall take appropriate protective measures regarding occupational safety and health, environmental protection, and ergonomics (extraction equipment, handling of wetted components with rubber gloves, etc.).

Due to the copper concentration, the used saline solution must be collected and disposed of separately.

5.1.3.2 Alternative to the Immersion Test

Alternatively, a 24 hour CASS test in accordance with DIN EN ISO 9227 can be carried out as the initiation step. In this case, however, the components must be positioned accurately inside the chamber to ensure complete exposure of the components.

- The components shall be positioned at an angle of 70 degrees $\pm$ 5 degrees from the horizontal position.

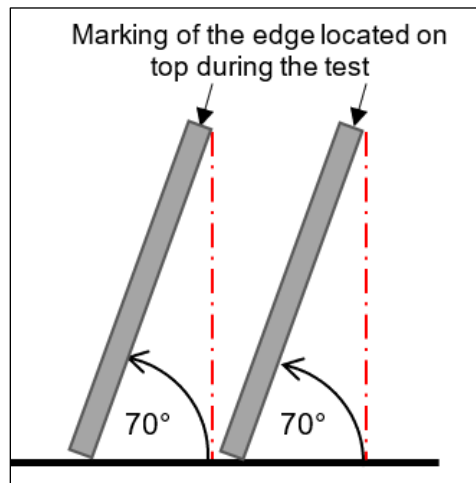


Figure 3 - Position of the components in the CASS test chamber

- Even exposure to the corrosion medium must be ensured; i.e., sufficient spacing between the components must be maintained so that they do not touch or cover each other and contamination with foreign corrosion products is prevented.
- Make sure that the component edge located on top in the CASS test is also located on top in the subsequent cyclic climate test. This should be labeled accordingly.
- Formation of stagnant moisture at the bottom edge of the components must be avoided.

5.1.3.3 Cyclic Climate Test 80-30

5.1.3.3.1 Test Cycle

A complete test cycle lasts 7 days ([Figure 4](#)) and consists of:

- One daily cycle A ([Figure 5](#)), constant climate phase, complete drying of the components.
- Six daily cycles B ([Figure 6](#)), cyclic climate phase, exposure of the components to temperature and humidity loading.

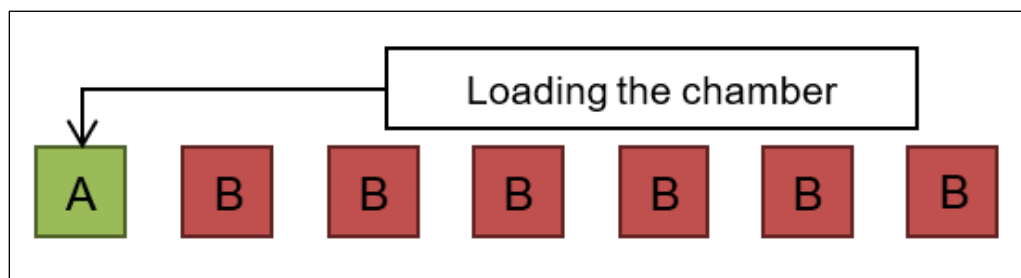


Figure 4 - Schematic representation of the test cycle

NOTE: The test specimens are loaded in the chamber (or removed from the chamber) only in the first cycle A of the test cycle in the assessment phase.

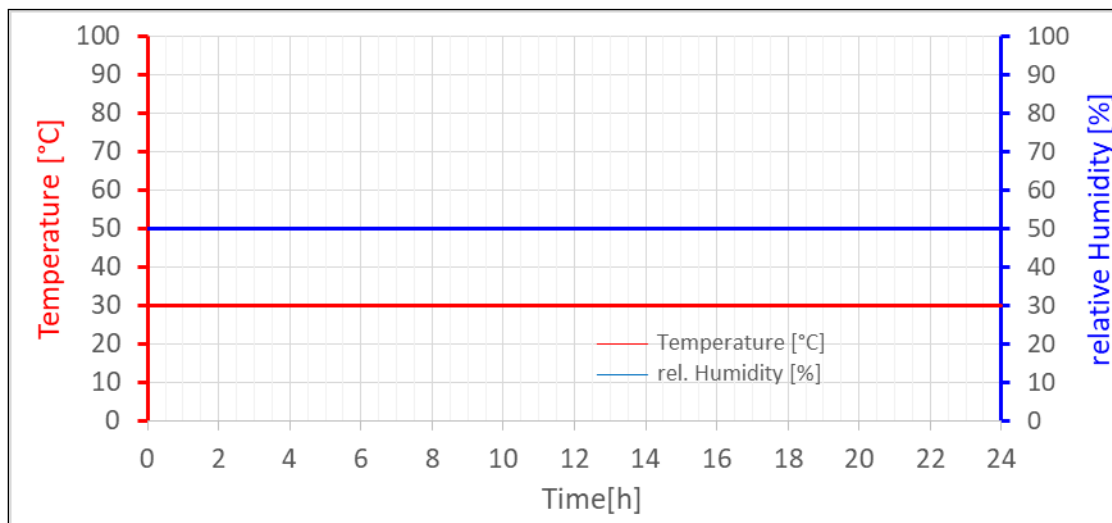


Figure 5 - Daily cycle A: Constant climate phase, complete drying of the components

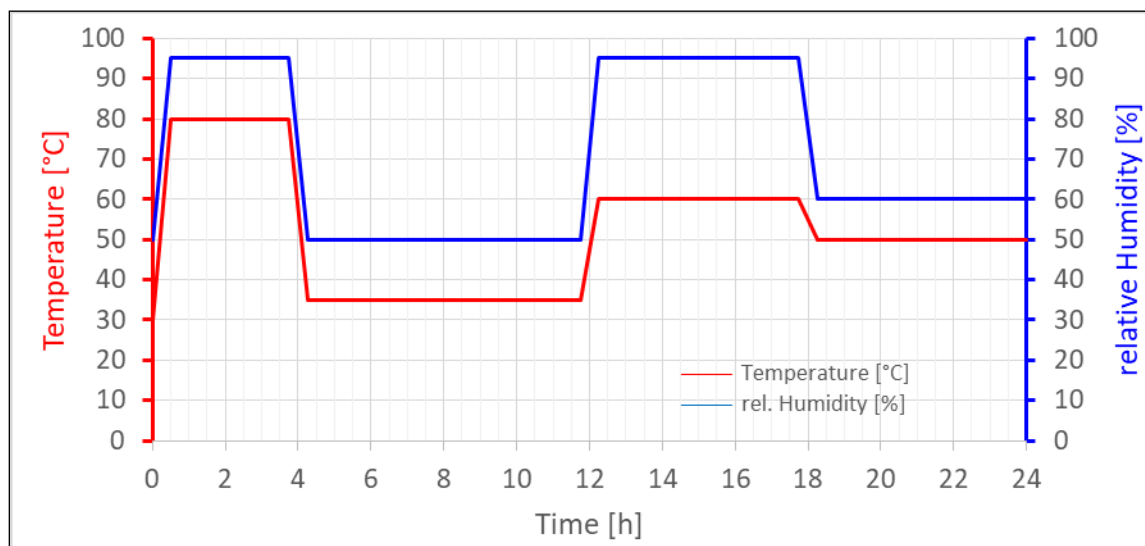


Figure 6 - Daily cycle B: Cyclic climate phase, components exposed to temperature and humidity loads

5.1.3.3.2 Test Duration

The test duration of the cyclic climate test is six complete test cycles (6 weeks). After 2 weeks of this test, the components are flushed once in an intermediate operation.

5.1.3.3.3 Intermediate Flushing

After two weekly cycles of the cyclic climate test 80-30, the condensers are immersed in a plastic pan (see [5.1.3.1](#)) into fully demineralized water (fully desalinated or deionized water with conductivity <5 µS/cm) to remove excess salt deposits on the surface:

- Immersion time: 5 minutes.
- Water temperature: 22 °C ± 3 °C.

- Quantity: 15 L $\pm$ 2.5 L. The level of the liquid must be approximately 10 to 20 mm above the condenser to ensure that the core area of the condenser surface is completely immersed. If the condenser is not completely immersed, either add containers or other objects to displace liquid to desired height while maintaining the same volume of liquid, or increase the volume of liquid and document the deviation.
- The condensers must be immersed individually.
- When condensers are immersed, they shall be moved lightly inside the immersion solution (in a lifting and lowering motion) to loosen the salt between the fins.
- After 5 minutes, the condensers are shaken five times (as described in [5.1.3.1](#)).
- The plastic pan shall be rinsed and then filled with new fully demineralized water for each condenser to be tested.

The condensers are then stored in the cyclic climate test chamber for another 4 weeks in accordance with the above-described cyclic climate program 80-30 test cycle sequence.

5.1.3.3.4 Test Position

The condensers shall be positioned in the cyclic climate test chamber in appropriate plastic fixtures to maintain a distance of at least 100 mm between the individual components and prevent contact with the CrNi steel sheet of the climate chamber walls.

The condensers shall be aligned parallel to the air flow in the climate chamber (see [Figure 7](#)).



Figure 7 - Example of test position of the components in the cyclic climate test chamber

5.1.3.3.5 Pressurization

As an option to determine leak initiation, the condenser can be pressurized to 2 bar. Pressure transducers or gages should be placed outside of the test chamber in order to protect them from the corrosive environment.

5.1.3.3.6 Test Interruptions

It is only permissible to interrupt the test sequence or to open the test chamber during cycle A. The test chamber may not be switched off during this period.

Longer interruptions of the cyclic climate test phases shall be avoided and noted in the test report. No interruptions during cycle B permitted.

5.2 Interpretation of Results, Documentation, and Acceptance Criteria

5.2.1 Leak Test

5.2.1.1 Test Conditions

All components shall be leak-tested at the end of the test; i.e., after six weekly cycles of the cyclic climate test 80-30.

The components are leak-tested under water for 5 minutes with air and/or nitrogen. The test pressure shall be defined in accordance with the component to be tested. For air conditioning condensers, an internal pressure of 20 bar absolute (2000 kPa) is recommended, but can be adapted to specific supplier or OEM specification.

The requirements/specifications for occupational health and safety measures for pressure tests shall be observed.

5.2.1.2 Assessment Criteria for Leak Test

No leakage in the area of the core or in the connection area of the tubes to the header of the condensers is permitted. If leaks are detected, the perforated areas shall be marked and documented by metallographic methods.

If no leakages are found during the test, a metallographic evaluation as described in [5.2.2](#) shall be carried out to document and evaluate the type and attack depth of potential corrosion areas in the core area of the condenser and at the connection area of the tubes to the collector tubes/header.

5.2.2 Metallographic Documentation of Corrosion Mechanism

5.2.2.1 Tube Segments

After the leakage test, three tube segments each with a minimum length of 100 mm shall be removed from the leak-free condensers in the following areas. Removal of the tubes may “clog up” the channels inside the tubes. The tube ends must therefore be ground open to allow the nitric acid to run off completely after cleaning.

The tubes in the corner positions 1, 2, 4, and 5 shall be removed at a minimum distance of 30 mm from the header and starting from the third tube from the outside (see description in [Figure 8](#), positions 4 and 5).

Position 3 is located at the center of the core area of the condenser.

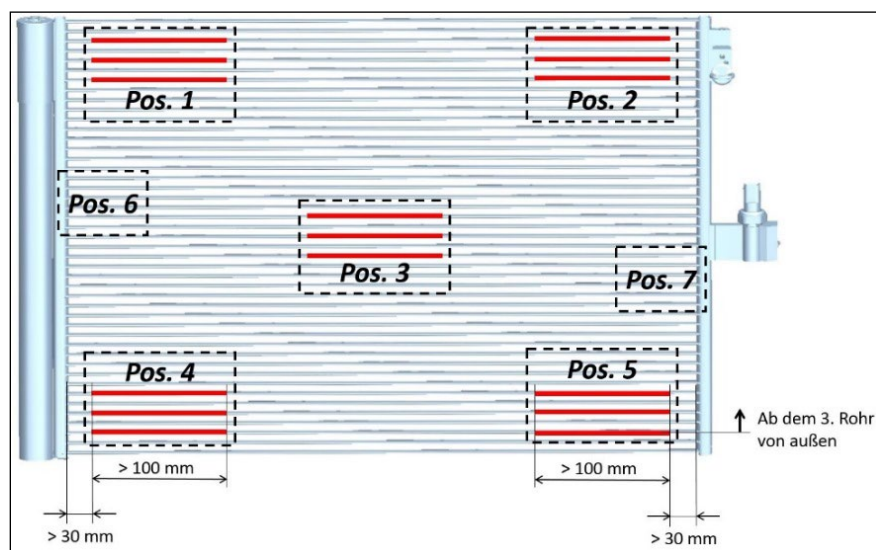


Figure 8 - Position of sampling points for the metallography assessment