AiAX Coatings

Corrosion Protection Handbook

AiAX Coatings

Corrosion Protection Handbook

Version 22.03 – March 2022

Via Torino, 14 - Ciserano 24040 (Bg) Italia
T +39 035 48 21 431
e.mail : spavi@spavi.it
www.aiaxcoatings.com
VAT n. 02086910169

INDEX

AiAX
Coatings

Introduction

In over 30 years of activities in the HVAC&R market we have accumulated a certain experience and noted the importance of preservation of energy efficiency during the life cycle of installations.

Many are the factors influencing the efficiency of an HVAC&R system: in short we can say that we go from the initial selection of the most appropriated system for the specific application to a correct use of the installed units and finally to good maintenance practices.
*In moving forward our mission of corrosion protection of finned pack heat exchangers of various HVAC&R pieces of equipment all over the world, we have realized that the subject is not of easy interpretation and valutation; therefore we have deemed it useful to publish this "**Corrosion Protection Handbook**" to make available our experience to all those interested to the corrosion problems.*

The present document contains theory and practical cases derived from our research and development sector in cooperation with some of the primary European manufacturers of high efficiency chillers and rooftops.
We do not pretend to have treated the subject in an exhaustive way but we feel sure that the achieved results can be of interest to the market operators more sensible to the corrosion subject on HVAC&R equipment and to the dangers that follow in terms of reliability and energy efficiency during the system life cycle.

Good reading !

AiAX Coatings

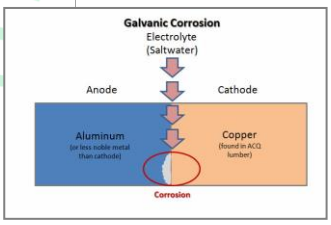
Corrosion in HVAC systems

Definition of corrosion

Let us start with a definition of a finned pack heat exchanger commonly called a coil. In its basic version it is formed by a round copper tube and an aluminium fin.
The coil is an important component of units like water chillers, aircooled condensers, dry coolers and from its performance depends most of the energy consumption of a cooling system.
In the coils the primary fluid running in the tubes can be: water , refrigerant or steam while the secondary fluid going through the fins is invariably air.
Let us now give a definition of **corrosion: it is a process which leads to the alteration or destruction of a metal**.
Metals are notoriously subject to corrosion and particularly from atmospheric agents. The two most common forms of corrosion are known as:
- galvanic corrosion
- corrosion from atmospheric impact

Galvanic corrosion

When two dissimilar metals are electrically connected in the presence of an electrolyte a reaction starts leading to the disappearance of the less noble metal.
In the case of a coil it is the aluminium, less noble than copper, that will be corroded.



Corrosion from atmospheric impact

We call in this way the corrosion created by a reaction with the environment. As said before the secondary fluid of a coil is always air. Unfortunately air is almost never pure and uncontaminate. In fact, very often, air contains elements which are highly corrosive for copper and aluminium.
Some examples of environments with polluted air:

1. Industrial ambients
2. Urban ambients
3. Rural ambients
4. Marine ambients

Outdoor ambient air can include elements that can generate corrosion to the exchangers generally used in HVAC Units.

1 Industrial ambients

The industrial areas are almost always associated with emission in the atmosphere of various pollutants like sulphur and nitrogen oxides. The combustion of solid fuels releases sulphur oxides (SO2, SO3) and nitrogen oxides (NOx). These gases accumulate in the atmosphere and return to the ground as acid rains or low pH dews (acid dews). In an industrial atmosphere there are normally also particles of metallic oxides, chlorides, sulphates, sulphuric acid, carbon and carbon compounds. These particles in the presence of oxygen, water or high humidity can be extremely corrosive.

2 Urban ambients

Densely populated areas are always associated with emissions in the atmosphere of car discharge gases and, during the heating periods, of high contents of combustion products. Both conditions increase the concentration of sulphur and nitrogen oxides.

3 Rural ambients

The rural ambients can contain high levels of ammonia deriving from fertilizer and animal drop-outs.

4 Marine ambients

Coastal areas in the proximity of the sea are characterized by an abundance of sodium chloride (salt) which is transported by spray, fogs and mist. The saline atmosphere induces per se corrosion but, most of all, acts as a catalyzer of corrosion in the presence of industrial emissions. A marine-industrial environment is probably the worst situation from the corrosion point of view.

Main effects of coil corrosion: loss of efficiency and increase of energy consumption

A coil is fundamentally a heat exchanger and heat is transferred through the tube surface to the fin. The fin is in close contact with the tube which is, in fact, expanded into the fin collar. The first effect of pollution on the fin is a deposit of dirt on it, partially isolating the secondary heat exchange surface from contact with the air. Further on, when the dirt particles have been in contact for a sufficiently long time and the corrosion process is started, (**corrosion from atmospheric impact**),the finned surface starts to deteriorate, decreasing the heat exchange capacity. One should not forget that the fin thickness is of the order of magnitude of 0.17 mm. and the corrosion does not take too long a time to eat up such a low thickness.

In the same time the galvanic corrosion, that appears at the bimetallic contact between copper and aluminium, erodes the collar eliminating the close contact between tube and fin. Decreasing the heat exchange even more. The disappearance of the collar exposes the tube; some crystals can be deposited and this can lead to a pitting corrosion which provokes a leak of the primary fluid. If this is refrigerant, as it is for all condensing coils, it will cause the stop of the unit, adding in the same time, additional pollution to the atmosphere.

Effects of corrosion on a typical air side Copper-Aluminium exchanger, installed on a unit located in a urban ambient, with high level of atmospheric pollution.

Corrosion Protection

The most common method of corrosion prevention is to coat the parts exposed to corrosion, avoiding the contact with the polluting agents. This method can be applied also to coils, however we must keep in mind some important points:

- **the coils are heat exchangers**. A coating acting as an insulating layer is not appropriate;

- **the fins have a special configuration** which increases the air turbulence thus improving the heat exchange, The coating must not modify the fin configuration;

- **the application of a layer of coat on both fin sides** reduces the air passage area. This generates a higher pressure drop which either reduces the air flow or increases the absorbed power.

Example of a typical Esempio di una batteria di scambio termico a pacco alettato protetta dalla corrosione

The above points have a vital importance and must be kept in mind when selecting the proper protection. There are however other protection features which are convenient:

1 - **good flexibility of the protection layer** to follow the metal thermal expansion/contraction;

2 - **dirt repellence**: the air passing through the fins deposits dirt which will adhere less easily if the coating is particularly smooth;

3 - **U.V. resistance** : quite important for coils exposed to the sun;

4 - **maintenance**: the protection, however good its quality, will have a resistance to athmospheric agents limited in time. It is advisable to re-apply the product as soon as signs of deterioration appear. As we shall see some coating methods do not allow re-applying the products;

5 - **reduced cost of application**: much as the method of application can be technically advantageous it must be economically significant.

The traditional solutions do not offer

the guarantees that Post-Coating can feature

In the market we have seen in the past several solutions to protect from corrosion but almost all had weak points in one or another direction.

Use of different metals: a possible solution is to employ a coil with **copper tubes and copper fins**. This surely eliminates the galvanic corrosion. But copper is attacked by sulphur gases which are often present in industrial ambients and not only there. The cost of the copper fin is, in any case, quite high. An even more costly solution is the **tinning of the copper fin**. If made by dipping the cost is really prohibitive. If obtained by using a **pre-tinned coil** it will have no effectiveness as the cuts deriving from the fin press moulding will uncover the underlying metal which is no longer protected.

Corrosion Effects on a typical Copper-Copper Coil

Surface coating: the basic idea is to eliminate totally the contact between the polluted air and the metal. We can distinguish two methods of application of the coating:

- Pre-coating
- Post-coating

Pre-coating: it is a layer of coat of few micron thickness applied on the aluminium coil before it enters the fin press for the fin moulding. The process implies a great number of cuts on the fin edge, on the collar and, if the fin is louvered, on thousands of louvers. The cuts eliminate the coating and expose the metal. In reality this is NOT a protection against the corrosion.

Post-coating: it is a procedure in which the coating is applied after the complete assembly of the coil. In this way the coating covers effectively all the finned surface including the fin edges. Until the coat remains in place there is no contact between metal and air. There is no doubt therefore that the post-coating method is the correct answer to corrosion problems.

Post-Coating: the complete solution for the corrosion protection of the exchanger in all its parts.

Post-Coating: a higher value compared to Pre-Coating

Obviously the post-coating has a higher cost compared to pre-coating for various reasons:

a) **transport costs**, as the treatment is almost always carried out in a factory different from that of the coil manufacturer;

b) **packing costs**, the coils must be protected for transport;

c) **cost of the product** which is of superior quality and is applied in higher thickness than that of the pre-coating process.

So in the end the initial cost of a pre-coating can be sometimes less that a post-Coating, on the other hand considering the long lasting value, including better efficiency (due to possibility of re-application) post-coating, quite often, offers a greater value for the customer than pre-coating.

Different systems of Post-Coating

Having already shown that the only method that makes sense from the point of view of corrosion protection is the post-coating one let us see which are the available methods:

1 by immersion

2 by spraying

3 by flooding

This first list of possible solutions must be immediately confronted with a fundamental and not to be ignored element: the anticorrosion protection must be re-applicable.

The experience shows, in fact, that there is no method that can guarantee indefinitely in time against the corrosion. It is always necessary a maintenance which keeps or reinstates the optimal resistance conditions of a just applied treatment. We repeat what already mentioned: any non re-applicable method has a time limited duration and should be considered an unvalid solution. The duration depends from ambient conditions and can , in limit cases, be of only few months..

The immersion method is not re-applicable by definition. There are also limitations in the coil size that can be treated as the immersion baths do not exceed 4-6 meters of length. The two other methods (by spraying and by flooding) are re-applicable and are the only systems which can, according to our experience, be considered safe from the point of view of corrosion protection.

THE ANTICORROSION PROTECTION MUST BE RE-APPLICABLE

A good anticorrosion protection must consider two factors:

Penetration: it is necessary that the protection coating is total, i.e. that also the coil internal surface, most difficult to reach, is coated. If a part of the surface is uncovered the corrosion can start in that point and, once started, will expand under the coat layer. Leaving uncovered spots is equivalent to render useless the whole treatment with waste of time and money.

Fin edge coverage: the most delicate point is surely the fin edge where the metal thickness is less than 200 micron and where, due to the limited surface support, it is higher the risk that the coating may not adhere perfectly. Furthermore the fin edge, more exposed to the air flow, can be subject to erosion from solid particles carried by the air.

The anticorrosion flooding process

AiAX COATINGS EXPERIENCES: THE ANTICORROSION FLOODING PROCESS

Years of experience have convinced us that the absolute security of penetration of the protection in the inner parts of the fin pack cannot be obtained only through a spraying procedure. In many cases the penetration stops at few centimeters from each side of the coil and the quality of the result depends substantially from the operator skill and attention.
For further protection of the fin edge, which we have noticed to be the critical point of the coil, a second coating by spraying is superposed to that applied by flooding.
In this way the protection of the whole fin pack is guaranteed, while the re-applicability on the fin edge is possible every time it becomes necessary.

Also on the side of the product, in parallel to our traditional products **AiAX Silver Flow** that is a polyurethane based special coating applicable with a flooding procedure and completely compatible with the **AiAX Silver Spray** coating, also polyurethane based, and applicable with a spraying procedure, we have introduced an innovation with the **AA Aqua Aero** which is water based, very often used to protect Microchannel heat exchangers completely in aluminium. These exchangers have a limited thickness, for this reason they are normally protected with the spraying method.

The flooding method and the use of a water based product represent a substantial progress in the state of the art of the anticorrosion protections of coils.

ORIGIN OF THE ANTICORROSION PROTECTION FLOODING PROCESS

The idea of coating by flooding was developed when the market demanded to protect the finned pack of industrial coils with a pack thickness much higher than the standard normally used with condenser of refrigeration units (3-4 rows maximum with a maximum thickness of around 120 mm). With a pack thickness over 200 mm the traditional spraying method, in most cases, does not guarantee a good penetration, whatever the nozzle pressure or the used procedure. The immersion method was the first answer to the penetration problem from many suppliers (even if in certain cases, the complete penetration is not guaranteed).

In any case the immersion method had and still has some disadvantages like:

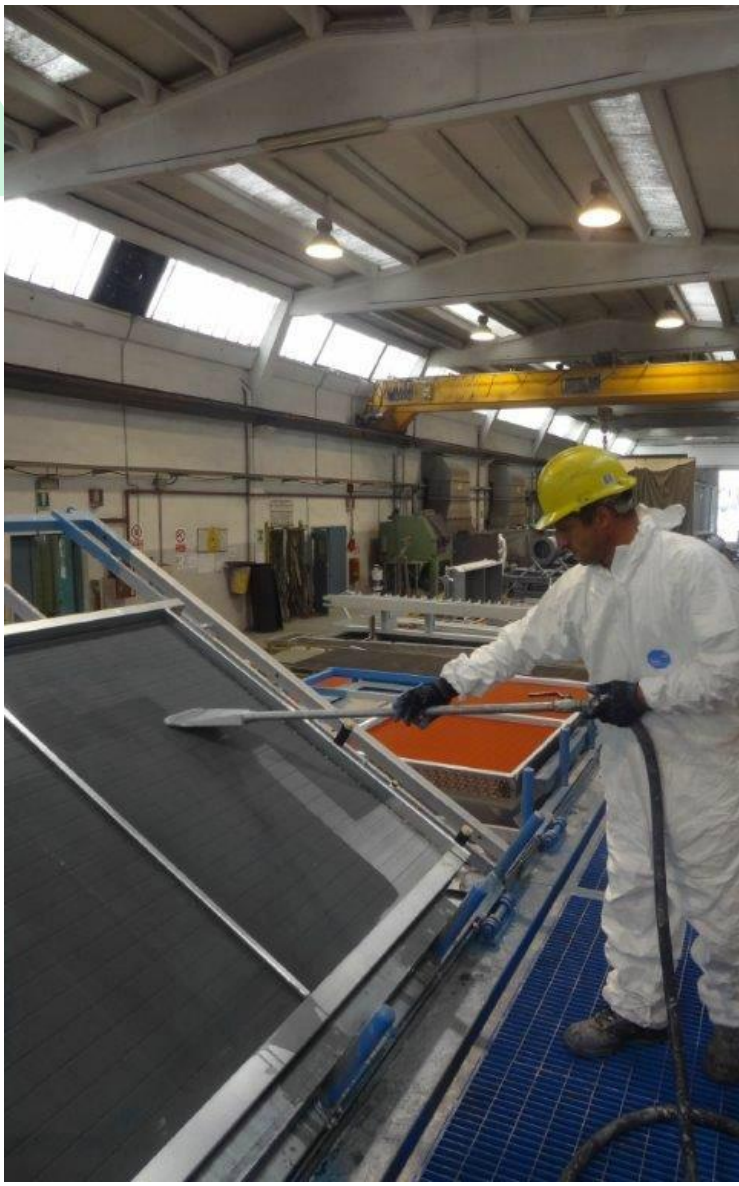
- The dimension of the bath in which the coil should be dipped is normally limited to only few meters of length.
- The quantity of chemical product to be used is far in excess of what adheres to the finned surface. The product characteristics, in almost all cases, requires that the product is removed from the bath

when the application cycle is finished. This leads to substantial losses of products which increase the operation cost.

- Many, if not all, the immersion products are not suitable also for spraying application. This means that a touch up of the finned surface, sometime after the first application, is not possible. The experience shows that, however good the product and the application method, after a certain time (depending on installation site ambient conditions) a maintenance intervention becomes necessary, particularly on the fin edge which, having a thickness of few micron, is subject to lose the protection due to erosion or corrosion. A touch up intervention on the fin edge, within a programmed maintenance, extends the life of a coil much beyond the life of other components of the same unit. If the product is not re-applicable by spraying and the touch up can be made only through another dipping process, it is quite evident that a regular maintenance cannot be carried out: it would be necessary to remove the coil to send it to the original applicator with clearly unbearable costs.

Exclusive flooding protection process developed by AiAX Italia

The flooding system is the answer that eliminates all the disadvantages of the other methods. Let us see the various steps:



- The coil is positioned on an inclinable support which can be moved from the horizontal to the vertical position (90° rotation)

- Any transportable coil length can be positioned on the support which is open at the extremes

- Under the coil is positioned a tank of width and length sufficient to take all the products percolating from the coil treatment. The tank has the form of an inverted pyramid at the base of which a container holds a sufficient quantity of product to pour over the coil. The product is pushed by a pump to the flooding outlet. In this way the quantity of product into the container is reduced to the bare minimum with a remarkable economic advantage.

- The flooding outlet distributes the product uniformly over the coil. The product goes through the coil by gravity and the product not adhering to the fins goes into the underlying tank. Thanks to the gravity force the penetration of any thickness of coil is guaranteed.

Once the flooding treatment is completed a further coating is applied by spraying to protect the fin edge which, as already mentioned , is the the part most exposed to corrosion. In the same way it will be possible to carry out maintenance interventions.

Application case study

Chiller capacity: 329 kW

Energy efficiency is a focal point in designing new buildings and in retrofitting old ones. The condenser coil of a chiller can lose part of its heat exchange capacity even in less than one year from the date of its installation and the velocity of deterioration depends from the local environment.

A case history: chiller of 329 kW cooling capacity. Estimation of Efficiency decrease due to the corrosion effect on condensing air side exchangers.

In order to evaluate the impact on energy costs of a chiller with untreated condenser coils we have analysed the energy consumption in conditions of average air pollution, typical of an urban environment.

The data included in this example are the results of studies made by our R&D department in cooperation with some major european manufacturers of high efficiency chillers and rooftop units. We do not pretend to have treated the subject in an exhaustive way but we feel sure that the end results are of interest to the energy conscious engineers.
The experience of the last fifteen years of direct observation shows that the condensing temperature of chillers increases in time with respect to initial conditions.

Particularly we noted that, as an average, to every degree °C of increase in the condensing temperature corresponds an increase of electric consumption of about 2% (consumption of the compressors only).

TAB.1

Timeline	*[°C] Condensing temperature increase Vs standard data*	*[%] Increase of electrical consumption (kWh) year by year compared to a new Unit*
End 1° year	+1	2%
" 2° "	+2	4%
" 3° "	+3,5	7%
" 4° "	+5	10%
" 5° "	+7	14%

The above situation does not take into account maintenance interventions on the coils, which is a typical case when the coils are not treated against corrosion and it is not required a specific maintenance in order not to render nil and void the warranty.

Let us take, as an example, a chiller with four scroll compressors of about 329 kW of cooling capacity (water 12-7°C and ambient air 35°C) with a compressor EER=3,17. The chiller is used in a comfort installation. We shall have about 3.000 hours of yearly operation with a bell shaped load profile which, for ease of understanding, we approximate as per the following table.

TAB 2

% Cooling capacity used	*Annual usage measured in hours/year*	*Compressors Absorbed Capacity kW*	*Total kWh consumption*
100%	150	104	15.600
75%	600	72	43.200
50%	1.500	40	60.000
25%	750	20	15.000
Total	3.000		133.800

The yearly total of kWh 133.800 is referred to a brand new unit. Given the coil deterioration of Table 1 the consumption will be:

TAB.3

Year	1° year	2° year	3° year	4° year	5° year	6° year
% of increase	/	2	4	7	10	14
kWh	133.800	136.530	139.375	143.871	148.667	155.581
Difference compared to a new Unit	/	2.730	5.575	10.071	14.867	21.781

In other words in the five years after the first year of operation there is an additional consumption of kWh 55.024 which at an average industrial cost of 0,17 €/kWh (Italy) yields a total of € 9.354.

To this cost, conservatively calculated, even if by broad outline, it should be added the longer time of chiller operation to reach the desired temperature level. The above example would be even more significant were the chiller operating in an industrial installation in which the yearly hours would be more than 3.000 and with a more onerous load profile. Again as an order of magnitude we use the same example in an industrial situation of process water cooling.

TAB 4

% Cooling capacity used	*Annual usage measured in hours/year*	*Compressors Absorbed Capacity kW*	*Total kWh consumption*
100%	1.500	104	156.000
75%	2.000	72	144.000
50%	1.500	40	60.000
Total	5.000		360.000

Due to the coil deterioration the consumptions will be those of Table 5.

TAB 5

Year	1° year	2° year	3° year	4° year	5° year	6° year
% of increase	/	2	4	7	10	14
kWh	360.000	367.347	375.000	387.097	400.000	418.605
Difference compared to a new Unit	/	7.347	15.000	27.097	40.000	58.605

In other words in the first five years after the first year of operation there is an additional consumption of kWh 148.049 which, at an average industrial cost of 0,17 €/kWh (Italy) yields a total of € 25.168.
It should be noted that we have assumed urban ambient conditions while in industrial areas conditions are definitely worse.

Basically even class A units, after a certain period of time, depending on ambient conditions of the site of operation, would decrease their performance without a proper anticorrosion treatment in the condenser coil.

Pay-Back starting from the 2°/ 3° year After the installation of the Chiller

As a cost index the application of an AiAX Coatings treatment on the coil of the example chiller would be worth less than one third of the added cost of Table 5.The pay back period would be around 3 years for a comfort installation and less than 2 years for an industrial application.

The application of an AIAX Coatings treatment reduces the risk of refrigerant leaks and of stopping the chiller and ensures an optimal performance for the whole life cycle of the installation provided there is an easy and low cost maintenance (periodical washing with water ad detergent).

Information about S.P.A.V.I. Srl

With AiAX Coatings, more than 30 years of HVAC experience

SPAVI srl, founded in 1991 has an activity of sand blasting, anticorrosion protection and industrial coating with adequate means of lifting and moving and a lifting capacity of up to 10 tons.

For several years SPAVI cooperated with AiAX Italia srl and has taken over AiAX activities at the beginning of 2022 ensuring to all customers a continuity of efficient and timely service.
The flooding coating structure, designed together with AiAX Italia over 20 years ago, is still today the only one operational in Italy, guaranteeing a perfect fin pack penetration associated with a low cost operation while maintaining corrosion resistance characteristics similar to other higher cost methods. The vast external spaces allow an easy and quick moving of the received coils.

In a period of macro-economic uncertainties the development of the GNP can only pass through a reduction of the energy costs and an increase in the efficiency of equipment and production methods.

AiAX Coatings offers an important contribution making it possible the almost always unrealized wish of maintaining the heat exchanger performance equal to that of the first day of operation for a prolonged period of time.

Quality and safety certifications


RINA

CISQ is a member of IQNet

CERTIFICATO N. 18970/08/S
CERTIFICATE No.

SI CERTIFICA CHE IL SISTEMA DI GESTIONE PER LA QUALITÀ DI
IT IS HEREBY CERTIFIED THAT THE QUALITY MANAGEMENT SYSTEM OF

S.P.A.V.I. S.R.L.

VIA TORINO, 14 24040 Ciserano (BG) ITALIA
NELLE SEGUENTI UNITÀ OPERATIVE / IN THE FOLLOWING OPERATIONAL UNITS

VIA TORINO, 14 24040 Ciserano (BG) ITALIA

È CONFORME ALLA NORMA / IS IN COMPLIANCE WITH THE STANDARD
ISO 9001:2015

PER I SEGUENTI CAMPI DI ATTIVITÀ / FOR THE FOLLOWING FIELD(S) OF ACTIVITIES

IAF:17

VERNICIATURA, SABBIATURA E TRATTAMENTI PER LA METALLIZZAZIONE DI MANUFATTI METALLICI IN CONTO LAVORAZIONE SU PROGETTAZIONE DEL CLIENTE

PAINTING, SANDBLASTING AND TREATMENT FOR METALIZATION OF MANUFACTURED METAL ITEMS ACCORDING TO CUSTOMER DESIGN

Prima emissione / First issue 29.12.2008
Data scadenza / Expiry Date 15.12.2023
Data decisione di rinnovo / Renewal decision date 09.12.2020
Data revisione / Revision data 09.12.2020

Paolo Teramo
Italy Management System Certification
Region, Senior Director

RINA Services S.p.A.
Via Corsica 12 - 16128 Genova Italy

IAF ACCREDIA 9GQ N° 002 A

FEDERAZIONE CISQ

The traditional solvent based products

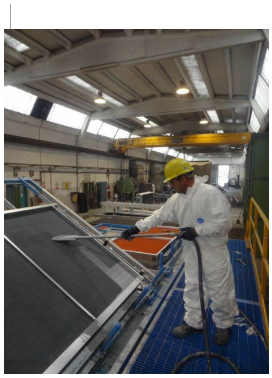
Designed for all types of finned coils with any thickness of the finned pack
- AiAX Silver Flow specific for flooding procedure
- AiAX Silver Spray specific for spraying procedure

The solvent based products, further improved, are used for the "Flooding Method" coating which is in absolute the most performing procedure for Round Tube Finned Pack coils.
The "Flooding Method" ensures penetration of the entire finned pack, and then the protection is excellent both against galvanic corrosion and against corrosion by accumulation of pollutant.
After the flooding of the entire finned pack it is normally don a further finishing spraing application to cover the edge of the fins. Double protection by "Flooding Method" and spray is the more serious approach so far experienced for a consistent corrosion protection over time.

Ahestetic appearance of the Protection "AiAX Silver Flow" and "AiAX Silver Spray"

The anticorrosion flooding process

We have set up a new application structure of the anticorrosion product by flooding the coil, developed on the recent years experience.
The experience shows that in comparison with the traditional coating systems available in the market, our flooding process guarantees a very good protection of the finned pack of any commercial thickness.
The spraying process will be reserved to those cases where the flooding method is not applicable for the geometry of the coil (frames and similar cases) or for specific request of the customer.
With these characteristics, our process is suitable for being used for all thickness of coils.



Our new innovative flooding process, suitable for being used for all thickness of coils.

Products

AiAX Coatings has a complete range of anticorrosion protections specifically suitable for different HVAC applications. The **technical characteristics** and the **safety data** of AiAX Coatings protections are included in two different documents that can be downloaded from www.aiaxcoatings.com.

• AiAX Silver Flow - AiAX Silver Spray

Anticorrosion protection specific for finned pack heat exchangers.
Recommended for all thicknesses of the finned pack.
Application is possible both for "Flooding Method" and spraying procedure.

Free download of the above datasheet from internet: www.aiaxcoatings.com.

Notes

AiAX Coatings

Corrosion Protection Handbook

Via Torino, 14 - Ciserano 24040 (BG) Italia
T +39 035 48 21 431 E-mail: spavi@spavi.it
www.aiaxcoatings.com P.IVA 02086010169

Distribuito da: