THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

EVALUATION OF NEW SURFACE COATINGS FOR CORROSION PROTECTION OF UNPEENED SPRINGS

Report No 381

by

L F Reynolds

MAY 1985

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SUMMARY

Recent developments have occurred in the metal finishing technology relating to protection of carbon and low alloy steels against the harmful effects of corrosion.

A number of the recently developed coatings have been examined in detail at SRAMA using neutral salt spray tests with subsequent fatigue testing of springs (made from both BS 5216 HD3 and BS 2803 HD wires, with a view to classifying the coatings for use in the spring industry).

The following coatings were investigated; pre-galvanised wire, electroplated zinc (Zn3) and cadmium (Cd3), with de-embrittlement and chromate passivation, mechanically plated zinc, Dacromet, Polyseal, Xylan XL and Ivadized.

Appropriately coated springs were exposed to neutral salt spray for times up to 240 hours, the time to red rust being taken as the criterion of protection afforded to the springs.

Coated springs were fatigue tested before and after exposure to salt spray for 96 hours and the effect on the limited life fatigue performance assessed.

In terms of efficacy of protection against neutral salt spray, the coatings could be classified into four groups, as follows: (1 = Worst, 4 = Best)

1. Pre-galvanised wire (24 hours)
2. Polyseal
3. Xylan XL, mechanically plated zinc, electroplated zinc
4. Dacromet, electroplated cadmium, ivadized (240 hours)

With the notable exception of Ivadizing, the fatigue life of all the springs was reduced significantly by coating.

Fatigue performance was not noticeably affected when springs were exposed for 96 hours to salt spray prior to fatigue testing.

It is concluded that, when costs are considered, all the new coatings, will be suitable for immediate use in the spring industry.

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MAY 1985

EVALUATION OF NEW SURFACE COATINGS FOR CORROSION PROTECTION OF UNPEENED SPRINGS

1. INTRODUCTION

The protection of steel springs against the effects of corrosion and corrosion fatigue has been the subject of several SRAMA reports.[1, 2, 3, 4]

In recent years, however, several new surface coatings for protection against corrosion have become commercially available. It is claimed by the suppliers that these coatings provide corrosion protection at least equal to that of electrodeposited zinc finishes, and hence it was deemed an opportune moment to examine the performance of the new coatings, both with respect to their appearance during salt spray tests, and their subsequent fatigue behaviour of the salt spray tested springs.

Hydrogen embrittlement can be a significant problem during the electroplating of steel springs. The recent developments in protective coating technology do not employ electrolytic deposition techniques, however, and hence it is claimed that hydrogen embrittlement of coated springs can now be avoided by eschewing electroplated finishes.

The costs of the new coating processes relative to the more usual zinc/cadmium electroplated finishes will obviously have a bearing on their adoption for general use in the spring industry, and hence some information regarding typical coating costs was also acquired during the course of the work.

The degree of protection afforded to springs by the surface coatings was assessed by two methods. Firstly by visual examination after the springs had been exposed to a salt spray test for times up to 240 hours. Secondly the residual life of the springs after exposure to salt spray conditions was determined by fatigue testing.

2. DESCRIPTION OF PROTECTIVE COATINGS INVESTIGATED

The surface coatings investigated are listed in Table I which also indicates the cost of coating, relative to an electrodeposited Zn to BS 1706: 1960: Class B (Zn3) finish after de-embrittlement and chromate passivation, and based on a 5000-10000 spring batch size. A brief description of the surface coatings is given below.

2.1 Electroplated Zinc and Cadmium

In addition to the more recent surface coatings, typical electroplated zinc and cadmium coatings, to Zn3 and Cd3 of BS 1706: 1960, were investigated after de-embrittlement. These results provided a basis for comparison with the behaviour of the other coatings examined.

In the event, four of the eight electroplated batches of springs were in fact supplied with a coating thickness which was intermediate between Zn3/Zn10 and Cd3/Cd10 respectively.

2.2 Mechanically Plated Zinc

This process is often termed "peen plating" or "impact plating".[5] The metal to be deposited is in the form of a powder which is held in suspension in a chemical solution. The metal is essentially cold welded to the steel surface as a result of impact by glass beads or other suitable media, during a barreling process.

Deposit thickness can be varied between 0.005 mm to 0.105 mm.

Although it is possible to achieve a very smooth and bright surface on parts plated in this manner, the conventional "blue-bright" mirror like lustre attainable by electroplating zinc cannot be obtained by mechanical plating.

Further details of this technique can be found in published data.[5]

A USA specification exists for Mechanical Plating of Zinc, namely ASTM B695-82, while a British specification for mechanical plating is now in preparation.

A normal commercial coating thickness of 0.007-0.012 mm was specified for the present work.

2.3 Dacromet

The Dacromet process was originally developed for the USA vehicle industry, all European operations being carried out under licence from Dacral SA in France.[6]

The process involves three principal stages:

a) Alkali cleaning to saponify dirt and lubricants followed by a short pickle in inhibited acid to remove oxide scale.

b) Coating in the Dacromet liquid, which consists essentially of a mixture of zinc metal flakes, chromic acid and an organic resin. When thoroughly wetted, the components are drained and spun to remove excess liquid.

c) The coating is cured by baking at 300°C. ± 15°C. Steps (b) and (c) are repeated as required to provide the desired coating thickness. The normal grades of coating thickness are:

   Grade A: 0.005 mm minimum

   Grade B: 0.008 mm minimum

   The Grade A Dacromet finish was used for the present work.

Typical vehicle and component manufacturers' specifications specific to Dacromet are:

British Leyland Engineering Standard: BLS.21.ZS.05
Ford Motor Co Engineering Spec: SAM-1P9108-A/B

2.4 Polyseal

Applied to a surface which has been cleaned in alkali and inhibited acid, this coating consists of a phosphate base with a double coat of resin lacquer, which is stoved at 200°C ± 15°C, and an oil seal finish.[7] A typical vehicle-manufacturers standard is British Leyland Engineering Standard BLS 21 FB 03 (Digit Codes 4 and 5).

Type 1 finish is a "one coat" Polyseal
Type 2 finish is a "two coat" Polyseal

Polyseal coated components generally have a black finish, but a range of coloured finishes can be supplied, upon request, for colour coding. The Type 1 Polyseal black finish was used in the present work.

2.5 Xylan XL

After cleaning in alkali and inhibited acid, the metal is phosphated after which the coating is applied. The coating consists of Polytetrafluorethylene (PTFE) combined in a resin polymer matrix, and is normally applied as a double coating, which is cured at 200°C ± 15°C.[8] Due to the lubricating properties of PTFE, the coating has very good resistance to rubbing and handling wear.

A range of coloured finishes is available for identification purposes, the blue finish being used for the present work.

2.6 Ivadizing

This aluminium coating is produced by a process of ion vapour deposition which is not confined to "line of sight" and which can therefore readily deposit aluminium into part recesses and cavities.[9]

The ion vapour deposition process essentially takes place in a chamber filled with inert gas to a pressure of 10 torr. After evaporation from resistance heated crucibles, aluminium ions are deposited onto the workpiece, in a glow discharge which accelerates the vapourized aluminium towards the components to be coated. The components reach a maximum temperature of 200-230°C during Ivadizing, and the parts do not require baking after Ivadizing.

Deposits can generally be provided in three grades of thickness and the coatings can be chromate passivated after deposition.

The general classes of coating available are as follows:

Class	Minimum Thickness (mm)
1	0.025
2	0.0125
3	0.0075

In general terms, a Class 2 deposit with passivation is recommended for most engineering applications, and this was used for the present work.

3. MATERIALS AND SPRING DESIGNS

Three spring wires, each 4 mm in diameter, were employed for this work, namely hard drawn carbon steel to BS 5216 HD3, obtained both as uncoated and zinc pre-galvanized wire, and hardened and tempered carbon steel 093A65 to BS 2803 HD. Tensile tests and microscopical examination of transverse microsections showed all the wires to be satisfactory with respect to tensile strength and defect/decarburization free surfaces. The tensile test results are shown in Table II together with the appropriate spring designs and low temperature heat treatments used for the three materials.

Springs were auto-coiled by a member firm, and were supplied to SRAMA after appropriate LTHT and pre-stressing to solid. Springs made from the three wires were identified by prefix as follows:

Wire	Prefix
BS 5216 HD3	D1
BS 5216 HD3 Pre-galvanized	DG
BS 2803 HD	H2

This identification prefix was retained throughout the work to avoid confusion.

Batches of the D1 (BS 5216 HD3) and the H2 (BS 2803 HD) springs were subsequently commercially coated with the appropriate protective finish.

Transverse microsections were prepared for spring selected at random from each batch of coated springs and the coating thickness was measured by means of a metallurgical microscope. The results of the coating thickness determinations are shown in Table III.

Where possible, average coating thickness was determined using "strip and weigh" methods and these results are also shown in Table III.

The electroplated and mechanical zinc coatings were stripped using a solution of antimony trichloride and hydrochloric acid, as stipulated in BS 1706: 1960.

The Dacromet and Ivadized coatings were removed by immersion in a hot solution of 20% sodium hydroxide, until hydrogen evolution ceased.

The thickness was then calculated using the relationship:

$$\text{Thickness (mm)} = \frac{W}{A} \times F$$

Where W = Coating weight, gm

A = Surface area of spring sample, mm^2

F = Density factor for coating

(Zinc = 140; Cadmium = 116; Aluminium = 370)

4. SALT SPRAY TESTS AND FATIGUE TESTING

Neutral salt spray tests, to the requirements stipulated in ASTM B117-73 and BS 5466 Part 1: 1977, were carried out using the Liebisch STR 400 salt spray test cabinet now in operation at the SRAMA laboratories.

4.1 Static Tests for Visual Assessment

For each coating type, batches of four springs were exposed to salt spray for up to 240 hours, the time taken for first evidence of red rust being adopted as the criterion of coating protection.

4.2 Dynamic Tests

For each coating, two batches of eight individually identified springs were prepared for salt spray exposure of 96 hours.

One of the batches was exposed unstressed to the salt spray.

The other batch of springs was first pre-loaded ten times to the maximum fatigue stress, to initiate possible damage to the coating beneath the end coil. This batch was then exposed to salt spray whilst maintained at the maximum fatigue stress to simulate the conditions likely to obtain in service. Stressing whilst undergoing salt spray tests was carried out using passivated 321S12 stainless steel jigs, from which the stressed test springs were electrically insulated using 3 mm thick plastic fibre-board at both ends of the springs, to avoid the potentially misleading electrochemical effects of differential metallic contact.

All fatigue tests were carried out on one forced motion eight station machine operating at 25 Hz.

The springs were fatigue tested between minimum and maximum stresses of 100 N/mm^2 and 850 N/mm^2 respectively, earlier tests on uncoated springs having established the fatigue life to be expected for components not exposed to salt spray. Springs surviving unbroken to 10^7 cycles were re-load tested to give an estimate of dynamic relaxation that occurred during fatigue testing.

5. RESULTS AND DISCUSSIONS

5.1 Static Tests

The results of the neutral salt spray tests for the hard drawn and the pre-hardened and tempered springs are presented in Fig 1, whilst the appearance of the springs, before and after 96 hours exposure to salt spray, is shown in Figs 2-4.

From the data of Fig 1, the coatings can be grouped as follows in terms of the efficacy of protection offered to corrosion by a neutral salt spray solution:

Coating Type in Order of Increasing Protection to Neutral Salt Spray (1 = Worst; 4 = Best)

1. Pregalvanized wire.
2. Polyseal.
3. Xylan XL, Mechanically Plated Zinc, Electroplated Zinc.
4. Dacromet, Ivadizing, Electroplated Cadmium.

All the coatings applied to springs performed better than pre-galvanized wire. Of the two non-metallic coatings, Xylan XL gave the best performance, this being equal to that displayed by electroplated zinc and mechanically plated zinc.

It is particularly instructive to compare the above grouping with that derived by consideration of the average thickness of the sacrificial coatings applied to the springs used for the bulk of this work.

Coating	Average Coating Thickness (mm)
Dacromet	0.004
Ivadize	0.004-0.006
Mechanical Zinc	0.004-0.008
Electroplated Zinc	0.005-0.018
Electroplated Cadmium	0.010-0.022

It is clear from this data that, for a given coating thickness, both the Dacromet and the Ivadize coatings are likely to be superior to electroplated cadmium, whilst Mechanical Zinc is equal to or slightly better than electroplated zinc.

5.2 Dynamic Tests

It should be emphasized that all fatigue tests were carried out on compression springs, which are stressed in torsion, and, in consequence, it cannot be assumed that the results will necessarily be representative of the behaviour of spring clips or torsion springs, for example, both of which are essentially stressed in bending.

5.2.1 Preliminary Fatigue Tests on "As Coated" Springs

The results of these tests are shown in Figs 5 and 6 for the hard drawn and the pre-hardened and tempered wire springs respectively.

With the exception of the Ivadized springs, which all survived unbroken to 10^7 cycles, coating the springs generally reduced their fatigue life relative to their uncoated fatigue performance, the reduction always being more marked for the pre-hardened and tempered wire components.

5.2.2 Fatigue Tests on Corrosion Tested Springs

The fatigue data derived from these tests is shown in Figs 7-10. Analysis of the data indicated that, in general terms, salt spray testing did not alter substantially the fatigue performance obtained for "as coated" springs prior to salt spray testing.

Examination of the diagrams appears to indicate that Dacromet was associated with fatigue lives which were lower than the electroplated cadmium, however. Statistical analysis using ANOVA techniques showed that the disparity in performance was more apparent than real, the difference being either non-significant or only significant at the 95% level of the F distribution. In practical terms, therefore, the fatigue performance of the Dacromet coated springs was very similar to that of the other coated springs with reduced fatigue lives.

Comparative data for the various coatings and materials are shown in Table IV, in which the fatigue results are expressed as a percentage of the mean fatigue life obtained for uncoated springs made from the appropriate wires. From this information, three general conclusions are clear:

i) With the exception of the Ivadized springs, the coatings were generally associated with reduced fatigue life. Salt spray testing did not cause further reductions in fatigue life, however.

ii) With the exception of the Ivadized springs, the fatigue performance of the coated springs made from pre-hardened and tempered wire were reduced to a greater extent than those coated springs made from hard drawn wire.

iii) With the exception of one spring, the Ivadized springs exhibited fatigue properties which were significantly better than the uncoated springs, even after 96 hours exposure to salt spray.

It is interesting to note that, for all but the Ivadized springs, surface coatings were associated with reduced fatigue life, expecially in the case of the samples made from pre-hardened and tempered wire.

It is possible that small amounts of hydrogen caused the observed reductions in fatigue life of coated springs, particularly since hardened and tempered steels are known to be more sensitive to this phenomenon than patented hard drawn steels. Previous work by other investigators has suggested that the fatigue life of springs can be significantly reduced by small amounts of hydrogen introduced both during acid cleaning and electroplating.[5] This is unlikely to be the sole reason, however, since Dacromet, Polyseal and Xylan treated springs were baked at temperatures of 200-300°C after coating.

5.2.3 Dynamic Relaxation

Measurements of dynamic relaxation, made on all springs which survived 10^7 cycles, gave the following results:

Parameter	Dynamic Relaxation %	
	Hard Drawn Wire (D1)	Pre-Hard & Temp Wire (H2)
Mean	0.8	2.5
Standard Deviation	1.9	1.4
No of Springs	29	23

These levels of dynamic relaxation would not be expected to substantially affect the possibility of springs surviving 10^7 cycles, and would not be expected to affect the validity of fatigue test results presented in this report.

6. APPLICATIONS

All of the surface coatings considered can be used for unpeened compression springs which can be stress relieved at temperatures of 300-400°C, and for BS 5216 torsion springs, which can be stress relieved at 280°C.

Care should be exercised in the selection of appropriate coatings for other springs, however, since the springs may experience changes in characteristics due to the curing temperatures used for resin based coatings.

Thus tension springs and all shot peened springs are usually stress relieved at a maximum temperature of 220°C, whilst BS 2803 torsion springs are rarely stress relieved above 250°C. As a result, Dacromet coatings (cured at 285-315°C) would not be appropriate for tension springs with initial tension, BS 2803 torsion springs or any shot peened springs requiring stress relief at 220°C. Alternative non-electrolyic coatings in these instances would be mechanically plated zinc, Xylan XL or Ivadized for example, the final decision being based on cost/performance requirements together with consideration of whether or not sacrificial coatings or electrical insulation are required for the particular application.

7. CONCLUSIONS

1. In order of resistance to neutral salt spray, the eight coatings can be grouped as follows, in order of increasing corrosion protection against formation of red rust (1 = Worst; 4 = Best).

    1) Pre-galvanised Wire
    2) Polyseal (Type 1)
    3) Xylan XL, Mechanically Plated Zinc, Electroplated Zinc
    4) Dacromet, Electroplated Cadmium, Ivadized

2. The costs of Polyseal, Xylan, Mechanical Zinc and Dacromet are broadly comparable to those for zinc electroplating with de-embrittlement and passivation. Dacromet, for example, shows considerable promise as a non-toxic replacement for cadmium plate, although some limitations in use may result from the Dacromet curing temperature of 285-315^{o}C.

3. With the exception of the Ivadized springs, the mean fatigue life of 4×10^5 cycles was reduced by coating, the magnitude of the reduction for pre-hardened and tempered springs being significantly greater than that for hard drawn springs.

4. Exposure to neutral salt spray for 96 hours did not cause any substantial and consistent changes in the fatigue performance of the coated components, irrespective of whether the springs were stressed or unstressed during the salt spray test.

5. There was clear and consistent evidence that, irrespective of material, Ivadizing was associated with significant improvements in fatigue resistance, all the "as coated" springs surviving unbroken to 10^7 cycles.

   After 96 hours exposure to neutral salt spray, 70% of the Ivadized springs survived unbroken to 10^7 cycles, and over 95% of the springs survived in excess of 10^6 cycles. Such improvements in fatigue life could be useful for springs too small to be shot peened. The small amounts of dynamic relaxation which occurred do not adequately explain this effect, which may result from subtle changes in the surface energy of the spring steel. Ivadizing was an order of magnitude more expensive than the other processes, and the price will need to be reduced substantially if advantage is to be taken of the potential improvements in both corrosion resistance and fatigue performance, in all except the most demanding applications.

8. RECOMMENDATIONS FOR FURTHER WORK

Although unpeened springs were used for the present work, a significant proportion of springs are shot peened to improve fatigue performance in service.

With the exception of Dacromet, all of the coatings investigated can be used on shot peened springs, and it would be useful to know if the fatigue resistance of such springs was maintained or improved by application of the new surface coatings now available.

It would also be useful to investigate the effects of the coatings on springs operating in bending, since a significant number of springs clips and torsion springs are likely to use the new coating processes.

The improvements in fatigue life associated with Ivadizing may prove useful to the designer of springs too small to be shot peened, if coating costs can be reduced.

It would be interesting to know if similar improvements accrue for stainless steel springs.

9. REFERENCES

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TABLE I PROTECTIVE COATINGS INVESTIGATED AND RELATIVE COSTS

Coating Type	Coating Ident	Cost Relative to Zn3 Electroplate*
Pre-Galvanised BS 5216	DG	∿ 0.75
Electroplated Zn+ (Yellow Passivation)	JZ (Y)	1
Electroplated Cd+ (Yellow Passivation)	JC (Y)	1.13
Electroplated Zn (Clear Passivation)	BZ (C)	1
Electroplated Zn (Yellow Passivation)	BZ (Y)	1
Electroplated Cd (Clear Passivation)	BC (C)	1.13
Electroplated Cd (Yellow Passivation)	GC (Y)	1.13
Mechanical Zn (Passivated)	MZ	1.15-1.2
Dacromet (Grade A)	DAC	1.15-1.2
Polyseal (Type 1)	PSEAL	1.15-1.2
Xylan XL	XYL	1.15-1.2
Ivadized (Class 2, with Passivation)	IVD	9.0

* All costs are relative to Zn3 electroplate with full de-embrittlement and passivation, and are intended for guidance only, but are based on a batch size of 5000-10000.

\+ Static testing only - fatigue data not generated for these samples.

TABLE II SPRING MATERIALS AND DESIGNS

Wire/Spring Parameter	Material and Spring Design		
	BS 5216 HD3 Hard Drawn (D1)	BS 2803 HD Oil Hardened and Tempered (H2)	BS 5216 HD3 Hard Drawn, Pre-Galvanized (DG)
Wire diam, mm	4.0	4.0	4.0
Outside coil diam, mm	34.0	34.0	34.0
Free length, mm (after stress relieving, end grinding and prestressing)	53.0	51.5	53.0
Stress relief	250°C/ ½ hour	400°C/ ½ hour	250°C/ ½ hour
Total coils	5.5	5.5	5.5
Ends: Closed and Ground			
Tensile Strength of Wire, N/mm^2	1580	1535	1630

TABLE III THICKNESS OF PROTECTIVE COATINGS ON SPRINGS

(See Table I for Coating Identification)

Coating Identification	Coating Thickness, mm			
	Local Thickness +		Average Thickness #	
	BS 5216 HD3 (D1 & DG)	BS 2803 HD (H2)	BS 5216 HD3 (D1 & DG)	BS 2803 HD (H2)
DG*	0.015-0.018	-	0.014	-
JZ	0.005-0.010	0.005-0.010	0.007	0.005
JC	0.005-0.013	0.005-0.010	0.010	0.013
BZ	0.012-0.020	0.015-0.023	0.016	0.018
BC	0.018-0.026	0.014-0.028	0.022	0.022
MZ	0.010-0.014	0.010-0.017	0.008	0.004
DAC	0.006-0.010	0.006-0.010	0.004	0.004
PSEAL	0.008-0.010	0.010-0.018	-	-
XYL	0.020-0.024	0.022-0.026	-	-
IVD	0.010-0.012	0.012-0.014	0.004	0.006

\+ Measured by Optical Microscopy

\# Measured by "Strip and Weigh" Technique

* Zinc Coating Generally Cracked and Discontinuous

TABLE IV MEAN FATIGUE LIFE OF COATED SPRING BATCHES AS % OF UNCOATED SPRING LIFE

Coating	As Coated		Neutral Salt Spray Tested for 96 Hours			
			Stressed at 850 N/mm^2		Unstressed	
	D1	H2	D1	H2	D1	H2
BZ	32	15	46	37	42	22
BC	46	26	45	30	39	24
MZn	44	26	49	44	43	34
Dac	34	25	33	19	25	19
P Seal	100	68	50	37	53	31
Xyl	56	37	43*	76	44*	51
Ivd	>2380 ‡	>2380 ‡	1544*	52*	408*	2234*
DG +	40		40		40	

* Minimum life of broken springs. Significant No. U/B at 10^7.

‡ All U/B at 10^7.

\+ as % of D1 results for uncoated springs.

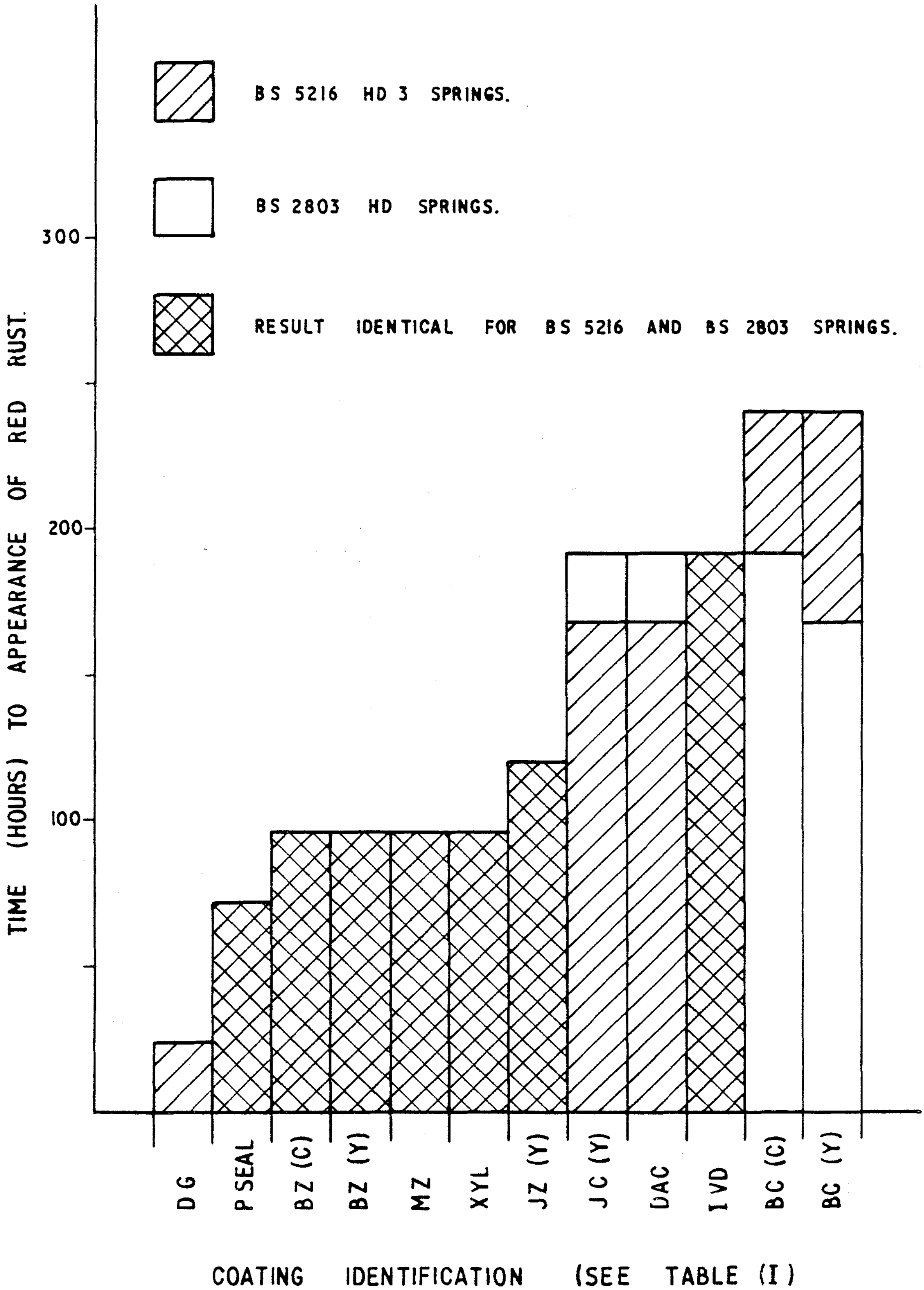
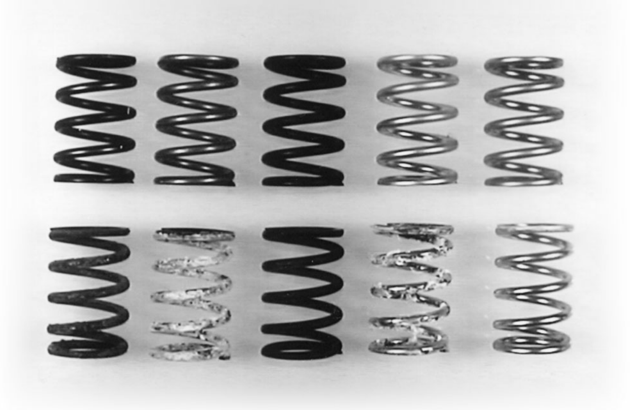


FIG. I. RESISTANCE OF PROTECTIVE COATINGS ON SPRINGS TO NEUTRAL SALT SPRAY CORROSION.



A/C

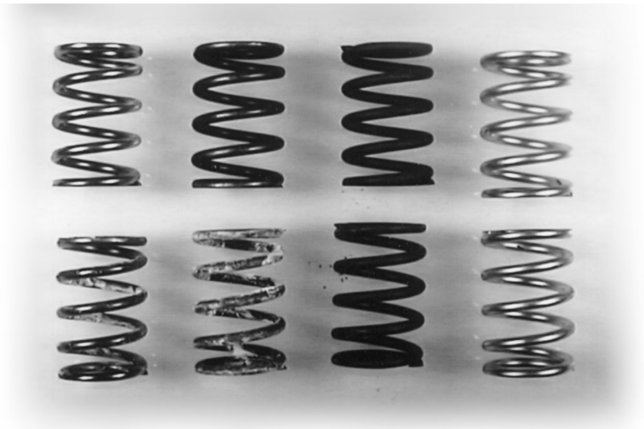
S/T

*   U/C   DG   PSEAL   BZ(C)   BZ(Y)   *

* See Table I for coating identification
A/C = Uncoated/As Coated
S/T = Exposed for 96 hours to Neutral Salt Spray

Fig 2

Appearance of springs before and after Neutral Salt Spray test.



A/C

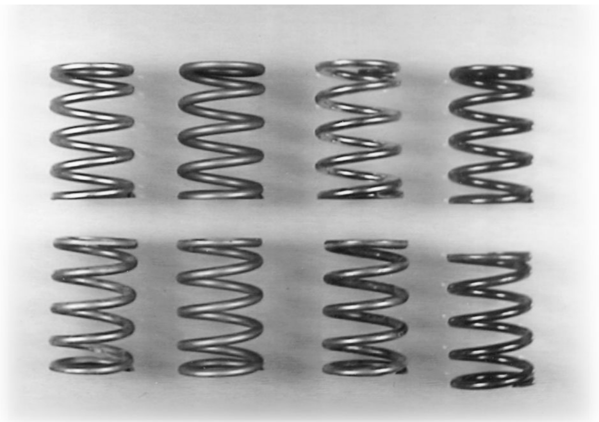
S/T

*   JZ (Y)   MZ   XYL   JC (Y)   *

* See Table I for coating identification
A/C = Uncoated/As Coated
S/T = Exposed for 96 hours to Neutral Salt Spray

Fig 3

Appearance of springs before and after Neutral Salt Spray test.



A/C

S/T

* DAC IVD BC (C) BC (Y) *

* See Table I for coating identification
A/C = Uncoated/As Coated
S/T = Exposed for 96 hours to Neutral Salt Spray

<u>Fig 4</u>

Appearance of springs before and after Neutral Salt Spray test.

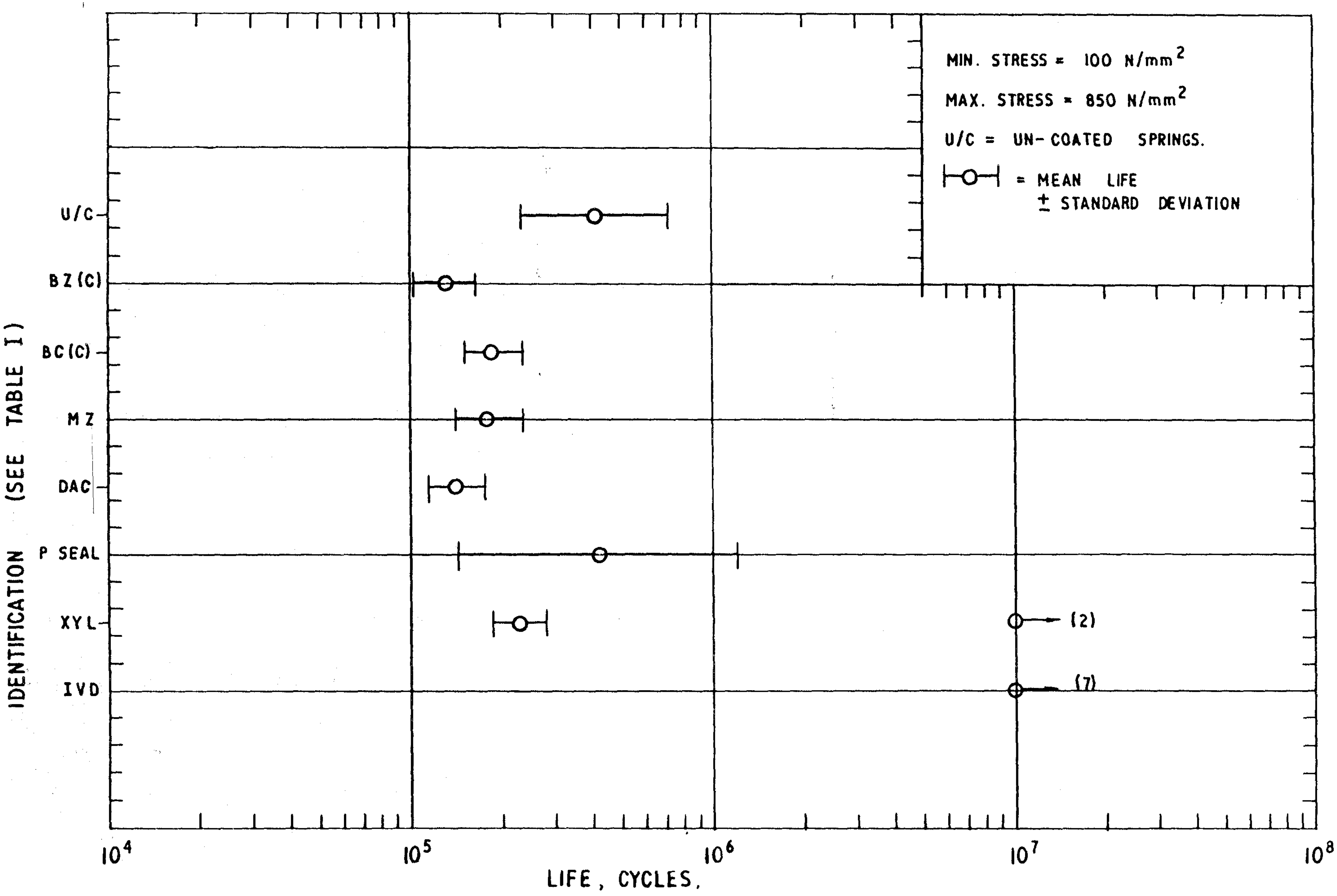


FIG. 5. EFFECT OF SURFACE COATINGS ON FATIGUE PROPERTIES OF BS 5216 HD3 UNPEENED SPRINGS.

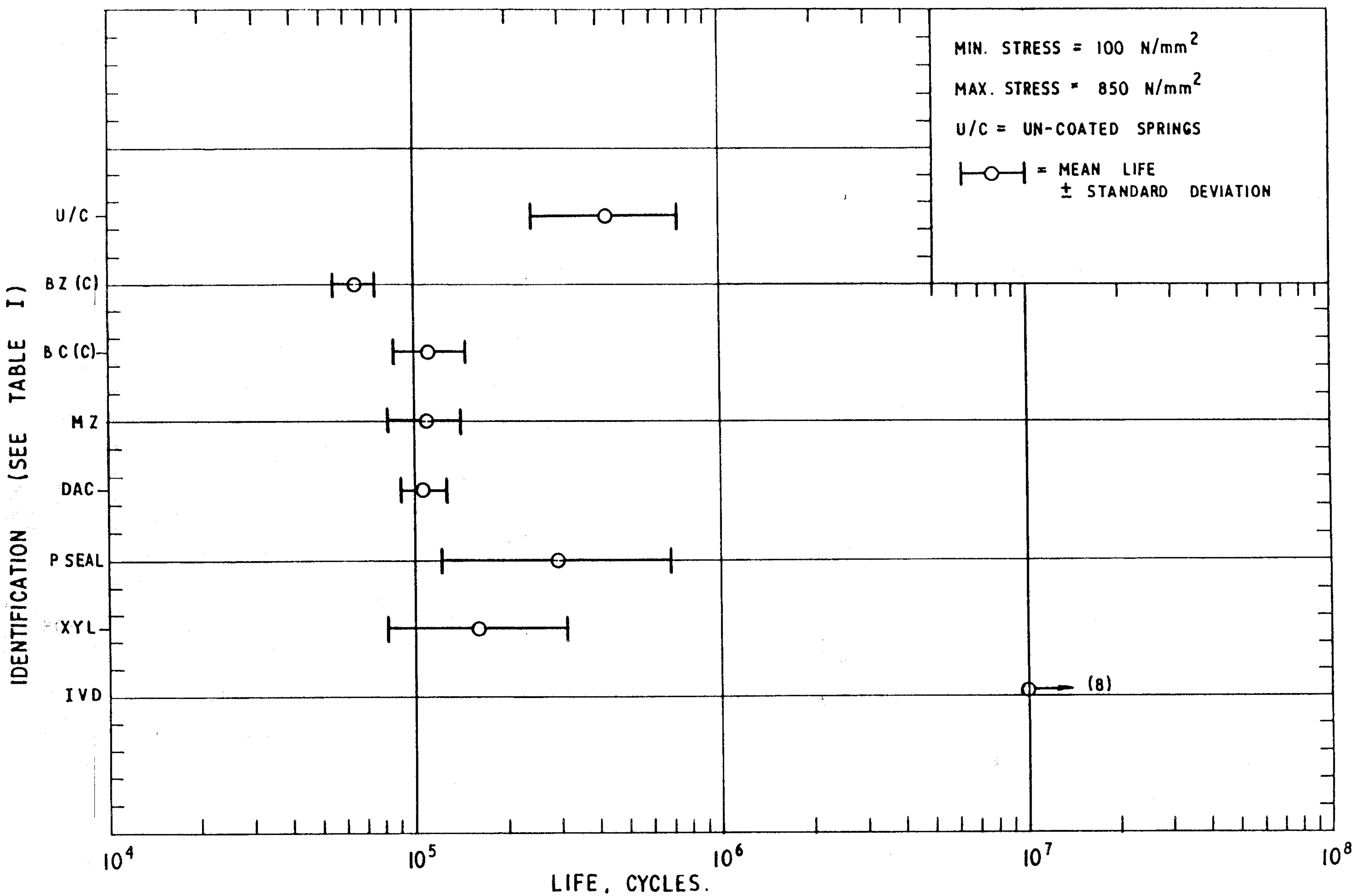


FIG. 6. EFFECT OF SURFACE COATINGS ON FATIGUE PROPERTIES OF BS 2803 HD UNPEENED SPRINGS.

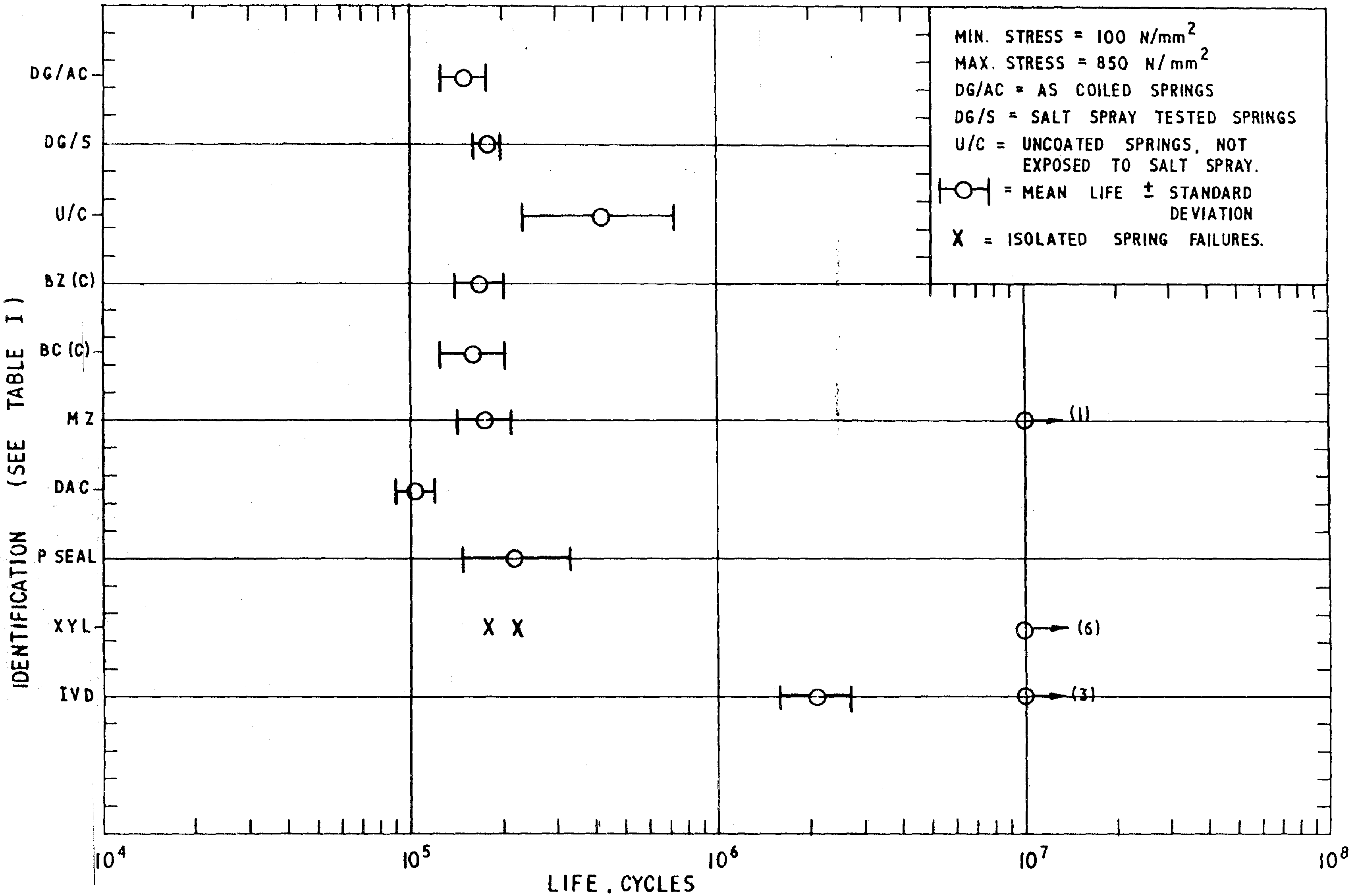


FIG. 7. FATIGUE PROPERTIES OF SURFACE COATED BS 5216 HD 3 UNPEENED SPRINGS AFTER 96 HOUR NEUTRAL SALT SPRAY EXPOSURE WHILST UNSTRESSED.

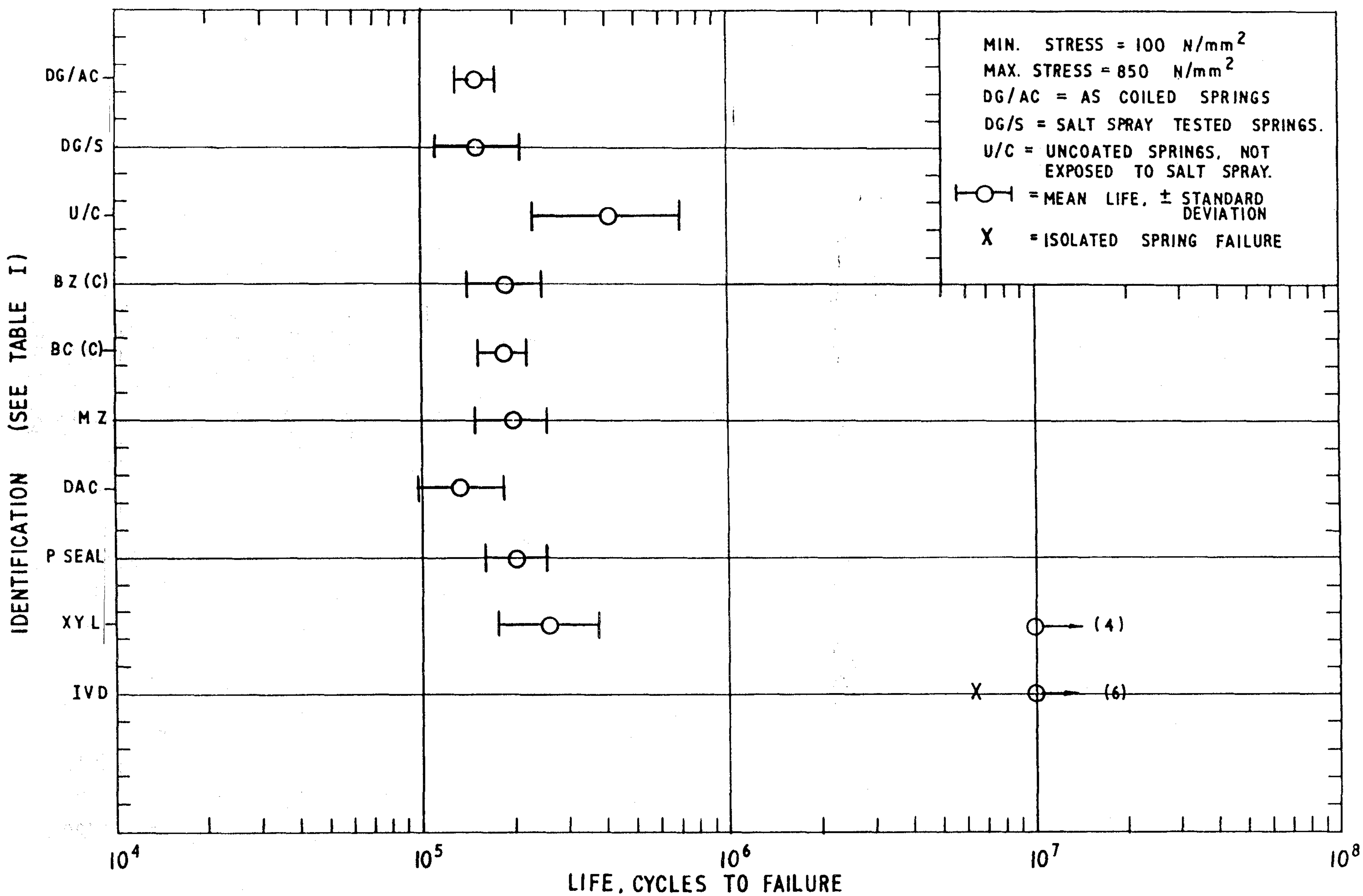


FIG. 8 FATIGUE PROPERTIES OF SURFACE COATED BS 5216 HD3 UNPEENED SPRINGS AFTER 96 HOUR NEUTRAL SALT SPRAY EXPOSURE WHILST STRESSED AT 850 N/mm^2

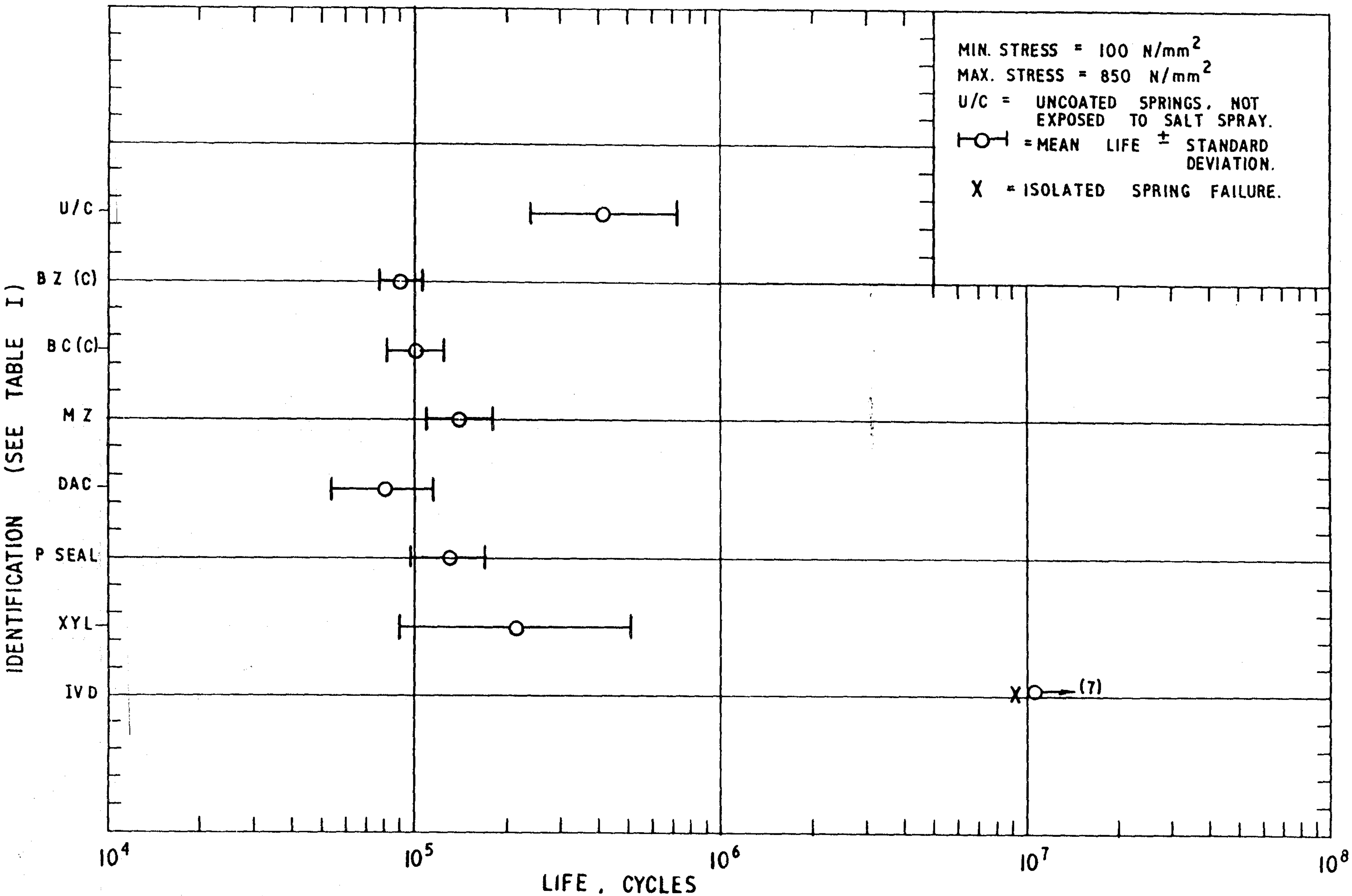


FIG. 9 FATIGUE PROPERTIES OF SURFACE COATED BS 2803 HD UNPEENED SPRINGS AFTER 96 HOUR NEUTRAL SALT SPRAY EXPOSURE WHILST UNSTRESSED.

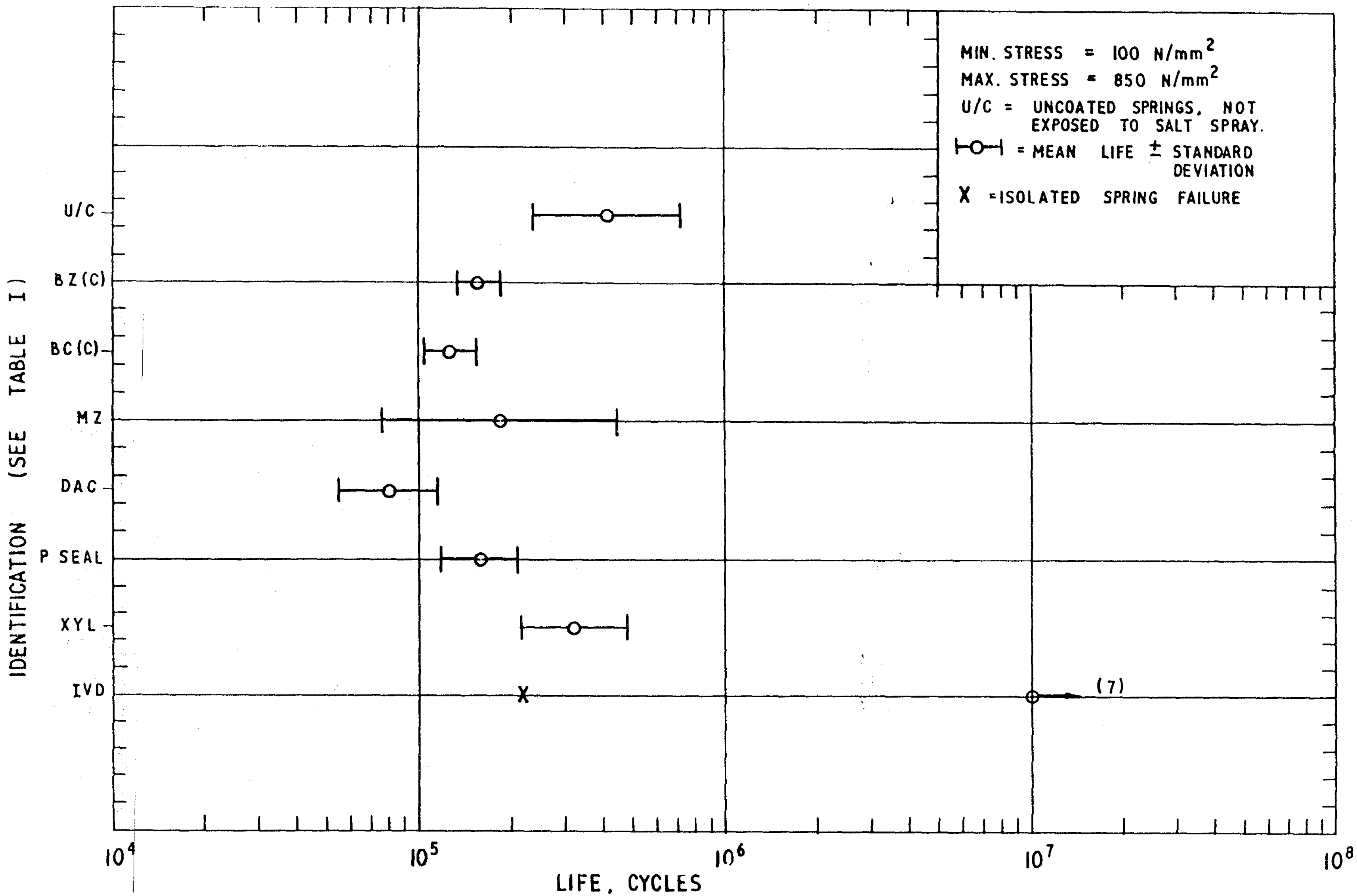


FIG. 10. FATIGUE PROPERTIES OF SURFACE COATED BS 2803 HD UNPEENED SPRINGS AFTER 96 HOUR NEUTRAL SALT SPRAY EXPOSURE WHILST STRESSED AT 850 N/mm^2