TRANE

Engineering Bulletin

Aluminum Fin Surface Oxidation on Air-Cooling Coils

⚠SAFETY WARNING

Only qualified personnel should install and service the equipment. The installation, starting up, and servicing of heating, ventilating, and air-conditioning equipment can be hazardous and requires specific knowledge and training. Improperly installed, adjusted or altered equipment by an unqualified person could result in death or serious injury. When working on the equipment, observe all precautions in the literature and on the tags, stickers, and labels that are attached to the equipment.

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TRANE TECHNOLOGIES

Introduction

Warnings, Cautions, and Notices

Safety advisories appear throughout this manual as required. Your personal safety and the proper operation of this machine depend upon the strict observance of these precautions.

The three types of advisories are defined as follows:

⚠WARNING	Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
⚠CAUTION	Indicates a potentially hazardous situation which, if not avoided, could result in minor or moderate injury. It could also be used to alert against unsafe practices.
NOTICE	Indicates a situation that could result in equipment or property-damage only accidents.

Background

The development of copious amounts of flaky, white powder from indoor coils has been a recognized industry issue for a couple decades now. The first known occurrences were reported on residential heatpump systems that used refrigerant as the heat transfer fluid. Commonalities between reported cases were coils constructed with bare aluminum fins in an air cooling/ dehumidifying application. The problem would surface during the heating season of the year when the dehumidifying coil's fin surface was dry of condensate and within the first couple years of operation of the equipment.

Large commercial equipment applications, while still rare, have also been reported as well as chilled water systems in a variety of light commercial and terminal products. As additional occurrences have been identified over the last 10 to 20 years, it has now been shown to happen to any type of dehumidifying coil with bare aluminum fins operating in a system that also supplies forced air heating during the winter season.

The incident rates have been low over the years and until recently limited to coastal areas mostly regionalized in the southern United States. With millions of aluminum fin coils shipped in the reported time period, problem jobs only number in the dozens. The phenomenon has been reported across additional geographical areas in the Southeastern and Midwestern United States, Europe and Asia. But, the primary regions have continued to be hot and humid climates or milder climates that had severe cooling seasons prior to development of the problem. Cases have not been reported in dry, arid climates or on coils that are in heating only applications utilizing hot water, hot glycol solution or steam. There are no documented cases with coils that have non-aluminum fins (copper, steel, etc.) or with coils that have fin surface coatings (corrosion resistant or hydrophilic).

System design does not seem to be an important contributing factor. A variety of applications have demonstrated the capability to produce the white flakes such as coils using either chilled water, chilled glycol solution or volatile refrigerant; 100 percent return air, 100 percent outside air or mixed outside and return air.

Once the coil has been installed and operated for a few cooling/heating seasons its vulnerability is drastically reduced. The phenomenon has only been reported within the first one or two heating seasons and has yet to be reported during a cooling season. Theories suggest that the coils might still be producing the white flakes during the cooling season, but the condensate on the fins formed from dehumidifying the airstream prevents the powder from becoming airborne and thus from being detected.

Figure 1. Looking at the leaving airside of a coil, aluminum oxidation can be seen uniformly across a heavily oxidized fin surface.

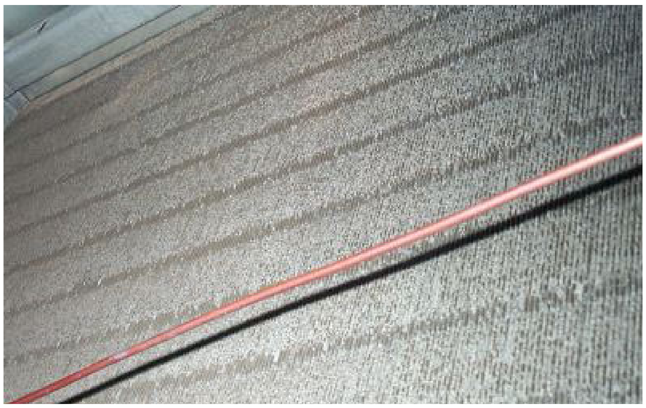

Figure 2. Drainpans are typically the first place that flakes accumulate. The amount of powder found can be noteworthy especially when no detectable breakdown of the fin surface is observed.

What is it?

Laboratory analyses conducted at multiple third-party laboratories have shown the white flakes to be aluminum hydroxide oxide.

Initially, most third-party laboratories will identify the substance as aluminum oxide (alumina) using simple tests.

The initial investigations concerning these occurrences utilized Scanning Electron Microscopy (SEM) to determine the elemental composition of the powder. The results were always aluminum and oxygen with trace amounts of sulfur, chlorine or other elements. There were never any agents present in sufficient quantities to cause this rapid oxidation of aluminum or any other metal in the unit. Lacking any other testing it was erroneously concluded that the flakes were aluminum oxide (Al_2O_3), commonly called alumina.

In the late 1990s, a sample of white powder was analyzed by X-Ray Defraction (XRD) to reveal the crystal structure of the powder. Combining the elemental composition and the crystal structure usually specifies the composition of a compound. In this case the composition is aluminum oxide hydroxide $AlO(OH)_2$. The SEM analysis had shown that the powder contains aluminum and oxygen but was incapable of identifying the presence of the hydrogen in the compound. The XRD analysis showed that the crystal structure of the powder was one that only occurs with hydroxides of aluminum and does not occur with oxides of aluminum. Aluminum oxide hydroxide forms on aluminum when it is nearly constantly wet. It is characterized as a white, flaky powder.

White powder is aluminum oxide hydroxide $AlO(OH)_2$. It is not aluminum oxide (Al_2O_3).

Details

Even today there has been no mechanism proposed that explains the set of events necessary to create a loosely-bound flake form of oxidized aluminum rather than the normally-formed, tenaciously-bound crystalline aluminum oxide. It is known that the aluminum surface corrosion occurs during cooling operation. The nature of the flakes formed suggests the coil must remain wet or damp for very long periods of time. The actual flaking occurs during heating operation when the coil is dry and hot. The flake shape allows for it to be easily entrained in the fast-flowing air through the coil and deposit quickly in the living space where air velocity is low. Experience tells us that once initiated, the formation of white flakes does not cease.

All indications seem to point to the initial catalyst being some type of jobsite specific condition. This conclusion has been drawn from the fact that multiple products from the same manufacturer that were made in different manufacturing plants on different dates, with different processes and process fluids, different materials and different cleaning procedures have all exhibited the white flakes on a single jobsite. The problem has repeated on a jobsite when a new coil was installed one to two years after the original installation with identical material construction. Since thousands of coils were produced and successfully installed and operated without incident by this manufacturing facility between the two problem jobs, it becomes evident that the common problem must be outside the manufacturing facility and not directly related to the coil construction or the materials. Multiple alloys of aluminum from aluminum mills all over the world have been used in coils that have been problematic. There are also accounts of job sites with multiple, competing manufacturers that were creating the white flakes at the same time.

Root cause analysis is very difficult due to the extremely low incident rates. With only a few cases out of hundreds of thousands of coils, there is very little evidence to collect and analyze. Because the initiating reaction is believed to occur during the cooling season, there is no evidence left when the coils begin to form flakes during the following heat season.

This condition has not been shown to be related to galvanic corrosion between aluminum and copper. The mechanism appears to be more related to aluminum oxidation and corrosion rather than galvanic action between dissimilar metals.

Figure 3. A close-up view of the fin surface shows the blackening and corrosion phenomena.

What are the safety risks?

When any type of substance is produced or emitted by a mechanical device whether it is liquid, solid or gaseous, it is common to inquire about the safety implications. Toxicology and pulmonology experts have been consulted in regards to the health affects of the aluminum hydroxide oxide powder and it has been shown to not be chemically harmful to people. These analyses also showed the physical size of these flakes to be too large to cause pulmonary problems if inhaled. Risks associated with inhalation, skin, and eye irritation are unwarranted.

How can the problem be fixed?

Because no single source or catalyst of the problem has been identified, the most common means to mitigate the problem has been to address the coil that is producing the white flakes. The coil is not necessarily the cause of the problem as illustrated above, but being the source of the flakes makes it a likely starting point.

As mentioned previously, replacing the coil with an identical coil could allow for the condition to return. This is not going to happen every time as jobsite conditions change over time, but reemergence of the problem is possible.

From a customer standpoint, the main complaint has been the house keeping issues of having white powder distributed from the HVAC ducts and diffusers. Post filtration or final filtration has been successfully applied in containing the flakes within the air handler systems or duct work. While not all systems will be conducive to applying additional filtration, it has been shown that very minimum particle efficient filters are more than capable or remove the large white flakes from the airstream. Field experience has shown that coil cleaning at best offers only short term relief as the flake production will inevitably return.

Replacing the affected coil with coated aluminum fins eliminates the problem. Common coatings would be some type of corrosion resistant coatings that are optional on some product lines. While this is easily accomplished in residential equipment, much more effort, time and cost is involved in replacing coils in large commercial equipment.

Using alternate materials for the fin surface such as copper or steel will also prevent the white flakes from forming since there is no aluminum material.

There is no known material treatment or coil cleaning process that will stop the chemical breakdown reaction.

Evaluations of jobsite conditions such as chemical treatments and cleaners, indoor pollution or outdoor pollution could help to determine causal relationships. Source control of the reaction catalyst will be the best approach to successfully eliminating the problem from reoccurring in the building.

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