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# PERFORMANCE OF ELECTRODEPOSITED NICKEL/CHROMIUM, ZINC, TIN-BISMUTH ALLOY COATING PANELS EXPOSED AT MANDAPAM CAMP

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ABSTRACT

**Bright nickel with a top layer of conventional chromium continues to be the one still in use as a decorative finish. Electrodeposited nickel plus flash chromium, zinc, and nickel-iron alloy plus flash chromium coatings on mild steel and tin-bismuth alloy on brass substrates were prepared by the Metal Corrosion Protection Institute, Sofia, Bulgaria which had been exposed at Mandapam Camp. The performance of the coatings was assessed for a period of one year. The protective schemes, Ni-Cu-Cr, Ni-Fe,Cr, Ni-Cr withstood upto six months in the highly corrosive site at Mandapam Camp.**

## INTRODUCTION

By and large, bright nickel with a top layer of conventional chromium continues to be the one still in use as a decorative finish. Indigenously developed bright-nickel, nickel-iron alloy coatings as well as the recent innovation of micro discontinuous chromium are yet to be commercially exploited. A nickel-chromium plating scheme which might lead to enhanced corrosion protection and substantial reduction in nickel thickness had already been studied [1]. In that study, mild steel panels were coated with bright nickel, duplex nickel and conventional/micro cracked chromium and the performance of these exposed panels at Mandapam Camp had been reported earlier. The results showed the emergence of duplex nickel plus micro cracked chromium combination as the most durable among the various protective coatings.

Close on the heels of these studies comes the exposure of about 180 panels from Bulgaria comprising multilayer coatings of nickel and chromium alloy coatings and zinc at Mandapam Camp. One of the areas of cooperation under the existing protocol between the CSIR and Bulgaria relates to the utilization of the exposure station at Mandapam Camp which is one of the most corrosive sites in the world, where metallic and other protective and decorative coatings corrode within a few months time.

### Systems studied

Listed below are the various protective schemes of decorative coatings on mild steel substrates prepared by the Metal Corrosion Protection Institute, Sofia, Bulgaria which had been exposed at Mandapam Camp.

1. Matte nickel + bright acid copper + bright nickel + flash chromium
2. Matte nickel + bright acid copper + bright nickel + seal nickel + flash chromium
3. Matte nickel + bright acid copper + nickel — iron + seal nickel + flash chromium
4. Matte nickel + bright acid copper + bright nickel + nickel seal + flash chromium (The thickness of bright nickel + seal is half of that of (2))
5. Matte nickel + bright acid copper + nickel iron alloy + flash chromium (Nickel iron alloy is less thick than that of (3)).
6. Matte nickel + bright acid copper + nickel iron alloy (Bright acid copper is of lower thickness).
7. Nickel — iron alloy (The same thickness as that of (6))
8. Bright nickel + seal nickel + flash chromium
9. Nickel — iron alloy + chromium flash
10. Acid zinc + coloured passivated zinc coating
11. Acid zinc + coloured passivated zinc coating (The thickness of acid zinc was ½ of that of (10)).
12. Cyanide zinc + coloured passivation
13. Cyanide zinc + coloured passivation (The thickness of cyanide zinc was ½ of that of (12 ).
14. Acid zinc + another type of coloured passivation (Coloured rainbow) (non standard)
15. Acid zinc + coloured rainbow passivation (non standard) (The thickness of acid zinc was ½ that of (14 ).
16. Tin — bismuth alloy designed for highly aggressive environments — plated on brass.
17. Tin — bismuth alloy for moderately aggressive atmosphere — plated on brass.

The thickness of the coatings :

Zinc : 12 — 15 μ and 24 — 28 μ
Copper : 21 μ
Nickel : Nickel-iron, bright nickel, nickel seal, the combination amounting upto a total of 12 to 24 μ. Chromium 0.3 to 0.4 μ.

### Exposure details

Metal coated mild steel panels measuring 15 cm × 10 cm were mounted in the open monel racks at 45° facing the sea and at a distance of about 50 metres from the sea. The panels were fixed on the stands by means of porcelain cleats. The meteorological data for Mandapam Camp is given below :

| | | |
|---|---|---|
| Maximum temperature | = | 32°C (average) |
| Minimum temperature | = | 24°C (average) |
| Relative humidity | = | 75% (average) |
| Total rainfall mm | = | 1401 |
| Salinity mdd | = | 4.5 (average) |

The total period of exposure was for one year. The performance of the coatings was assessed after a period of one month, three months, six months and one year.

**Evaluation of performance**

At the end of the first month the coatings were found to be intact and corrosion had not started setting in. But at the end of three months when the panels were inspected, it was found that corrosion attack had already started.

The following are the observations noted at the end of three months and six months respectively.

**Table I : Evaluation of different protective schemes**

| Protective schemes | Observations at the end of 3 months | 6 months |
|---|---|---|
| 1. Ni-chromium coatings including seal nickel | Mildly affected, rust had started setting in | A number of large rust spots all over the specimens. Some of the specimens were heavily affected |
| 2. Nickel-iron coatings | Mildly affected | A number of rust spots all over the specimens. |
| 3. Zinc coloured passivated coatings | Heavily affected white rusting all over the panels | Completely damaged with worn-off white rust remaining at places |
| 4. Tin-bismuth alloy coatings | Heavily affected uniformly all over the specimens | Completely damaged |

The exposed panels were removed after a period of one year. The specimens were assessed for their performance against corrosion according to guidelines given in British specification and ASTM standards [2] and the results are given in Table II.

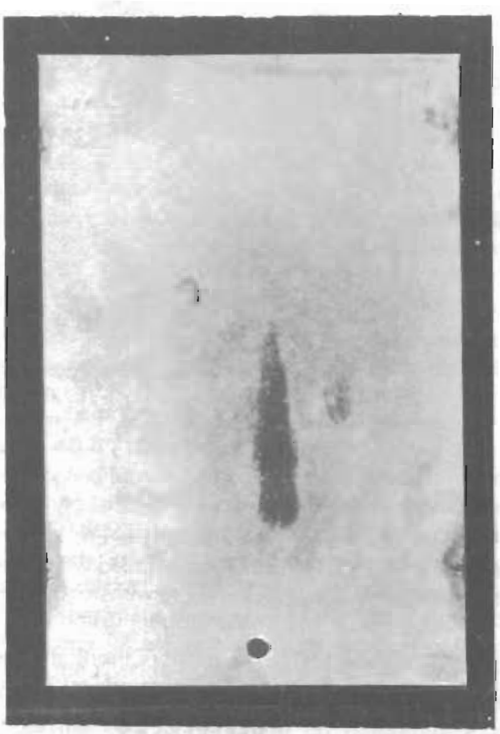
**Table II : Evaluation of exposed specimens**

| Specimens of metallic coatings | Observations at the end of 3 months Appearance | Protection | 6 months Appearance | Protection | 12 months Appearance | Protection |
|---|---|---|---|---|---|---|
| 1. Matte nickel + (acid) bright copper + bright nickel + flash Cr. | 8 | 8 | 7 | 5 | 6.5 | 3 |
| 2. Matte nickel + bright copper (acid) + bright nickel + seal nickel + flash Cr. | 8 | 8 | 8 | 5 | 7 | 3 |
| 3. Matte nickel + bright copper (acid) + iron nickel alloy + nickel seal + flash Cr. | 7 | 8 | 7 | 5 | 6 | 3 |
| 4. Matte nickel + bright copper (acid) + bright nickel + nickel seal (Half that of 2) | 8 | 8 | 8 | 5 | 6.5 | 3 |
| 5. Matte nickel + bright copper (acid) + nickel iron alloy + flash Cr. (Less thick than that of 3) | 7 | 6 | 6 | 4 | 5 | 2 |
| 6. Matte nickel + bright copper (less thick acid) + Ni-iron alloy | 5 | 4 | 3 | 1 | 0 | 0 |
| 7. Nickel-iron alloy (Same thickness as in 6) | 5 | 4 | 3 | 0 | 0 | 0 |
| 8. Bright-nickel + nickel seal + flash Cr. | 7 | 7 | 6 | 6 | 5.5 | 3 |
| 9. Nickel-iron alloy + flash Cr. | 7 | 6 | 6 | 4 | 5 | 2 |
| 10. Tin-bismuth alloy (on brass plates) for aggressive atmosphere | 5 | 5 | 3 | 1 | 0 | 0 |
| 11. Tin-bismuth alloy (for moderately aggressive atmosphere) | 5 | 4 | 3 | 1 | 0 | 0 |

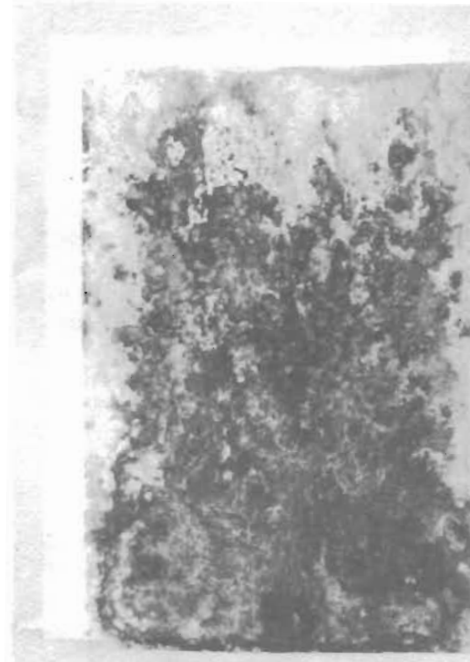
| Area of defect (in per cent) | Rating |
|---|---|
| 0 | 10 |
| 0 to 0.1 | 9 |
| 0.1 to 0.25 | 8 |
| 0.25 to 0.5 | 7 |
| 0.5 to 1.0 | 6 |
| 1.0 to 2.5 | 5 |
| 2.5 to 5.0 | 4 |
| 5 to 10 | 3 |
| 10 to 25 | 2 |
| 25 to 50 | 1 |
| $>50$ | 0 |

It is obvious from the Table that the performance of nickel-iron/Cr combination (1 and 2) and bright-nickel/Cr combination (3) are same as seen from the photographs (1 and 2) and observations recorded in the Table II. The performance of protective schemes with lower thickness (4-6) is given in Table II. It is seen from the Table that the performance of Ni-Fe alloy (No. 7) failed within six months and the photograph No. 4 indicates the total failure at the end of one year, whereas the same Ni-Fe alloy with flash chromium

1. *Matte nickel + (Acid) bright copper + bright nickel + flash chromium*



2. *Matte nickel + (Acid) bright copper + Nickel-iron alloy + Nickel seal + flash chromium*

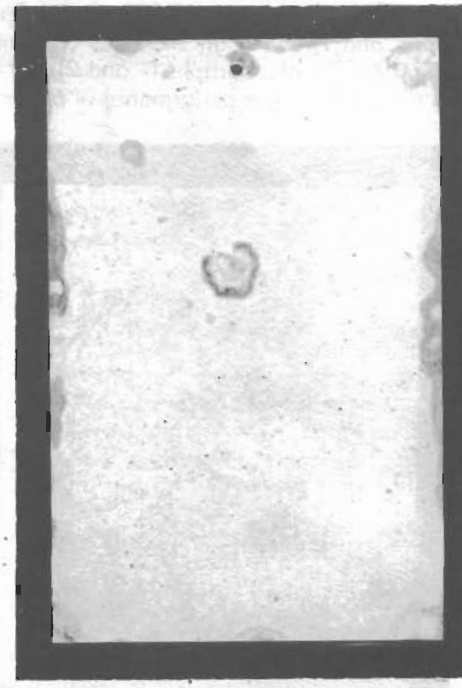


3. *Matte nickel + (Acid) bright copper + Nickel-iron alloy (less thick)*

4. *Nickel-iron alloy (The same thickness as in (3)*

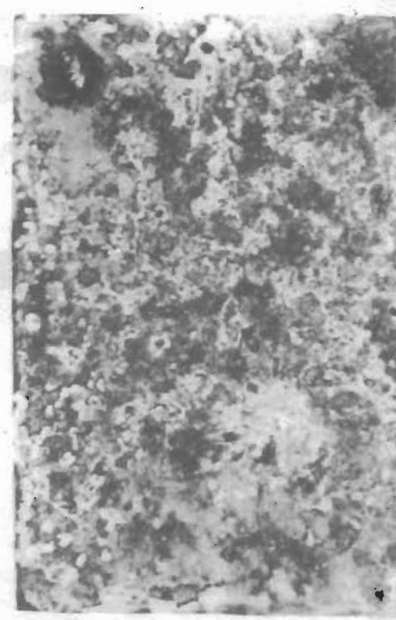
the performance is better than Ni-Fe alloy alone (refer photograph 5). The performance of bright nickel + nickel seal + flash chromium and nickel-iron alloy + flash chromium are same at the end of 12 months exposure (see photograph 6). It is seen from

5. *Nickel-iron alloy + flash chromium*



6. *Bright-nickel + seal nickel + flash chromium*

7. *Tin-bismuth alloy (on brass substrate) (for aggressive atmosphere)*



8. *Zinc coating*

photograph 7 that the protective scheme based on tin-bismuth alloy on brass plate failed completely within six months and brass substrates are visible. The protective scheme with zinc coatings (acid or cyanide bath) on mild steel panels exposed at Mandapam Camp failed within three months. At the end of six months the coatings peeled off from the surface. It is seen from photograph 8 that the zinc protective coatings failed completely.

## CONCLUSION

All the protective schemes failed at the end of 12 months. The protective scheme 6-11 as in Table II failed within six months. The protective scheme 1-6 (Ni-Cu-Ni-Cr) withstood upto six months in the highly corrosive site at Mandapam Camp.

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## REFERENCES

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