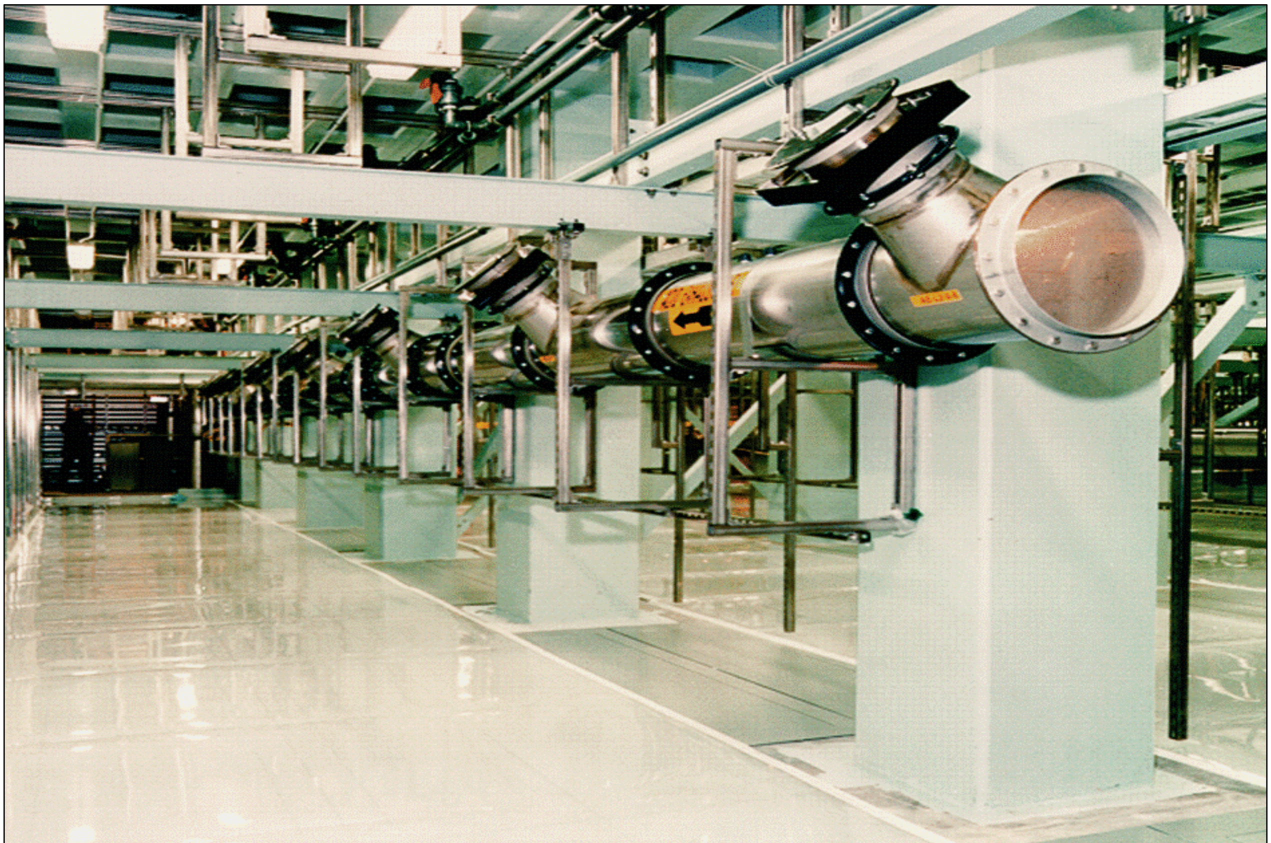

Halar® ECTFE
Electrostatic Powder Coating
Processing Guide

Solvay Solexis

SOLVAY

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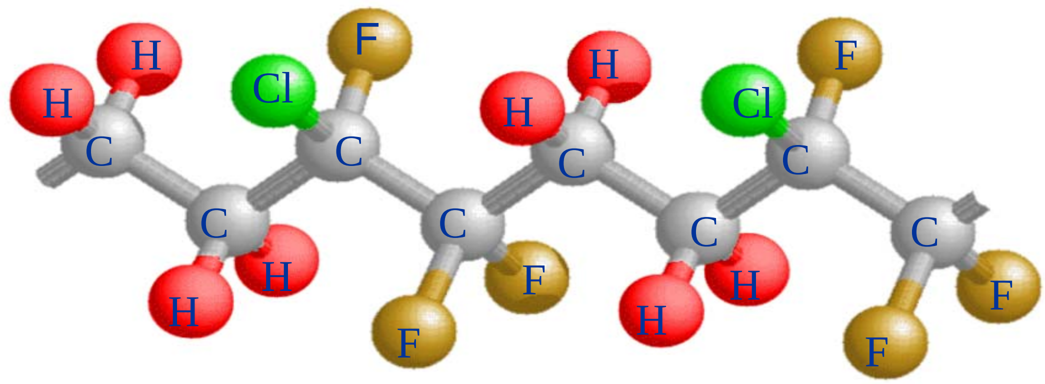
INTRODUCTION

Halar ECTFE is a copolymer of ethylene and chlorotrifluoroethylene. It is a semicrystalline and melt-processable fluoropolymer from Solvay Solexis, manufactured at its ISO-certified plant in Orange, Texas USA.

The chemical structure of Halar is shown below:

Chemical structure of Halar ECTFE



Halar provides excellent chemical resistance and electrical insulating properties over a broad-use temperature range from cryogenic to 150ºC (according to UL test). It is a tough material with excellent impact strength and is one of the best fluoropolymers for permeation resistance.

Halar is particularly suitable for use as a coating material in protection and anti-corrosion applications thanks to its unique combination of properties.

- Thermal, chemical and permeation resistance
- Surface properties
- Purity
- Mechanical properties
- Flame resistance
- Dielectric properties
- Processability
- Adhesion to substrate

Today Halar is extensively utilized in chemical and pharmaceutical processes, semiconductor fabs, refineries, power plants as well as for many other different applications in contact with highly corrosive or ultra-pure chemicals, like strong inorganic bases and strong mineral and oxidizing acids.

PRODUCT FORMS

This brochure has been prepared to familiarize processors with the Halar fluoropolymers which have been formulated specifically for use in powder coating.

Halar fluoropolymer is a thermoplastic resin that can be processed by virtually any technique applicable to other plastics like polyethylene, PVC, or polypropylene and is available in:

- Powder form for powder coating
- Pellet form for extrusion, injection & compression molding, melt blown fiber

Table 1. available powder grades for electrostatic powder coating

Grade	Typical use and main features
6014	Topcoat. Clear.
6014F	Topcoat. Clear. Low Melt Index. High Build.
6614	Primer. Green.
6514	Primer. Black.
6914	Primer. Gray. Low Melt Index. High Build.
9414	Primerless. Off-white. Improved water vapor permeation resistance over 6014.
3404DA	Primerless. Off-white. Food-contact compliance.

HALAR POWDER COATING ADVANTAGES

Powder coating process offers a number of advantages over solvent-based coatings. No solvents or thinners are required for powder coating. Less air turnover is needed in view of the fact that ovens do not need to remove solvent. Being VOC free, powder coating eliminates also the need for specialized and expensive equipment to remove air and water pollutants. An additional benefit is the reduction of the toxicity and explosion hazards associated with many liquid coatings. Generally, overspray is non-hazardous waste or, at worst, solid hazardous waste. The processing advantages of powder coating frequently results in fast application cycles and this may lead to significantly reduced production costs compared to many liquid coatings.

Compared to sheet lining, powder coatings offer a seamless protection which is not dependent on the thermal rating of adhesive systems. Powder coated surface smoothness is generally same or better than a sheet and has no welds, seams and joints, that are potential weak spots.

Powder coating has been used for parts of custom design and complicated geometry thanks to excellent wrap-around and edge coverage. Uniform coating thicknesses are easily achievable despite thickness variations of the substrate.

In particular, Halar powder coating offers many unique advantages. Final thickness of Halar powder coating normally varies from 0.2 to over 2 mm. Coatings greater than 1 mm are termed “High Build” coatings. The Halar powder application bake temperatures are 250-290°C. The most common substrate for Halar coating is stainless or carbon steel. Other metals (copper, aluminum, titanium), glass, carbon, and ceramics have been successful coated with Halar.
Recognized processing benefits offered by Halar powder coating include flexibility in coating application and easy thickness control as well as machinability and field repair capability in case of mechanical damage
Reliability of quality and supply is a further major advantage that makes Halar the material of choice for high demanding applications in the corrosion protection field.

TYPICAL APPLICATIONS

Halar powder coatings are employed as corrosion protection coatings in the chemical process, pulp and paper, pharmaceutical, food processing, and semiconductor industries. Halar is recommended when the part being coated will be used for handling of strong acids and strong bases at temperatures at which other plastics cannot be used, and where corrosion resistant metals would be attacked or become too expensive.

Halar is particularly used in the Chemical Process Industry (CPI) as a powder coating material for universal corrosion protection. Typical applications include coating of vessels, reactors, piping systems, pumps, valves, centrifuges, agitators, impellers, hoods, filters, sieve plates, caustic collectors, electroplating equipments, storage tanks and ductworks. Halar powder coated process components have been successfully put into operation, in some cases, for many years.

Since 1990 Halar coating is used on exhaust ducts in semiconductor fabs thanks to excellent combination of chemical and fire resistance. Today Halar ECTFE is part of hundreds of duct system installations in tens of plants all over the world.

Halar is also recommended for high purity fluid systems in semiconductor, pharmaceutical and biotech industries, particularly where the process surface must be smooth, chemically inert and resistant to bio-fouling. Thanks its superior purity, Halar does not contribute to contamination, prevents corrosion and protects the quality of the products being produced. Halar powder coatings are so smooth that a study measured lower biofilm growth (organic surface film) than on electro-polished stainless steel surfaces.
For these reasons, Halar powder coatings are effectively used for Ultra Pure Water handling too.

CHEMICAL RESISTANCE

Halar shows excellent chemical resistance and exceptional barrier properties over a wide range of temperatures.

Nowadays Halar is unanimously accepted and acknowledged as top-performance coating for universal corrosion control (pH 1-14).

Halar is hydrophobic (no influence of water and moisture) and virtually unaffected by most harsh chemicals commonly encountered in the industry today. Among those substances that Halar fluoropolymer is resistant to are strong mineral and oxidizing acids, alkalis, metal etchants, liquid oxygen and most organic solvents.

Furthermore, it exhibits outstanding exterior durability (stability to UV light and weather) and resistance to high energy radiation.

Typical of fluoropolymers, Halar is attacked by metallic sodium and potassium. Halar however is very resistant to sodium or potassium hydroxides, depending on exposure time and temperature.

Halar and other fluoropolymers can become slightly plasticized by contact with certain halogenated solvents, but this effect does not normally impair its usefulness.

Halar has found use in chlorine and chlorine dioxide scrubbers using strong sodium hydroxide solution, in desulfurization plants where high temperature resistance to SO_x is required, in metal pickling and plating tanks using chromic acid mixtures, in semiconductor work benches exposed to mineral acids & hydrogen peroxide mixtures, in the storage of concentrated sulfuric acid and in the manufacture of sodium chlorate.

Table 2. Chemical Resistance - ECTFE vs. ETFE comparison

Chemical	Concentration (% by weight)	T (°C)	Residence time (days)	ECTFE	
				Weight change (%)	Changes in mech. prop.
H_2SO_4	98	121	30	+0.7	I
HCl	37	121	30	+0.9	I
HF	50	121	30	+0.3	I
HNO_3	50	50	30	+0.1	I
H_2O_2	30	88	30	+0.1	I
Chlorine Water	sat. sol.	40	30	+0.7	I
NaClO	15	100	30	+0.1	I
NaOH	30	121	30	-0.1	I
TMAH	25	100	30	+0.6	I
Methanol	100	65	30	+0.5	I

Note: data obtained at atmospheric pressure by immersion of compression molded specimens according to ASTM D 543 specification for chemical testing of plastic materials
I = insignificant A = reduced 25-50% B = reduced 50-75%

HALAR GRADES

Halar topcoat grades

There are several grades of Halar fluoropolymer in powder form for use in powder coatings.
Generally, Halar 6014 is used to build final coating thicknesses from 0.2 mm to 1 mm.
Halar 6014F has a higher molecular weight and can be used to build over 1 mm of final coating thickness.

Property	HALAR 6014	HALAR 6014F
Melt Flow Index (g/10’ @ 275°C, 2.16 kg)	9 to 15	5 to 9
Melting Point (°C)	220 to 227	220 to 227
Typical Process Temperatures (°C)	260-280	260-280

Data not for specification purposes

Halar primer grades

Halar primer grades are applied prior to the topcoat. They can be deposited directly to substrates by electrostatic powder coating technique. Halar primer maximizes adhesion to substrate and helps to protect against lift-off even if the coating is damaged. Furthermore, Halar primer grades can hide any surface color variations or imperfections of the substrate underneath. Besides black, green and gray, other colors are virtually possible with an intermediate pigmented coat.

Data not for specification purposes

Property	HALAR 6614 (Green)	HALAR 6504 (Black)	HALAR 6914 (Gray)
Melt Flow Index (g/10’ @ 275°C, 2.16 kg)	9 to 15	9 to 15	5 to 9
Melting Point (ºC)	220 to 227	220 to 227	220 to 227
Filler Base	epoxy	mineral	mineral
Typical Process Temperatures (ºC)	260-280	260-280	260-280

Halar filled grades

Halar 9414 has been designed to offer improved resistance to permeation, specifically to water vapor.
Halar 3404DA is suitable for use in applications where food contact compliance is required.
They can be applied directly on grit-blasted substrates primerless.

Property	HALAR 9414 (Off-white)	HALAR 3404DA (Off-white)
Melt flow index (g/10 min @ 275°C, 2.16 kg)	1	2
Melting Point (ºC)	240 to 245	240 to 245
Filler Base	mineral	mineral
Typical Process Temperatures (ºC)	250-265	250-265

Data not for specification purposes

HALAR COATING ADHESION

Several ASTM test methods describe adhesion testing between different materials.
In the Table below, a collection of ASTM methods is listed for reference.

Test method	Description
ASTM D 903	180°peeling (one rigid layer and one flexible)
ASTM D 1876	T-peel between two flexible layers
ASTM D 3807	Two layer 'Sandwich' type test for semi-flexible layers
ASTM D 3528	Three layer 'Sandwich' type with shear test
ASTM D 3163	Two layer 'Sandwich' type with shear stress
ASTM D 3167	Floating roller (one rigid and one flexible with fixed angle)
ASTM D 1781	Climbing drum (one rigid and one flexible with angle=roll radius)
ASTM D 429, method E	90° peeling (flexible on rigid)
ASTM D 897	-

Strip peel test has been used according to an internal procedure by applying a constant rate loading to a specimen (see Figure 1) in order to measure adhesion strength of Halar coatings with the following assumptions.

- Material is linearly elastic.
- The geometry, and therefore, the energy stored within the region of large bending, does not change with peeled length.
- Debond lengths are long enough so that a portion of the peel specimen has no curvature.
- The base plate is mechanically rigid (no energy is stored in the plate itself).

The coated part is horizontally fixed with a vice. Two parallel lines are traced with a cutter, at a distance of 10 to 15 mm. (This distance is indicated as "W" in Figure 1).
An edge of this stripe is lifted from the substrate with a cutter first and then with a chisel. As soon as a 10 mm edge is raised, this free portion of the stripe is fixed with a clamp. The clamp is connected to a dynamometer and pulled with an angle of 90° (see Figure 1).
The highest adhesion is reached when it is not possible to peel off the coating from the substrate without breaking it (film rupture).

PLEASE NOTE: It is important to take into account that this test is destructive. In general, damaged or scratch areas on the coating can be repaired. Of course, the smaller the peeled or cut area, the easier the repair will be. If the damaged surface exceeds a certain area, the whole part will need to be recoated.

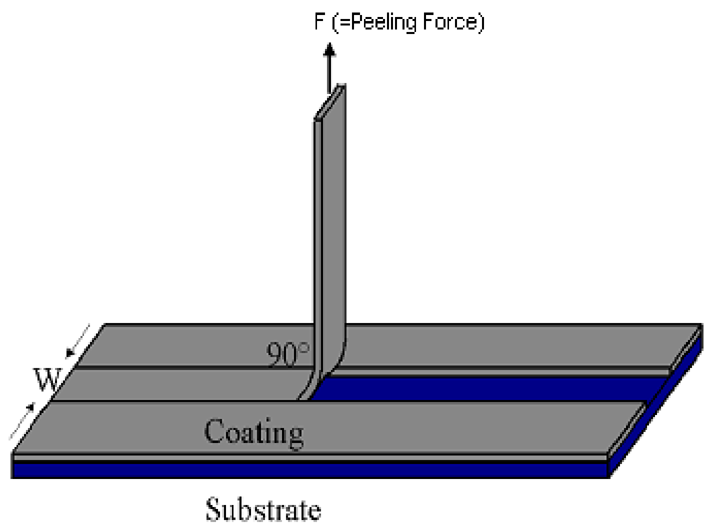


Figure 1. Peel test

Adhesion Development

Halar powder coatings are designed to consistently develop excellent adhesion on substrates of different kinds.
When proper conditions are adopted, the bond strength which is achieved between the substrate and the Halar coating (correctly applied) is so high that is well in excess of the tensile strength of the polymer itself.

There is anyway a variety of experimental factors affecting the actual adhesion strength between a coating and a substrate in general.

Adequate substrate preparation before coating is always imperative for best results.

It is prerequisite to bake the Halar coating at an adequate temperature for a sufficient period of time.

To show how Halar powders develop adhesion on a metal substrate, stainless steel plates were preheated to 290°C, sprayed with Halar primer and Halar topcoat (without primer) and baked at 275°C for a given period of time. Figure 2 shows the adhesion formation profiles at these processing conditions. Suitable residence time at a given oven temperature must be granted to achieve optimum adhesion. At these conditions, the peel strength will then exceed the tensile strength of the Halar coating. Halar primer begins to develop its initial adhesion before Halar topcoat without primer. The use of a primer is also beneficial to secure best adhesion of Halar coatings for long term service and/or under harsh environment conditions.

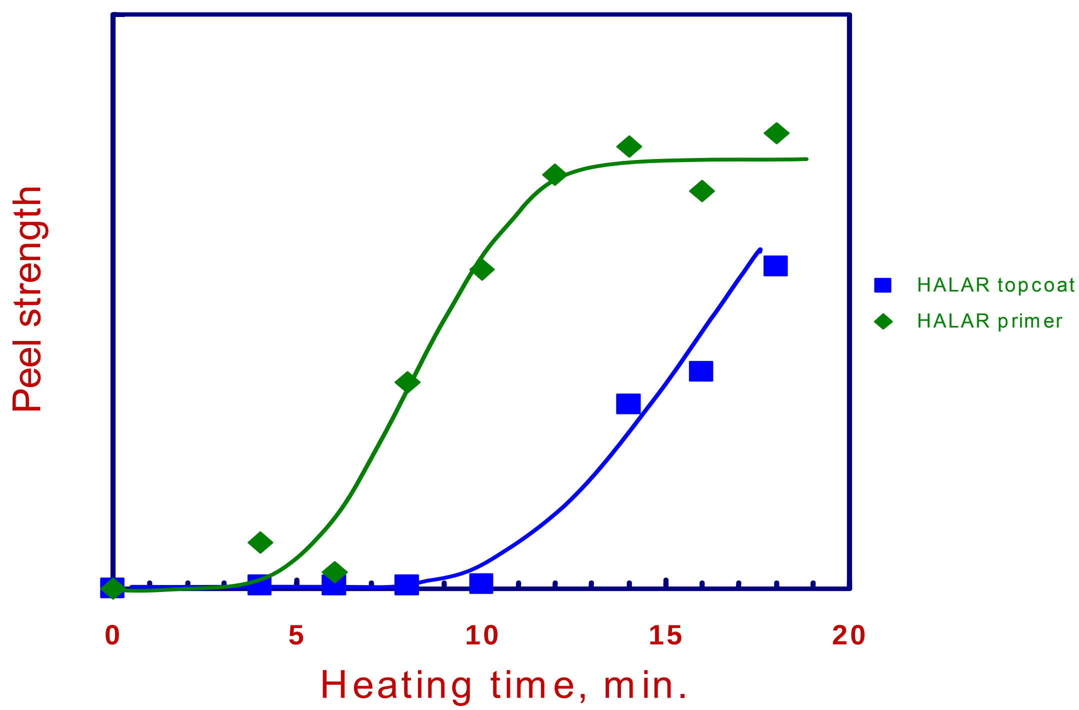


Figure 2. 90° Peel; Speed: 2.5 cm/min.; Preheating: 290°C; Bake: 275°C. Film thickness: 0.25mm

HALAR vs. ETFE PROPERTIES

Some of the advantages of Halar fluoropolymer over other coating materials are listed below.

Halar:

- is mainly applied by electrostatic powder coating technique.
- can also be applied by fluidized bed dip coating technique.
- demonstrates excellent corrosion protection - not attacked by strong acids, bases, and other inorganic chemicals.
- provides tough, hard coatings with good abrasion resistance and excellent impact strength.
- exhibits low thermal expansion characteristics.
- shows optimum surface properties (non-stick, low contact angle and surface tension).
- gives superior fire safety (V-0 rated , LOI of 60).
- is resistant to high energy radiation.

A detailed comparison of Halar vs. ETFE is given in Table 3.

Table 3. Halar vs. ETFE properties comparison

Properties	HALAR	ETFE
Specific Gravity	1.68	1.70-1.72
Max Continuous Service Temperature (ºC)	150	150
Typical Process Temperature (°C)	250-280	280-320
Linear Temperature Expansion Coeff. (10^{-5}/ºC)	8	10-13
Flexural Modulus ASTM D 790 (MPa @ 22°C)	1700	900-1200
Tensile Modulus ASTM D 638 (MPa @ 22°C)	1700	490-1300
Yield Stress ASTM D 638 (MPa @ 22°C)	32	14-22
Tensile Strength ASTM D 638 (MPa @ 22°C)	48	39-43
Rockwell Hardness ASTM D 785	R90	R50
Shore Hardness ASTM D 2240	D75	D61-67

Properties	HALAR	ETFE
Flammability	V-0	V-0
UL-94	Halar ECTFE has received a UL 94 V-0 rating in thicknesses as low as 0.18 mm, making it superior to ETFE which receives a V-0 rating in thickness only as low as 1.6 mm	
Oxygen Index	60	30-50
ASTM D 2863(%)	Limiting Oxygen Index is a measure of flame retardant property and ease of extinction. The higher the percentage, the lower the flame spread and smoke generation.	
Volume Resistivity ASTM D 257 (ohm.cm)	10^{16}	10^{17}
Dielectric Constant		
at 1 kHz	2.5	2.6
at 1 MHz	2.5	2.6
at 60 Hz	2.6	2.6
Dielectric Strength (kV/mm , 3 mm thick)	14.5	14.5
Dissipation Factor		
at 1 kHz	0.002	0.0008
at 1 MHz	0.009	0.005
at 60 Hz	0.0009	0.0007
Water Absorption ASTM D 570 (%)	<0.01	0.03
Permeability (cm^3(STP)·mm/m^2·atm·24h·10^2)		
O_2 @ 25°C	0.2	0.7
N_2 @ 25°C	0.1	0.2
H_2O(vapour) @ 25°C	7.5	98
Permeability (g·mm/m^2·24h)		
HCl 37% @ 50°C	0.5	1.7
Methanol @ 50°C	0.3	1.2
H_2O(liq.) @ 50°C	0.5	1.6
Low Temperature Embrit. ASTM D 746 (ºC)	<-76	<-100
IZOD Impact Strength (J/m @ 25ºC, notched)	no break	no break
Pencil Hardness ASTM D 3363	4B	6B

HALAR POWDER COATING TECHNIQUE

Design Considerations

In designing any object which is to be given a protective coating, the final specified coating system to be used should be taken into consideration. First of all, size of the part to coat is limited by oven of the applicator. Then, whenever possible, the object should be designed so that the desired protection of the base material can be achieved with maximum processing ease and efficiency. The following factors should be considered.

Halar fluoropolymer is unique in that it can be applied to a broad range of substrates. Halar powders can be used to coat essentially any material that can withstand the processing temperatures of 260-290°C.
A deep knowledge of the composition of the substrate and the condition of the surfaces before coating is anyway indispensable since it determines maximum preheat temperature and thermal expansion characteristics. Dimensional and thermal stability of the substrate at the bake temperature of Halar is a prerequisite.

Sharp corners may cause thinning out on outside corners and the possibility of pull-out on inside corners. Each sharp edge and corner should be radiused as much as possible to allow the coating to fully cover the whole surface of the substrate. Wherever practicable, minimum radius of 6 mm (R6) is recommended. Similarly, all sharp protrusions should be removed or rounded. Welds should be smooth, even and free from spatters.

Accurate design consideration must be given to provide accessibility to all surfaces to be coated. When large parts and vessels in particular are to be electrostatically powder coated, the design should necessarily accommodate access for coating. All powder coatings have trouble penetrating deep depressions. Complex shapes, deep depressions, voids or holes should all be avoided or redesigned to allow successful electrostatic powder coating operation.

Equipment needed for coating

- Air circulating oven capable of maintaining ± 5ºC throughout the oven.
  The size of the oven is not critical except that it should be selected based on the size of the parts intended to be coated.

- Blasting equipment.
  White metal finish by NACE standards with 0.075-0.10 mm profile required on parts that are to be coated. Abrasive materials like 60 mesh corundum Al_2O_3 or carborundum SiC are recommended.

- Electrostatic power coating equipment consisting of a) spray booth grounded for electrostatic powder deposition, b) powder dispensing equipment, c) electrostatic spray gun manually settable.
  Hyflon powder coatings can be used in conventional electrostatic coating equipment either in manual or automatic powder spray booths utilizing a negative Corona charge gun. In any case, it is recommended to make use of electrostatic coating apparatus which consents the manual configuration of the process parameters (voltage and amperage setting in particular).

- Superb housekeeping to avoid cross contamination of coating materials.

Substrate preparation

It is always essential to undertake an excellent process of pretreatment of the surfaces to be coated.
There are a number of options to the type and extent of the pretreatment operation.
The selection and intensity of surface preparation prior to coating will be closely related to the nature (and the original state) of the substrate.
All of the following prefinishing steps should be followed to obtain best possible adhesion and corrosion resistance.

Previous coatings, greases, oils and other deposits should be removed. These can be burned off at sufficiently high temperatures without harming the part to be coated.

Porous castings should be heated to 400°C for several hours to drive off any entrapped gases that could cause the formation of pinholes or gas pockets in the coating.

All surfaces to be coated must then be thoroughly roughened by abrasion.
Mill scale and other oxides should be completely removed by abrasion to a White metal NACE No.1 / SSPC-SP5 “White Metal Blast Cleaning” finish. Grit blasting should be performed also to remove all dirt, rust, mill scale or other foreign material or residue. Clean abrasive is required.
Grit-blasting or abrasion is imperative to obtain good adhesion of thick coatings. In fact, high surface roughness increases the effective surface area and enhances the mechanical anchoring which keeps the coating well bonded to the substrate. Grit-blasting with aluminum oxide or silicon carbide of 16 mesh can be used. An Ra profile of minimum 10 micron is recommended as a rule (minimum 50 micron peak-to-valley).
Residual dust from blasting and abrasion should be then blown off with clean, dry air. A light cleaning with a solvent should be given as the final preparation step. Alternatively, light cleaning with a chlorinated solvent and clean rag can be used. All possible care should be taken to avoid deposition of lint onto the part. Do not use paper towels.
Following cleaning, all surfaces should be handled only by means of clean gloves or tongs. Parts should be coated immediately.

Preheating

Typically Halar powders are applied on the hot substrate (hot-flocking process).

There is relatively poor heat transfer between a gas (air) and a solid (metal parts, carbon steel or stainless) despite the usage of an air circulating oven. Therefore it should not be a surprise that parts 15-mm thick and over may take several hours to uniformly come close to oven temperature.

The part being coated with Halar has to be preheated in the oven for a sufficiently long time to obtain a uniform part temperature of 260-290°C. Selection of the exact part surface temperature will depend upon the thermal mass, size and geometry of the part. Small thin parts should be at higher temperature since they will cool more quickly. Also the preheating time of the bare substrate prior to the Halar primer or topcoat deposition is a function of thermal inertia of the part (directly related to the thickness).

Primer Application

The Halar primer is applied on hot preheated surfaces using normal electrostatic powder coating technique. In this case, 75-150 micron thick coating of the primer can be obtained in a single coat. It is important that the whole surface is thoroughly covered with the primer. Consider that the primer is not intended to increase the overall coating thickness.

1. After preheating, take the part out of oven.

2. Apply immediately an even coat of Halar primer to the grounded part, while still hot, using a suitable electrostatic spray gun.

For the application of Halar powders it is recommended to use of an electrostatic corona gun manually settable. Typical gun voltage and amperage are in the range of 30-50 kV (negative) and 20-25 µA, respectively.
Coating thickness of the Halar primer can be obtained in the range of 75-150 micron with a single coat.
It is important to spray equal amount of powder on both thick and thin substrate areas.

3. The primer coat should be baked in the oven at 260º-280ºC substrate surface temperature for a sufficient time to achieve optimum adhesion.

During spraying, on thick parts with large heat storage capacity, the Halar powder will progressively keep melting for some time whereas on thin areas the Halar powder will remain white (unmelted powder), much sooner. For the same reason, inside the oven, thin sections will heat up quicker and therefore locally the Halar material will undergo a higher thermal load. As a result, for complex parts with thin and thick sections, residence time and oven temperature shall both be fine tuned merely to avoid long temperature exposure of Halar and thus eliminating the possible onset of polymer degradation. Conversely, too short oven times may result in poor coating quality (rough surface, low adhesion, etc.).

The primer coat may not flow out into a smooth glossy liquid coating. Usually, it bakes as a uniform, dull coating that may be rough and strongly adhering to the substrate. The uniformity of the dull color, more than gloss, is a good indication that the Halar primer has been baked appropriately. A rougher surface provides an excellent means of promoting adhesion between the Halar primer and the topcoat.

If two powder pots and one or two electrostatic spray guns are available, then it is possible to apply Halar topcoat directly after the Halar primer deposition. Due to the heat and the charge on the part, the white powder will adhere and flow out. Spraying of the Halar powder should be stopped when the part is lightly covered with white powder. Care should be taken to ensure that excess powder is not applied since bubbles of air may be trapped within the coating. In addition, the topcoat powder acts as an indicator of when the primer is properly cured. When the Halar topcoat powder melts into a glossy surface the primer is fully baked.

Topcoat Application

Topcoats of Halar fluoropolymer should be applied to hot parts immediately after the primer is fully baked, using normal electrostatic powder coating technique.

1. Apply Halar topcoat evenly until the surface is covered with white Halar powder.

As before, it is recommended to make use of an electrostatic corona gun manually settable. Typical gun voltage and amperage are in the range of 30-50 kV (negative) and 20-25 µA, respectively. When coating thick parts with large heat storage capacity, the Halar powder will progressively keep melting for some time whereas on thin areas the Halar powder will remain white (unmelted powder), much sooner. Still, it is important to spray equal amount of powder on both thick and thin substrate areas.

2. Flow out the topcoat in the oven at 260-280ºC substrate surface temperature.

The time required to flow out the Halar powder into a uniform glossy fluid coat will depend upon the thermal mass, size and shape of the part as well as the oven temperature.
Proper flow out is indicated in the oven by a wet glossy surface with no orange peel appearance.

Also the temperature recommendations will vary with part mass and geometry. The most important consideration is to use the lowest practical temperature and shortest oven cycle time at that temperature.

High gloss coatings are best made at higher temperature (270-290°C) and shorter time; but this depends again on the design of the substrate.

Nevertheless, it is not advisable to use too high oven temperature as some portions of the part may heat up faster than others and lead to problems of pull back, dripping or even degradation. Hot and cold spots in the oven can also lead to such problems especially if too high oven temperatures are used.

4. Following the above instructions, subsequent topcoats should be deposited to hot part as soon as the previous coat flows out to a glossy surface.

   Coating thickness of the Halar topcoat can be obtained in the range of 150-250 micron with each coat. The final coating thickness will depend upon the service conditions and environments the coated part is meant for. Recommended final thickness to provide the widest chemical and permeation resistance for anticorrosion coating is 800-1000 micron.

   Depending on the size of the part and the residence time in the oven, the temperature may be decreased by 10°C for every successive coat but the oven temperature should not be below 260°C.

5. After flowing out the final topcoat, take the part outside the oven and allow it to cool uniformly, especially for parts of large thermal mass, in a clean area at ambient temperature.

Quenching in water or rapid air cooling with a fan is not recommended since either process will result in thinning of the polymer on outside corners and possible pull-out on inside corners. Halar primer is effective in reducing these problems.

To avoid sagging and dripping, which will be cause of irregular coating thickness, it is suggested to rotate the piece starting at least after the third coat. If it is not technically possible to make the piece rotate continuously inside the oven, it is suggested to give a 90° rotation (1/4 round) at each coat, starting at least from the third one. Of course, the rotation system depends on many factors, as geometry, weight and position of the piece, which must be all taken into account.

Extended oven cycles and extreme temperature cycles (e.g. cooling to room temperature between coats) wastes energy and leads to poor coatings. A Halar coating job once started should not be interrupted. Re-heating from room temperature will put too much additional thermal stress on the already deposited Halar (primer or topcoat) with again risk of degradation of the polymer.

PROCESS STEPS FOR ELECTROSTATING COATING WITH HALAR

1. Degrease the part to be coated with a suitable solvent or thermally treat it at 350-400°C for some hours. Porous castings should be heated to 400°C for several hours to drive off any entrapped gases that could cause the formation of pinholes or gas pockets in the coating.

2. Roughen the surfaces to be coated by abrasion. Recommended profile depth is 0.05 mm minimum. Grit blasting should be performed also to remove all dirt, rust, mill scale or other foreign material or residue. Any residual dust should then be removed with clean, dry compressed air.

3. Preheat the part to 260-290ºC.

4. While the part is still hot, apply the Halar primer using an electrostatic powder gun with voltage of 30-50 kV (negative) and amperage of 20-25 µA.

5. Bake the Halar primer by heating in the oven at 260-280ºC. In all cases the Halar fluoropolymer should be left in the oven only for sufficient time to fully fuse the coating. Longer time at high temperatures increases the possibility of degradation, sagging and dripping.

6. Take the part out of the oven and while still hot apply Halar topcoat using an electrostatic gun with voltage of 30-50 kV (negative) and amperage of 20-25 µA.

7. Bake the Halar topcoat by heating in the oven at 260-280ºC. In all cases the Halar fluoropolymer should be left in the oven only for sufficient time to fully fuse the coating. Longer time at high temperatures increases the possibility of degradation, sagging and dripping.

8. Repeat topcoat deposition and flow out (150-250 micron per coat depending on the part) until desired final thickness is achieved. Under the conditions described above, five to six coats (1 primer + 4/5 topcoats) should allow at least 1 mm thickness all over the surface.

9. Following the final flow out step, the part should be air cooled.

PIGMENTATION

Halar fluoropolymer is supplied in various powder grades as an unpigmented powder.

Coloring of Halar fluoropolymer can be accomplished on purpose incorporating thermally stable compatible pigments into the Halar powder by dry-blending prior to spray coating process.

The required pigment concentration normally is in the range of 0.25-0.50% but can vary with coating thickness and the desired level of color intensity.

The pigmented Halar powder is generally applied as intermediate coat(s) directly over the Halar primer. Clear Halar topcoat is then used to complete the final coating construction and obtain the desired thickness.

TESTING

The performance of Halar coatings is dependent upon substrate pretreatment, primer system, adhesion, thickness, and continuity of the Halar film. Continuity and thickness should be checked on all Halar coatings. Since knife-adhesion tests are destructive, they should be performed on test pieces not intended for actual end-use. A magnetic gauge requiring no external power source may be used to determine the coating thickness on parts of most geometrical shapes. Where a source of AC current is available, thickness gauges that require power may be used on non-magnetic metal parts.

Halar coatings are mainly used to protect metal surfaces from highly corrosive environments. Consequently, no flaws or pinholes can be tolerated. Continuity tests on coatings should be made at a voltage potential of 7 kV for coatings of about 1 mm, using a regulated DC tester.
Different thickness shall require different test voltage setting. Voltages that are too high may burn holes in a coating that is thick enough to give good performance. It’s known that repeated applications of high voltage electrical field can induce polarization phenomena in the coating, which can significantly affect the electrical properties of the material. The consequence may be that repeated applications of the high voltage probe may lead to spark tests failures even without the presence of pores or pinholes. So it is recommended that the coating is submitted to the minimum number of spark testing. Furthermore, soft brush must be used for testing in order to minimize the risk of scratching or damaging the coating during testing.

Therefore, to anyone without coating experience it is recommended to verify the quality of the applied coatings, carrying out the following tests on flat plates (e.g. 100 x 100 x 3 mm carbon steel) coated on one side:

a. **Appearance** - should have a smooth appearance with no blisters, bubbles or sagging.

b. **Uniformity** - coating thickness should be as uniform as possible.

c. **Continuity** - spark testing should be performed to find pinholes in the coating (there should be none). Apply 7 kV DC per 800-1000 micron thick coating.

d. **Adhesion** - optimum adhesion is achieved when it is not possible to peel off the coating from the substrate without breaking it.

THICKNESS CORRECTION

If the part (or a limited surface of the part) does not have the required final thickness:

1. clean the part with clean rag and solvent and heat it in the oven at 200°C until the part reaches oven temperature.

2. set the oven at 240°C and leave the part until it reaches this actual temperature.

3. heat the part at the desired process temperature for the normal coating procedure (see Figure 3); in any case, it is suggested to remain on the lower end of the temperature range (close to 260°C)

4. apply the powder on the area with the lower coating thickness, then bake it in the oven until a smooth and glossy surface is reached on the whole part.

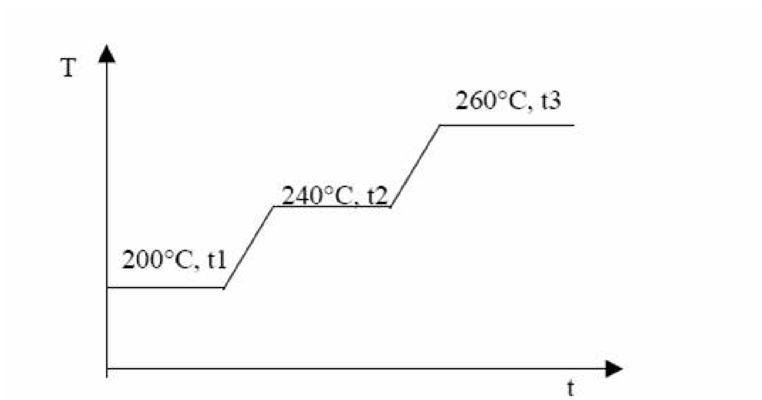


Figure 3.

PATCHING

When localized repairs or modifications are required (e.g. after identification and isolation of a pinhole accomplished by the spark testing process) it is suggested to apply locally a Halar film as a patch. The use of a Halar rod is also practicable.
It is possible to obtain a clear Halar film of the desired thickness by applying Halar topcoat without primer on a smooth flat substrate (e.g. glass) and subsequently removing the film from the substrate. The procedure is the following.

1. Lightly scratch the coating in the area being repaired by means of sand paper.

2. Clean the surface from any trace of dirt, dust, grease, oil or any other kind of external contamination.

3. Apply a Halar film on the area to be repaired. The film can be fused using hot air gun (T≈ 350°C) and kept pressed on the area of repair, by using for example an Algoflon® PTFE impregnated glass fabric, in order to achieve the suitable adhesion between the film and the coating.

4. After the area has cooled down to room temperature, the integrity of the coating shall be checked once again only locally in the repaired area by spark testing.

In case it is be necessary to repair blisters or entrapped contaminations, it is better, when possible, to remove the damaged coating area by scratching it off before applying the Halar film.
This procedure must not be used to repair Halar coatings when the damaged area is too wide or severely impaired.

PART RECOVERY

If the coating is poor and not satisfactory, Halar coating can be stripped off and the part can be recovered in the following way.

5. Place the coated part in an oven (with adequate outside exhaust venting) above 400°C. Place a shallow pan under the Halar coated part.

6. Heat the part and allow the main portion of the Halar coating to melt and drip off the part and into the pan underneath.

7. Remove the pan containing the melted Halar from the oven.

8. Allow the part to remain in the oven approximately four hours or until the Halar fluoropolymer is reduced to a char.

9. Remove the char by wire brushing.

10. Recoat by following the standard procedure described above.

Caution: the thermal degradation products of Halar fluoropolymer include HCl and HF gas. Inhalation of these gas should be avoided since they are materials which can endanger human health. In areas where fluoropolymers are heated above 260°C, adequate ventilation to the outside is recommended. Exhausted oven is also recommended to prevent risk of fume inhalation for the people working near the oven.

SAFETY AND TOXICOLOGY

Before using Halar powders consult the product Material Safety Data Sheet and follow all label directions and handling precautions. Please contact Solvay Solexis for a copy.

Please read the “Guide to the Safe Handling of Fluoropolymers Resins” published by the Fluoropolymers Division of The Society of the Plastics Industry and Solexis Material Safety Data Sheet (MSDS) prior to handling or processing any Halar grade.

See MSDS also for detailed advice on waste disposal methods.

As with all polymer materials exposed to high temperatures, good safety practice requires the use of adequate ventilation when processing Halar. Ventilation should be provided to prevent exposure to fumes and gases that may be generated. Excessive heating may produce fumes and gases that are irritating or toxic.

STORAGE OF HALAR PRIMER AND TOPCOAT

The primer and topcoat should be stored in a dry cool place, preferably at temperatures not exceeding room temperature. An air-conditioned room or a refrigerator is adequate. Storing the primer in a freezer will not impair its performance.

In all cases, the Halar powders should be allowed to come to room temperature slowly to prevent moisture condensation before use.

Caution: no edibles should be stored in the refrigerator or the freezer when the Halar primer or other chemicals are also stored. The usual precautions for safe storage and handling of Halar powders must be enforced according to Material Safety Data Sheet and experience.

TROUBLE SHOOTING

Indicated Problem	Causes	Recommended Solutions
1. Thin Coating	1. Low application voltage	1. Use higher voltage
	2. Low substrate temperature	2. Preheat (further) the substrate
	3. Poor ground	3. Check part ground
2. Poor finish (rough coating appearance)	1. Too thin coating	1. Increase coating thickness by applying additional topcoat layers
	2. Improper flow out conditions	2. Increase flow out time and/or oven temperature
3. Poor adhesion	1. Failure to use primer	1. Use Halar primer
	2. Improper flow out conditions	2. Increase flow out time and/or oven temperature
	3. Inadequate surface treatment	3. Treat the surface properly by following the suggested procedure of pretreatment
	3.1 Presence of rust or grease	3.1 Degrease grit-blast the part to remove surface contaminants
	3.2 Too smooth surface after grit- blasting	3.2 Grit-blast again with coarser grit
4. Poor edge coverage, pull-out on inside corners	1. Sharp edges or corners	1. Radius all edges and corners (minimum recommended radius is 6 mm)
	2. Too rapid cooling after flow out	2. Quenching or rapid air cooling with a fan are not recommended
5. Pinholes in the coating	1. Porous substrate evolving gases at flow out temperature	1. Degas substrate by heating it for several hours at a temperature well above processing temperatures (350 - 400°C)
	2. Inadequate surface treatment	2. Grit-blast properly to remove surface contaminants
	3. Too high flow out temperature	3. Decrease flow out temperature
	4. Use of wet and/or oil contaminated air to deposit powder	4. Clean dry air must be used. Water or oil will cause bubbles in Halar coating
	5. Very rough, pitted substrate part	5. Remove major surface irregularities prior to grit-blasting

Indicated Problem	Causes	Recommended Solutions
6. Bubbles in coating on substrate surface - coating color beige to dark brown	1. Polymer degradation due to improper flow out conditions	1. Decrease flow out temperature and/or flow out time
7. Ripples in coating, material sagging and dripping	1. Improper flow out conditions	1.a. Decrease oven temperature and/or time in oven 1.b. Rotate part after each hand, starting at least from the third hand 1.c. If part has large flat surfaces, position part so that the surfaces are horizontal

Locations

Solvay Solexis maintains its world headquarters in Italy. In other European countries as well as NAFTA, South America and Asia, Solvay Solexis representatives are based in local Solvay offices.

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