

## PROTECTIVE COATINGS SYSTEM FOR NUCLEAR POWER PLANT AND CORROSIVE ENVIRONMENTS

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### ABSTRACT

Different areas in the nuclear facility require protective coatings which in addition to having the normal properties should withstand nuclear radiation as well as the rigorous decontamination schedule. At present in our country coating system comprising of inorganic zinc rich primer, epoxy undercoat and top coats all of which are imported are made use of for this purpose by Nuclear Power Board (BARC). Difficulties in procuring these materials, deterioration during transit and other drawbacks have led to the development of these coating systems indigenously. The indigenisation would help not only in import substitution but also in having a strict control over the quality of the product.

The physical and protective properties of the indigenously developed system comprising of primer undercoat and finish coat and those of the imported system are evaluated by various tests and the results are presented in this paper.

**Key words:** Protective coating, zinc-rich primer

### INTRODUCTION

The industrialisation of a country is mainly dependent on the quantum of energy it produces. Programmes for the production of electrical energy have hence assumed greatest importance in every developing nation [1]. The depletion of fossil fuels such as oil, coal and gas has led to the development of other methods of power generation among which nuclear power based electricity generation, has emerged as the chief and widely used method. Ecological consideration also favours the use of nuclear power as there is no smoke or fume evolution. The electricity produced by the nuclear power station now accounts for 10-20% of the total electricity produced in the world. This figure will increase in future as thermal power generations will become cheaper because of escalating oil and coal prices. In India at present there are four operating nuclear power stations and six more are nearing completion and there will be 32 nuclear power stations in India by 2000 A D to meet the power demand.

When the materials are exposed to different environments they undergo corrosion and the extent of attack varies from material to material depending upon the presence of humidity, solid and gaseous pollutants, temperature, surface condition etc. The protection of materials by paint coatings is one of the well established methods. Economical and practical considerations play an important role in the selection of suitable paint schemes, and generally longer service life with minimum maintenance coating systems are preferred.

Organic coatings are used more widely for the protection of steel, concrete and other non-ferrous surfaces in nuclear reactor establishments [2]. There are two distinct types of areas in nuclear power plants, one the normal areas as those existing in the conventional power generating plants and the other found only in nuclear power generating plants, generally called Nuclear Class I areas, consisting of the reactor containment building, ancillary buildings, work areas and associated equipment. In these areas of application one will find not only the service conditions, maintenance work and traffic normally associated with conventional areas but also radiation caused by the reactor core and cooling systems. The organic molecules in the coatings on exposure to radiation get excited or ionised. The absorption

of radiation energy leads to cross-linking thereby increasing the hardness of the molecule. In the case of halo-generated compounds, halogen evolution occurs leading to the rupture of carbon-halogen bond. The deterioration of organic coatings of saturated hydrocarbons type is more when compared to aromatic compounds. Therefore, the selection of organic binders has to be made in such a way that the film does not readily deteriorate on exposure to radiation. Further, during decontamination procedures [3], the coating will be subjected to rigorous treatment with hot water, acid and detergent solutions, In some cases, such physical methods as abrasion, erosion and ultrasonic cleaning are also employed for decontamination of the coating surface. The coatings should withstand such severe treatments. At present, India has to depend on import of coating materials used in nuclear reactor establishments. No equivalent indigenous products are available. The amount of paint required for a plant is of the order of a few thousand litres. The demand for organic coatings will increase in future with increase of the number of atomic power stations in India. At present, the proprietary paint system consisting of three paints (i) primers (ii) undercoat and (iii) finish coat, have been imported under the trade name Dimet-cote (Primer), Amercoat - 64 and Amercoat - 66. Several difficulties are being experienced in getting these materials in time and testing their qualities. shelf - life or total deterioration of the paints. The above said difficulties have forced the Nuclear Power Board to explore the possibilities of indigenisation of the production of these coatings. The indigenisation will not only help in eliminating the dependence on foreign company and in saving the foreign exchange but also in having a strict control over the quality of the product. Hence the Nuclear Power Board, BARC sponsored the work to CECRI. This paper deals with the radiation resistant paint systems developed by the CECRI, Karaikudi.

### EXPERIMENTAL

Three paint systems have been developed at CECRI for use in the nuclear reactor establishments. The primer developed at the Institute is a two pack system. The contents of the two packs are mixed before use. One pack, contains zinc metal powder as pigment and the other pack contains sodium silicate solution as binder. In this case, the primer protects the metal

substrate by galvanic action as well as by barrier protection. It is also called welding primer. The metal powder is slowly added to the binder with stirring and mixed well so that the metal powder disperses uniformly. The paint can then, be, coated by brush or sprayed, on sand blasted mild steel. The undercoat developed in CECRI is a two pack epoxy paint. In this paint, epoxy resin is used as binder. Polyamide is used as the curing agent. Pigments such as rutile - titanium dioxide and other extenders are incorporated in this binder. It is ground in a ball mill using porcelain balls till the desired fineness of grinding is achieved. The paint is removed and the consistency is adjusted with the solvent. The finish coat is also based on the epoxy resin incorporating rutile titanium dioxide and extenders and ground well as in the case of undercoat. The curing agent in this case is also polyamide. The physical properties of the liquid paints were determined.

#### Preparation of painted panels and their testing

Mild steel panels of different sizes pickled in inhibited hydrochloric acid or sand blasted were used for application of coating. The paint scheme was applied by brush or spray to a specified thickness with an interval of 24 hours to 48 hours. The paint scheme consists of primer, undercoat and finish coat. The physical and chemical properties of the mild steel panels coated with the formulations developed at CECRI and the imported paints have been compared.

##### (1) Specific gravity

The specific gravity was determined with the help of weight per gallon cup.

##### (2) Viscosity

It was determined by using Ford Cup No. B-4.

##### (3) Dry film thickness

Dry film thickness of the coating was measured by Elcometer.

##### (4) Fineness of grind

Fineness of grind was determined by using Hegmen Gauge.

##### (5) Scratch hardness

Scratch hardness was measured according to B.S. 3900 using a scratch hardness tester.

##### (6) Impact resistance

This was measured by falling weight method according to ASTM specification G 14 - 77.

##### (7) Gloss

Gloss was measured at 45° as per ASTM specification D 523 - 78.

##### (8) Extensibility

Extensibility was measured by conical mandrel bend apparatus according to ASTM specification D 522.

##### (9) Adhesion

Adhesion of coatings was assessed by two methods.

(a) Tape test: Adhesion was tested according to ASTM specification D 3359 - 68.

(b) Sandwich pull off technique: Quantitative values for adhesion were determined by Sandwich pull off technique using a Hounsfield Tensometer.

##### (10) Abrasion

Abrasion values were determined by Taber Abraser. The weight loss per 1000 revolutions under a 1000 gm load of the coating was determined.

#### Determination of resistance to chemicals/solvents

(1) Immersion studies in distilled water, 2% nitric acid, 5% sodium chloride and 10% teepol were carried out. The painted mild steel panels of size 7 x 5 cm were immersed in the above mentioned solutions for 3 months and the observations were made periodically.

(2) Immersion in hot water: The painted panels were immersed in hot water (i) at 57°C for 30 minutes and (ii) at 90°C for 10 minutes.

(3) Immersion in petrol: The painted panels were immersed in petrol for 3 months.

(4) Exposure to wet steam: The painted panels were exposed to wet steam at 77°C and 120°C for 30 minutes respectively.

#### Accelerated tests

##### (1) Accelerated weathering

(a) U V exposure: The painted panels of size 15 x 10 cm were exposed to U V radiation in Q U V accelerated weathering tester of Q - panel company for 500 hours.

(b) Condensation: The painted panels were tested in Q C T condensation tester of Q - panel company for 500 hours.

(2) Salt spray (fog) test: The test was conducted as per ASTM specification B 117 - 73.

##### (3) Radiation and decontamination resistance tests:

The tests were conducted by BARC. The painted panels were exposed to high energy radiation source and the decontamination properties of the painted panels determined by subjecting the coated panels to various decontamination procedures.

##### (4) Welding tests

The zinc sodium silicate primer was coated on blasted mild steel panels and weldability tests were carried out as per ASME Section IX at Narora Atomic Power Plant site. It was possible to weld through coated plates for joining the same without any slag inclusion on the weld or any other loss in the quality of the welded joints. The joint was subjected to dye penetration and radiographic tests for detection of flaws, if any, before subjecting to the tensile and bend tests.

## RESULTS AND DISCUSSION

The physical properties of the liquid paint and coated panels are given in Tables I and II for both the developed and imported paint systems.

The results obtained for various tests for developed paint were found to be comparable with those of the imported paint samples. The physical, chemical and corrosion resistant properties of the panels coated with the complete paint scheme consisting of primer, undercoat and finish coat of the developed and imported systems are indicated in Tables III and IV.

It is seen from Table III that the physical properties of the coated panels are more or less the same for both the developed and imported paints. Table IV gives the chemical resistance and corrosion resistance properties of the coated panels of both the developed and imported paints. It is seen from the Table that the values obtained in all the tests are similar for both the paint systems. The developed paint system was found possess excellent radiation resistance - (found to be performing well even after 386 M rad dose when other systems, the performance of which were simultaneously evaluated, had totally failed even at an earlier stage of radiation) and passes the welding test and the decontamination test. The undercoat and finishing paint were coated on concrete panels and it was found that the adhesion of the coating was good and the performance of the paint in all the tests also is good.

Table I: Physical properties of the liquid paint

No.	Properties	Primer		Undercoat		Finish coat	
		Developed at CECRI	Imported	Developed at CECRI	Imported	Developed at CECRI	Imported
1.	Thickness per coat $\mu$	50-75	50-75	30-40	30-40	80-120	100-125
2.	Curing time						
a.	Touch dry in minutes	15	15	60	60	30	60
b.	Recoatibility in hours	48	48	24	24	24	24
3.	Coverage (Sq.m/lit.)	8-10	8-10	5-6	8-9	4-5	4-5

Table II: Physical properties of the painted panels

No.	Properties	Primer		Undercoat		Finish coat	
		Developed at CECRI	Imported	Developed at CECRI	Imported	Developed at CECRI	Imported
1.	Taber Abrasion (Loss in mg)	217	167	110-120	133	47.5	13
2.	Scratch hardness (gm, for 40 $\mu$ thickness)	—	—	1300	1100	2000	1800
3.	Extensibility 1/4" mandrel (6.35 mm)	—	—	Passes	Passes	Passes	Passes
4.	Adhesion:						
a.	Tape method	Passes	Passes	Passes	Passes	Passes	Passes
b.	Sandwich pull of method kg/cm <sup>2</sup>	101.55	103.25	103.74	103.25	91.00	94.50
5.	Impact resistance cm	5	5	5	2	15	15
6.	Gloss at 45° angle	—	—	—	—	100	100

Table III: Physical properties of the panels coated with complete paint scheme (primer + undercoat + finishing paint)

No.	Properties	Developed at CECRI	Imported
1.	Taber Abrasion (loss in mg)	15.3	13
2.	Scratch hardness gms	Over 3000	3000
3.	Extensibility 1/4" Mandrel (6.35 mm)	Passes	Passes
4.	Adhesion:		
a.	Tape method	Passes	Passes
b.	Sandwich pull of method kg/cm <sup>2</sup>	80.50 (Cohesive failure of undercoat)	80.50 (Cohesive failure of undercoat)
5.	Impact resistance, cm	5	2
6.	Gloss at 45° angle	90	90

Table IV: Chemical and corrosion resistance properties of the paint scheme (primer + undercoat + finishing paint)

No.	Properties	Developed at CECRI	Imported
Immersion Tests:			
a)	Distilled Water	No change even after 3 months	No change even after 3 months
b)	2% Nitric acid	-do-	-do-
c)	5% Sodium hydroxide	-do-	-do-
d)	Detergent (Teepol)	-do-	-do-
e)	Hot water		
i)	at 57°C for 30 minutes	No change	No change
ii)	at 90°C for 10 minutes	No change	No change
f)	Petrol (3 months)	Colour fades	Colour changes to yellow
g)	Exposure to wet steam		
i)	Exposure at 77°C for 30 minutes	No change	No change
ii)	Exposure at 120°C for 30 minutes	No change	No change
h)	Accelerated weathering for 500 hr.		
i)	U - V exposure	Yellowing of top coat	Yellowing of top coat
ii)	Q - C - T condensation	No change	No change
iii)	Salt spray (fog) test (for 500 hr)	No change	No change

**CONCLUSION**

The studies showed that using indigenous raw materials a suitable primer, undercoat and finishing paint having the desirable physical, chemical and corrosion resistance properties for use in Nuclear Power Station, can be formulated. Based on the studies it is possible to draw material specifications acceptance criteria. These protective paints can also be used in other highly corrosive environments.

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