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nVent HOFFMAN Powder paint coating system

WHITE PAPER

This document describes nVent HOFFMAN's process for its standard powder coating system, differentiating two major parts: pretreatment and application of powder paint coat.

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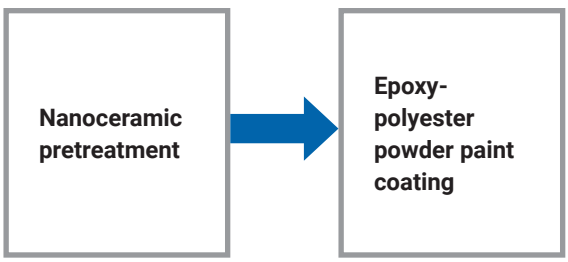
Introduction

nVent HOFFMAN's powder paint coating systems protect enclosures that require resistance against corrosion, scratching, and ageing. The use of powder coating offers several advantages compared to solvent based systems. Superior coat properties, such as adhesion, can be obtained, since many coat defects can be traced to incorrect solvent balance. Powder coating allows for a controlled film thickness, a more durable finish and a wide range of coatings for customization for functional or decorative finishes. In general, powder coatings are easy to use, resistant, cost effective, and environmentally friendly.

nVent HOFFMAN'S STANDARD POWDER PAINT COATING SYSTEM



nVent HOFFMAN's standard powder coating system comprises chemical pretreatment of the surface, followed by an epoxy-polyester RAL 7035 powder paint coating.

Unprotected metal in almost any environment is subject to corrosion, since a physicochemical interaction causes changes in the metal's properties which often results in damage. The main barrier against corrosion is corrosion protection systems by paint; this is a combination of chemical pretreatment according to the required corrosivity category and a paint coating.

More demanding usage conditions and increased quality requirements create a need for verified data on the durability of corrosion protective coating systems. ISO 12944 is the main international standard for corrosion protection of steel structures by protective paint systems.
Although this standard is restricted to structures of not less than 3 mm thickness, paint products which dry or cure at ambient conditions, and does not cover powder coatings, it serves as general framework for testing enclosure corrosion protection systems by paint.

nVent HOFFMAN's customization service comprises different finish options to cover most requested applications. Outdoor locations are exposed to ultraviolet

Scope

light from the sun and weather conditions, where polyester powder coating provides excellent protection to UV light. Locations with high salinity or chemical atmospheres are more challenging in terms of corrosion. For these environments, an additional protective primer should be employed.

nVent HOFFMAN regularly verifies the quality of the finish by means of tests performed at the factory. The purpose of these tests is to perform rapid analysis for discontinuities, pores, or damage. Tests include environmental factors, like salt spray test, as well as mechanical factors, like bending or cupping. This document describes nVent HOFFMAN's process for its standard powder coating system, differentiating two major parts: pretreatment and application of powder paint coat.

A chapter is dedicated to customization options, specifically the coatings offered for outdoor and harsh environments.

Basic concepts about corrosion resistance according to ISO 12944 are introduced, together with the different corrosive environments, C1 to C5, which an enclosure can face when installed.

To verify consistent coating quality, several tests are regularly performed at nVent HOFFMAN's factory. These tests are listed with their main attributes.

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nVent HOFFMAN's standard powder coating

The process comprises initial pretreatment, followed by powder paint coating. The metal surface is cleaned, dirt, grease, and residues from production are removed, followed by chemical treatment to enhance paint adhesion and corrosion resistance. The powder paint coating involves three steps: The enclosure is dried, powder paint is applied, and then it is stoved for polymerization. The result is a very thin layer of nanoceramic material on the metal surface and a paint layer of 60-90 µm on the top.

Paint layer - Epoxy/polyester (60–90 µm)
Nanoceramic pretreatment
Substrate (steel surface)

Painting line layout

The automated painting line consists of a closed loop with pretreatment, drying, powder paint application, and polymerization in an oven. The enclosures are slotted in line and hooked off after a process which takes on average 90 minutes and runs for a distance of 300 meters.

Pretreatment process

This process comprises several stages of cleaning and surface preparation. The steel used arrives covered in oil, which protects it from rust. When the enclosure parts arrive for the painting process, they carry dirt and residues from previous manufacturing processes like punching, welding, bending or cutting. The cleaning stages remove all this unwanted matter. The pretreatment is the conversion of the surface using a chemical process. Conversion includes removal of the impure surface layer and turning it into a surface which allows for good corrosion resistance and paint adhesion. This is to bond well with the powder during the subsequent powder coating process. The objectives of the pretreatment can be summarized as:

Impurities such as solid particles and salts must be removed;
The steel surface must be cleaned from dirt, grease and oil;
Good adhesion of the powder coating to the steel surface must be obtained;
Corrosion resistance must be improved to secure powder coating permanence.

Pretreatment is especially important in painting processes which do not involve solvents, such as powder coating, unlike liquid paints that contain solvents. Surface preparation depends on the metal, the type of surface, its conditions, and the performance required.

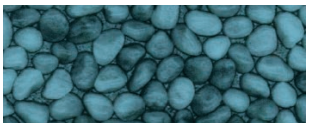
There are three pretreatment technologies normally used in the industry:
Iron phosphate, the most frequently used with powder coatings;
Zinc phosphate, which offers a higher level of corrosion performance but is less environmentally friendly than iron phosphate;

Nanotechnology, the most modern technology with higher corrosion resistance, better adhesion properties and the most environmentally friendly technology.

For many years, nVent HOFFMAN has used iron phosphate pretreatment in the painting process. In recent years, the process changed to nanoceramic pretreatment, which offers the following advantages to the finished product and the painting process:

Very good results in terms of corrosion resistance;
Better powder paint adhesion;
Benefits in safety and process handling;
Environmentally friendly.

Substrate surface after pretreatment:
left iron phosphating (FePhos), right nanoceramic.



nVent HOFFMAN's standard powder coating

nVent HOFFMAN's pretreatment process comprises six stages:

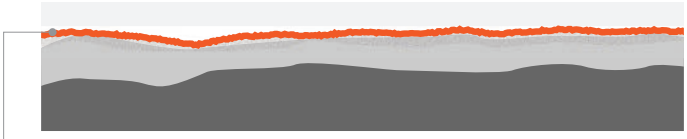
1	2	3	4	5	6
Alkaline degreasing 1	Alkaline degreasing 2	Tap water	Demi water	Nanoceramic	Fog

Stage 1 and 2, Cleaning (Alkaline degreasing)

To increase the effectiveness of pretreatment, the parts must be cleaned prior to the nanoceramic stage to remove soils from the surface. Three types of cleaners are normally used: Solvent, acid and alkaline. nVent HOFFMAN uses alkaline cleaners, as these deliver optimum results on organic soils, and are versatile enough to clean the surface effectively. During the alkaline degreasing stages, the oil plus organic and inorganic contaminations, which could affect the nanoceramic process, are removed from the steel surface. The ph-value is 10, which is an aggressive alkaline solution.

RESIDUES: Oil, organic substances, inorganic substances

Stage 3, Rinse (tap water)



In this stage the chemicals from the previous stage are removed, preventing contamination of subsequent stages.

Stage 4, Rinse (demi water)

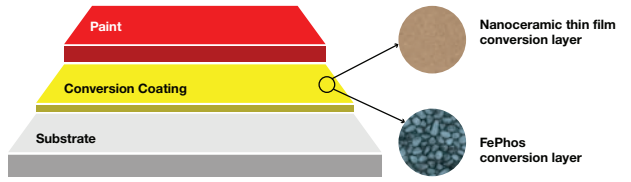
During this stage all residues of salts are removed.
The conductivity of the demi water is constantly monitored and controlled below a threshold value.

Stage 5, Nanoceramic

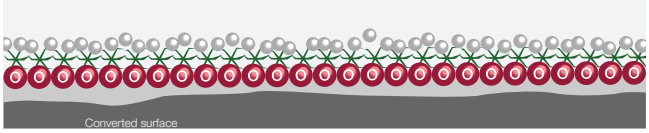
By passing through this bath, a thin layer of nanoceramic material is deposited on the surface of the part, making it practically closed to corrosion penetration and improving the corrosion resistance of treated metal surfaces from a chemical point of view:

Stage 6, Rinse (fog demi water)

This final stage terminates chemical reactions from previous stages.



Comparison with previous FePhos conversion layer



Standard powder paint

Powder coating is a dry finishing process, based on electrostatic application of paints composed of polymer resins, combined with curatives, pigments, and other additives. All these components are melted, mixed, cooled, and ground into a uniform powder.

The components of powder paints include:

- Resin/curing agents: Components that cure to form a coating film called binder. These components provide mechanical, chemical, and outdoor properties, as well as corrosion resistance;
- Fillers: Inorganic components providing abrasion resistance, hardness;
- Pigments: Provide colours to the finish coating;
- Additives: Provide certain textures, gloss, and flow.

Epoxy-polyester paint is used when flexibility, adhesion, toughness, and corrosion resistance are required.
This coating is based on epoxy resins, which give excellent resistance to solvents and other chemicals, and provide a good corrosion protection layer. The paint has very good chemical characteristics: It is not flammable and contains no heavy metals like lead or cadmium.

nVent HOFFMAN applies an epoxy-polyester structured powder coating to the colour, RAL 7035, according to the DIN 43.656 standard. Some beneficial characteristics are:

- Intended for interior use;
- Good chemical resistance;
- Good mechanical performance.

Powder paint coating process

Drying

First, the enclosure parts are dried in an oven, to eliminate moisture remaining from the pretreatment stages.

Powder application

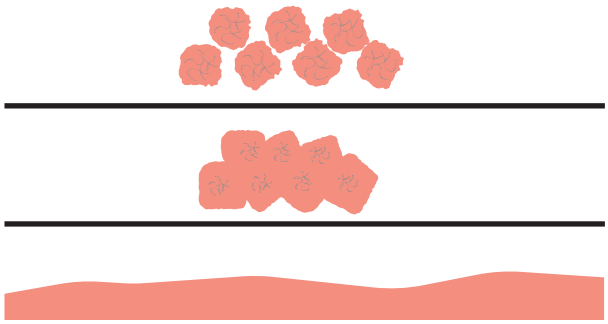
Next, a spray machine applies an electrostatic charge to the powder particles, which are attracted to the enclosure parts hanging from the electrically grounded painting line.
The electrostatic powder painting process gives a tough surface and a good build-up on corners and edges.
Good adhesion ensures that the paint does not crack or split when the material is drilled or punched.

nVent HOFFMAN's standard powder coating

Polymerization

Following the application of the powder paint, the enclosure parts enter a polymerization oven, where the powders chemically react to produce long molecular chains very resistant to breaking down. Polymerization bonds the powder together into a uniform layer of paint. To achieve proper curing, two conditions must be met: Correct temperature and time. A cured thermoset powder coating will not melt in case of re-heating.

After the whole process is completed, the thickness of the paint layer is verified with electronic metering devices and checked to make sure it is in the range 60-90 µm.



Customization of protective finish options

Powder coating of enclosures and accessories can be customized in different ways, and some products that are not powder coated as standard can be painted, such as stainless steel or aluminium. Powder paints are available in a wide range of colours in textured or fine-textured effects and can be custom matched to meet customer requirements.

This document focuses on customization to select the appropriate finish protection for an enclosure according to two criteria of the final location: Whether it is indoors or outdoors, exposed to sunlight and weather conditions; or it is in a normal or a harsh environment, which may be polluted or contain high salinity and chemicals in the atmosphere. It is also possible to combine both protection systems for the case that the enclosure is located outdoors in a harsh environment.

The following table summarizes the finish options depending on the location of the enclosure:

	Normal environment	Harsh environment
Indoor	Standard paint	Primer + Standard paint
Outdoor	100% polyester paint	Primer + 100% polyester paint

Polyester paint for outdoor

Designed for exterior environments, the 100% polyester coating is a powder paint coat that offers excellent light and weather resistance from a single coat finish on a variety of substrates. The enhanced heat resistance of polyester paint powders makes them ideal for use where colour retention on surfaces exposed to continuous heat is required. They are also available in a wide range of colours in textured or fine-textured effects and can be custom matched to meet customer requirements.

- Excellent UV stability for exterior application;
- Good heat resistance;
- TGIC* free.

Paint layer 100% polyester (60-90 µm)

Nanoceramic pretreatment

Substrate (steel surface)

*(Triglicydyl isocyanurate crosslinkers)

Overview of protective coating processes

Different powder coating system alternatives are available depending on the environment in which the enclosures will be installed. As outlined above, the standard powder coating system is sufficient for normal atmosphere and indoor applications: 100% polyester coating for outdoor applications, and an additional primer pretreatment for enhanced corrosion protection in harsh environments.
Depending on the location and environment in which the enclosure will be installed, nVent HOFFMAN offers these different powder coating system combinations:

Primer coating for harsh environments

If requested for harsh environments, a primer coating may be applied before applying the standard powder paint coating. A primer is a layer of paint product intended to provide additional properties to the final coating. It is not intended as a durable finish surface; its focus is on improving other properties, such as corrosion resistance, filling, or acting as a binding layer in between that improves adherence between the metal surface and the paint coats.

nVent HOFFMAN's primer is a pure epoxy barrier protective powder coating, designed to enhance corrosion protection of mild steel. It can also be used on a wide variety of substrates and environments. Its wide curing conditions, good edge coverage and enhanced degassing properties make it a very versatile primer.

The primer powder is applied in the paint booth in the same way as for a customized enclosure. Right after it is stoved in the oven for polymerization. The layer thickness applied is 60/80 µm to ensure maximum protection.

Some features of the primer are:

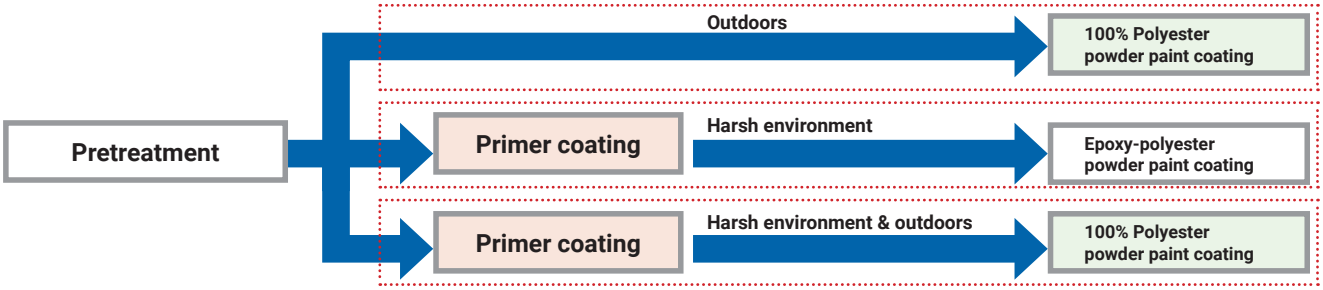
- Increases corrosion resistance from 480 hrs up to 1000 hrs of neutral salt spray test, performed according to ISO 9227;
- Thermosetting epoxy;
- Particle size suitable for electrostatic spray.

Paint layer (60-90 µm) Epoxy-polyester

Primer layer (60-80 µm)

Nanoceramic pretreatment

Substrate (steel surface)



Corrosion protection systems by paint according to ISO 12944

The ISO 12944 standard defines the concept of protective paint systems and deals with features that are important in achieving adequate corrosion protection by paint systems, from surface preparation and quality tests, to maintenance and design guidelines.

ISO 12944 deals with several topics such as the type of structure, surface and surface preparation, whether uncoated, treated with zinc, or galvanized. From the three environments mentioned in the standard, only the atmospheric environment is dealt with in this document. A relevant topic of the standard is the corrosivity C-categories, which are described later. Further topics which can be found in the standard include the types of protective coating systems, the type of work (new or maintenance), and the durability of the protection system.

The standard serves as a general framework in the enclosure industry for corrosion protection systems by paint, although it is actually restricted to structures of not less than 3 mm thickness, paint products which dry or cure at ambient conditions, and does not cover powder coatings.

Concepts

Coat:	A continuous layer of metal material or film of paint, resulting from a single application.
Corrosion:	Physicochemical interaction between a metal and its environment which results in changes in the properties of the metal which may lead to impairment of the function of the metal.
Corrosion stresses:	Environmental factors which boost corrosion.
Atmosphere:	A mixture of gases, and normally also aerosols and particles, that surround an object.
Durability:	The expected lifetime of a protective coating system.
Paint:	A pigmented coating material, in liquid, paste, or powder form, which, when applied to a substrate, forms an opaque film having protective, decorative or other specific properties.
Protective coating system:	The sum total of coats applied to a substrate to provide corrosion protection.
Protective paint system:	The sum total of the coats of paints applied to a substrate to provide corrosion protection.
Substrate:	The surface to which the coating material is applied to.

Classification of atmospheric corrosion environments

The environmental impact on enclosures varies with corrosivity. Atmospheric environments are presented in six categories according to the mass loss per unit surface after a year of exposure. Examples of existing environmental factors which promote corrosion are listed for each category.

Atmospheric corrosion takes place in a film of moisture on the metal surface. Corrosion is favoured by high humidity, condensation, and higher pollution levels.
Exposure to open-air climatic influences, such as rain and sunshine, favours corrosion.
ISO 12944-2 divides the atmospheric corrosivity into the following six categories:

Corrosivity category	Examples
C1: Very low	Heated buildings with clean atmospheres, such as offices and schools.
C2: Low	Unheated buildings where condensation may occur, such as depots. Low level of pollution, such as rural areas.
C3: Medium	Production rooms with high humidity and some pollution, such as food-processing plants and laundries. Urban and industrial areas with moderate sulphur dioxide pollution. Coastal areas with low salinity.
C4: High	Chemical plants, swimming pools, coastal ship and boatyards. Industrial areas and coastal areas with moderate salinity.
C5: Very high	Buildings or areas with almost permanent condensation and with high pollution. Industrial areas with high humidity and aggressive atmosphere and coastal areas with high salinity.
CX: Extreme	Industrial areas with extreme humidity and aggressive atmosphere. Offshore areas with high salinity and industrial areas with extreme humidity and aggressive atmosphere and sub-tropical and tropical atmospheres.

The standard recommends exposure of regular specimens to determine the corrosivity category applicable in each case.

Durability

This concept is an estimate of the life of a protective paint. The standard introduces three time-spans regarding durability of the corrosion protection system.

Durability	Time range
L Low	2 to 5 years
M Medium	5 to 15 years
H High	15 to 25 years
VH Very High	More than 25 years

A statement is made in the standard to clarify that the warranty time for the coating system is independent of the durability range, where the first, the warranty, is usually shorter than the second, i.e. the durability.

Corrosion protection systems by paint according to ISO 12944

Artificial environment tests and test durations

The standard ISO 12944-6 provides certain lab performance test methods and requested time in hours for each aforementioned corrosivity C-category. The methodology first requires a Water Condensation Test ISO 6270 to be followed by the Neutral Salt Spray Test ISO 9227. Additionally, cyclic ageing test for category C4-VH, C5-H and C5-VH is required.

The following table shows the number of test hours required for each C-category:

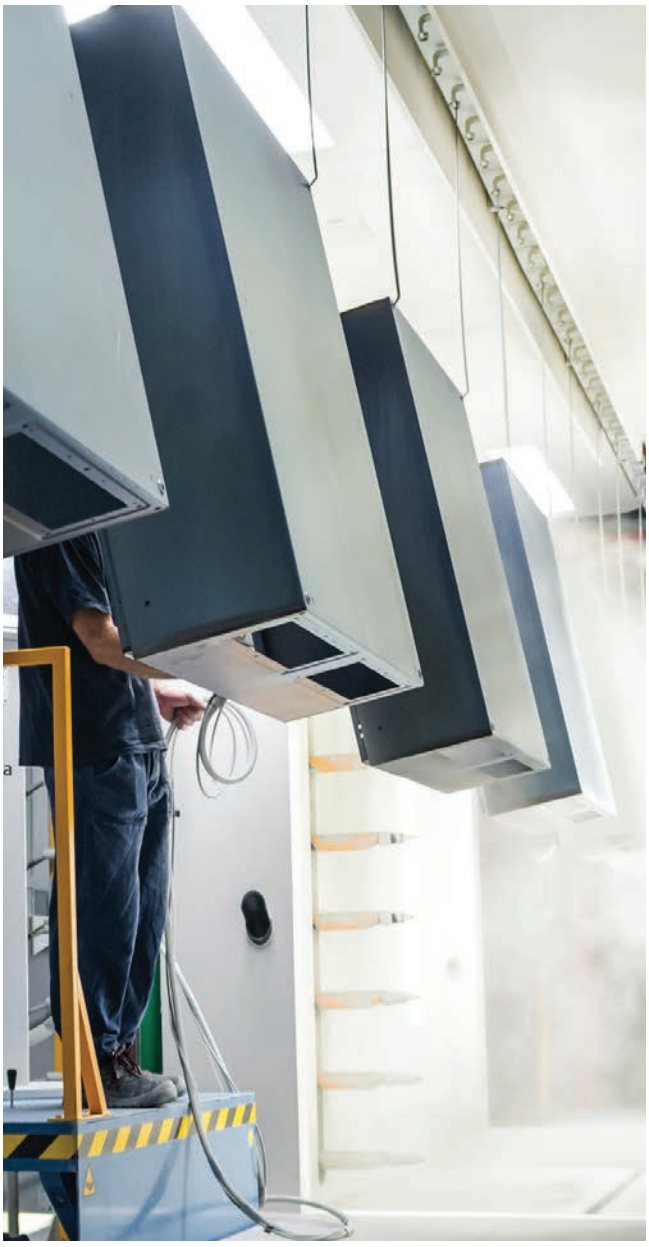
Corrosivity categories ISO 12944-6	Durability	Water condensation test ISO 6270	Neutral salt spray test ISO 7253:1996	Cyclic ageing test ISO 12944-6
C2	Low	48	-	-
C2	Medium	48	-	-
C2	High	120	-	-
C2	Very High	240	480	-
C3	Low	48	120	-
C3	Medium	120	240	-
C3	High	240	480	-
C3	Very High	480	720	-
C4	Low	120	240	-
C4	Medium	240	480	-
C4	High	480	720	-
C4	Very High	720	1440	1680
C5	Low	240	480	-
C5	Medium	480	720	-
C5	High	720	1 440	1680
C5	Very High	-	-	2688

nVent HOFFMAN's standard powder paint coating system has been tested successfully for the requirements of category C4 medium durability.

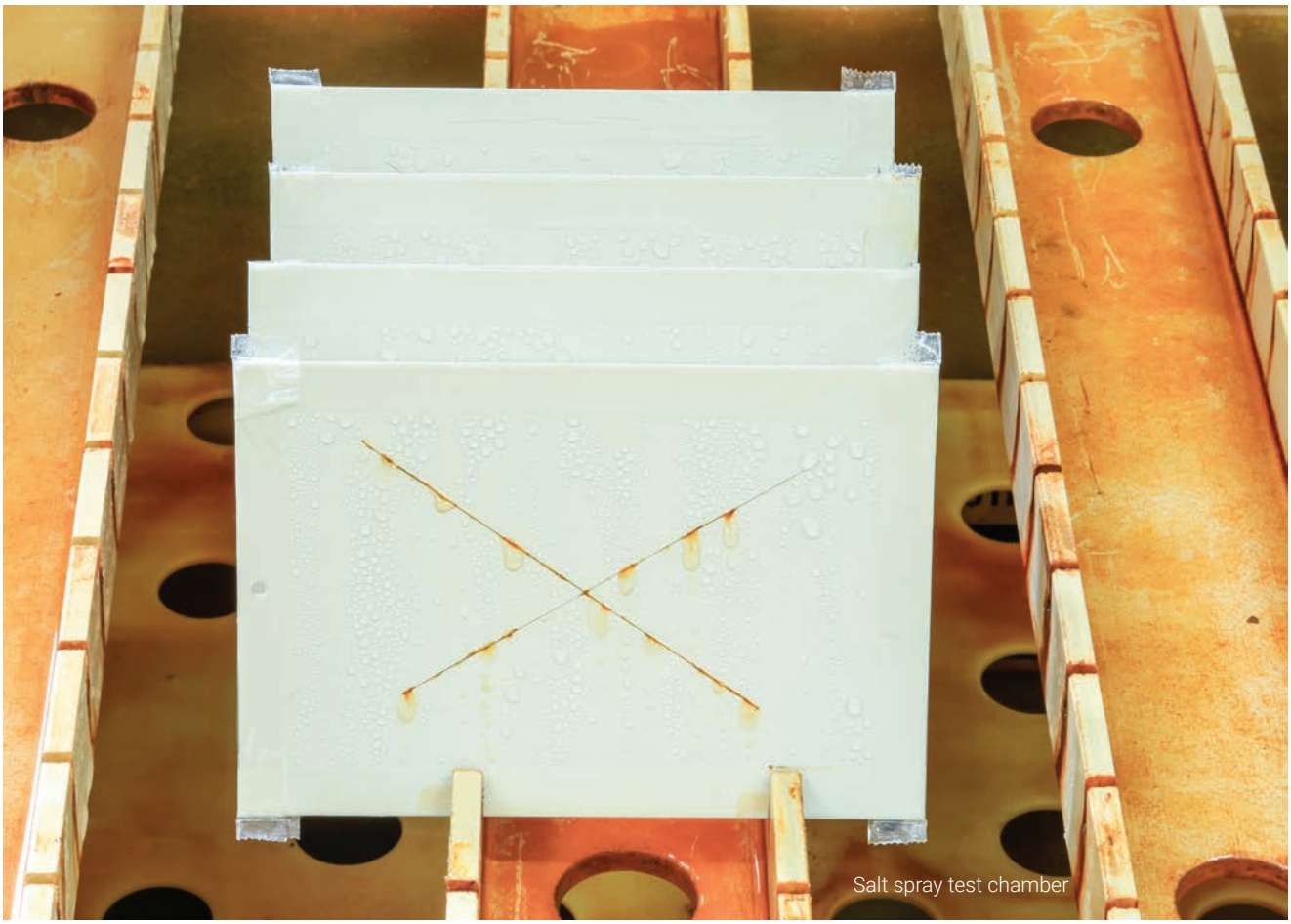
nVent HOFFMAN's optional harsh environment powder paint coating system "Primer + 100% polyester" has been tested successfully for the requirements of category C5 medium durability and C4 high durability.

Test results on Water Condensation and Neutral Salt Spray tests, matching the test hours of category C4 and C5, medium durability, and C4, high durability, are available.

A declaration can be found in the annex of this document.



Factory laboratory performance tests


Salt spray test chamber

Artificial environment tests

Water condensation test ISO 6270

This test is carried out to determine any defects in the protection of the test specimens against corrosion. The test is designed to clarify the behavior of the coatings and evaluate any defects which may develop in humid ambient atmospheres.

Test method	The water condensation test is performed in accordance with the standard ISO 6270. The values will be described as having blisters quantity 0, size 0, and degree of rusting Ri0. The size of blisters is visible only with x10 magnification. Adhesion check at every 100 hours.
nVent HOFFMAN acceptance criteria	After 240 hours for the standard coating: Blistering 0(S0) to ISO 4628-2 Rusting Ri0 to ISO 4628-3
Frequency	One sample per week.

nVent HOFFMAN's results in terms of hours of condensation tests are summarized in the following table:

nVent HOFFMAN powder coating system	Water condensation test ISO 6270
Standard	240
Harsh environment	720

Neutral salt spray test ISO 9227

Salt spray tests are carried out to validate the paint system, but not the substrate (mild steel, stainless steel, aluminium). Salt spray tests are carried out for suitability and rapid analysis of discontinuities, pores and damage. There is no relation between the action of salt spray and the resistance to corrosion, or the use of results from salt spray as a guide to long term characteristics of the coating.

Test method	According to the standard ISO 9227:2017. The values will be described as detachment of paint in mm from both sides of the cut. Adhesion check every 100 hours.
nVent HOFFMAN acceptance criteria	≤ 2 mm on both sides of the cut after 480 hours for the standard coating.
Frequency	One sample per week

nVent HOFFMAN's results in terms of hours of neutral salt spray tests are summarized in the following table:

nVent HOFFMAN powder coating system	Neutral salt spray test ISO 9227
Standard	480
Harsh environment	1000

Factory laboratory performance tests

Mechanical analysis tests

Impact test

Test method	The standard ISO 6272:2004/BS 3900-E3 is used to assess the resistance of a dry film of paint, varnish, or related product, to separation from a substrate by impact of a weight. The method specified is carried out as a 'pass/fail' test with a single specified load applied to assess compliance with a particular specification.
nVent HOFFMAN acceptance criteria	No visual cracks on paint using a 0.5 kg weight from a 50 cm height.
Frequency	Every 2 hours.

Impact test

Scratch test (adhesion)

Test method	BS EN ISO 2409 and BS 3900-E6 are alternative names for the same method which is used to assess the resistance of a dry film of paint, varnish, or related product, to separation from a substrate when a right-angle lattice pattern is cut into the coating and penetrates through to the substrate. Grid of 2 mm base.
nVent HOFFMAN acceptance criteria	G0-G1 Detachment of small flakes of the coating at the intersections of the cuts. A cross-cut area not greater than 5% is affected.
Frequency	Daily.

Scratch test

Cupping test

Test method	Forming of indentation by pressing a punch with a spherical end against a test piece clamped between a blank holder and a die, until a through crack appears. ISO 1520.
nVent HOFFMAN acceptance criteria	No visual cracks at 5 mm depth.
Frequency	Daily.

Cupping test

Polymerization test

Test method	A swab of cotton wool saturated in MEK solvent (Methyl-Ethyl-Ketone) is rubbed softly back and forth on the test surface 30 times in each direction within 30 seconds. After 30 minutes an assessment is made. The polymerization quality is assessed according to the following ratings: 1. The coating is very dull and quite soft; 2. The coating is very dull and can be scratched with a finger-nail; 3. Slight loss of gloss; 4. No perceptible change. Cannot be scratched with a finger-nail.
nVent HOFFMAN acceptance criteria	Ratings 3 and 4 are satisfactory.
Frequency	Every 2 hours.

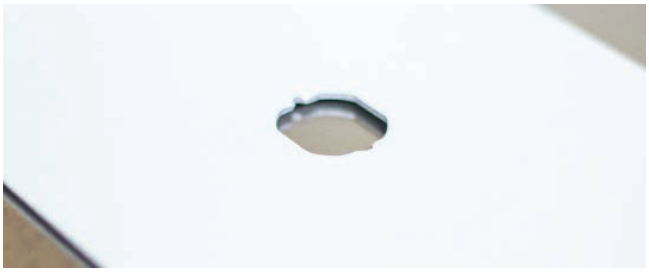
Factory laboratory performance tests

Bending test (flexibility)

Test method	Standards BS EN ISO 1519 and BS 3900-E1 are alternative names for the same method which is used to assess the resistance of a dry film of paint, varnish, or related product, to cracking/detachment from a metal substrate when subjected to bending round a cylindrical mandrel. (30 mm Mandrel).
nVent HOFFMAN acceptance criteria	No visible cracks.
Frequency	Every 2 hours.

Punching test

Test method	Drilling and die-punching on a sample from the painting line.
nVent HOFFMAN acceptance criteria	Maximum 2 mm lack of adherence around the hole.
Frequency	Every 2 hours.



Overpainting

For cases where a customer is interested in overpainting a standard nVent HOFFMAN enclosure with a different colour, it is possible to apply a new paint coating to the enclosure. It is necessary to clean and prepare the enclosure surface carefully before the new coating with the desired colour can be applied. The use of 2-component paints based in polyurethane or epoxy resins has been tested.
The paint manufacturer's instructions must be followed.
If there are doubts, a compatibility test should be performed in advance.

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Declaration of Conformity

Issued by Hoffman Enclosures, Inc.

Declare at our sole responsibility, that nVent HOFFMAN's Standard

Epoxy/Polyester powder paint coating system

For nVent Hoffman brand product ranges

MCS, MCD, MCF, MCI, MKS, MKD, MAS, MAD, MAP, STB
MCSS, MCDS, EKSS, EKDS, EKDS-4X, ASR, ADR, AFS, SSTB

To which this declaration relates, has been successfully tested according to:

ISO 6270 Paints and varnishes–Determination of resistance to humidity –Part 2: Condensation

Acceptance criteria: after 240 hours, blistering 0(S0) to ISO 4628-2 and rusting Ri0 to ISO 4628-3..

ISO 9227 Corrosion tests in artificial atmospheres - Salt spray tests

Acceptance criteria: after 480 hours, corrosion creep ≤ 2 mm from scribe.

These results match the test procedure for corrosivity categories C4 medium in standard ISO 12944, which are:

240 hours condensation test to ISO 6270

480 hours salt spray test to ISO 9227

Authorized by: _____ 3/10/2025

Tom Hurney **Date**

Technology Mgr., Product Compliance and Approvals

Subject to Change Without Notice DOC: CE-DoC-EN_Paint-C4-M Rev B

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Declaration of Conformity

Issued by Hoffman Enclosures, Inc.

Declare at our sole responsibility, that nVent HOFFMAN's Harsh Environment

Primer and 100% Polyester powder paint coating system

For nVent Hoffman brand product ranges

MCS, MCD, MCF, MCI, MKS, MKD, MAS, MAD, MAP, STB
MCSS, MCDS, EKSS, EKDS, EKDS-4X, ASR, ADR, AFS, SSTB

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Acceptance criteria: after 480 hours, blistering 0(S0) to ISO 4628-2 and rusting Ri0 to ISO 4628-3..

ISO 9227 Corrosion tests in artificial atmospheres - Salt spray tests

Acceptance criteria: after 1000 hours, corrosion creep ≤ 2 mm from scribe.

These results match the test procedure for corrosivity categories C4 High and C5 Medium in standard ISO 12944, which are:

480 hours condensation test to ISO 6270

720 hours salt spray test to ISO 9227

Authorized by: _____ 3/10/2025

Tom Hurney **Date**

Technology Mgr., Product Compliance and Approvals

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