Eurovent Industry Recommendation / Code of Good Practice

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EUROPEAN INDUSTRY ASSOCIATION

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# Corrosion protection of Air Handling Units

First Edition

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Eurovent, 80 Bd A. Reyers Ln, 1030 Brussels, Belgium
secretariat@eurovent.eu

# Document history

This Eurovent Industry Recommendation / Code of Good Practice supersedes all of its previous editions, which automatically become obsolete with the publication of this document.

## Modifications

This Eurovent publication was modified as against previous editions in the following manner:

| Modifications as against | Key changes |
|---|---|
| 1st edition | Current document |

# Preface

## In a nutshell

**This Recommendation sets out the principles of good practice for corrosion protection of air handling units. It explains how to correctly match the corrosion resistance of materials and components of air handling units to the corrosivity of the operating environment. The first two chapters establish the fundamentals of corrosion protection, corrosivity categories, and testing methods for corrosivity resistance of various materials. The third chapter gives recommendations on properties of materials and components depending on the environmental corrosivity category classified according to EN ISO 9223. The last chapter provides guidance for the design of air handling units for specific applications, with detailed guidelines for swimming pool units. The Recommendation provides a tool to planners, contractors, and investors to verify that an air handling unit is properly adapted to their needs in terms of corrosion protection.**

## Authors

This document was published by the Eurovent Association and was prepared in a joint effort by participants of the Product Group 'Air Handling Units' (PG-AHU), which represents a vast majority of all manufacturers of these products active on the EMEA market.

Particularly important contributions have been provided by Martin Törpe (editorial team leader), Kees van Haperen, Harald Svedung, Peter Müller, Thomas Richter, David Black and Martin Carlson.

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## Important remarks

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## Contents

## Foreword

Even the best air handling unit needs to be adapted to the environmental atmosphere in which the unit is running. The installation place, the quality of the outdoor air, and the tendency of corrosion by the extract air can all affect the lifetime of the air handling unit. In this Recommendation, members of the Eurovent Product Group 'Air Handling Units' provide guidelines on how to correctly match the materials and components of the unit to the corrosivity of the operating environment, both interior and exterior. In case of inadequate corrosion protection, proper functioning of the unit over its assumed service lifetime (typically 15-20 years) cannot be guaranteed. The guidelines were developed based on the expertise and experience of Eurovent members. Yet, it must be noted that unambiguous test results on the durability of complex products like air handling units are not available. Thus, the information presented in the Recommendation must be considered as indicative and, under no circumstances, technically binding. Nevertheless, the guidelines are useful for planners, contractors, and investors to verify whether a product meets the corrosion protection requirements for the actual operating environment and application.

# 1. Introduction to corrosion protection and corrosivity categories

Corrosion resistance refers to the ability of a material to prevent a reaction with adverse elements that can deteriorate it. Different materials have differing levels of intrinsic corrosion resistance. That said, there are methods or treatments that can be applied to materials to improve their corrosion resistance such as painting or hot dip galvanising, or a combination of these methods with coating.

## 1.1 Factors influencing the risk of atmospheric corrosion

The dominant type of corrosion that air handling units are exposed to is atmospheric. The risk of atmospheric corrosion and the rate at which this corrosion occurs are primarily dependent on the following parameters:

- The relative humidity of (inside or outside) air where the steel structure is located
- The risk of condensation (depending on the relative humidity, the temperature of the steel, and the velocity at which the air is moving)
- The concentration of corrosive pollutants (gases, solids, or liquids), such as sulphur dioxide, acids, alkalis, or salts

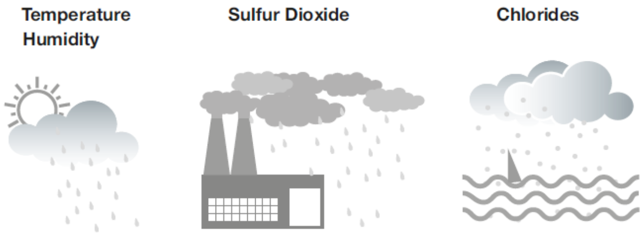

Figure 1: Factors influencing the risk of atmospheric corrosion

## 1.2 Atmospheric corrosivity categories and the durability range

A general classification of atmospheric corrosivity is defined in ISO 9223 and referred to in ISO 12944 (see Table 2 in paragraph 2.2). Both standards describe typical environments corresponding to each corrosivity category.

ISO 12944 introduces a classification of durability with regards to corrosion resistance, with the following three ranges:

| | |
|---|---|
| Low (L) | 2 to 5 years |
| Medium (M) | 5 to 15 years |
| High (H) | More than 15 years |

The durability range must not be understood as the 'guarantee range'. Durability is a technical consideration that can help the owner to set up a maintenance programme. A guarantee period is a major issue and is subject to dedicated clauses in the contract. The guaranteed time is usually shorter than the durability range. There are no rules that link these two periods of time.

### 1.2.1 Time of wetness

Besides the pollution level, the prevailing relative humidity of the environmental air has a huge impact on atmospheric corrosion. Atmospheric corrosion is a process that takes place in a film of moisture on the metal surface. The moisture film may be so thin that it is invisible to the naked eye.

The corrosion is increased by the following factors:

- An increase in relative humidity
- The occurrence of condensation (surface temperature at or below dew point)
- An increase in the amount of pollution in the atmosphere

Experience has shown that significant corrosion is likely to take place if the relative humidity is above 80% and the temperature above 0°C. However, if pollutants or hygroscopic salts are present, corrosion occurs even at much lower humidity levels. The atmospheric humidity and air temperature in a particular region of the world will depend on its climate.

The combination of temperature and humidity where significant corrosion is likely to take place can be expressed in a figure defined as 'time of wetness'. The time of wetness is defined in the standard as the period during which a metal surface is covered by adsorptive and/or liquid films of electrolyte capable of causing atmospheric corrosion.

The following table with different types of climates and associated calculated time of wetness (RH > 80%, $t_{DB}$ > 0°C), is derived from ISO 12944-2.

| Type of climate | Calculated time of wetness at RH > 80% and $t_{DB}$ > 0°C [h/year] |
|---|---|
| Extremely cold | 0 to 100 |
| Cold | 150 to 2.500 |
| Cold temperature<br>Warm temperature | 2.500 to 4.200 |
| Warm dry<br>Mild warm dry<br>Extremely warm dry | 10 to 1.600 |
| Warm damp<br>Warm damp, constant | 4.200 to 6.000 |

**Table 1: ISO 12944-2: Calculated time of wetness for various types of climates**

## 1.3 Corrosion protection measures

There are several measures for corrosion protection. Primarily they include preventing corrosion and protecting the material. The set of available measures is depicted in Figure 2.

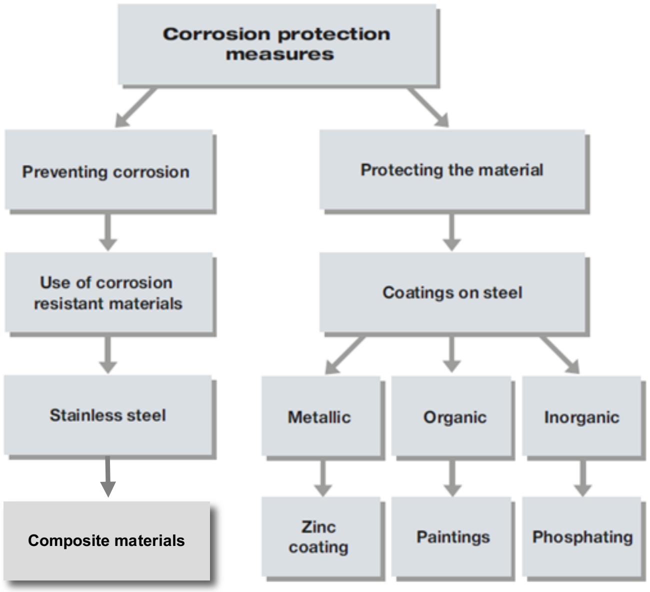

Figure 2: Corrosion protection measures

# 2. Classification and testing method for corrosivity resistance

## 2.1 Different forms of corrosion

Depending on their properties, the different materials used in ventilation units can potentially undergo different degradation processes. Polymeric materials can degrade by oxidation at elevated temperatures, hydrolysis by reaction with water, and by photolysis during exposure to UV radiation. By corrosion we normally mean degradation of metals by some sort of oxidative process often involving water, salt, and other impurities as well as by electro-chemical processes between materials, one being less noble than the other, or driven by, e.g., oxygen concentration gradients inside crevices or underneath delaminating paint layers.

### 2.1.1 Uniform surface corrosion

During atmospheric corrosion on a flat surface, metal may be uniformly dissolved from the surface. The metal is oxidised while oxygen in the air together with water on the surface is being reduced. This produces metal hydroxide that, e.g., in the case of iron is soluble and runs of the surface as rust.

### 2.1.2 Pitting corrosion

Stainless steel and aluminium are examples of passive alloys or metals protected by an insoluble metal oxide layer. Impurities like chloride ions can cause local damage to the protective oxide layer and cause local anodic dissolution forming pits on the metal surface.

Surface- and shallow pitting corrosion on metal surfaces has a well-defined rate of metal loss depending on temperature, humidity, time of wetness and the concentration of corrosive contaminants in the local environment.

### 2.1.3 Crevice corrosion

Inside cracks or crevices between two surfaces corrosion can occur in the presence of water as the limited diffusion of oxygen from the air leads to different oxygen concentrations inside the crevice.

Oxygen reduction occurs in the outer part of the crevice where the oxygen concentration is high and anodic dissolution of metal occurs in the deeper parts of the crevice leading to localised corrosion like, e.g., paint delamination or decay of washers, gaskets, overlap regions, etc. Crevice corrosion is highly dependent on crevice width, type of materials, time of wetness as well as to the corrosive environment.

### 2.1.4 Stress corrosion

In some materials like austenitic stainless steel, localised corrosion in the tips of cracks can occur under significant mechanical stress in highly corrosive environments. This is a relatively fast process that can lead to mechanical failure within a few years.

High temperatures during welding can lead to sensitisation of stainless steel as chromium is depleted from the grain boundaries in the material. This may lead to local intergranular corrosion.

Hydrogen assisted cracking can occur in high strength steels. Hydrogen formed during corrosion processes may decrease toughness or ductility of such materials.

### 2.1.5 Galvanic corrosion

Galvanic corrosion occurs locally where two different metals, one being less noble than the other, that are in electrical contact with each other, share a common corrosive electrolyte.

On a galvanised carbon steel washer used to fasten a stainless-steel detail the zinc coating will quickly be dissolved, and the bare carbon steel will continue to corrode away.

Ideally, the corrosion products of zinc will form a protective layer and passivate the steel substrate of galvanized carbon steel where it is exposed such as in scratches and at cut edges. That is if the exposed steel surface is small compared to the amount of zinc available and the zinc corrosion products are not dissolved given the corrosive environment.

## 2.2 Classification of corrosive environments

As mentioned in the above, factors influencing atmospheric corrosion are temperature, humidity, sulphur dioxide and chlorides. An increase in temperature generally increases chemical reaction rates of the corrosion processes. On the other hand, increased temperatures leading to shorter time of wetness may decrease the rate of corrosion. Corrosion takes place where there is a moisture film on the metal surface, which may be formed if the relative humidity is above 80% on clean surfaces. In the presence of contaminants such as chlorides, a moisture film can be formed at even lower levels of relative humidity. Chlorides contribute to the formation of soluble corrosion products that do not form any protective layer. Chlorides also directly attack the protective oxide layer on stainless steel and aluminium surfaces. The corrosion rates of zinc, steel, aluminium, and stainless steel are dramatically increased by the presence of sulphur dioxide in the atmosphere as the sulfuric acidification of the electrolyte contributes to the solubility of the corrosion products.

By measuring the metal loss over time on small sample coupons of steel, zinc, aluminium, and copper, the corrosivity class of an environment can be monitored according to ISO 9223. If atmospheric parameters such as temperature, humidity, concentrations of chlorides and sulphur dioxide are known, dose-response functions available in the standard can also be used in order to estimate the corrosivity class of the environment. Methods to estimate long-term corrosion for different materials can be found in ISO 9224. Typical environments categorised by metal loss measurements are described in the ISO 9223 standard:

| Corrosivity category C | Corrosion level | Typical environments Indoor | Typical environments Outdoor |
|---|---|---|---|
| C1 | Very low | Heated spaces with low relative humidity and insignificant pollution, e.g. offices, schools, museums. | Dry or cold zone, atmospheric environment with very low pollution and time of wetness, e.g. certain deserts, Central Arctic / Antarctica. |
| C2 | Low | Unheated spaces with varying temperature and humidity. Low frequency of condensation and low pollution, e.g. storage, sports halls. | Temperate zone, atmospheric environment with low pollution ($SO_2 < 5$ µg/m$^3$), e.g. rural areas, small towns. Dry or cold zone, atmospheric environment with short time of wetness, e.g. deserts, subarctic area. |
| C3 | Medium | Spaces with moderate frequency of condensation and moderate pollution from production processes, e.g. food processing plants, laundries, breweries, dairies. | Temperate zone, atmospheric environment with medium pollution ($SO_2$: 5 to 30 µg/m$^3$) or some effect of chlorides, e.g. urban areas, coastal areas with low deposition of chlorides. Subtropical and tropical zone, atmosphere with low pollution. |
| C4 | High | Spaces with high frequency of condensation and high pollution from production processes, e.g. industrial processing plants, swimming pools. | Temperate zone, atmospheric environment with high pollution ($SO_2$: 30 to 90 µg/m$^3$) or substantial effect of chlorides, e.g. polluted urban areas, industrial areas, coastal areas, without spray of salt water or, exposure to strong effect of de-icing salts. Subtropical and tropical zone, atmosphere with medium pollution. |
| C5 | Very high | Spaces with very high frequency of condensation and/or with high pollution from production processes, e.g. mines, caverns for industrial purposes, unventilated sheds in subtropical and tropical zones. | Temperate and subtropical zone, atmospheric environment with very high pollution ($SO_2$: 90 to 250 µg/m$^3$) and/or significant effect of chlorides, e.g. industrial areas, coastal areas, sheltered positions on coastline. |
| CX | Extreme | Spaces with almost permanent condensation or extensive periods of exposure to extreme humidity effects and/or with high pollution from production processes, e.g. unventilated sheds in humid tropical zones | Subtropical and tropical zone (very high time of wetness), atmospheric environment with very high $SO_2$ pollution (higher than 250 µg/m$^3$) including accompanying and production factors and/or strong effect of chlorides, e.g. extreme industrial areas, coastal and |

| | | | |
|---|---|---|---|
| | | with penetration of outdoor pollution including airborne chlorides and corrosion-stimulating particulate matter. | offshore areas, occasional contact with salt spray. |

**Table 2: Classification of atmospheric corrosivity categories**

For stainless steels, however, this corrosivity classification is not strictly applicable as corrosion processes involving stainless steel depends to a larger extent on exposure to chlorides and sulphur dioxide and may be mitigated to some extent by exposure to washing by rain. A scoring system for evaluating the suitability of stainless-steel grades that takes these terms into account can be found in EN 1993-1-4. Still there may be a correlation between stainless steel corrosion and the more severe ISO 9223 corrosivity classes.

## 2.3 Test methods

For a product or a material, a corrosion protection class can be determined that is related to the technical life span in a corrosive environment with the corresponding corrosivity class. Time to formation of red rust on galvanised carbon steel is shorter in an environment where the zinc layer dissolves quickly. A thicker zinc layer thus gives a higher corrosion protection class.

For consistent corrosion processes, the level of corrosion protection can be measured in shorter time using accelerated tests involving, e.g., high chloride concentrations, high humidity and elevated temperatures. Care must be taken, however, not to induce corrosion processes that are not relevant for the application.

Neutral salt spray test, EN ISO 9227 involves continuous wet conditions that may prevent the formation of protective corrosion products and may therefore give misleading results compared to natural exposure testing.

Cyclic corrosion test, EN ISO 16701 includes dry periods to mimic natural conditions allowing for the formation of protective corrosion products and has been shown to give a better correlation to natural exposure.

Cyclic corrosion test with exposure to UV radiation, ISO 20340 mimics natural photolysis or photo assisted hydrolysis of organic materials like plastic, paint, adhesives, etc. This can be used to rate combinations of materials and designs in terms of technical life span and resistance to degradation.

Rather than to accelerate degradation it is generally more informative to look closely for early warnings of corrosion after a limited natural exposure time. This can be done using electrochemical, analytical and microscopy methods.

Inspections and analysis of degradation processes involving ventilation components in the field is an important source of information.

# 3. Recommended properties of materials for construction of air handling units

This chapter presents recommendations on the appropriate quality of materials or applied corrosion protection measures depending on the corrosivity category of the environment for construction of air handling units for general ventilation applications.

Since air handling units are complex products comprising numerous parts, the part (or component) featuring the lowest (worst) category must be considered in the evaluation of the corrosivity resistance category of the unit as a whole.

**The presented rating of corrosivity category resistance correspond to durability of 20 years.**

## 3.1 Air handling unit casing and internal assembling elements

This section applies to all parts which comprise the casing of the air handling unit. These include fixed panels, hatches, inspection doors, and the construction frame (if applicable). Minor internal parts like partition plates or fastening elements for components (exchangers, filter frames, fan, silencer splitters, etc.) are also covered.

Table 3 gives a general and indicative overview of materials that can be typically used in environments of various corrosivity. The list is not exhaustive. It does not exclude the use of other materials that can be demonstrated by the manufacturer to be compliant with the relevant corrosivity category.

In order to verify suitability for environmental conditions, the manufacturer should always declare the detailed specifications of the applied materials and be able to provide evidence of their corrosion resistance.

Examples of detailed specification for the material listed in Table 3 are presented in Annex I. These examples are not exhaustive, and the annex will be systematically supplemented with new compliant material appearing on the market in subsequent editions of the recommendation.

| Corrosivity category (interior or exterior) | General material type<br>For examples of detailed specification for each position see Annex 1 |
|---|---|
| Up to C2 | Galvanised steel sheet Z275 (Continuously hot-dip zinc coated low carbon steel, Sendzimir process) according to EN 10346 |
| Up to C3 | Coated steel sheet in RC3 category according to EN 10169 (coating ≤ 25 µm) |
| | Aluminium zinc-coated steel sheet AZ150 according to EN 10346 |
| Up to C4 | Aluminium zinc-coated steel sheet AZ185 according EN 10346 |
| | Aluminium alloys according to EN 573 |
| | Stainless steel sheet 304 according to AISI |
| | Coated steel sheet in RC4 category according to EN 10169 (coating > 25 µm) |
| | Powder coated steel sheet, paint system for C4 according to EN ISO 12944 |
| Up to C5 | Zinc-Magnesium-coated steel sheet ZM310 according to EN 10346 |
| | Powder coated steel sheet, paint system for C5 according to EN ISO 12944 |
| Up to CX | Composite materials |
| | Stainless steel sheet 316L according to AISI |

**Table 3: Rating of materials for air handling unit casing construction**

### Additional remarks

- The lifetime of the suitable materials in the table for C2, C3 and C4 will dramatically decrease if the time of wetness is considerably higher than those corresponding to the defined climate zones (see paragraph 1.2.1).
- With sheet thickness > 1.5 mm adequate protection of cut-edges must be considered unless stainless or powder coated.
- Where water often comes into contact with the cut edge of metallised or coated steel sheet material, concealing the cut edge can provide good protection against edge corrosion and especially against paint delamination.

## 3.2 Air dampers and weather louvers

The same guidelines as in paragraph 3.1 apply for airflow control or shut-off devices and elements protecting air openings against weather conditions. If a damper or louver is made of various materials, the one with the lowest corrosivity resistance must be considered in the assessment.

## 3.3 Plate heat exchangers

This section applies to the crossflow and counterflow plate heat exchangers of which the main components are the plates and the housing. The by-pass damper (if applicable) should meet recommendations as in paragraph 3.1.

| Corrosivity category (interior) | Materials for plate exchanger construction | |
|---|---|---|
| | Plates | Housing |
| Up to C3 | Aluminium plates<br>Polymer membrane (enthalpy exchanger) | Aluzinc, galvanised steel or aluminium |
| Up to C4 | Epoxy coated aluminium plates | Powder coated galvanised steel or powder coated aluminium |
| Up to C5 | Stainless steel 1.4571, 1.4404 (316L or 316Ti) | Stainless steel 1.4571, 1.4404 (316L or 316Ti) |
| Up to CX | Polypropylene | Polypropylene |

**Table 4: Rating of plate heat exchangers**

## 3.4 Rotary heat exchangers

The main elements of rotary heat exchangers are the rotor, the housing, and the drive system. Table 5 gives recommended minimum requirements for each type of exchanger (condensation, enthalpy and sorption).

| Corrosivity category (interior) | Materials for Rotary Exchanger construction | | | | |
|---|---|---|---|---|---|
| | Rotor (material storage mass) | | | | |
| | Condensation | Enthalpy | Sorption | Rotor housing | Drive system (motor) |
| Up to C3 | Aluminium | Aluminium treated | Aluminium coated with molecular sieve / silicagel | Galvanised steel / aluzink | Standard |
| Up to C4 | Aluminium epoxy coated | not available | Aluminium coated with molecular sieve / silicagel | Galvanised steel / aluzink coated (min. 25 µm) | Standard, coated min. 120 µm |

| | | | | | |
|---|---|---|---|---|---|
| Up to C5 | Aluminium with 2,5% magnesium proportion | not available | Aluminium coated with molecular sieve | Galvanised steel / aluzink coated (min. 80 µm) | Grey cast iron, coated min. 150 µm |
| Up to CX | Aluminium with 2,5% magnesium proportion | not available | Aluminium coated with molecular sieve | Galvanised steel / aluzink coated (min. 80 µm) | Grey cast iron, coated min. 150 µm |

**Table 5: Rating of rotary heat exchangers**

## 3.5 Heating and cooling coils

This section provides guidance on the materials to be used for elements of heating and cooling coils.

| Corrosivity category (interior) | Materials for coil construction | | | Notes |
|---|---|---|---|---|
| | Fins | Tubes / headers | Housing and drip tray (if applicable) | |
| Up to C3 | Aluminium | Copper / Copper or steel | Galvanised steel | 1 |
| | Pre-coated Aluminium | Copper / Copper or steel | Galvanised steel | 1, 2 |
| Up to C4 | Aluminium | Copper / Cooper | Aluminium or stainless steel | 3 |
| | Pre-coated Aluminium | Copper / Cooper | Aluminium or stainless steel | 2, 3 |
| | Stainless steel 304 | Stainless steel 304 | Stainless steel 304 | 4 |
| Up to C5 | Copper | Copper | Stainless steel 304 or 316 | 5 |
| | Stainless steel 316 | Stainless steel 316 | Stainless steel 316 | 6 |
| | Complete coil coated by the cationic epoxy polymer using an electro-coating process | | | |
| Up to CX | Stainless steel 316L | Stainless steel 316L | Stainless steel 316L | |
| | Completely coated coil after coil-assembly. Treatment with a suitable coating. | | | 7 |

**Table 6: Rating of coils**

**Clarification notes:**

1. If steel headers are used, they should be properly coated with a painting system suitable for the relevant corrosivity category.
2. Pre-coated aluminium fins can be used to inexpensively increase resistance to mild air pollution.
3. Aluminium fins are suitable for heating coils. Pre-coated aluminium fins should be used for cooling coils.
4. Entire coil in stainless steel. Stainless steel should not be used in chlorinated environments.
5. Assuming environment where copper is not degraded, mainly used in marine applications.
6. Entire coils in acid-proof design. 316 should generally be avoided in chlorinated environments.
7. A coating treatment after the assembly of the coil requires a larger fin spacing to guarantee full penetration of the coating between the fins. If the coating is correctly applied standard coil material with stainless steel frame could be used.

# 4. Design guidelines for specific applications

The previous chapter provides general recommendations on the materials to be used for components and parts of air handling units depending on the environmental corrosivity category.

It is not always easy to determine this category, especially considering that, as explained previously, corrosion resistance is a function of:

- The relative humidity of (inside or outside) air where the steel structure is located
- The risk of condensation (depending on the relative humidity, the temperature of the steel and the speed at which the air is moving)
- The concentration of corrosive pollutants (gases, solids, or liquids), such as sulphur dioxide, acids, alkalis, or salts

Furthermore, for some applications, in addition to the atmospheric corrosivity, other factors affecting corrosion resistance (e.g. use of corrosive cleaning agents) must be considered.

Therefore, this chapter gives recommendations on the design for specific applications of air handling units. These guidelines are based on the expertise and experience of Eurovent members.

Particularly comprehensive recommendations are presented for indoor swimming pools.

## 4.1 Units operating in sea atmosphere

The corrosion effect by sea atmosphere comes from fine salt particles in the air and higher humidity. The corrosion risk from sea atmosphere depends on the distance between the location of the air handling unit and the sea. Empirically, it is known that the effect of marine atmospheres extends principally some few hundred meters from the shoreline and decays rapidly further inland. As coastal corrosion rate depends on the concentration of chloride in the atmosphere, the influence of wind and surf zone on the production of saline droplets has a great impact. The complexity of phenomena associated with marine atmospheric corrosion makes it difficult to devise a model that covers all scenarios.

In case of a longer distance (e.g. more than 10 km) from the sea, the corrosion effect by marine atmosphere is negligible. Shorter distances need corrosion protection measures to protect metallic materials in air handling units. The easiest way to protect air handling unit casing components is to have a coating on them, which can fulfil the requirements for corrosion class C5. Stainless steel needs to be at least quality 316L (1.4571). Normally special corrosion protection measures are necessary only on the supply air side and in case of weatherproof units for the whole casing system outside. Air handling units in offshore applications need to be fully protected.

## 4.2 Industrial and agricultural applications

In the food industry, the main consideration is the use of materials which are easily cleanable and highly resistant to disinfectants. Stainless steel or powder coated galvanised steel fulfil those requirements. Especially in the extract air from smoked meat end products, corrosion protection based on stainless steel or non-metallic components is recommended.

## 4.3 Laboratories

Ventilation of laboratories is mandatory. The extract air from such applications can be expected to be polluted and special protection measures should be applied. In this case, stainless steel 304 is not the best solution if chlorides can occur in the air. The use of non-metallic components or a good coating on metallic materials are the options for corrosion protection in this application.

## 4.4 Indoor swimming pools

Air handling units for indoor swimming pools are, like any other unit with heat recovery, exposed to four types of air:

- **Extract air (ETA):** Air flow leaving the swimming pool and entering the air treatment system (inlet extract unit)
- **Exhaust air (EHA):** Air flow leaving the extract air treatment system and discharged to the atmosphere (outlet extract unit)
- **Outdoor air (ODA):** Air flow entering the system from outdoors before any thermal air treatment (inlet supply unit)
- **Supply air (SUP):** Air flow entering the swimming pool after any thermal air treatment (outlet supply unit)

The external casing is exposed to outdoor air in case of outdoor installation or ambient air in the building when the unit is installed inside.

The corrosive environment classification (pollution level) of the air, in combination with the relative humidity and temperature, is the decisive factor for the risk of corrosion of materials that are exposed to the air.

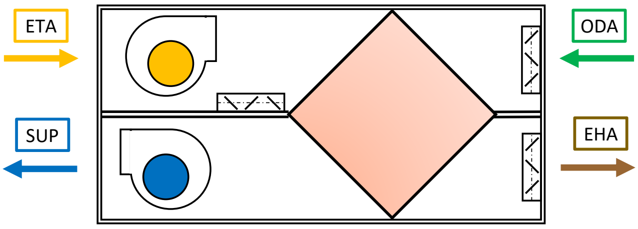

Figure 3: Simplified sketch swimming pool unit

Two international standards deal with the pollution levels of air (EN 16798-3 for ETA, EHA, ODA, SUP and EN-ISO 9223 for IDA, ODA). This recommendation will use the categories as defined in EN-ISO 9223 (see chapter 2.2). EN-ISO 12944, relevant for this recommendation, is a series of standards that deal with the protection of steel structures against corrosion by paint systems. Part 2 of EN-ISO 12944 (Classification of environments) refers to EN-ISO 9223 for the classification of environment.

**Note:** EN-ISO 9223 describes a swimming pool as an example of a typical environment with corrosivity category C4. The materials mentioned in paragraph 3.1, as generally suitable for C4, cannot be used for the casing of an air handling unit in swimming pools due to the specific concentration of nitrogen trichloride in the extracted air.

### 4.4.1 Exposure levels casing and components

#### 4.4.1.1 Extract air

The extract air of a swimming pool in general has a temperature between 28°C and 32°C with moisture content around 14,5 g/kg dry air. The corresponding relative humidity then is between 60% and 50%. Between the extract air inlet and the heat recovery, the extract air unit with integrated components is exposed to dry air with concentrations of chloramines (nitrogen trichloride).

#### 4.4.1.2 Exhaust air

The exhaust air downstream the heat recovery section will reach the saturation point up to outdoor temperatures of roughly 12°C. Between 12°C and 20°C outdoor temperature, the relative humidity of the exhaust air will be over 80%.

Hence the exhaust part of the extract unit with its built-in components is exposed to saturated air or air with a high relative humidity during many operating hours per year. Condensation of water vapour and volatile gases on casing surfaces is in many cases inevitable, particularly for outdoor units.

The wet air with concentrations of nitrogen trichloride is very corrosive. Due to these conditions, the exhaust part of the air handling unit is the most critical part for the risk of corrosion for both casing and components!

#### 4.4.1.3 Outdoor air

Between the fresh air intake opening and the heat recovery component, the supply unit is exposed to outdoor air. The risk of corrosion depends on the corrosivity category and prevailing relative humidity and temperature of the outdoor air. Time of wetness (total annual hours with relative humidity above 80% and temperature above 0°C) for a great part of Europe will be above 2.500 hours/year (see also chapter 1.2). This means that the corrosive environment not only depends on the concentration of pollutants in the air but is increased by the humidity.

#### 4.4.1.4 Supply air

The supply air side of the unit downstream the heat recovery component is exposed to either dry outdoor air or a (dry) mixture of extract air and dry outdoor air. The relative humidity for both operating modes will be far below 80%, so there is no increased risk of corrosion due to high time of wetness.

#### 4.4.1.5 External casing

The external casing of outdoor units is exposed to the corrosivity category of the outdoor air. The external casing of indoor units is exposed to the ambient air in the plant room. If the plant room is not separated from the pool hall, then the external casing (similar to the internal casing of the extract part) is exposed to dry air with concentrations of (tri)chloramines.

### 4.4.2 Recommended casing materials

Many air handling unit manufacturers will use the same casing construction materials for the entire air handling unit. In this case, the casing construction should be suitable to withstand the worst corrosive environment (corrosivity category).

If the design of the air handling unit enables the application of different materials with different corrosion resistances in one casing construction, a distinction between unit parts (as explained above) may be chosen.

The following materials for the individual unit parts (as defined in 4.4.1) are recommended.

#### 4.4.2.1 Extract part

Fibre reinforced polymer (composite materials) for the entire casing construction (corner posts, mullions, panel-plates and assembly accessories). Some examples of commonly applied composite materials are glass fibre reinforced polyester, glass fibre reinforced polyurethane, glass fibre reinforced polyamide, etc.

In EN-ISO 9223 a swimming pool is described as an example for a typical indoor atmospheric environment of corrosivity category C4. EN-ISO 12944-5 specifies protective paint systems for steel structures. The standard also defines 3 categories of durability: low 2-5 years, medium 5-15 years, and high > 15 years.

Since the normal lifetime of an air handling unit is expected to be more than 15 years it is recommended to use a paint system with high durability for a steel (or aluminium) casing construction, defined as suitable for corrosivity category C4.

Surfaces not directly exposed to the passing air or ambient air should have the same protective paint system!

Example of a suitable paint system according EN-ISO 12944-5 for high durability:

- **Priming coating:** 80 µm dry film thickness primer with zinc dust pigment
- **Paint system:** 2-3 layers subsequent coats with nominal dry film thickness 280 µm

It is recommended to demand certified proof from the (paint) supplier for the claimed corrosivity category and durability range (> 15 years).

Most familiar and commonly applied stainless steel alloys (AISI 304, 304L, 316 and 316L) are (often) not suitable to be applied in swimming pools. Crucial for the selection of suitable stainless-steel grades is the cleaning protocol of the material surfaces.

Surfaces not regularly cleaned demand a higher corrosion resistance grade.

For stainless steel, not subject to regular cleaning, the following materials are suitable:

| Material number (EN 10088) | | UNS number |
|---|---|---|
| 1.4565 | X2CrNiMnMoNbN 25-18-5-4 | S 34565 |
| 1.4529 | X1NiCrMoCuN 25-20-7 | N 08926 |
| 1.4547 | X1CrNiMoCuN20-18-7 | S 31254 |

**Table 7: Stainless steel not subject to regular cleaning**

For stainless steel parts and components that are subject to regular cleaning, the following stainless-steel grades are suitable:

| Material number (EN 10088) | | |
|---|---|---|
| 1.4401 | X5CrNiMo17-12-2 | AISI 316 |
| 1.4404 | X2CrNiMo17-12-2 | AISI 316L |

**Table 8: Stainless steel subject to regular cleaning**

The preconditions (cleaning protocol) to apply AISI 316 and 316L are not met for air handling units!

Application of the higher-grade stainless-steel alloys has its practical restrictions due to price level and availability of the materials for panel plates, posts and mullions. **As a general rule, it is not recommended to apply stainless steel for air handling unit casings.**

Galvanised steel is not suitable in situations where it will regularly become wet. It is therefore not recommended to use galvanised steel for the casing construction because there is always a significant risk of condensation on the internal casing surface in the extract part; particularly in outdoor units and on cold bridges in indoor units, installed in relatively cold plant rooms.

Application of aluminium or aluminium alloys is not recommended if surfaces are (frequently) exposed to condensates. Only if relative humidity can always be limited to 70%, aluminium might be applied.

Therefore, the same consideration and recommendation as for galvanised steel apply. **It is not recommended to apply galvanised steel nor aluminium (alloys) for air handling unit casings.**

#### 4.4.2.2 Exhaust part

The exhaust part of an air handling unit for swimming pools is exposed to the worst conditions regarding the risk of corrosion as explained in 4.4.1.

The following materials can be utilised:

- Fibre reinforced polymer (composite materials) for the entire casing construction (corner posts, mullions, panel plates and assembly accessories). Further information is given in section 4.4.2.1
- Steel or aluminium with a paint system suitable for corrosivity category C4 with high durability (see also section 4.4.2.1).

It is discouraged to use stainless steel, aluminium or galvanised steel. Further information is given under headline section 4.4.2.1.

#### 4.4.2.3 Outdoor part

The outdoor part of the supply unit is exposed to the corrosivity category of the outdoor air.

It is recommended to follow the requirements in chapter 3.1.

#### 4.4.2.4 Supply part

The supply part of the unit normally is exposed to dry air. The dry air can be outdoor air or a mixture of recirculated air and outdoor air.

For recommendations on applied materials, the requirements in chapter 3.1 can be applied, taking into account that the time of wetness for this unit part will be very low.

#### 4.4.2.5 External casing

For outdoor units, the same recommendations as for the outdoor part apply.

For indoor units, the recommendations for the extract part are advised. Depending on the thermal bridging class, condensation on the external surface of the outdoor section of indoor units may occur and this should be considered in the choice of materials.

However, if the plant room is completely separated from the pool hall, exposure to a lower corrosivity category may be assumed (C2 or C3) and the material requirements from chapter 3.1 can be adopted.

### 4.4.3 Recommendations for components

The position of a component in the air handling unit is the determining factor for the utilisation of certain materials. The exposure levels for components are defined and explained in section 4.4.1.

A distinction between casing and components should be made however, because the risk of condensation on components is much lower than on the internal casing. This is because components are fully positioned in the air stream and will have (in steady-state condition) the same temperature as the passing air flow (except thermal components).

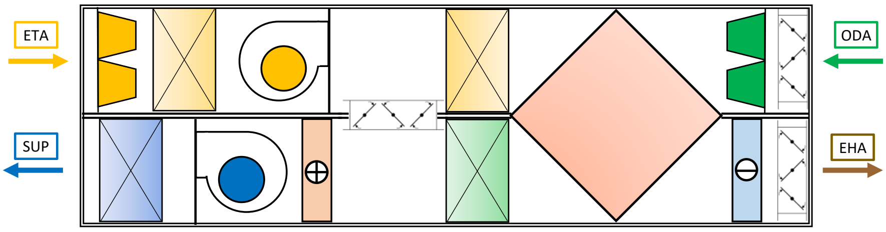

**Figure 4: Sketch swimming pool unit with components**

Appropriate materials for components in the various unit parts are described hereafter.

### 4.4.3.1 Heat recovery device

The heat recovery device is exposed to all the airstreams in the unit. It is also the partition between the defined unit parts. Utilised materials have to be corrosion resistant for the exhaust air (most aggressive air) or outdoor air if the corrosivity category outdoors is extremely high.

Stainless steel, suitable for corrosivity category C5 and CX, is however not appropriate for the exhaust air from swimming pools.

Suitable materials for heat recovery components are specified below:

- Plate heat exchangers with epoxy coated aluminium plates and powder coated galvanised steel housing (C4 coating with high durability)
- Plate heat exchangers with plates, frame and housing made of plastic
- Rotary heat exchanger with epoxy coated aluminium condensation rotor with coated shaft and powder coated steel/aluminium housing

### 4.4.3.2 Fans

The majority of standard fan assemblies consist of a composite, aluminium or coated steel impeller with a (coated) aluminium drive motor. The support construction for the impeller, motor and inlet cone are made of galvanised steel. The scroll fan housing is usually also made of galvanised steel. The normal position of the extract fan is upstream the heat recovery component. The supply fan is usually positioned downstream the heat recovery. In the aforementioned fan positions, standard fan constructions may be used, because condensation will normally not occur.

Some control applications demand that the extract fan is built in downstream the heat recovery device. Although this position is discouraged, sometimes customers persist in having this configuration. In such a case the entire fan assembly shall have an extra corrosion resistant coating on metal impeller, motor, support construction and housing (if applicable).

### 4.4.3.3 Filter frames

For the filter frame in the extract part, galvanised steel can be used. It is not advised to use stainless steel filter frames.

Filter frame material in the outdoor part shall be suitable for the corrosivity category of the outdoor air. For recommendations on applied materials, the requirements in chapter 3.1 can be applied.

#### 4.4.3.4 Heating coil or condenser

The heating coil or condenser is always positioned downstream the heat recovery in the supply part. The recommended coil construction shall be made of copper tubes and headers or coated steel headers, epoxy coated aluminium fins and galvanised steel coil frame.

#### 4.4.3.5 Cooling coil or evaporator

A cooling coil or evaporator in a unit for swimming pools usually functions with a heat pump and is located in the exhaust part downstream the heat recovery device to recover additional thermal energy from the exhaust air. The air at the coil inlet is saturated or has a high relative humidity during many operating hours. The exhaust air downstream the cooling coil is always saturated.

The minimum required coil construction shall be made of copper tubes and headers or coated steel headers, epoxy coated aluminium fins and galvanised steel coil frame. The lifetime of such a coil however is probably less than 15 years and possible replacement costs should be taken into account.

Recommended is a fully coated standard coil construction (copper tubes and headers, aluminium fins, galvanised frame). The fin spacing must be adapted to the coating process.

#### 4.4.3.6 Attenuators

Depending on the position of the splitters in the air handling unit, the following minimum material requirements are recommended.

- Splitter casings and resonance plates (if applicable) in the extract part or supply part made of galvanised steel or aluminium zinc-coated steel.
- Splitter casings in the outdoor part shall be suitable for the corrosivity category of the outdoor air. For recommendations on applied materials, the requirements in chapter 3.1 can be applied.

The positioning of splitters in the exhaust air should be avoided. If however this attenuator position is inevitable, the splitter casing and resonance plates (if applicable) shall be made of galvanised coated steel or plastic.

The absorption material of the splitters is corrosion resistant.

#### 4.4.3.7 Dampers

Depending on the position of the damper in the air handling unit, the following minimum material requirements are recommended.

- Dampers in the extract part or supply part made of aluminium or galvanised steel.
- Damper construction in the outdoor part shall be suitable for the corrosivity category of the outdoor air. For recommendations on applied materials, the requirements in chapter 3.1 can be applied.
- Dampers in the exhaust part are exposed to saturated air during many operating hours. Recommended material for a damper in the exhaust air is epoxy or powder coated aluminium or galvanised steel. Plastic fiberglass reinforced dampers can also be utilised.

The minimum required material for the damper construction shall be aluminium or galvanised steel. The lifetime of such a damper however is probably less than 15 years, but these materials are acceptable if replacement is easy.

#### 4.4.3.8 Louvers

Outdoor units are often equipped with louvers on the exhaust air and outdoor air opening.

- Dampers in the extract part or supply part made of aluminium or galvanised steel.
- Louvers mounted on the outdoor air opening shall be made of materials suitable for the corrosivity category of the outdoor air. For recommendations on applied materials, the requirements in chapter 3.1 can be applied.
- Louvers on the exhaust opening shall be made of epoxy or powder coated aluminium or galvanised steel. Plastic louvers or grids can also be applied.

Untreated aluminium or galvanised steel dampers probably have a lower durability than 15 years but may be used if replacement is easy.

#### 4.4.3.9 Droplet eliminators

Eliminator blades are (almost) always made of plastic (PP) and can be applied at any position in the air handling unit.

Droplet eliminators in the outdoor part shall be appropriate for the corrosivity category of the outdoor air. It is recommended to use plastic eliminator blades in a metal framework or plastic frame.

Suitable materials for the metal framework can be taken from the table in chapter 3.1.

Recommended materials for droplet eliminators in the exhaust part are plastic eliminator blades in a plastic frame or coated metal frame.

### 4.4.4 Important design and operating considerations

The casing design and construction is the most critical item for air handling units for swimming pools. The typical application of the unit implies that condensation on both the internal and external casing surface will frequently occur.

Not only the corrosion risk due to the direct contact of the applied casing materials with the passing air stream or ambient air shall be considered, but also the penetration of moisture in the casing construction. The vapour pressure differential is the driving force for vapour transport into the casing construction.

A vapour tight panel construction is strongly recommended to avoid condensation on the inside of the outer panel plate or vice versa. Condensate in the panel construction may cause severe internal corrosion which is not visible at first sight. Finally, water will start dripping out of the panel and cause a puddle of water on the floor of the plant room.

The risk of condensation increases with the temperature difference between inside and outside and the moisture content of the warm air. Outdoor units in cold climates, indoor units in cold plantrooms and the outdoor part of units installed in warm and humid plant rooms will suffer most from condensation problems.

Moisture penetration in the slots between panels and framework (posts and mullions) is an issue, similar to moisture penetration into panels. Most air handling units have a single airtight sealing in the outer plane of the casing. It means that the cold bridges are easily accessible for water vapour transport from the inside of the unit.

As a result, the water vapour will condensate on the cold bridges and after a while water will drip on the floor. This will not only cause puddles of water, but it may also cause unexpected corrosion if the materials are not resistant to the corrosivity of the condensed water.

Double sealings on panels and inspection doors should be considered!

Switching off the air handling unit when the swimming pool is closed may also cause huge condensation problems in the unit, particularly if the unit is installed outdoors or in a cold plantroom. The air handling unit will cool down rapidly after it has been switched off.

The high vapour pressure difference between the swimming pool and the inside of the unit causes vapour transport through the ductwork (supply and extract) to the unit if the unit openings are not properly closed by dampers.

Switching off the unit is therefore not an option unless the unit is equipped with high leakage class dampers on the extract and supply opening. And even then, some condensation in the entire unit is inevitable.

## 5. References

[1] EN 10169 - *Continuously organic coated (coil coated) steel flat products. Technical delivery conditions.*

[2] EN 10346 - *Continuously hot-dip coated steel flat products for cold forming. Technical delivery conditions.*

[3] EN 16798-3 - Energy performance of buildings. Ventilation for buildings. For non-residential buildings. Performance requirements for ventilation and room-conditioning systems (Modules M5-1, M5-4).

[4] EN ISO 12944 - *Paints and varnishes. Corrosion protection of steel structures by protective paint systems.*

[5] EN ISO 16701 - *Corrosion of metals and alloys. Corrosion in artificial atmosphere. Accelerated corrosion test involving exposure under controlled conditions of humidity cycling and intermittent spraying of a salt solution.*

[6] EN ISO 9223 - Corrosion of metals and alloys — Corrosivity of atmospheres — Classification, determination and estimation.

[7] EN ISO 9227 - Corrosion tests in artificial atmospheres. Salt spray tests.

[8] ISO 20340 - Paints and varnishes — Performance requirements for protective paint systems for offshore and related structures.

# Annex I

## Examples of detailed specification of materials

Table 9 below supplements Table 3 in paragraph 3.1 and provides examples of detailed material specifications. The list of examples is not exhaustive, and the annex will be systematically supplemented with new compliant material appearing on the market in subsequent editions of the recommendation.

**Table 9: Examples of detailed material specifications**

| Corrosivity category (interior or exterior) | Materials for casing construction | |
|---|---|---|
| | Material general type | Example material details |
| Up to C2 | Galvanised steel sheet Z275 (continuously hot-dip zinc coated low carbon steel, Sendzimir process) according to EN 10346 | Minimum zinc thickness 18 - 20 µm |
| Up to C3 | Coated (pre-painted) sheet steel in RC3 category according to EN 10169 | Coating thickness ≤ 25 µm |
| | Aluminium zinc-coated steel sheet according to EN 10346 | Alu-zinc 55% aluminium, 43,4% zinc, 1,6% silica.<br>Minimum thickness 20 µm<br>(EN 10125 – AZ 150) |
| Up to C4 | Aluminium zinc-coated steel sheet according EN 10346 | Alu-zinc 55% aluminium, 43,4% zinc, 1,6% silica.<br>Minimum thickness 25 µm<br>(EN 10125 – AZ 185) |
| | Aluminium alloys according to EN 573 | AlMg3 (94,2% - 97,4% sea water resistant aluminium)<br>EN AW – 5754 |
| | | Al 99,5 (minimum 99,5% Al)<br>EN AW – 1050 |
| | | AlMgSi0,5 - EN AW-6060 |
| | | AIMg0,7Si - EN AW-6063 |
| | | AlMgSi0,5 - EN AW-6060 and powder coated 50µm |
| | | AIMg0,7Si - EN AW-6063 and powder coated 50µm |
| | Stainless steel sheet 304 according to AISI | Material number 1.4301 according to EN 10088 |
| | | Material number 1.4509 according to EN 10088 |
| | Coated (pre-painted) sheet steel in RC4 category according to EN 10169 | Coating thickness > 25 µm |
| | Powder coated steel sheet | Paint system according to EN ISO 12944 and suitable for category C4 |
| Up to C5 | Powder coated steel sheet | Paint system according to EN ISO 12944 and suitable for category C5 |

| | | |
|---|---|---|
| | Zinc-Magnesium-coated steel sheet according to EN 10346 | ZM 93,5% zinc, 3,5% aluminium and 3% magnesium ZM 310 18-31 µm |
| Up to CX | Composite materials | Fibre reinforced non-metallic compositions |
| | Stainless steel sheet 316L according to AISI | Material number 1.4404 according to EN 10088 |

**Additional remarks**

- The lifetime of the suitable materials in the table for C2, C3 and C4 will dramatically decrease if the time of wetness is considerably higher than those corresponding to the defined climate zones (see paragraph 1.2.1).
- With sheet thickness > 1.5 mm adequate protection of cut-edges must be considered unless stainless or powder coated.
- Where water often comes into contact with the cut edge of metallised or coated steel sheet material, concealing the cut edge can provide good protection against edge corrosion and especially against paint delamination.

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Eurovent is Europe's Industry Association for Indoor Climate (HVAC), Process Cooling, and Food Cold Chain Technologies. Its members from throughout Europe represent more than 1.000 organisations, the majority small and medium-sized manufacturers. Based on objective and verifiable data, these account for a combined annual turnover of more than 30bn EUR, employing around 150.000 people within the association's geographic area. This makes Eurovent one of the largest cross-regional industry committees of its kind. The organisation's activities are based on highly valued democratic decision-making principles, ensuring a level playing field for the entire industry independent from organisation sizes or membership fees.

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