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A COMPARATIVE STUDY ON ANTI-CORROSION PROTECTION BETWEEN WATER-BASED AND SOLVENT-BASED PAINTS[1]

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Abstract
Current analysis evaluates the performance of hydrosoluble paints compared to paints with organic solvents, based on their anti-corrosive characteristics. Metal corrosion is highly relevant when economical viability is taken into consideration. Viscosity, application and adherence tests on a surface were undertaken to elaborate and test a high temperature resistant hydrosoluble system. Tests not only aimed at anti-corrosion protection but also evaluated the coloring differences of painted panels when exposed to high temperatures (600°C). The theoretical yield was also assessed by comparing results obtained from water-based systems and those from solvent-based ones for the same application. In the case of the water-based system, formulation tests with two different silicon-based resins were undertaken which were specifically developed for hydrosoluble systems. Replacement of organic solvent by a hydrosoluble-based paint did not affect significantly any physical and chemical characteristic of the paint.
Key words: Corrosion; Water-soluble paints; Solvent-based paints; Adherence.

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1 INTRODUCTION

Technological changes in the paint coating industry have had an evolutionary trend. According to Fazenda,[1] the use of hydrosoluble coatings were triggered by paint manufacturers through improvements in their production and by consumers always seeking state-of-the-art products. On the other hand, metal corrosion is highly significant in terms of economical feasibility. According to Callister,[2] 5% of an industrialized nation´s revenue are spent in the prevention of corrosion and in the maintenance or substitution of deteriorated or contaminated products by corrosion. Current analysis deals with formulations of high temperature-resistant hydrosoluble paints for use in industrial ovens, boilers and car exhaust pipes. Tests involving application and adherence in metal surfaces were undertaken for the elaboration of a high temperature-resistant hydrosoluble system. Coloring differences of painted panels when exposed to high temperatures (600°C) and their theoretical yield were assessed by comparing results from water- and solvent-based systems. According to Fazano,[3] film formation in water-based paints has its limitations. Evaporation rates of its volatile components should be compatible to water evaporation rate. The water-based system was comparatively evaluated for the same application by formulation tests in two different silicone-based resins developed specifically for hydrosoluble systems.

2 MATERIALS AND METHODS

A highly suggestive formulation obtained from a color manufacturer-supplier was used for the development of a hydrosoluble paint. Tests were performed with two different silicone-based resins, each with a different percentage and type load. Figure 1 shows the schedule of tests with the formulations and the proposed formulation.

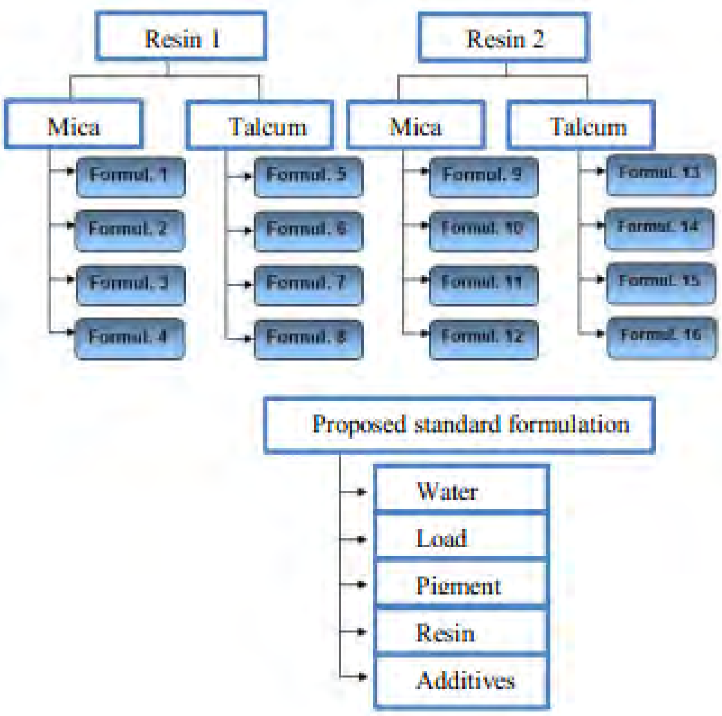

Figure 1. Schedule of formulations undertaken and the proposed formulation.

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Assays performed are given below.

2.1 Viscosity Assay

Paint viscosity was measured by the flow time of the liquid using a Ford Glass n. 4 (OMICRON). A homogeneous sample was collected and adjusted at 25°C. The method was based on the flow time of a paint volume on a calibrated orifice. Time in seconds was converted into mm^2/s (kinematic viscosity). According to Fazenda,[1] paint volume is defined by measurement and by the angle of the glass bottom coupled to the measurements of the orifice on which the paint flows. Assays were undertaken in triplicate and results were given in logarithmic means.

2.2 Application of Paint in a Paint Cabin

Cleanness of components in paint cabin, furnished with a water curtain, from manufacturer Real Equipamentos Industriais, and conventional paint pistol JGA 503, from Devibelss, were evaluated. Air pressure was calibrated between 40 and 60 lbs and adjusted between 20 and 30 cm distance from the application surface. The surface for painting was cleansed with a biodegradable aliphatic solvent.

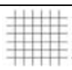
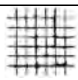
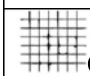
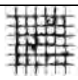
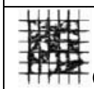
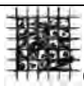
2.3 Evaluation of Temperature Resistance

The metal panels were painted and left for one hour to dry. Panels with no surface defects were placed in a Quimis furnace 318D21, for one hour, at 600°C for thermal resistance test. When dried, the painted samples were removed from the furnace, cooled and the coloring was compared with panels which were not subjected to high temperatures. Color standard was then analyzed.

2.4 Evaluation of Adherence to Metal Surfaces

Adherence test was performed following ASTM D 1000/04, with a blade and template, by making right angle crossed cuts to reach the layer. A semi-transparent adhesive band, 25 mm wide and a 32 g/mm adhesion, was employed. The paint was then pulled at an angle close to 180°, and the area under analysis was evaluated according to enhancement. Adherence was classified following Table 1.

Table 1. Parameters for the classification of adherence degrees

 Gr 0: No area with enhanced film.	 Gr 2 : Area with enhanced film, approximately 15% of the squared area.
 Gr 1: Area with enhanced film, approximately 5% of the squared area	 Gr 3: Area with enhanced film, approximately 35% of the squared area.
 Gr 4: Area with enhanced film, approximately 65% of the squared area.	 Gr 5: Area with enhanced film, approximately 85% of the squared area.

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3 RESULTS

Several formulations with variations in load, resin, water, pigments and additives were developed from the proposed standard formulation (Table 2).

Table 2. Proposed formulations tested for resins 10/10/2012

Resin - Manufacturer 1								
Loads	Mica				Talcum			
Formulations	01	02	03	04	05	06	07	08
Resin (%)	53	52	60	56	51	55	60	60
Water (%)	9	9.5	8	9	18	14	9.5	10
Load (%) + Pigment	30	28.5	28	32	25	27	26	27
Additives (%)	8	10	4	3	6	4	4.50	3
Resin – Manufacturer 2								
Load	Mica				Talcum			
Formulations	09	10	11	12	13	14	15	16
Resin (%)	53	52	60	56	51	55	60	60
Water (%)	9	9.5	8	9	18	14	9.5	10
Load (%) + Pigment	30	28.5	28	32	25	27	26	27
Additives (%)	8	10	4	3	6	4	4.50	3

3.1 Viscosity Assay

Viscosity in non-Newton systems is not constant and depends on temperature and on other factors, such as type of preparation, handling, rest time, following Netz and Ortega.[4] Viscosity assay was performed with all the formulations developed. Table 3 shows the results.

Table 3. Viscosity provided by the analysis of paints produced

Resin - Manufacturer 1								
Loads	Mica				Talcum			
Formulations	01	02	03	04	05	06	07	08
Viscosity (s)	31	35	30	34	38	35	33	31
Resin - Manufacturer 2								
Loads	Mica				Talcum			
Formulations	09	10	11	12	13	14	15	16
Viscosity (s)	32	35	30	33	35	34	32	30

According to NBR 5.489,[5] Orifice n. 4 is the type used in paints for industry, car building and premises. Viscosity band for the orifice lay between 20 and 100 s. Formulated paints complied with standard determined by NBR 5.489, with viscosity standard ranging between 30 and 40 s.

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3.2 Paint Application in Painting Cabin

Types of paints produced were applied to metal panels with an air pistol in a painting cabin, as described above. When time for paint cure elapsed, the visual aspect of the painted metal panels was observed. Formulations were chosen according to performance in Table 4.

Table 4. Behavior of paint formulated with different resins and applied to metal panels

Resin - Supplier 1								
Loads	Mica				Talcum			
Formulations	01	02	03	04	05	06	07	08
Visual aspect	GOOD	GOOD	BAD	BAD	GOOD	GOOD	BAD	BAD
Surface defects	NO	NO	YES	YES	NO	NO	YES	YES
Resin Supplier 2								
Loads	Mica				Talcum			
Formulations	09	10	11	12	13	14	15	16
Visual aspect	GOOD	GOOD	BAD	BAD	GOOD	GOOD	BAD	BAD
Surface defects	NO	NO	YES	YES	NO	NO	YES	YES

As highlighted in Table 4, formulations 03, 04, 07, 08, 11, 12, 15 and 16 were eliminated from following studies due to surface defects and unacceptable visual aspects. According to BYK,[6] surface defects negatively affected the paints optic and protective qualities. Silicone-based additives, registered by BYK, may have caused surface defects since the difference of the material´s surface tension may have occurred because of solvent evaporation rates, reaction to resin cure or surface contamination. The formulation which manifested surface defects had also silicone-based additives and may have caused incompatibility to the resin, also silicone-based, and thus caused high surface tension and the formation of troughs.

3.3 Evaluation of temperature resistance

Assay was performed only with paints that had an acceptable visual aspect and on surfaces 20 µm – 40 µm thick and without any defects. Further, the paints were cured for 1 hour at 600°C so that color differences of the paints under analysis could be analyzed by comparing them to the panel painted with current organic solvents-based system.
Formulations with great variations in coloring and whiteness, which would impair application, were discarded. Table 6 provides results on visual aspect and color difference after exposure to heat.

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Table 5. Results of panel aspect exposed to a temperature of 600°C for 1 hour

	Resin 1				Resin 2			
Loads	Mica		Talcum		Mica		Talcum	
Formulations	01	02	05	06	09	10	13	14
Visual aspect	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD
Color difference	YES	NO	NO	YES	YES	NO	NO	YES

All types of paint which revealed different color strengths when compared to organic solvent-based standard system were discarded from the next assays. According to Ching,[7] pigment dispersion and dispersion additives in the preparation of paints greatly affect the external features. A paint´s bad performance is the result of the use of non-appropriate additives which cause unacceptable surface visual aspect and coating power.

3.4 Evaluation of adherence in metal surfaces

Adhesion may be defined as a condition in which two surfaces are perfectly bonded by interstitial forces as in electrostatic charges. A coating´s adherence capacity is directly linked to one of its main aims, or rather, the protection of the surface, as described by Fazano.[3]
Adherence was determined by the template cutting method. The comparative parameter for the acceptance or non-acceptance of the paint under analysis consisted of the result from the previously approved organic solvents-based paint featuring Gr 1 as adherence degree standard. Table 6 provides results from tested formulations.

Table 6. Results of the formulations´ adherence degree analysis

	Resin 1				Resin 2			
Loads	Mica		Talcum		Mica		Talcum	
Formulations	01	02	05	06	09	10	13	14
Adherence degree	Gr 2	Gr 1	Gr 1	Gr 2	Gr 2	Gr 1	Gr 1	Gr 2

Adherence results are greatly influenced by cleaning conditions of the surface on which the paint is applied, as quoted by Moretti,[8] and by other factors such as the inclusion or not of adherence-triggering additives. Formulations 01, 06, 09 and 14 were excluded since they failed to reach the same adherence degree as that of the organic solvents-based paint. Only four formulations, two with resin 1 and two with resin 2, were submitted to the final tests.

3.5 Determination of the Theoretical Yield

Rate of paint yield may be measured by the painted area applied done with one liter of paint. The above parameter is highly important in the evaluation of feasibility in manufacture and commercialization. Table 7 shows results from paint yield.

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Table 7. Results for theoretical yield in m^2/L

	Resin 1		Resin 2	
Loads	Mica	Talcum	Mica	Talcum
Formulations	02	05	10	13
Yield (m^2/L)	11.7	10.04	9.28	8.65

Yield comprised losses due to the application method, conditions of application and painter´s training which, from experimental evaluations, was calculated at 30% as a parameter for reference. Results were highly relevant since the theoretical yield obtained was above that of organic solvents-based paints (7 m^2/L). Moreover, the paint had a lower impact on the environment and on human health.

4 DISCUSSION

Results show that formulations 02, 05, 10 and 13 may replace current organic solvents-based paint since formulation provided the paint with the best application qualities. After several comparative assays between current solvent-based paint system at high temperature and the water-based paint, the authors concluded that the replacement of organic solvent-based paint by a hydrosoluble one did not alter significantly the paint´s physical and chemical qualities. The quality of the material and the protection characteristics were maintained even though its dilution in water was possible. From the technical point of view, the project is viable. It is an interesting suggestion for the paint market to evaluate costs and analyze them from the customers´ point of view. They may compare costs within the current system (paint + solvent) and its peer (paint + water).

5 CONCLUSION

Results provided the following conclusions:
The preparation of paints is the most important step throughout the whole process. Homogeneity, viscosity, coating power, surface defects, consistency, stability and other factors depend on paint preparation. It should be highlighted that after defining the formulations, each dose was prepared at least three times, with the help of paint experts, so that the best preparation would be guaranteed;
Viscosity in all the formulations was coherent with the preparation and with the prime matter used; consequently, an excellent paint application in the paint cabin was possible;
For excellent assays the correct paint layers were obtained because of the applier´s experience and the precise regulation of the painting equipment which provided an adequate coating to the surface within specifications;
The formulations under analysis showed highly varied results with regard to resistance to temperature; consequently, the correct pigment dosage and prime matter could be evaluated for resistance to a temperature of 600°C for one hour.
With regards to adherence to metal surfaces, results showed variations between GR1 and GR2; they may have occurred due to the correct or incorrect additives and to inadequate surface preparation.
Yield rates were satisfactory since they were higher than those for organic solvents-based paint in current use.

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