

TALAT Lecture 5204

Organic Coating of Aluminium

16 pages, 8 figures

Level: Advanced I

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Objectives:

- To describe the different steps of the coating process and to give information about the test methods
- To select organic coatings for the protection of aluminium or to achieve specific surface properties

Prerequisites:

- Knowledge of corrosion protection and surface pretreatments of aluminium
- TALAT Lectures 5101, 5102, 5201, 5202

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5204 Organic Coating of Aluminium

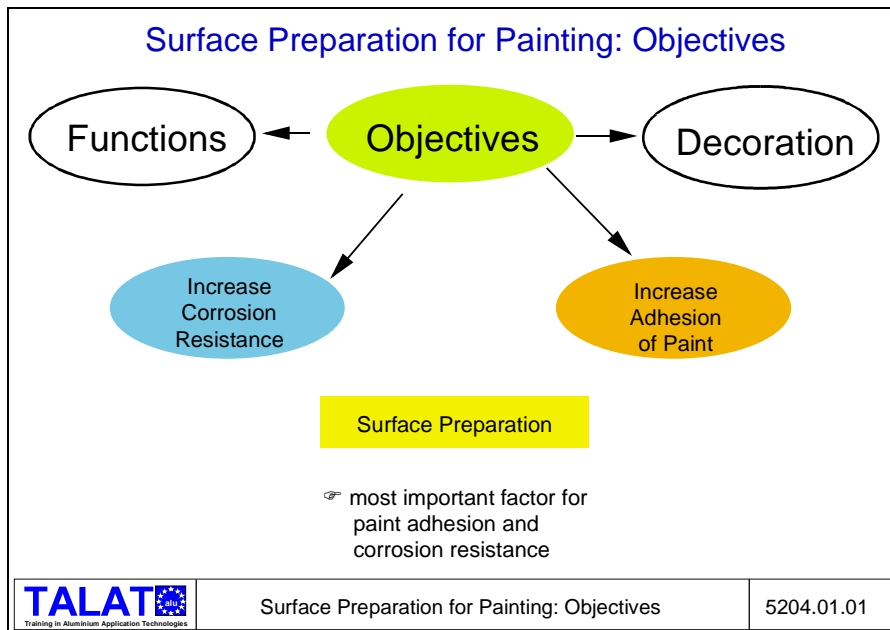
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5204.01 Reasons for Painting Aluminium

The main reasons for painting aluminium alloys are (**Figure 5204.01.01**)

- decoration (which includes colouring);
- resistance to corrosion
- several functional reasons, e.g.
 - tribology
 - solar radiation absorption
 - insulating against heat and electricity



5204.02 Terms and Definitions of Organic Coatings

The main components of paint and lacquers are binder, pigment and volatile solvents and thinners.

The binder is responsible for the coherence within the paint film and for its adherence to the substrate. Sometimes, if the binder is brittle a plasticizer is added.

The pigment is primarily responsible for colour and hiding power but it plays an important role for the physical properties of the film. In anti corrosion primers the pigments have inhibitive or rust preventing properties. In top paints the pigments are flake-like particles in order to increase the oxygen diffusion path.

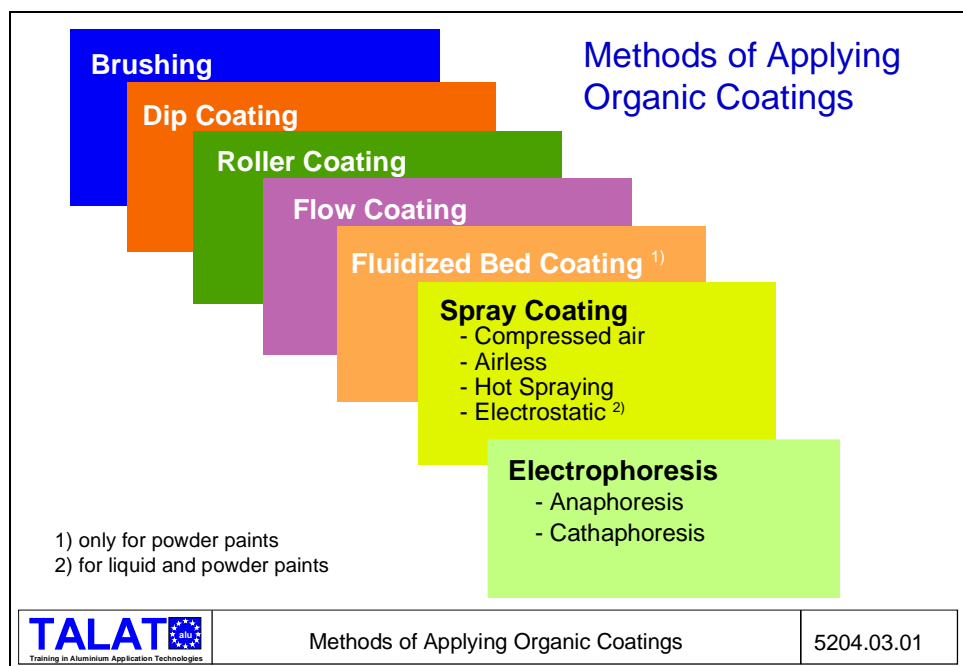
A solvent is used if the binder is a solid substance at ambient temperature. The solvent is of importance not only for the applicability of the paint but affects also adherence and other properties.

Thinner is a volatile liquid that is added to the paint to reduce its viscosity before application.

Lacquer contains a binder which consists of an organic film forming substance often dissolved in a solvent.

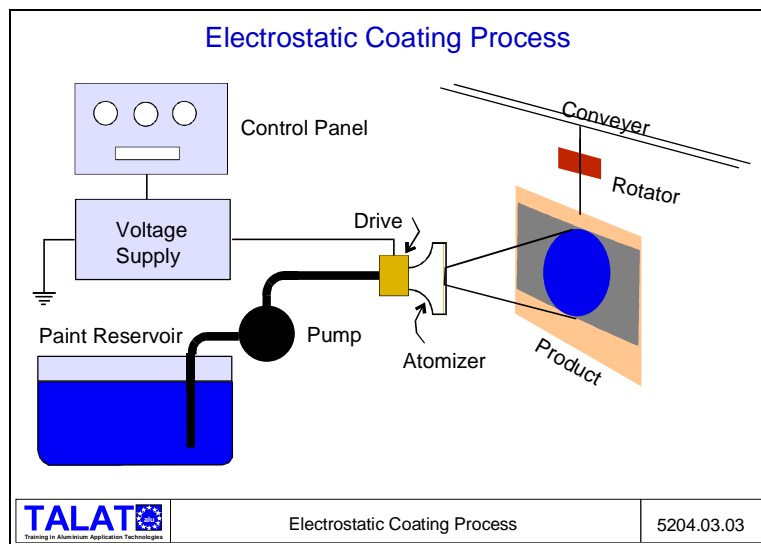
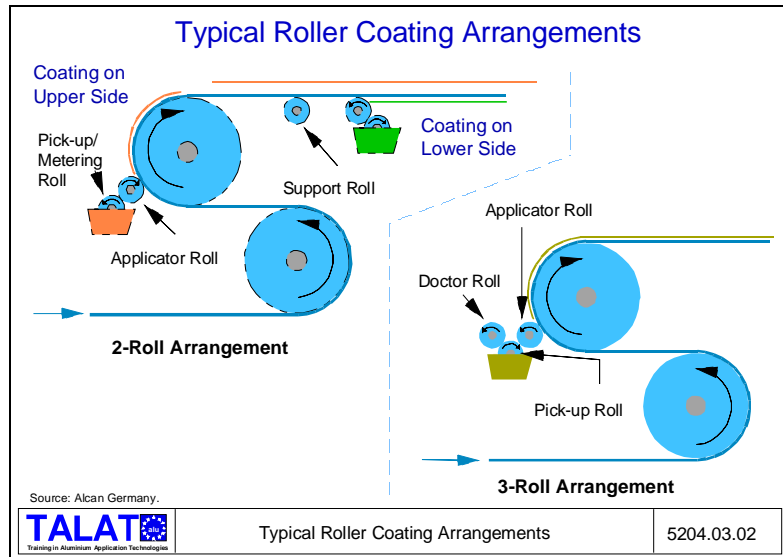
5204.03 Methods of Application

(Figure 5204.03.01)



The different methods of applying organic coatings are:

1. Brushing
2. Dip coating
3. Roller coating (**Figure 5204.03.02**)
4. Flow coating
5. Fluidized bed coating
6. Spray coating :
 - Compressed air
 - Airless
 - Hot spraying
 - Electrostatic (**Figure 5204.03.03**)
7. Electrophoresis



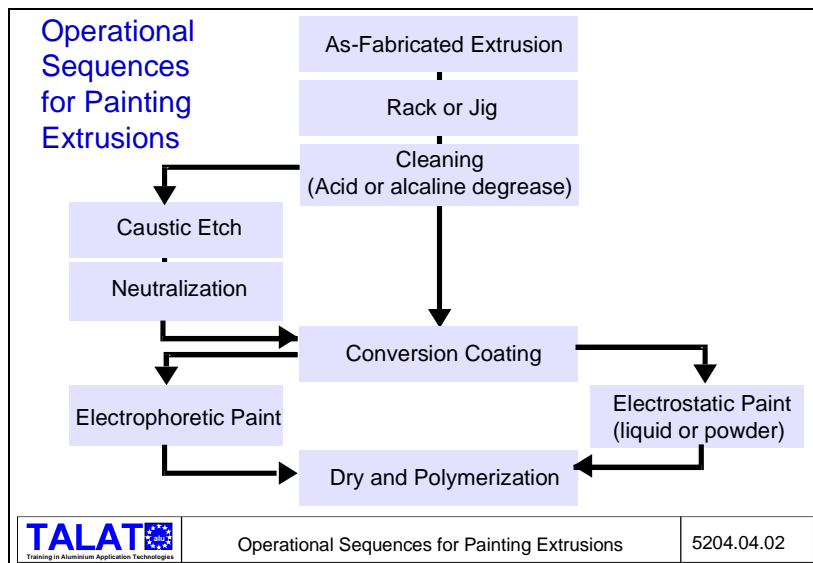
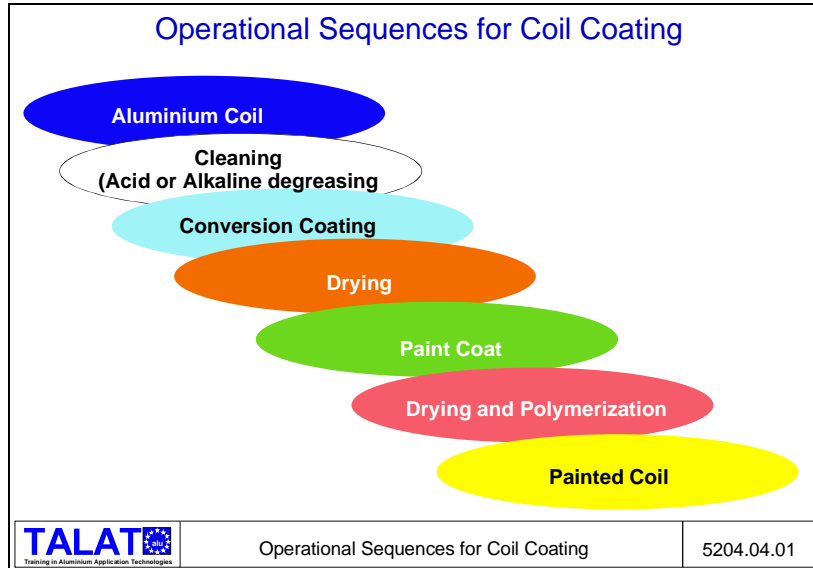
5204.04 Organic Coating Systems

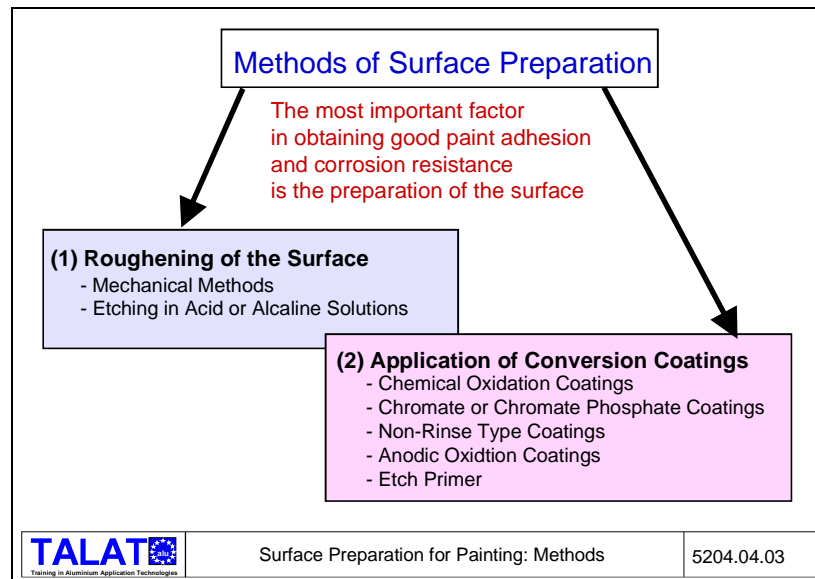
The operational sequences are : (Figures 5204.04.01, Figure 5201.04.02) :

- Surface preparation
 - Pretreatment for powder coating, paints and lacquers
 - Pretreatment for electrophoretic coatings
- Primer
- Finishing paints
 - Air drying coatings
 - Stoving finishes

Surface Preparation

The most important factor in obtaining good paint adhesion is the preparation of the surface (**Figure 5204.04.03**).





Various pretreatment systems have been discussed in **TALAT Lectures 5201 and 5202** but chemical conversion coatings are the most widely used form of pretreatment when painting of aluminium.

Aluminium can be pretreated with

- amorphous phosphates
- zinc phosphates
- chromating
- phosphochromating
- phosphofluozirconium coating

Pretreatment for Powder Coatings, Paints and Lacquers

No surface pretreatment other than chemical conversion coating (chromating or phosphochromating) according to DIN 50939 may be used for powder, paint and lacquer coatings. Fully deionized water must be used for the final rinse prior to coating. The conductivity of the dripping water must not exceed a maximum of 30 $\mu\text{S}/\text{m}$ at 20°C. The conducting power should only be measured for open sections and not for hollow sections. The last rinsing water dripping off is decisive for the calculation. Other methods of pretreatment may only be used with the Executive Committee's approval.

Pretreatment parts must not be stored for more than 16 hours. As a rule, they should be coated immediately after pretreatment. The risk of insufficient adhesion increases the longer the parts are stored.

The parts must never be stored in an atmosphere that is dusty and detrimental to them. Good atmospheric conditions must always be maintained in the storage area.

All workers handling pretreated parts must wear clean textile gloves to avoid

contamination of the surface.

The parts must be dried at the following temperatures :

yellow chromating : maximum 65°C
green chromating : maximum 85°C

Pretreatment for Electrophoretic Coatings

All parts to be coated must be cleaned by adapted treatment in an alkaline or acid solution.

The cleaned surfaces must be rinsed in fully deionized water with a maximum conductivity of 30 μS at 20°C prior to coating. The surface must be wettable with water.

The parts must be coated immediately.

Primer

The application of a first or primer coat is essential for all structural aluminium except that to be used under only mildly corrosive conditions. The primer is a bonding coat and its main properties are good adhesion and flexibility. It invariably contains metallic inhibitive pigments. Zinc chromate is by far the most popular pigment.

For less severe conditions, red iron oxide may be employed, while strontium, barium and calcium chromates are also useful in admixture with zinc chromate.

Finishing Paints

The technology of paint systems is an exceedingly complex subject which must be considered as being outside the scope of this course. There is a very wide range in the basic types of organic coating and these can also be used in various combinations to provide a virtually infinite variety of properties. The following is a brief list of the principal types of finishes used. In this field there is a very important and rapid evolution.

Air Drying Coatings

alkyd based finishes
 chlorinated rubber resins
 cellulose
 vinyl and acrylic polymers
 solution-type vinyl resins
 pigmented vinyl
 acrylics
 catalysed air drying coatings

Stoving Finishes

alkyd amines
 epoxy ester resins
 solution type epoxy resins
 vinyl resins
 plastisols
 organosols
 thermosetting acrylics
 polyester coatings
 silicone coatings
 polyamide imide polymers
 fluoropolymers


Figure 5204.04.04 gives a survey of the properties of various coating paints.

Relative Properties of Various Paints
 at a typical film thickness of 20 - 25 µm

Coating Type	Ease of Application	Stoving Conditions	Flexibility	Abrasion Resistance	Solvent Resistance	General Chemical Resistance	Chalking Resistance	Corrosion Protection	Dirt Retention	Cost
Acrylic	1	2	3	3	2	2	3	2	2	low
Silicone Acrylic	1	2	3	3	2	2	2	2	3	med
Exterior Alkyd	1	2	3	3	2	3	3	2	3	low
Polyester	3	2	2	3	2	2	3	2	2	low
Silicone Polyester 2)	2	3	3	2	2	2	2	2	5	med
Polyvinylidene Fluoride 1)	1	4	1	1	1	1	1	1	2	very high

1) Usually used with an epoxy primer
 2) May be used over a primer

1 = best
 5 = worst

 Training in Aluminium Application Technologies	Relative Properties of Various Paints	5204.04.04
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Top Coats

1. **Cellulosics:** nitrocellulose, cellulose acetate and cellulose acetate butyrate
2. **Alkyds:** straight drying oil modified phthallic anhydride types, or acrylic-modified
3. **Acrylic lacquers**
4. **Chlorinated rubber**
5. **Vinyls:** solution vinyls and vinyl-acrylic combinations
6. **Catalyzed epoxies, polyurethanes and polyesters.**

The trend today in product finishes in mass production is to use these coatings for postpainting in the following sequence of popularity, and for the purpose indicated:

- **Amine-alkyd:** this is the lowest cost and most popular type
- **Acrylic enamel** (thermosetting acrylic): also very popular for automotive and general use
- **Polymethane** (PUR): high mechanical and chemical resistance
- **Polyesters:** these are in reality oil-free alkyds. Good for severe exposure to salt atmospheres, soap, etc. Popular in appliance finishes.
- **Epoxy lacquers:** very good adhesion
- **Silicone:** modified alkyds, acrylic and polyesters. Very high performance on most properties

Powder Coatings on Aluminium for Architectural Applications

Thermoplastic powders:

polyethylene	(PE)
polyvinylchloride	(PVC)
polyamide(PA)	

Thermosetting powders:

epoxy powder	(EP)
acrylic powder	
polyurethane powder	(PUR)
polyester powder	(PES)

5204.05 Quality Control of Finished Products

- Test Methods
- Specifications for coating

Test Methods

Gloss	
Thickness of coating	ISO 2360
Adhesion	ISO 2409
Buchholz indentation	ISO 2815
Cupping test	ISO 1520
Resistance to cracking on bending	ISO 1519
Impact test (for powder coating only)	ECCA T5 with 2.5 Nm.
Kesternich test	ISO 3231 (0.2 l of SO ₂ - 24 cycles)
Acid salt spray test	ISO 3769 (1.000 hours)
Machu test (Short-time corrosion test)	
Artificial weathering and radiation of coatings (DIN 53231)	
Weathering test	
Polymerisation test (for paints and lacquers only)	
Resistance to mortar	
Resistance to boiling water	
Condensed water constant atmosphere	(DIN 50017)
Solvent test	

Certain tests may be carried out on the finished products themselves but the full range of tests must be performed on test panels processed concurrently with a production batch.

The test panels must be made of the alloy AA 5005 H 24 0.8 mm thick (AlMg1 1/2-hard) unless otherwise approved by the Technical Committee. If this thickness is not obtainable, test panels with a thickness of 1 mm may also be used.

Tests using chemicals and corrosion tests should preferably be performed on extruded plates in AA 6060 (AlMgSi 0.5).

- Gloss

ISO 2813 using incident light at 60° to the normal.

Note : if the significant surface is too small or unsuitable for the gloss to be measured with the gloss meter, the gloss should be compared visually with the reference sample (from the same viewing angle).

Category 1 :	0	-	30	+	5	units
Category 2 :	31	-	70	+	7	units
Category 3 :	71	-	100	+	10	units

(permissible variation from the nominal value).

- Thickness of coating ISO 2360

The thickness of the coating on each part to be tested should be measured at no less than five measuring points (1 cm²) with 3 to 5 single readings taken at each point. The average of the single readings taken at one measuring point gives the measurement value recorded in the inspection report. If any measurement value is less than 80% of the required coating thickness, the part in question is unsatisfactory and falls under the reject samples of column 3 in the table in section E.1 d.

The average of all the measurement values on one part must be at least the required value for the coating thickness. If the average is below the required value but above the 80% mark, the part in question is not satisfactory and falls under the reject samples in column 3 of the table in section E.1 d). The inspection will, however, be deemed unsatisfactory if the average value of a part is less than 80% of the required coating thickness.

1. powder coating	60 µm
2. paints and lacquers	
a) PVDF two layers	30 µm
b) PVDF(metallic) three layers	45 µm
c) silicon polyester without primer (minimum 20% silicon resin)	30 µm
d) other thermosetting paints	50 µm
e) two-component paints	50 µm
3. electrophoretic coating	25 µm

Other coating systems may require different coating thicknesses, however they may only be applied with the approval of the Executive Committee.

- Adhesion ISO 2409

According to paragraph 5,2,4, of ISO 2409, a 3M adhesive tape no. 250 (ASTM D 3359) or equivalent must be used. The spacing of the cutters must be 1 mm for coating thicknesses up to 60 µm and 2 mm for more than 60 µm.

- Kesternich test ISO 3231 (0.2 l of SO₂ - 24 cycles)

In condensed water variable atmosphere containing sulphur dioxide.

No infiltration beyond 1 mm of the scratch.

- Machu test (Short-time corrosion test)

This test is used for in-house control in coating plants and is listed by way of a recommendation.

The surface of the sample should be scratched down to the base material with a suitable graving tool before the sample is immersed in the test solution.

NaCl	50	g/l	
CH ₃ COOH (glacial)	10	g/l	
H ₂ O ₂ (30%)	5	g/l	
test temperature	37		°C

testing time 48 hours

The pH of this solution is 3.0 - 3.3. After 24 hours, another 5 g/l H₂O₂ (30%) should be added and the pH adjusted. A new solution must be prepared for each test.

No infiltration beyond 0.5 mm of the scratch.

- Artificial weathering and radiation of coatings (DIN 53231)

accelerated SUNTEST

weathering test (original Hanau Quarz Lampen GmbH) with :
luminous intensity 150 klux
black panel 40 °C
temperature
special UV filter

3 minutes wet - 17 minutes dry cycles.

After 1,000 hours' exposure, the samples should be rinsed with fully deionized water and checked for :

gloss retention ISO 2813
angle of incidence 60°
total colour change reflectance spectrophotometer (glasser cube root method)
or CIELAB formula according to DIN 6174

3 colour measurements are to be made in different places at least 50 mm apart on the cleaned, weathered sample and on the unexposed reference sample.

1. Gloss retention : the loss of gloss after the accelerated weathering test must not be more than 50% of the original value.
2. Colour change : according to the values in the annexed table 2.

- Weathering Test

Florida test (natural weathering) according to ISO 2810. The test must start in April.

The samples must be exposed to the elements in Florida for 1 year, facing 5° south.

Dimension of the samples : 100 x 305 x 0.7 - 0.8 (mm).

In order to determine the reflectometer value, the samples should be cleaned in a 1% aqueous surfactant solution by rubbing them lightly with a soft sponge. The upper surface should be free from streaks as far as possible. The residual gloss on the cleaned sample must be at least 50%.

Color variances : 3 color measurements are to be made in different places at least 50 mm apart on the cleaned weathered sample and arithmetic evaluation are as follows :

1. a spectrometer or a colorimeter applying the three filter method must be

used (according to DIN 5033 sections 4 and 6);

2. the measuring geometry is 45/0 or alternatively 8/d or d/8 eliminating surface reflection (according to DIN 5033 section 7);
3. the colorimetric analysis must be made for the standard source D65 and ten-degree normal observer (according to DIN 5033 sections 2 and 7).

- Polymerisation Test (for paints and lacquers only)

Saturate a swab of cotton wool with a solvent specified by the paint or lacquer manufacturer and approved by the Technical Committee. Within 30 seconds, rub it lightly back and forth 30 times in each direction over the part to be tested.

After 30 rubs back and forth, the loss of gloss must not be more than 5 units (according to B.1;.m).

- Resistance to mortar

The mortar should be made of sand, lime and water. This represents type N according to ASTM C 207.

Minimum requirement : after 24 hours in the testing cabinet, the mortar must be easy to remove without leaving any residues. Any mechanical damage to the coating caused by grains of sand may be disregarded.

- Resistance to boiling water

1. 2 hours in boiling, deionized or distilled water. Remove the sample and allow it to cool down to room temperature. Apply an 18 mm wide strip of 3M adhesive tape no. 250 (ASTM 3359) or equivalent to the surface, ensuring that no air is trapped. After one minute, remove the tape at an angle of 45° with a sharp even pull.

2. Pressure cooker test

Add deionized water to a pressure cooker with an internal diameter of about 200 mm to a depth of 25 mm and place a test sample measuring 50 mm in it.

Place the lid in position and heat the pressure cooker until steam escapes from the valve.

The weighted needle valve must be adjusted to produce an internal pressure of 100 + 10 kPA (1 bar). Continue heating for 1 hour, time from the moment when steam first escapes from the valve. Cool the pressure cooker, remove the sample and allow it to cool down to room temperature. Apply an 18 mm wide strip of 3M adhesive tape no. 250 (ASTM 3359) or equivalent to the surface, ensuring that no air is trapped. After one minute, remove the tape at any angle of 45° with a sharp even pull.

Note : to be used for powder and electrophoretic coatings only.

There must not be any defects or detachment after 2 hours in boiling deionized or distilled water or after 1 hour in the pressure cooker. Some colour change is acceptable.

- Solvent test

Prescribed solvent for liquid coatings : MEK.
Prescribed solvent for liquid coatings : xylene.

For this solvent test, a cotton wool swab saturated with the appropriate solvent is placed on the test panel for 30 seconds.

The polymerization quality is assessed according to the following ratings :

1. The coating is very dull and quite soft.
2. The coating is dull and can be scratched with a finger-nail.
3. Slight loss of gloss.
4. No perceptible change.

Ratings 3 and 4 are satisfactory. Ratings 1 and 2 are unsatisfactory.

- Sawing, milling and drilling

The coating must not crack or chip when sharp tools are used.

- Buchholz indentation

Minimum 80 with the specified required coating thickness.

- Cupping test according to Erichsen

minimum 5 mm for powder coating
minimum 5 mm for paints and lacquers
minimum 3 mm for two-component paints and lacquers
minimum 5 mm for electrophoretic coatings

These values must be achieved with the specified required coating thickness. Using normal corrected vision, the coating of the test panel must not show any signs of cracking.

- Resistance to cracking on bending

Bending around a 5 mm mandrel.

Using normal corrected vision, the coating of the test panel must not show any signs of cracking.

- Impact test (for powder coating only) 2,5 Nm

Using normal corrected vision, the coating of the test panel must not show any signs of cracking.

- Acid salt spray test

No detachment of infiltration beyond 1 mm of the notch.

- Condensed-water constant atmosphere

Minimum requirements : no blistering after 1000 hours; maximum infiltration at the cross is 1 mm.

5204.06 Literature

General :

Parfitt, G.: "Organic Coating", Dekker.

"Metals Handbook" , ASM, Vol. 5 "Surface Cleaning, Finishing and Coating".

Munger, C.G.: "Corrosion Prevention by Protective Coatings", NACE, Houston 1984.

Specific Aluminium :

"Metals Handbook" , ASM, Vol. 13 "Corrosion", p. 399.

5204.07 List of Figures

Figure No.	Figure Title (Overhead)
5204.01.01	Surface Preparation for Painting: Objectives
5204.03.01	Methods of Applying Organic Coatings
5204.03.02	Typical Roller Coating Arrangements
5204.03.03	Electrostatic Coating Process
5204.04.01	Operational Sequences for Coil Coating
5204.04.02	Operational Sequences for Painting Extrusions
5204.04.03	Surface Preparation for Painting: Methods
5204.04.04	Relative Properties of Various Paints at a Typical Film Thickness of

	20-25 μ m
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