LONGTERM RESEARCH PERFORMED ON ANTI-CORROSIVE PAINT SYSTEMS APPLIED TO METAL CONSTRUCTIONS IN THE SCHELDT NEAR OOSTERWEEL

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I. INTRODUCTION

The cell "Anticorrosive systems" of the studygroup "Floor barriers in the Scheldt near Oosterweel" decided that all Belgian paint manufacturers could propose a total of thirty selected paint systems.

All 30 systems would be tested during a 10-year period (1980-1990) on a mooring constructed near Oosterweel. The actual testing was set up on three levels (above water, underneath water and within the tidal area) with external circumstances approaching those in which the systems would later have to appear as solid, protective coatings against both corrosion and erosion.

The results would also be applied to constructions in maritime - industrial surroundings such as the Belgian coast and the harbour of Antwerp.

A number of criteria were set evaluating the behavioral characteristics of the various systems during and at the end of the exposure period.

Test results retained ten systems of an outstanding and closely resembling quality.

Thus, this research allows for designers to select the most appropriate and adequate paint system for a particular construction considering both practical, economical and colour aspects.

II. PREPARATION

Test plates (pictures 1 & 2) and moorings

Test plates L x W x D = 30 x 30 x 1 cm out of ordinary construction metal Fe 360 D show similar irregularities as those appearing in ordinary, full scale steel constructions on a relatively small surface : corners, sharp edges, round hole, bolts, welds, welded U and a crosslike scratch carving into the paint system unto the carrier. In reality the relation between the irregularities and the total surface is much more favourable.

Each paint system was tested by exposure of test plates on three levels : above water, underneath water and within the tidal area.

During the 10-year period of exposure each plate was steadily fixed unto the mooring. The spot where the plate was attached unto the mooring is marked on the drawing representing each mooring per level.

The sides of the testplates were incarved with notches representing their respective identification numbers. The plates were positioned in such a manner that the welded U is directed towards the researcher.

Drawing 2

A notch on the upperside of the mooring represented :

- leftside : a plate installed above the water surface.
- middle : a plate installed within the tidal area.
- rightside : a plate installed below the water surface.

For all 30 paint systems the incarved notches represented the following :

each notch on the rightside	represents	10 units
" " " " underside	"	5 units
" " " " leftside	"	1 unit

Each test plate was attached to the azobe girders of the mooring by polyamide nuts, bolts and washers on the four corners of each plate.

II.2 Applied paints

Paints are sometimes prematurely withdrawn from the market before their trial period has been fully expired. Before concluding upon the efficiency of a certain paint an exposure period of at least ten years should be respected.
Therefore all paints applied to the 30 systems were scrutinously examined :

- quantitatively : weight percentage of binding agent, pigments and solvants
- qualitatively : analysis of binding agent, pigment and solvant according to

1992, 10e Havencongres, Antw.

kind, by classical chemical analysis.

The application methods are those described in Gardner-Sward's "Paint Manual", 1978, 3rd edition.

II.3 Paints applied to the test plates

All test plates for one specific paint systen were simultaneously being sandblasted with corondum to the degree Sa 3. By preserving the plates within dry surroundings during the first 48 hours after sandblasting, the initially achieved quality of the surface remained unaffected. The primer was applied within 24 hours before applying the following layers and a drying time of circa one day was respected.

During the first week the room temperature reached 23 +- 2 o C during the application and drying period with a relative humidity of 50 +- 10 %.

During the application and during the drying time the test plates were vertically hung up in the two upper eyes desgined for the bolts. Before applying the actual coating, these uncovered spots as well as all sharp edges were brushpainted. Nonetheless, these spots were generally still insufficiently protected (because layers were too thinly brushed). Moreover, considering their relatively small surface against the total of the plate, spots like these should not be given too much significance in the final and global evaluation.

48 hours after application of the first layer, the test plates were hung up in an unheated though sheltered space for at least one month. For each layer the application method was choosen in function of its technical possibilities. If various systems were applicable, the researchers firstly examined whether they were technically capable to apply a particular system to the compact sample on a laboratory scale. The manner in which a final, large-scale construction was to be painted was only of secondary importance.

The application was based on the following materials :

1. brush
2. airles spray
3. airspray
4. airspray with pressure pot
5. airless hot spray

II.4. Preliminary evaluation after painting within the lab and before installation

Both front- and backsides were photographed. All pictures taken during and after the exposure period were taken by the same persons departing from the same parameters as during the first photosession.

The thickness of the various layers was measured on 11 different spots (drawing 3). Both during and after exposure, the thickness was measured in exactly the same manner and on exactly the same spots (matrix. garbarite).

The film thickness was measured by the following apparatus :

1) for layers thicker than 300 micrometers : Mikrotest type F. Here measurement is based on magnetism. The measurement range varies between 0 and 1 mm with a maximal deviation of 10 % + 0,010 mm.

2) layers smaller than 600 micrometers were measured by a Minitector model 150 type FN 24 employed by the company Elcometer. The apparatus disposes of a one solar sond. The measurement range various between 0 and 600 micrometers, with a maximal deviation smaller than 5 % provided that calibration is carried out on a similar surface as that being painted (influence of rugosity, conductivity of material).

The principle of measurement was based upon induction-electromagnetism.

It should be marked that large industrial apparati such as described above are not designed for relatively small and complicated test plates such as used in this research. Among others they seriously complicate obtaining a uniform film thickness over the entire surface as prescribed by the manufacturers. Therefore, before drawing any final conclusions, we should be aware of possible deviating results for similar applications on full scale constructions.
Other departures from prescribed instructions (e.g. using paintbrush rather than airless spray) were only allowed after approval by the manufacturers involved.

III. CONTROLS CARRIED OUT DURING THE 10-YEAR EXPOSURE PERIODE (1980-1990)

Seven intervening controls were carried out on the test plates above water and within the tidal area. All parameters were marked on the control chart (table 1). Test plates of about 1 to 1,5 years old were quite often found to display signs of silt, algal growth and shellfish. Therefore, in order to establish accurate thickness measuremants and secondly, in order to detect possible hidden defects, it was necessary to carry out a complementary control measurement after washing off all deposits. These intervening controls were quite informative with respect to the development and further evolution of rust and other defects or damages (self-adhesive effect or not).

IV. FINAL EVALUATION

Having been exposed for 10 years, all 90 plates (30 systems tested on three levels) were removed, washed off and transported to a research laboratory for a final evaluation.

IV.1. Photographs

Once again colour photographs were taken from the front- and the backside of each plate. All plates placed within the tidal area showed colour changing and algal growth. Some plates were affected by chalking. All plates installed under water were affected by algal growth and shellfish. Nonetheless, neither of these phenomena led to the development of rust or other defects. In general, the plates themselves show little variation in appearance.

IV.2. Rust

IV.3. Defects

The entire plate was checked for rusting with respect to its total surface and irregularities according to the European rustscale (NBN T-22-163).

Other defects such as blistering, peeling, burets, etc., were evaluated according to the standard NBN T-22-162/163/164/165.
The evaluation of rust and defects evidently makes up for the most important part of the final evaluation. In essence, every system was examined with respect to its protective characteristics against rust.
Thus, the importance of rusting exceeded such phenomena such as colour changing or blistering.

The evaluation of the various protective systems assumes that rusting and other defects should always be examined in view of the total surface of of the carrier. Thus, it is assumed that rust affecting the entire surface is more obnoxious than rust affecting merely the scratch carving into the paint.
Factors deciding upon the harmfulness of defects are their number per cm3 and their relative size (density e.g. size of blisters),

Disregarding rare exceptions, the evaluation evidently shows that all systems led to highly satisfactory results within air. Seeing that the research was based upon rigourously selected, solid systems, these results are perhaps not entirely surprising.
A number of systems behaved most satisfactorily underneath the water though badly within the tidal area. Opposite results were also perceived. Nonetheless, the majority of the systems manifestly conformed to the requirements on all three levels.

Departing from the above criteria, 10 out of 20 systems were selected as highly qualitative systems. Moreover - all factors taken into account - these systems were of an obvious superior quality than all other systems. Neither of these 10 systems appeared to be affected (or merely to a small degree) by rust and/or defects.

Table 2

For each layer table 2 shows the technical designation of the paint used (kind of binding agent and pigment), the application method (code 1 to 5 of chapter IV.3) and the film thickness recommended by the paint manufacturers.

IV.4. Erosion

IV.4.1. Thickness measurements

When comparing the test results perceived in the lab with those perceived during the 10-year exposure period, we perceive an increase in thickness (swelling) within the tidal area varying between 3 to 18 % and an increase of 7 to 30 % underneath the water. These varying values are predominantly due to three factors :

* The paint systems were evidently not applied with filmographs and small displacements of the feet of the measuring apparatus sometimes led to differing values : the matrix (garba-

rite) did not necessarily guarantee that all measurements were performed on exactly the same spots.

* The measurement devices themselves showed deviations.

* The perceived deviations were primarily due to the film absorbing water. Indeed, if films were entirely water resistant, all paint systems would be of external duration. The applied paint systems, on the other hand, were thick systems inevitably including the risk of solvent retention and this allowing the water to permeate into the film.

IV.4.2. Tests for abrasion resistance

This test was performed with an apparatus described in " M.O.W. Wegenverf " (M.O.W. Traffic Paint).
It included pouring sand from a height of 130 cm through a mouthpiece measuring 20 mm in length and 8 mm in diameter, onto steel. The researchers closely followed the evolution of the film thickness by comparing the initial values of the films with its respective values after being poured over with 50 kg and 100 kg. of sand.

The abrasion values, measured in micrometers per 10 kg of sand, remained relatively stable for paints belonging to the same paint system.
The various systems, however, displayed mutual variations. Systems g, h, i and j displayed an abrasion value of a dozen of micrometers per 10 kg of sand. Systems b. c. d and e displayed an abrasion value of 100 to 150 micrometers per 10 kg of poured down sand.
Yet, in comparison with earlier studies these results are rather well.

IV.4.3. Adhesion processes

Adhesion was determined by measuring the perpendicular power, expressed in kg/m2, necessary to pull off a test piece (plot) from the paint by means of the Seaberg apparatus. The test piece was attached to the paint by a two component epoxy glue.

The adhesion test was performed on five different positions on every plate. The observed values were expressed in kg/cm2. The study also included a description of the kind of fracture, which is definitely as important as is the adhesion value.

During the application of the paint systems the parameters were set in an ideal way. This explains why all ten systems showed values well over 50 kg/cm2. The type of fracture was either cohesive (*) or it occurred between glue and plot. These values are definitely positive.

(*) By cohesive fractures we refer to fractures taking place either within the layer or in between layers without showing any difference in appearance.

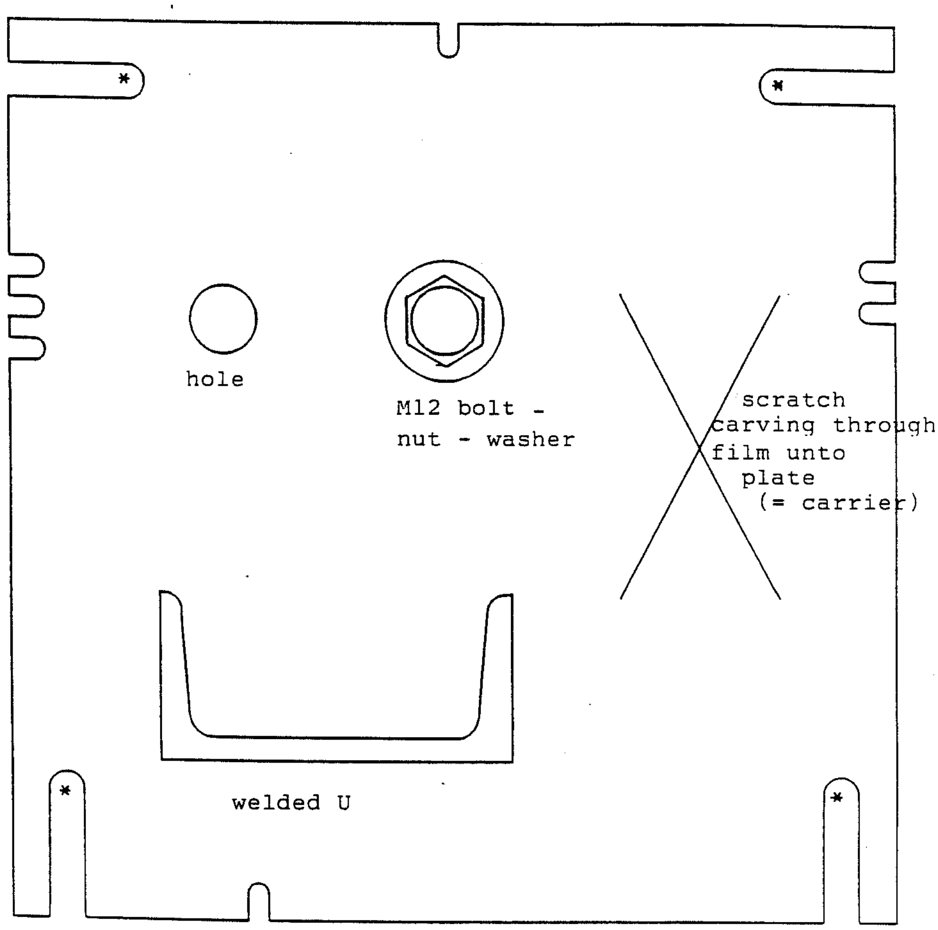
C O N C L U S I O N

The entire study has been very succesful. It allows designers to choose the most suitable system for specific metal construction.
Designers are given the possibility to choose between various systems not only on the basis of financial, economical and practical grounds, but also taking into account climatological considerations such as temperature and relative humidity.

Drawing 1

TEST PLATE

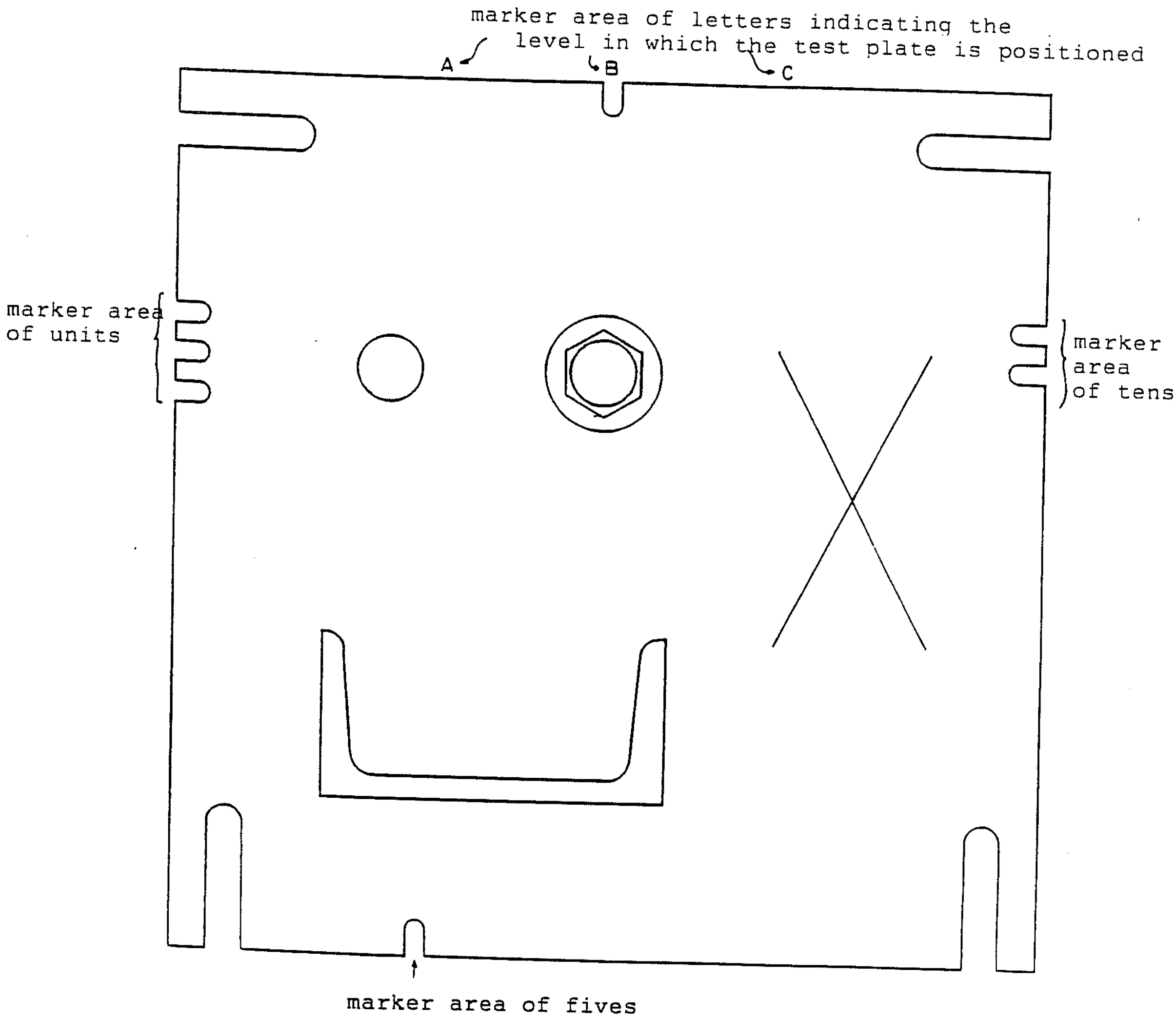
LxWxD = 30x30x1 (cm)



* notches attaching the test plate unto the girder

Drawing 2

MARKING

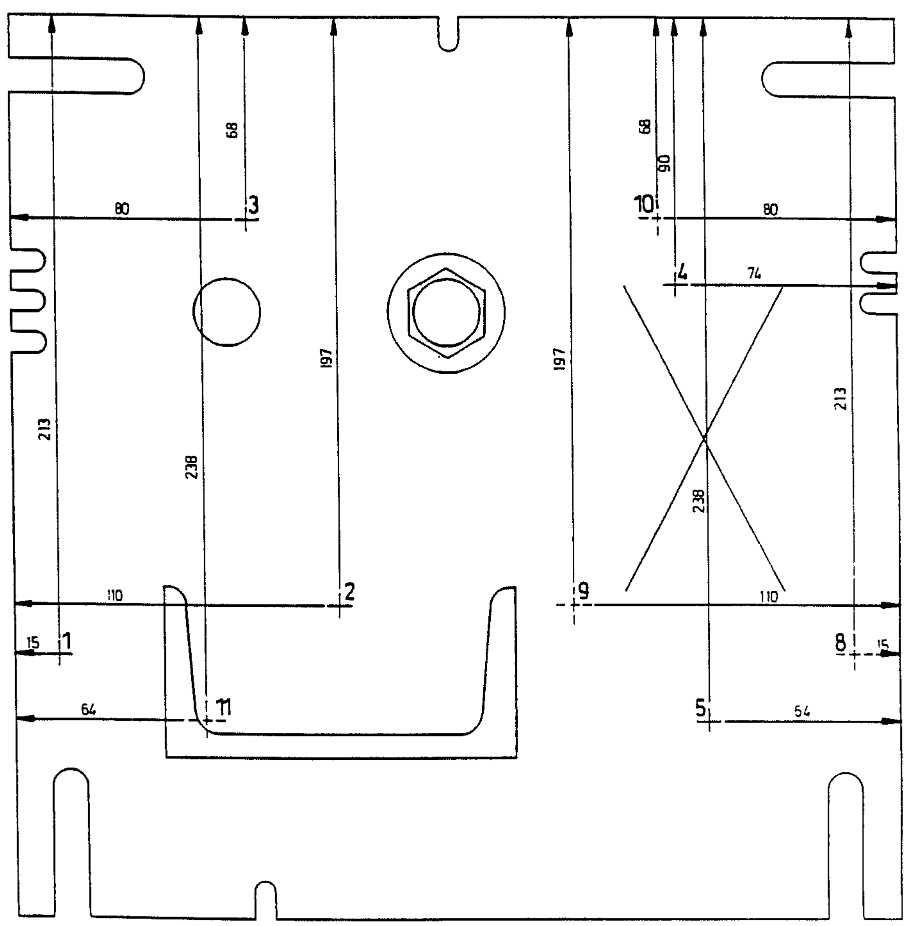


THIS EXAMPLE REFERS TO TEST PLATE 20 + 5 + 3 = 28

INSTALLED WITHIN ZONE B (= TIDAL AREA)

Drawing 3

LOCATIONS OF THICKNESS MEASUREMENTS



measurements on frontside

measurements on backside

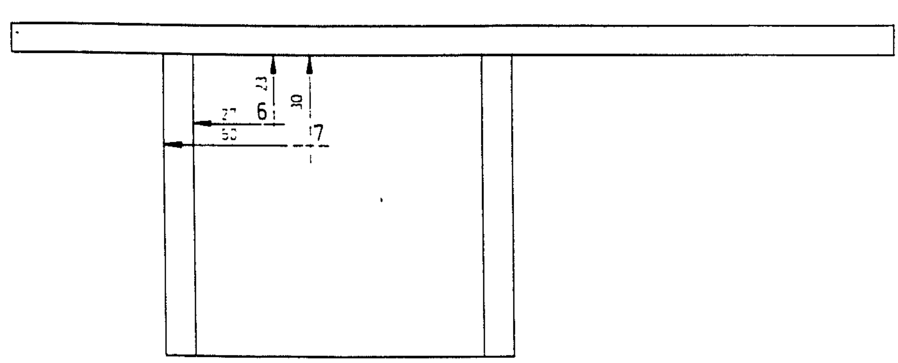


Table 1

CONTROL CHART

System number : ....   Date : ../../..

1.PHOTOGRAPH FRONT / BACK   yes O / no O

2) APPEARANCE

2.1. Natural condition

A. Rust

	none	little	much	remarks
scratch				
bolt				
U				
Surface				

B. Colour

Uniform   yes O / no O
Dirty   yes O / no O

Oil O   Algae O   Others O

C. Other aspects

Bursts O   Blistering O   Others O

2.2 After washing off with sponge and clear water

easily washable   yes O / no O
chalking   yes O / no O
colour changing   yes O / no O
mechanical damages   yes O / no O
where ?

3. THICKNESS MEASUREMENTS (1 to 11)

4. REMARKS

Table 2

	1ST LAYER	THICKN. MICRON	MANNER OF APPL.	2ND LAYER	THICKN. MICRON	MANNER OF APPL.	3RD LAYER	THICKN. MICRON	MANNER OF APPL.	4TH LAYER	THICKN. MICRON	MANNER OF APPL.	COLOUR
a	air-humidity preserving poly-isocyanate resin with zinc dust	50	3	air-humidity preserving poly-isocyanate resin with micaceous iron oxide	120	3	air-humidity preserving poly-isocyanate resin with micaceous iron oxide	120	3	air-humidity preserving poly-isocyanate resin	50	3	white
b	epoxy (bisphenol A) with amino hardener and lead metal	25	1	epoxy (bisphenol A) with amino hardener and coal tar pitch	300	2	epoxy (bisphenol A) with amino hardener and coal tar pitch	300	2				black
c	air-humidity preserving poly-isocyanate resin with zinc dust	50	3	air-humidity preserving poly-isocyanate resin and micaceous iron oxide	50	3	air-humidity preserving poly-isocyanate resin with coal tar pitch	150	2	air-humidity preserving poly-isocyanate resin with coal tar pitch	150	2	black
d	epoxy (bisphenol A) with amino hardener and red iron oxide	40	3	epoxy (bisphenol A) amino hardener and coal tar pitch	400	5							black
e	epoxy (bisphenol A9 poly-amido hardener and zinc dust	40	4	epoxy (bisphenol A) with poly-amido hardener and iron oxide - aluminium	40	3	epoxy (bisphenol A) poly-amido hardener and coal tar pitch	170	2	epoxy (bisphenol A) with poly-amido hardener and coal tar pitch	170	2	black
f	air-humidity preserving poly-isocyanate resin with zinc dust	50	4	air-humidity preserving poly-isocyanate resin with coal tar pitch	150	2	air-humidity preserving poly-isocyanate resin with coal tar pitch	150	2				black
g	epoxy (bisphenol A) with poly-isocyanate (TDI), red iron oxide strontium chromate	50	3	epoxy resin (bisphenol A) with amino in reactive thinner	550	5							light green
h	epoxy (bisphenol A) with poly-isocyanate (TDI), red iron oxide and strontium chromate	50	3	epoxy resin (bisphenol A) with amino in reactive thinner	550	5							beige
i	epoxy (bisphenol A) with poly-isocyanate (TDI), red iron oxide and strontium chromate	50	3	Polyester with alkyl-phthalic peroxide and aluminium silicate	550	5							grey/ black
j	epoxy (bisphenol A) poly-amido hardener with iron oxide, red lead and lead chromate	100	3	epoxy (bisphenol A) with poly-amido hardener and micaceous iron oxide	150	3	epoxy resin (bisphenol A) with poly-amido hardener	100	3				grey/ bleu

Manner of application : 1. brush 2. airless spray 3. air spray 4. airspray with pressure pot 5. hot airless spray