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FURTHER EVALUATION OF NEW SURFACE COATINGS FOR SPRINGS

Report No. 414

by

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SUMMARY

This report completes the current series of tests evaluating new coating systems for corrosion protection of springs.

Paint, plastic, resin and metallic systems applied to springs were evaluated in terms of their ability to confer resistance to red rust when exposed to neutral salt spray.

The work clearly identified both the electroplated aluminium and the Deltatone systems for salt spray resistance in excess of 500 hours, whilst PVC plastic gave over 250 hours protection. Electro-cathodic paint gave good protection, but the corrosion resistance was critically dependent upon good preparation of the spring surface prior to paint application. The non-sacrificial systems were generally more susceptible to failure beneath the end tips of the springs.

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springs ranked by failure at end tip.

VII Neutral salt spray results for coated and preloaded springs ranked by failure on active coils.

VIII Suggested coating systems for salt spray protection of springs which may be load tested after coating.

FURTHER EVALUATION OF NEW SURFACE COATINGS FOR SPRINGS

1. INTRODUCTION

Recent SRAMA reports have examined several of the new paint, plastic and metallic coatings which are now available for protecting springs against corrosion.[1,2] The present report essentially completes the evaluations, documenting the results of the following tests:

i) Ongoing environmental exposure tests to BS3900: Part F6, carried out on both unpeened and shot peened test panels made from mild steel strip.

ii) Neutral salt spray tests of coated unpeened springs to the requirements of ASTM B117-73 and BS5466: Part 1: 1977, for the range of new coatings detailed below.

It should be noted that salt spray tests will only rank the coatings in terms of resistance to the salt spray, and these results should not be interpreted as a measure of resistance to corrosion in the real environment.

2. COATINGS EXAMINED AND EXPERIMENTAL TECHNIQUES

2.1 On-going Environmental Exposure Tests

The coatings examined are shown in Table I for ease of reference. Both unpeened and shot peened test panels were simultaneously tested under outside atmospheric conditions on the laboratory roof using special corrosion racks constructed in accordance with the conditions laid out in BS3900: Part F6.

The racks were inclined at 45° to the horizontal and were positioned, facing towards the equator, away from any protection or overshadowing by neighbouring objects. The panels were held in place by electrically insulating fibre washers to prevent contact with the steel rack and thus avoid any effects of electrochemical corrosion.

2.2 Neutral Salt Spray Tests

Twenty-one coating systems were examined during this work. To maintain the required compatibility with previous work, unpeened compression springs made from 5mm diameter carbon steel wire were used for the neutral salt spray tests.

The springs were made from oil tempered wire conforming to BS 2803:1980 HS 095A65, the design being as follows:

Wire diameter = 5mm
Outside diameter = 42mm
Total coils = 5.5
Free length = 64mm
(After stress relieving, end grinding and prestressing)

Corrosion testing to the requirements of ASTM B117-73 and BS 5466: Part 1: 1977 was carried out using the Liebisch STR400 salt spray test cabinet at the SRAMA laboratories. After coating, both preloaded and un-preloaded springs were exposed to salt spray for up to 1200 hours. As in previous work, two criteria were adopted as definitions for coating failure, namely:

i) First appearance of red rust under the end coil, and

ii) First appearance of more general coating breakdown, identified by red rust on the active coils of the springs.

2.3 Coating systems examined

With two exceptions all the systems are claimed to avoid hydrogen embrittlement due to the coating processes.
The coatings examined are shown in Table II, together with approximate coating costs. Table II also shows the results of coating thickness measurements obtained for the metallic and resin/metallic systems which might be expected to provide some sacrificial protection during service.

A more detailed description of the coatings examined by neutral salt spray is as follows:

i) Phosphate and black enamel

Applied by dipping.

ii) Electropaint

A one coat paint finish applied by electrodeposition without phosphate pre-treatment, and subsequently cured at 180°C.

iii) Phosphate and electropaint

Phosphate pretreatment followed by electro-cathodic deposition of paint. Cured by stoving at 180°C for 30 minutes.

iv) Two coat Deltatone

The Deltatone coat essentially consists of zinc metal bonded with an organic resin, which is subsequently cured by stoving at 185-210°C for 30 minutes.[3]

v) Phosphate and two coat Deltatone

Phosphate pre-treatment followed by Deltatone treatment as above.[3]

vi) Phosphate Two coat Deltatone and Two coat Deltaseal with PTFE additions

Phosphate and Deltatone finish as above, followed by dip/spin application of Deltaseal. The Deltaseal coat does not contain metallic zinc, but does contain zinc based compounds to inhibit the onset of corrosion. A range of colours is available for identification of parts.[3]

vii) Electroplated Aluminium

Coating begins with a thin electroplated nickel flash from a high efficiency nickel sulphamate bath.

Aluminium is subsequently plated from a toluene based electrolyte which does not involve hydrogen generation, hence the process is claimed to avoid the problems of hydrogen embrittlement which can be associated with electroplated zinc or cadmium.

For the present work, the springs were given the recommended coats of 0.005mm nickel and 0.015mm aluminium with a final yellow chromate passivation treatment.[4]

viii) Mechanical Zinc

A surface coating of zinc essentially produced by cold welding zinc powder to the steel surface by the impact of glass beads, or other suitable media, during a barrelling process. A coating thickness of 0.01mm was specified for the present work.

ix) Mechanical Tin/Zinc

An intimate mixture of tin/zinc which is cold welded onto the steel surface using techniques similar to those used for coating with mechanical zinc. A coating thickness of 0.012mm was specified for the present work.

x) PC80GS PVC plastic coat with adhesive primer

Springs were cold primed and were then coated at 280-320°C using a fluidized bed technique.[5]

xi) Polypropylene plastic coat

Three types of coating were tested, as follows.

PPA21 (10); PPA31(11); PPA61(12)

Adhesive primers were not required for these plastic coatings, which were applied by the fluidized bed technique.[5]

In general, the three formulations were stated to exhibit the following characteristics.

PPA21*: Good exterior weather resistance

PPA31: Good resistance to water based chemicals.

PPA61: Softer than PPA21/31, with better resistance to stress cracks and improved adhesion.

*This formulation discontinued 1987.

xii) SP95R Nylon, without primer and with adhesive primer

The springs were nylon coated at 220-350° using a fluidized bed technique.[5]

xiii) P3353 Epoxy coat

After cold coating by electrostatic spray, this epoxy coat was cured by stoving at temperatures between 160-210°C.[5]

xiv) Calvinac HR321 Phenol formaldehyde resin

This self priming coat was applied to a lightly grit blasted spring surface, and was subsequently cured at a temperature of 150°C.[6] However, grit blasting is not recommended for springs due to the possible adverse effects upon fatigue properties.

xv) Oztelloy stainless steel electroplate

This recently developed coating is essentially an electroplated 0.002/0.005mm flash of stainless steel alloy, a typical composition by weight as follows:

55% Cr, 35% Fe and 10% Ni

The process is intended as a substitute for bright chromium plating. As with chromium electroplate, the appearance of the Oztelloy finish is highly dependent upon the surface finish of the 0.02/0.025mm nickel undercoat.

It is claimed that the Oztelloy process provides better corrosion resistance than the equivalent chromium plate since, unlike chromium, the stainless steel plate is essentially free from microcracks.[7]

Three coating systems were tested in the present work, as follows, the nickel undercoat in each case being reported as having a typical thickness of 0.02mm.

Electroless nickel (not heat treated) + Oztelloy
Electroplated bright, duplex nickel + Oztelloy
Electroplated dull, smooth nickel + Oztelloy

It is clear that, of these three systems, only the electroless nickel would be expected to avoid the problems of hydrogen embrittlement often associated with electroplating processes. However, none of the systems would be expected to provide sacrificial protection for the springs.

3. RESULTS

3.1 Environmental tests

The results of the tests are shown summarised in Table III, which is essentially an extension of previously reported work.

3.2 Neutral salt spray tests

These tests essentially produced a large body of raw data.

As an aid to practical application, the coatings have been ranked in order of increasing corrosion protection against both end tip and active coil failure. The ranked data are shown in Tables IV and V for un-preloaded springs and in Tables VI and VII for preloaded springs.

4. DISCUSSION

The environmental test results shown in Table III clearly indicate that the corrosion resistance of the phosphate and electro-cathodic paint system is superior to that of the black enamel paint systems. Furthermore, the environmental test results for electro-cathodic paint appear to confirm the findings of previous work which suggested that shot peening may reduce the protection offered by paint coatings to the onset of rusting.[2] The remaining eight systems are still on test with no evidence of failure after 12050 hours exposure.

The neutral salt spray results for un-preloaded springs, shown in Tables IV and V, suggest that end coil failures play a significant role in breakdown of most of the paint and plastic coatings. Tables VI and VII, for springs preloaded after coating, further indicate that the end coil effects are generally exacerbated by loading of the coated springs, probably as a result of the coating losing integrity and/or adhesion beneath the end tip. These findings therefore confirm the results of earlier work at SRAMA.[2,8,9]

A summarised and practical classification of the time to first red rust is shown in Table VIII.

This classification takes account of any significant reductions in coating life resulting from early breakdown of the coating beneath the end tips of both the un-preloaded and the preloaded springs. Coating breakdown at the end tip can be due to a number of factors, the most likely being poor penetration at the end tip during coating and/or damage beneath the end tip during loading of the coated springs.

The summarised results clearly indicate that all the metallic/resin based sacrificial coatings exhibited salt spray resistance equal to or better than the 96 hours minimum generally expected of zinc electroplated and passivated springs.[1]

However, of the non-sacrificial coatings, only the phosphate + electro-cathodic paint and the PVC PC80GS plastic coats were capable of meeting this minimum 96 hour requirement after end coil effects were considered. It is particularly important to note that omission of the phosphate pretreatment significantly reduced the corrosion protection offered by the electro-cathodic paint system.

Deltatone and electroplated aluminium surmounted end coil effects to give salt spray resistance of 500 hours and 1000 hours respectively. Coating costs for these two systems appear to be competitive with those for conventional zinc or cadmium electroplating.

The neutral salt spray technique is a particularly searching test of corrosion resistance. Consequently, those coatings which did not meet the minimum 96 hour requirement may still be suitable for many less arduous environments. Applications may include identification, protection during storage and/or springs operating in essentially dry conditions. Coating cost is likely to be particularly important for such applications, whilst appropriate environmental testing may be a more suitable method of assessing the corrosion resistance of these coatings.

Finally, none of the coatings examined required curing at temperatures higher than 150-200°C. Consequently they may have application for extension springs, torsion springs and springs which have been shot peened.

5. CONCLUSIONS

1. Deltatone and electroplated aluminium conferred the best resistance to corrosion by neutral salt spray, with 500 hours and 1000 hours resistance respectively.

2. Phosphated and electro-cathodically painted springs gave the best salt spray resistance of all the paint systems considered. However, omission of the phosphate pre-treatment significantly reduced the corrosion resistance of electro-cathodic paint.

3. Of the plastic coatings examined, only the PVC PC80GS system conferred significant resistance to salt spray corrosion.

4. The continuing environmental tests have confirmed that the corrosion resistance of the phosphate and electro-cathodic paint system is significantly better than that of the phosphate and black enamel system. The other eight systems showed no evidence of corrosion after 12050 hours, and remain on test at SRAMA[2]

5. The environmental tests suggest that shot peening of the metal surface before painting may significantly reduce the corrosion resistance of subsequently applied paint finishes.

6. REFERENCES

1. Reynolds, L.F., "Evaluation of new surface coatings for

corrosion protection of unpeened springs." SRAMA Report No. 381, May 1985.

2. Ibid., "Evaluation of paint and plastic coatings for springs." SRAMA Report No. 400. August 1986.

3. Delta GBN Ltd. data brochure, 1985.

4. Bakker, S.J., HGA Galvano-Aluminium B.V., private communication, July 1986.

5. Wiltshire, D., Plascoat Systems Ltd., data sheets and private communication, August 1986.

6. Hill, S.A., Lithgow Saekaphen Ltd., data sheets and private communication, October 1986.

7. Hutchinson, P.J., B.C.I. Permalite Limited, data brochure and private communication, August 1986.

8. Timmins, P.F., "The corrosion fatigue resistance of plastic coated helical compression springs." SRAMA Report No. 258, March 1976.

9. Hale, G., "The effectiveness of paints as corrosion protectives for carbon steel springs." SRAMA Report No. 299, September 1978.

TABLE I PROTECTIVE COATINGS ON ENVIRONMENTAL TEST AND COSTS RELATIVE TO PHOSPHATE AND BLACK ENAMEL COAT

Coating Type	Cost*
Black Enamel Only	0.83
Phosphate + Black Enamel	1.0
Phosphate + Electro-Cathodic	1.25
Phosphate + Polyester Powder	2.5
Phosphate + Epoxy Powder	2.1
Nylon	5.6
PTFE	8.3
Sermetel 725	83.0
Sherardized Only	1.2
Sherardized + Zinc Phosphate Passivation	1.4
Sherardized + Zinc Phosphate and Chromate Passivation	1.6

*Costs were provided by coating suppliers, and are necessarily approximate but are based on a batch size of 10,000 springs, weighing 0.5 tonne.

TABLE II SURFACE COATINGS EXAMINED BY NEUTRAL SALT SPRAY TESTS AND COSTS RELATIVE TO PHOSPHATE AND BLACK ENAMEL COAT

Coating Type	Cost*	Coating Thickness mm
Phosphate + black enamel	1.0	--
Electro-painted	1.3	--
Electro-cathodic only+	1.3	--
Phosphate + electro-cathodic	1.5	--
Mechanical zinc	1.4	0.02 (Note 1)
Mechanical tin/zinc	1.7	0.01 (Note 2)
Zinc electroplated (for ref.)	4.0	0.005-0.010 (Ref 1)
Two coat Deltatone	3.7	0.02 (Note 3)
Phosphate + Deltatone	4.3	0.015 (Note 3)
Phosphate, Deltatone and Deltaseal with PTFE	5.0	0.03 (Note 3)
Electroplated aluminium	7.0	0.025 (Note 4)
Electrostatic epoxy (Duraguard P3353)	9.5	--
PVC with primer (PC80GS)	12.0	--
Polypropylene (PPA21)	13.0	--
" (PPA31)	13.0	--
" (PPA61)	13.0	--
Nylon SP95R, without primer	15.0	--
Nylon SP95R, with primer	16.0	--
Phenol formaldehyde resin, (Calvinac HR321)		--
Electroless Ni and electroplated stainless steel (Oztelloy)+	cost data not available	--
Electroplated bright Duplex Ni and Oztelloy stainless steel		--
Electroplated smooth Ni and Oztelloy stainless steel		--

* Costs were provided by coating suppliers, and are necessarily approximate but are based on a batch size of 10,000 springs, weighing 1 tonne.

\+ Un-prestressed springs only

$ Local thickness estimated by microscopical examination.

Note 1 Approx. 10% of surface without coat
Note 2 Approx. 25% of surface without coat
Note 3 Approx. 5% of surface without coat or with very thin coat.
Note 4 Composed of 0.005mm nickel + 0.025mm aluminium.

TABLE III RESULTS OF ENVIRONMENTAL TESTS ON COATED TEST PANELS (From Ref.2)

Coating*	Time to Appearance of Red Rust (Hours)				Shot Peened as % Unpeened Life	
	Edge of Panels		Flat Surface Of Panels			
	Unpeened	Peened	Unpeened	Peened	Edge Failure	Flat Surface Failure
Black Enamel Only	288+	48+	3744+	120+	17	3
Phosphate & Black Enamel	888	120	3744	888	14	24
Phosphate & Electro-Cathodic	12050	2544	12050	2544	21	21

* Remainder of coatings (shown in Table 1) still on test with no evidence of failure at 30/3/87 (12050 hours)

\+ Significant peeling of paint film at 12050 hours.

TABLE IV NEUTRAL SALT SPRAY RESULTS FOR AS-COATED (UN-PRELOADED) SPRINGS, RANKED BY FAILURE AT END TIP

Rank No.	Coating	Hours to first red rust
1	Electropainted	20
2	Polypropylene PPA21	"
3	" PPA61	"
4	Electroless Ni & Oztelloy stainless steel	"
5	Electroplated smooth Ni & Oztelloy stainless steel	"
6	Nylon SP95R, without primer	37
7	Electrostatic epoxy Duraguard P3353	"
8	Electroplated bright duplex Ni & Oztelloy stainless steel	"
9	Phosphate & black enamel	58
10	Polypropylene PPA31	"
11	Nylon SP95R, with primer	"
12	Electro-cathodic paint only	99
13	Phenol formaldehyde resin, Calvinac HR321	141
14	Mechanical tin/zinc	250
15	Phosphate & electro-cathodic paint	"
16	PVC PC80GS	341
17	Phosphate, Deltatone & Deltaseal with PTFE	689
18	Phosphate & Deltatone	1263
19	Deltatone only	"
20	Mechanical zinc	1263 no rust
21	Electroplated aluminium	" " "

TABLE V NEUTRAL SALT SPRAY RESULTS FOR AS-COATED (UN-PRELOADED) SPRINGS, RANKED BY FAILURE ON ACTIVE COILS

Rank No.	Coating	Hours to first red rust
1	Electropainted	20
2	Electroless Ni & Oztelloy stainless steel	"
3	Electroplated smooth Ni & Oztelloy stainless steel	"
4	Electroplated bright duplex Ni & Oztelloy stainless steel	37
5	Polypropylene PPA21	58
6	Electro-cathodic paint only	"
7	Phosphate & black enamel	99
8	Mechanical zinc	121
9	Mechanical tin/zinc	250
10	Nylon SP95R, without primer	295
11	Electrostatic epoxy Duraguard P3353	"
12	Polypropylene PPA61	689
13	" PPA31	"
14	Phosphate, Deltatone & Deltaseal with PTFE	"
15	Phosphate & Deltatone	1263
16	Deltatone only	"
17	Nylon SP95R, with primer	1263 no rust
18	Phenol formaldehyde resin, Calvinac HR321	" " "
19	Phosphate & electro-cathodic paint	" " "
20	PVC PC80GS	" " "
21	Electroplated aluminium	

TABLE VI NEUTRAL SALT SPRAY RESULTS FOR COATED AND PRELOADED SPRINGS, RANKED BY FAILURE AT END TIP

Rank No.	Coating	Hours to first red rust
1	Electropainted	20
2	Polypropylene PPA21	"
3	" PPA61	"
4	Nylon SP95R, without primer	"
5	Phosphate & black enamel	37
6	Electrostatic epoxy Duraguard P3353	"
7	Phenol formaldehyde resin, Calvinac HR321	"
8	Nylon SP95R, with primer	58
9	Polypropylene PPA31	80
10	Mechanical zinc	99
11	Phosphate, Deltatone & Deltaseal with PTFE	141
12	Phosphate & electro-cathodic paint	"
13	Mechanical tin/zinc	182
14	Deltatone only	689
15	Phosphate & Deltatone	1263
16	PVC PC80GS	1263 no rust
17	Electroplated aluminium	" " "

TABLE VII NEUTRAL SALT SPRAY RESULTS FOR COATED AND PRELOADED SPRINGS, RANKED BY FAILURE ON ACTIVE COILS

Rank No.	Coating	Hours to first red rust
1	Electropainted	20
2	Phosphate & black enamel	37
3	Polypropylene PPA21	58
4	Nylon SP95R, without primer	"
5	Electrostatic epoxy Duraguard P3353	80
6	Mechanical zinc	99
7	Mechanical tin/zinc	250
8	Phenol formaldehyde resin, Calvinac HR321	295
9	Phosphate & Deltatone	"
10	Phosphate, Deltatone & Deltaseal with PFTE	525
11	Polypropylene PPA61	689
12	" PPA31	"
13	Deltatone only	"
14	Phosphate & electro-cathodic paint	1263
15	Nylon SP95R, with primer	1263 no rust
16	PVC PC80GS	" " "
17	Electroplated aluminium	" " "

TABLE VIII SUGGESTED COATING SYSTEMS FOR SALT SPRAY PROTECTION OF SPRINGS WHICH MAY BE LOAD TESTED AFTER COATING

Coating system for first red rust at end tip or active coil				
<96 hours	96 hrs. minimum	250 hrs. minimum	500 hrs. minimum	1000 hrs. minimum
Electropainted	Mechanical zinc	PVC PC80GS	Deltatone	Electroplated Aluminium
Polypropylene (PPA21, 31 & 61)	Mechanical tin/zinc	Phosphate & Deltatone		
Nylon SP95R	Phosphate/ electrocathodic paint			
Phosphate/ black enamel	Phosphate/ Deltatone/ Deltaseal with PTFE			
Oztelloy stainless steel				
Electro-cathodic paint only				
Electrostatic epoxy P3353				
Phenol formaldehyde HR321				