THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

THE EFFECT OF HOT PRESTRESSING ON THE LONG TERM RELAXATION BEHAVIOUR OF SPRINGS AT ELEVATED TEMPERATURES

First Progress Report

by

M. O'Malley, B.Sc.

Report No. 350

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SUMMARY

Hot prestressing is a well established technique for reducing the relaxation of springs used at elevated temperatures. This investigation set out to examine whether the benefits of hot prestressing were long lasting or only a temporary phenomenum. The work was carried out using four common spring materials; BS 5216 NS2, BS 2803 GII, low chromium-vanadium and BS 2056 En 58A wires. Having established appropriate prestressing temperatures for each material and test temperature, tests were carried out at various stress levsl for time periods of up to 3000 hours.

The results have shown that the effects of hot prestressing are long term, and that when the level of prestress is high and the operational stress is less than 50% of the prestress level, the springs will exhibit either recovery or only very low levels of relaxation.

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9. Long term relaxation at 100°C of hot prestressed BS 5216 NS2 springs.
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11. Long term relaxation at 100°C of hot prestressed BS 2803 GII springs.
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1. INTRODUCTION

Work at SRAMA[1] has shown that, over long periods of time at elevated temperatures, springs can exhibit fairly high levels of relaxation; higher than previously expected. Other tests carried out by the Association have established the fact that hot prestressing of springs will improve their relaxation resistance [2,3,4]. However, as these tests were only short term, it is not known if the benefits obtained are a permanent feature, or whether they gradually diminish over extended periods of time. From recent work[5] it appears that the benefits obtained by hot prestressing springs for ambient temperature service are permanent, but it is only speculation as to whether this would be the case for springs intended for operation at elevated temperature. It was, therefore, felt that an investigation to establish this fact would be useful.

2. MATERIALS INVESTIGATED

It was decided to use the same four materials as had been used in the ambient temperature investigation[5], i.e. a BS 5216 NS2, a BS 2803 GII and a BS 2056 En 58A (all 2.8 mm diameter wire) and also a 2.5 mm diameter low chromium-vanadium wire. The chemical composition and mechanical properties of these four wires are as quoted in the previous report[5]. Springs were produced to the dimensions listed in Table I and were given the appropriate heat treatments after coiling.

3. HOT PRESTRESSING

As previously[5] the springs were hot prestressed using the SRAMA hot prestressing machine. The springs were compressed, at temperature, to 90% of their solid length prior to being quenched to ambient temperature.

An initial series of tests were carried out on hot prestressed springs to establish the most appropriate prestressing temperature for each material and test temperature. For each material and test temperature, 3 springs were prestressed at each of a range of test temperatures and then relaxation tested at a stress of 800 N/mm^2 for up to 500 hours. The results of these tests are illustrated in Figures 1 - 8.

Once the most appropriate prestressing temperatures for each material and test temperature had been established, a further series of tests were carried out using batches of 10 hot prestressed springs at each of the stress levels listed in Table II. These tests were carried out for up to 3000 hours, and the results are presented in Figures 9 - 16.

4. RESULTS AND DISCUSSION

The results of the initial series of tests were analysed using standard regression techniques in order to produce "best fit" lines and so determine the most appropriate prestressing temperature for each material and test temperature. The prestressing temperatures thus chosen for the main series of tests are listed in Table II. It can be seen from the results (Figures 1 - 8) that a considerable improvement in terms of relaxation resistance was gained by hot prestressing the springs. A comparison of the results for hot and cold prestressed springs after 500 hours is given in Table III.

The results for the main series of tests were also analysed using standard linear regression techniques in order to produce 50% and 95% confidence lines. At the 600 N/mm^2 stress level it was found that, with the exception of the low chromium-vanadium at 200^{o}C., the results could not be analysed using these techniques due to the near horizontal nature of the curves.

At this stress level very low levels of relaxation of even slight recovery was experienced, and this is probably a reflection of the conditions of prestressing. The results were, therefore, analysed using an analysis of variance or "Anova" technique, which showed that, although there did seem to be a slight variation of the relaxation with time, the spring to spring variation greatly outweighed this phenomenum. The 50% confidence lines plotted for this stress level are thus the mean values of the test data for each specific material and test temperature.

It can be seen from the results that even after 3000 hours the improvements in relaxation resistance obtained by hot prestressing springs are still apparent and do not appear to diminish with increasing time. The amount of improvement obtained depends on the material, the prestressing conditions and the test conditions, i.e. after being given the same hot prestressing treatment, springs relaxation tested at 600 N/mm^2 will show a greater percentage improvement in relaxation resistance than springs tested at 800 N/mm^2 (see Table IV). Thus for the 600 N/mm^2 stress level this improvement was seen, in the majority of cases, as recovery not relaxation. Unfortunately, it was not possible to continue the tests beyond 3000 hours and so it is impossible to predict if the springs at the 600 N/mm^2 stress level would eventually exhibit relaxation.

5. CONCLUSIONS

1. The improvement in relaxation resistance obtained by hot prestressing springs for elevated temperature application appears to be a long term effect.

2. After hot prestressing, springs operating at fairly low stress levels (i.e. about 50% of the prestressing level) will exhibit either recovery or very slight relaxation.

3. Under identical prestressing conditions, the percentage improvement in relaxation resistance is inversely proportional to the operational stress, i.e. the higher the operational stresses the lower the percentage improvement in relaxation resistance.

6. REFERENCES

1. O'Malley, M., "The Long Term Relaxation Behaviour of Compression Springs Manufactured from Carbon and Stainless Steel Wires". SRAMA Report No. 325.

2. Gray, S. D., "The Effect of Hot Prestressing on the Fatigue and Relaxation Properties of Helical Compression Springs Manufactured from Low Alloy Steel Wire". SRA Report No. 234.

3. Heyes, P. F., "The Effects of Hot and Cold Prestressing on the Fatigue and Relaxation Properties of Compression Springs made from Cr-V Steel Wire". SRA Report No. 248.

4. Hale, G. E., "The Effect of Hot Prestressing on the Relaxation Behaviour of Compression Springs Coiled from En 58A Hard Drawn Stainless Steel Wire". SRAMA Report No. 306.

5. Brummitt, K., "Hot Prestressing of Springs for Ambient Temperature Service: First Progress Report". SRAMA Report No. 340.

6. O'Malley, M., "The Long Term Relaxation Behaviour of Spring Materials: Second Progress Report". SRAMA Report No. 349.

TABLE I SPRING DESIGN DATA

Materials	BS 5216 NS2	BS 2803 GII	Low Cr-V	BS 2056 En58A
Wire diameter (mm)	2.8	2.8	2.5	2.8
Mean coil diameter (mm)	22.4	22.4	22.5	22.4
Free length after LTHT and cold prestressing (mm)	44	44	45.5	44
Active coils	3.5	3.5	3.5	3.5
Total coils	5.5	5.5	5.5	5.5
LTHT	250°C for ½ hr	300°C for ½ hr	400°C for ½ hr	500°C for ½ hr
Solid stress (N/mm^2)	1350	1350	1300	1350

TABLE II HOT PRESTRESSING TEMPERATURES AND STRESS LEVELS USED IN MAIN SERIES OF TESTS

Material	Hot prestressing temperature (°C)	Test temperature (°C)	Test stress levels (N/mm^2)
BS 5216 NS2	250	100	600, 800, 1000
	300	150	600, 800, 1000
BS 2803 GII	350	100	600, 800, 1000
	350	150	600, 800, 1000
Low Cr-V	350	150	600, 800, 1000
	400	200	600, 800, 1000
BS 2056 En 58 A	500	200	600, 800, 1000
	500	250	600, 800, 950

TABLE III COMPARISON OF RELAXATION RESULTS AFTER 500 HOURS FOR HOT AND COLD PRESTRESSED SPRINGS

Material	Test Temperature (°C)	Prestressing Temperature (°C)	% Relaxation at 800 N/mm²		% Reduction in relaxation.
			Cold Pre-stressed +	Hot Pre-Stressed x	
BS 5216 NS2	100	250	8.8	0.3	97
	150	300	15.3	3.0	80
BS 2803 GII	100	350	7.5	-0.3	104
	150	350	12.2	0.6	95
Low Cr-V	150	350	12.6	0.9	93
	200	400	18.4	3.2	83
BS 2056 En 58A	200	500	7.4	1.9	74
	250	500	10.4	2.4	77

\+ Mean of 3 samples

x Mean of 10 samples

TABLE IV COMPARISON BETWEEN HOT AND COLD PRESTRESSED SPRINGS AFTER 2000 HOURS

Material	Test Temperature (°C)	Test Stress (N/mm²	% Relaxation		% Improvement
			Cold Pre-stressed	Hot Pre-stressed	
BS 2803 GII	150	600	13.2 (1)	-1.9	114
		800	15.9 (1)	1.1	93
Low Cr-V	200	600	17.4 (6)	0.3	98
		800	21.2 (6)	4.6	78
BS 2056 En58A	250	600	4.2 (1)	-0.7	117
		800	6.1 (1)	3.6	41

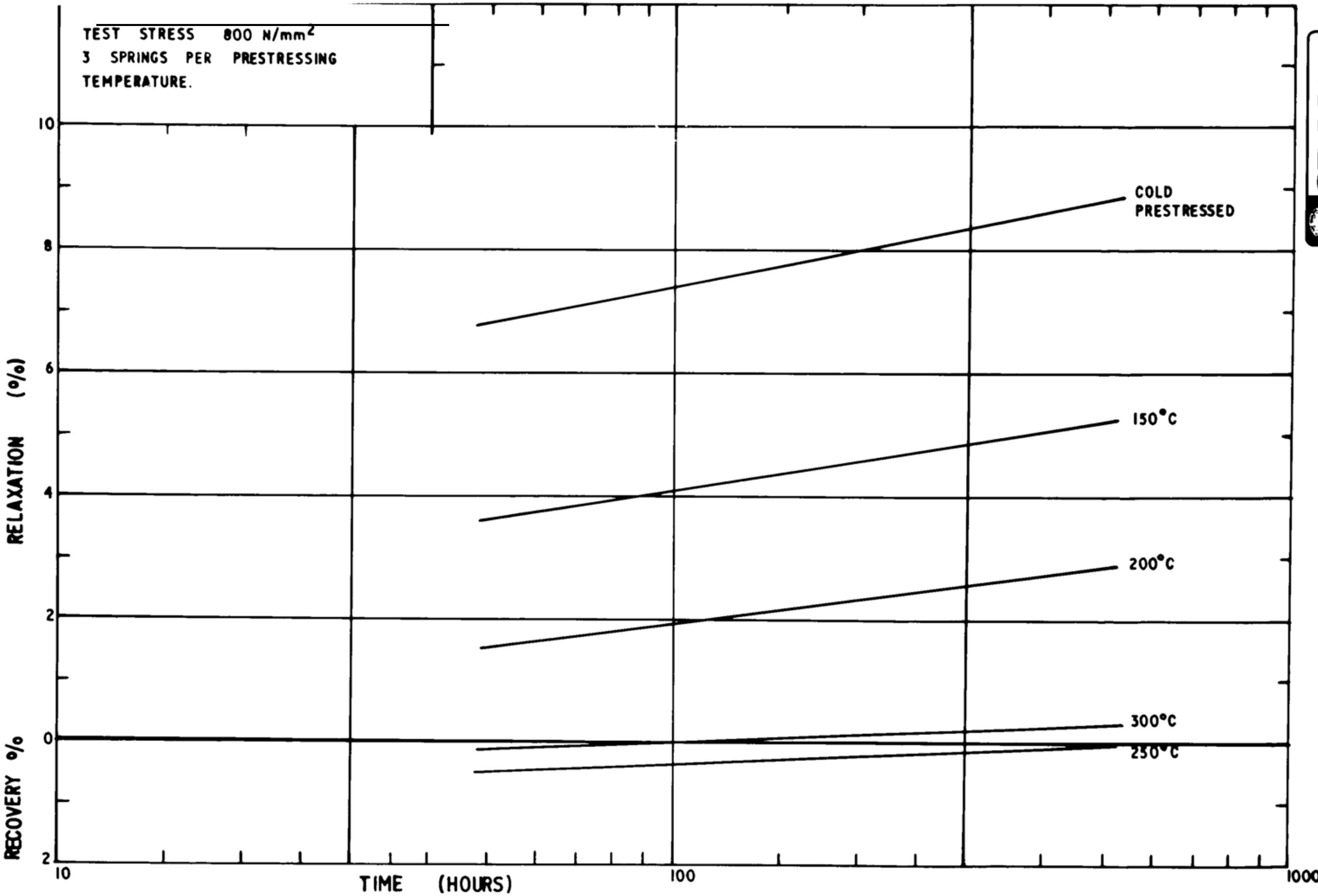

FIG. 1. EFFECT OF PRESTRESSING TEMPERATURE ON TIME RELAXATION OF BS 5216 NS 2 SPRINGS AT 100°C.

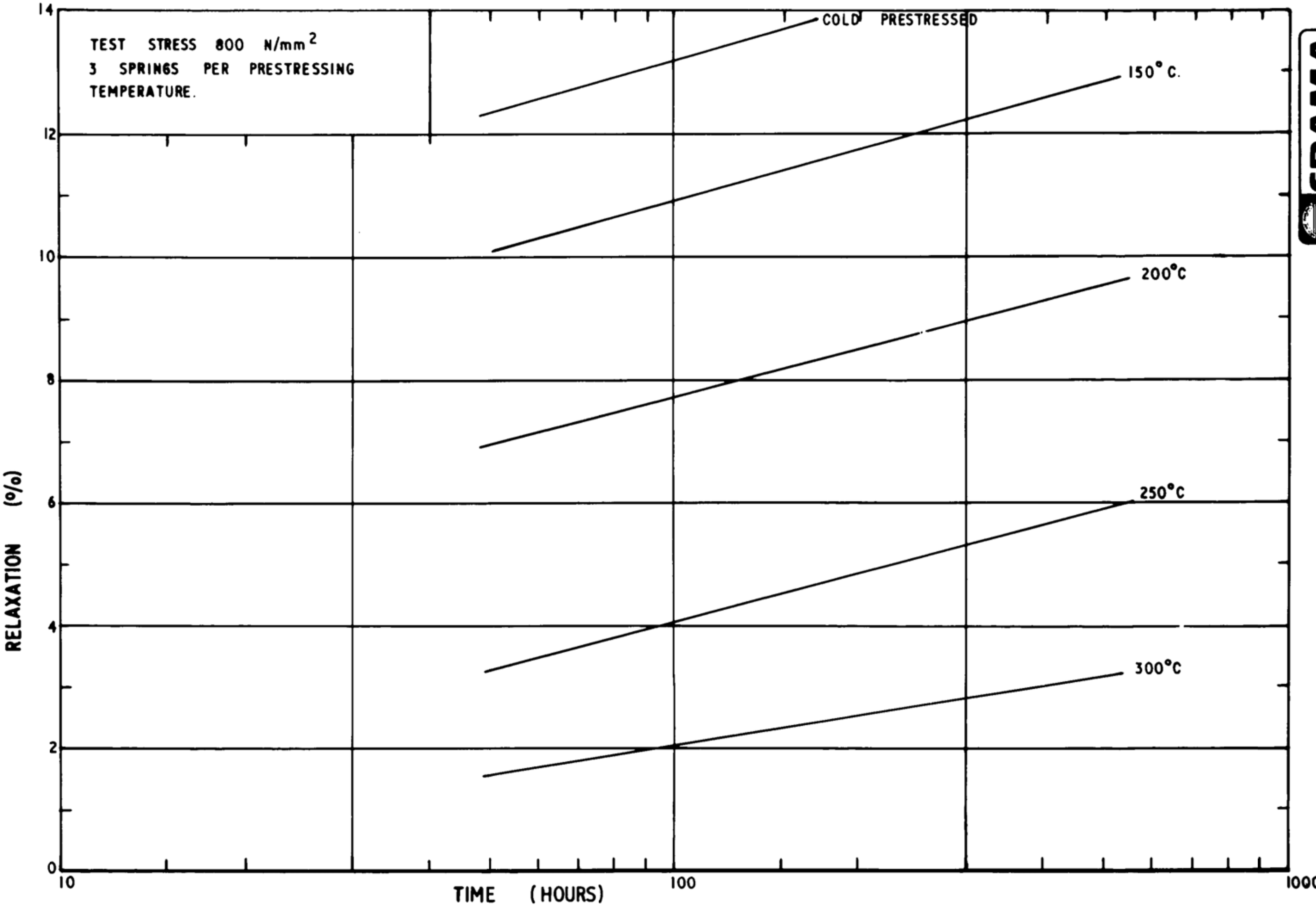

FIG. 2 EFFECT OF PRESTRESSING TEMPERATURE ON TIME RELAXATION OF BS5216 NS2 SPRINGS AT 150°C.

SRAMA

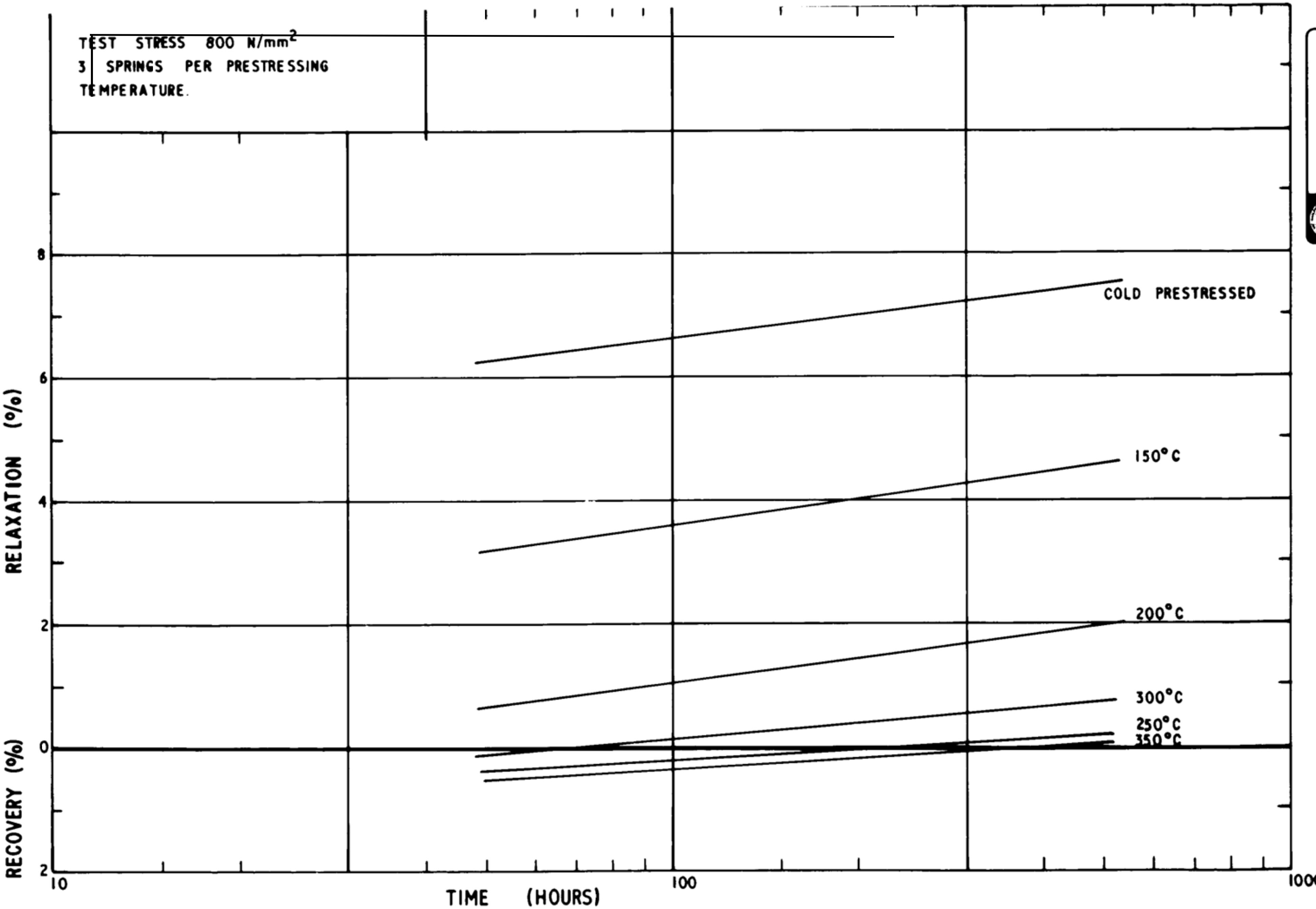

FIG. 3. EFFECT OF PRESTRESSING TEMPERATURE ON TIME RELAXATION OF BS 2803 G II SPRINGS AT 100°C.

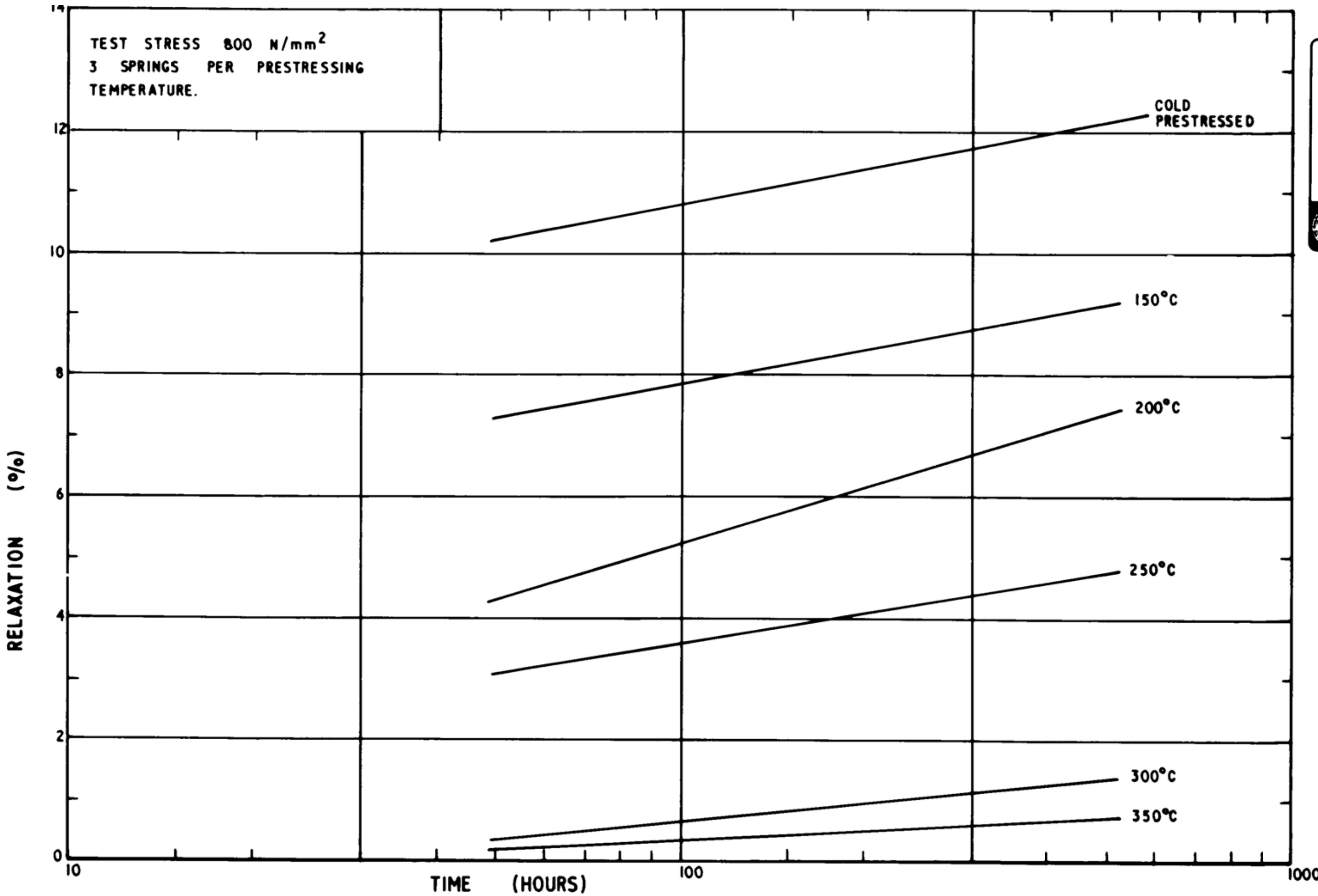

FIG. 4. EFFECT OF PRESTRESSING TEMPERATURE ON TIME RELAXATION OF BS 2803 G II SPRINGS AT 150°C.

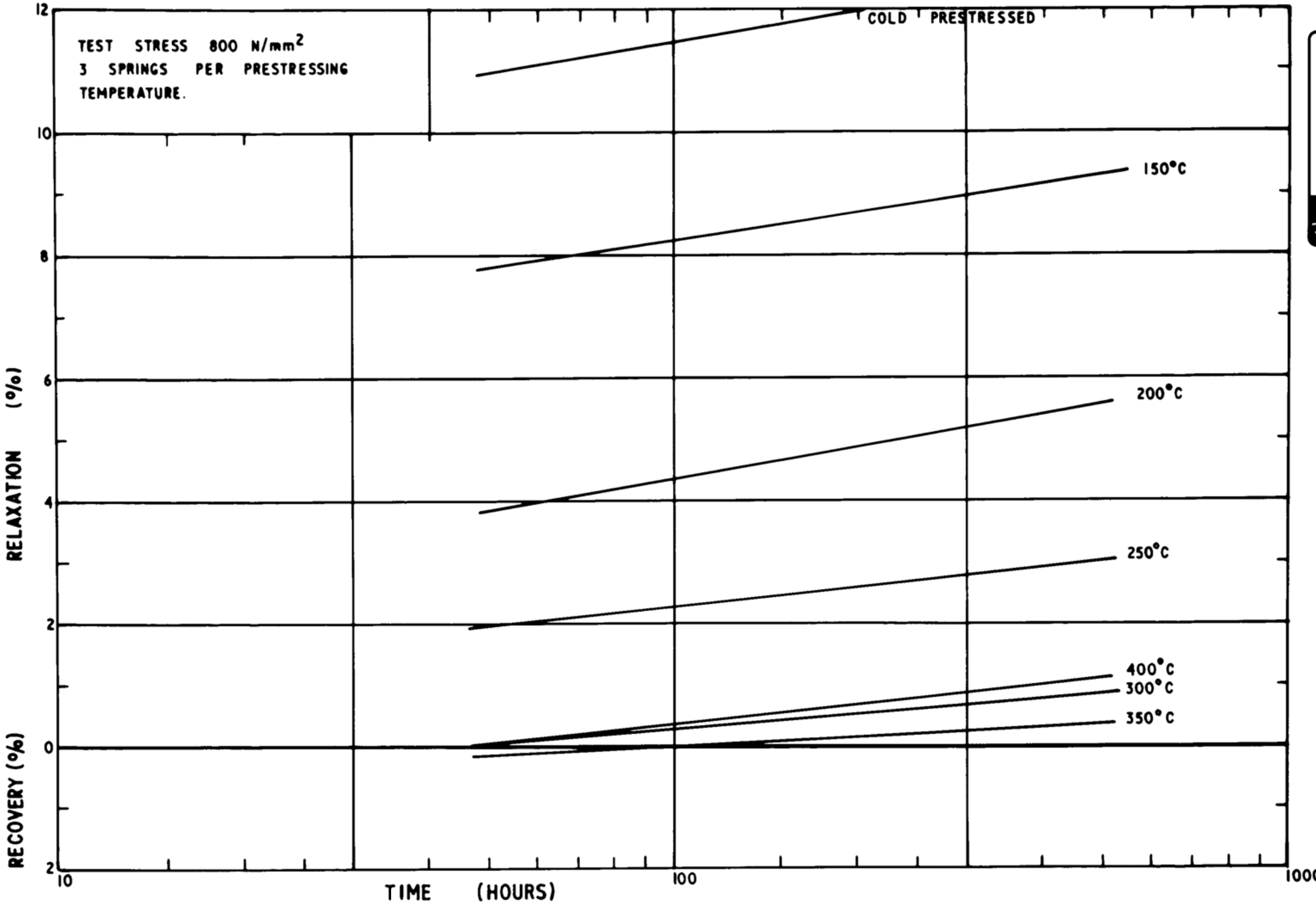

FIG. 5. EFFECT OF PRESTRESSING TEMPERATURE ON TIME RELAXATION OF LOW Cr-V SPRINGS AT 150° C.

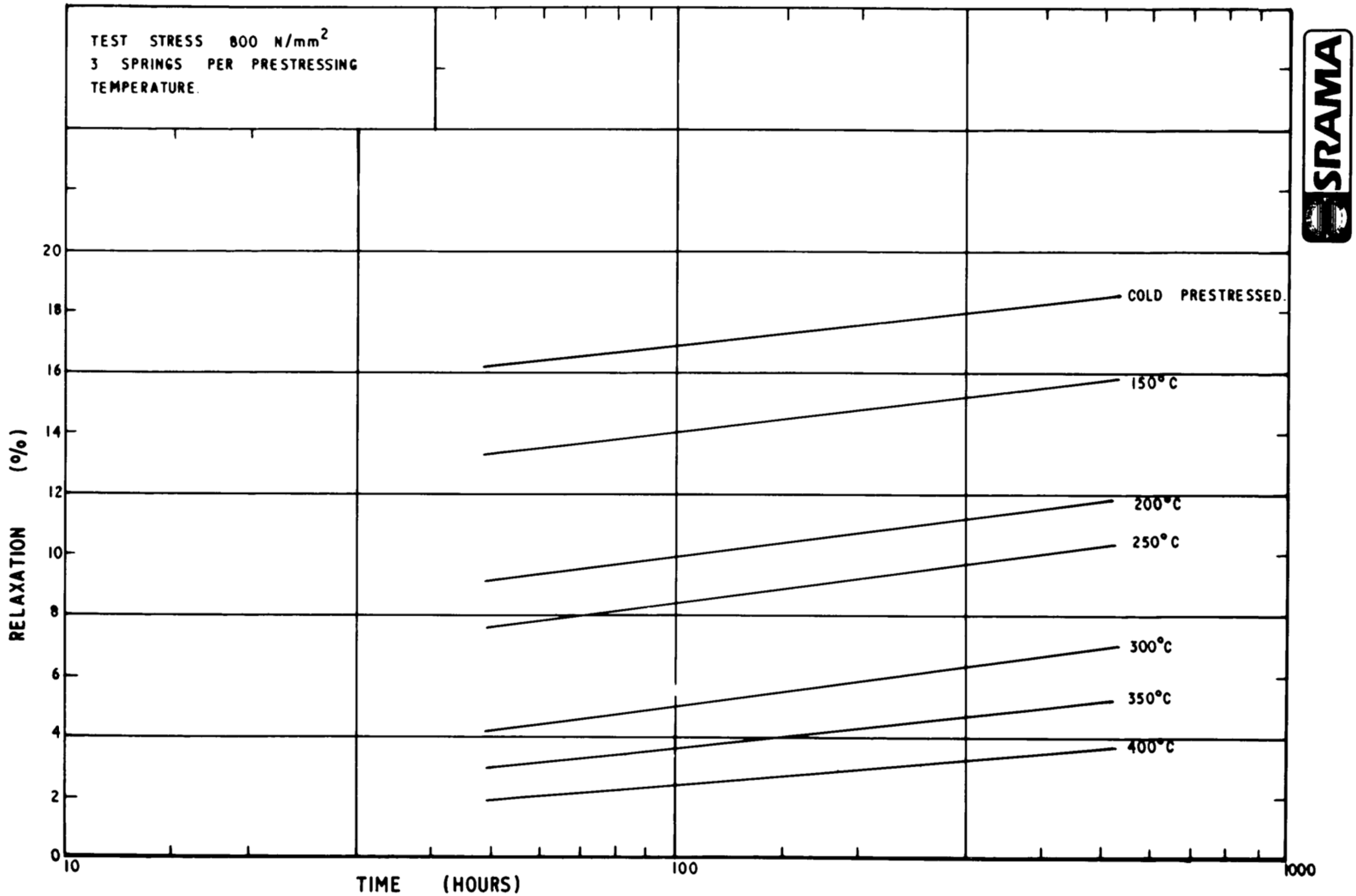

FIG. 6. EFFECT OF PRESTRESSING TEMPERATURE ON TIME RELAXATION OF LOW Cr-V SPRINGS AT 200°C.

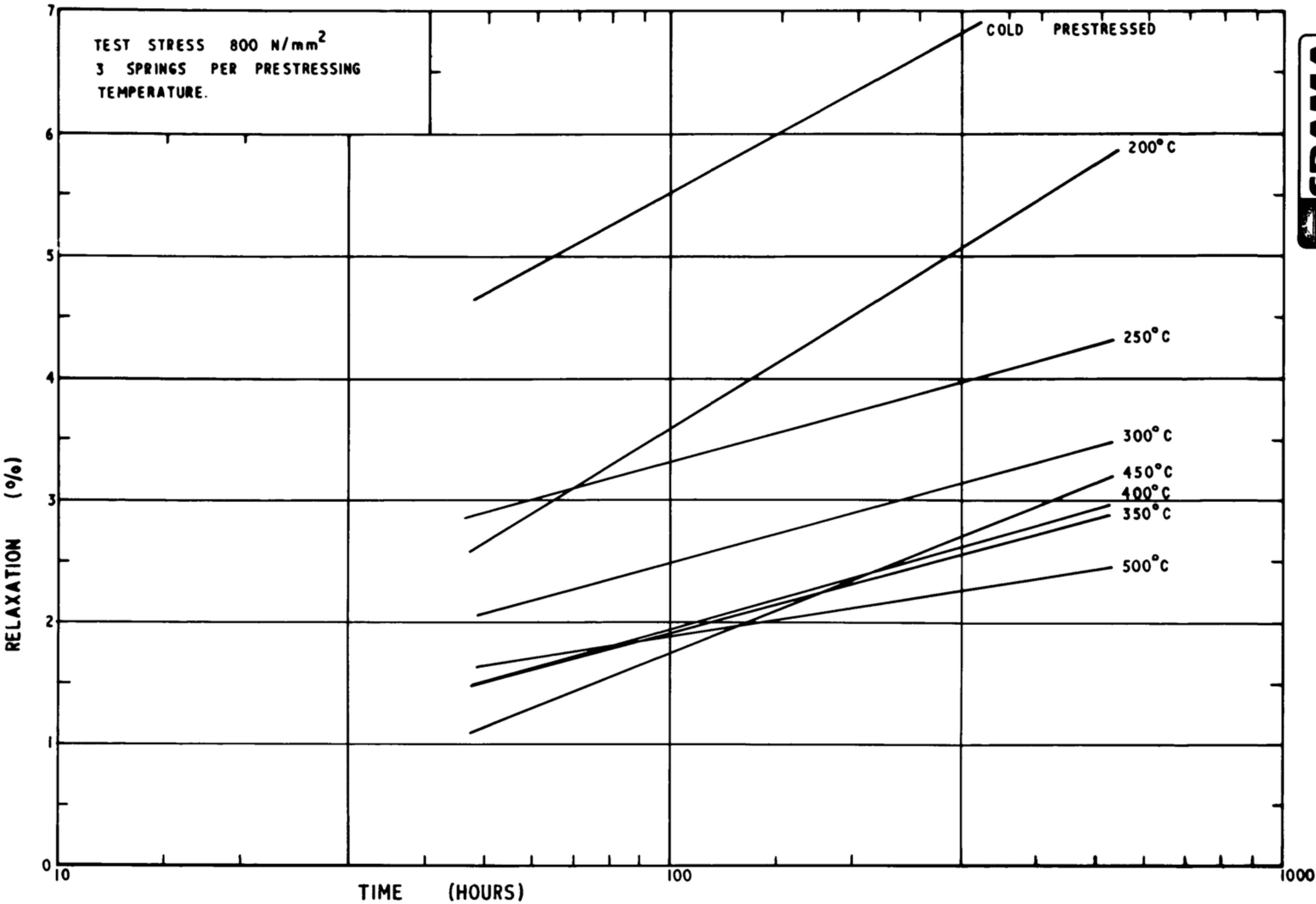

FIG. 7. EFFECT OF PRESTRESSING TEMPERATURE ON TIME RELAXATION OF BS 2056 En 58 A SPRINGS AT 200°C.

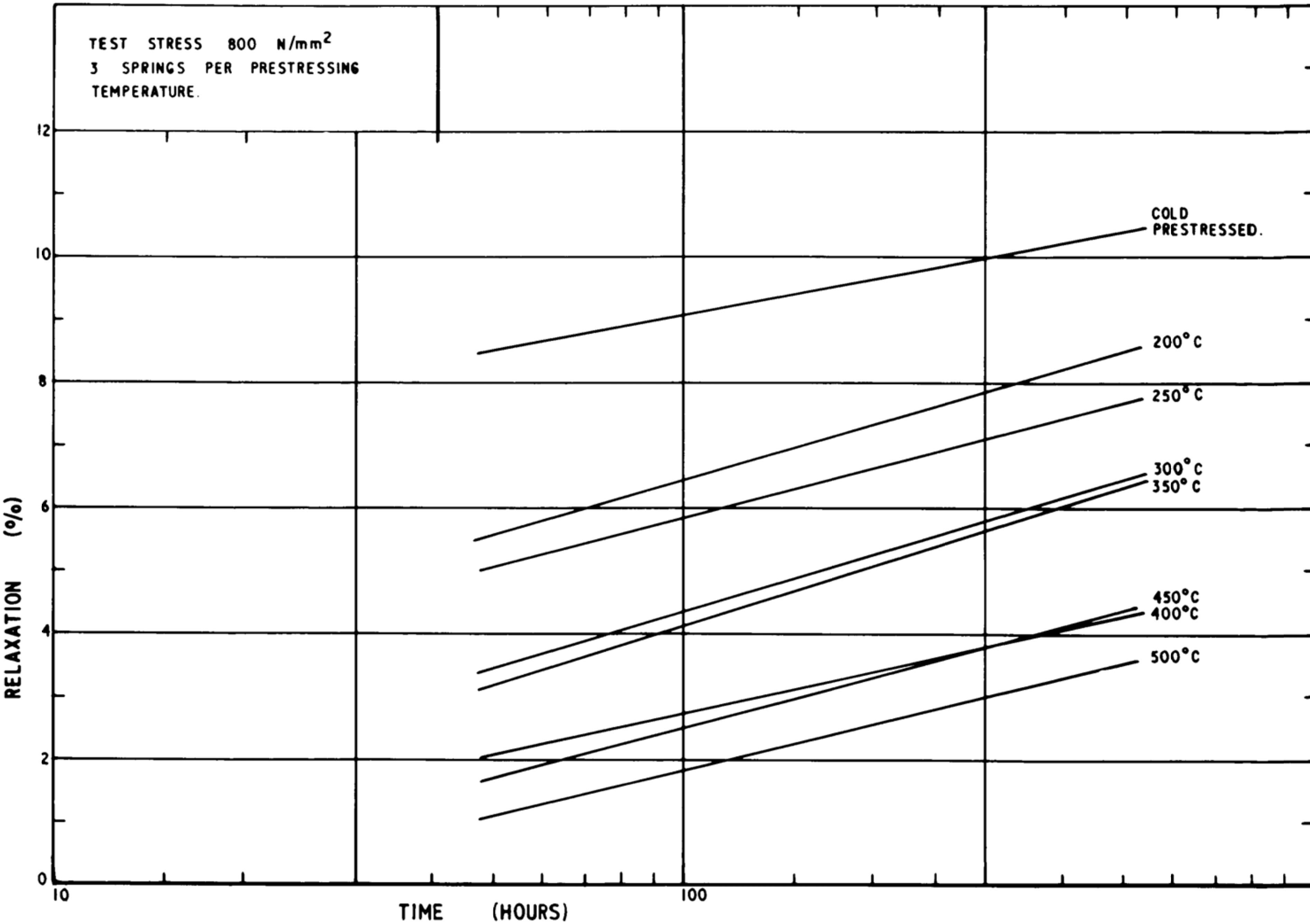

FIG. 8. EFFECT OF PRESTRESSING TEMPERATURE ON TIME RELAXATION OF BS 2056 En 58 A SPRINGS AT 250°C.

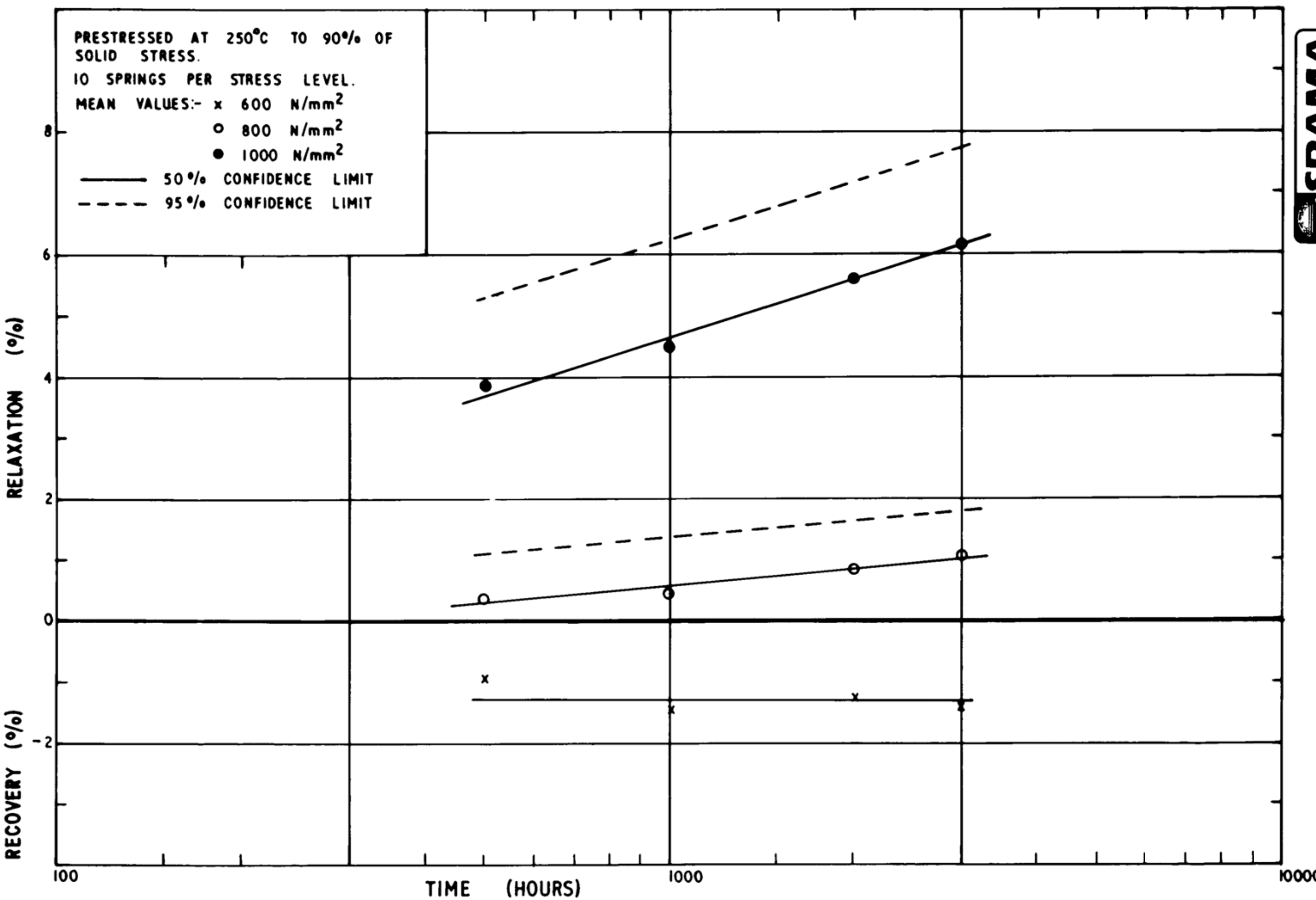

FIG. 9. LONG TERM RELAXATION AT 100° C OF HOT PRESTRESSED BS 5216 NS 2 SPRINGS.

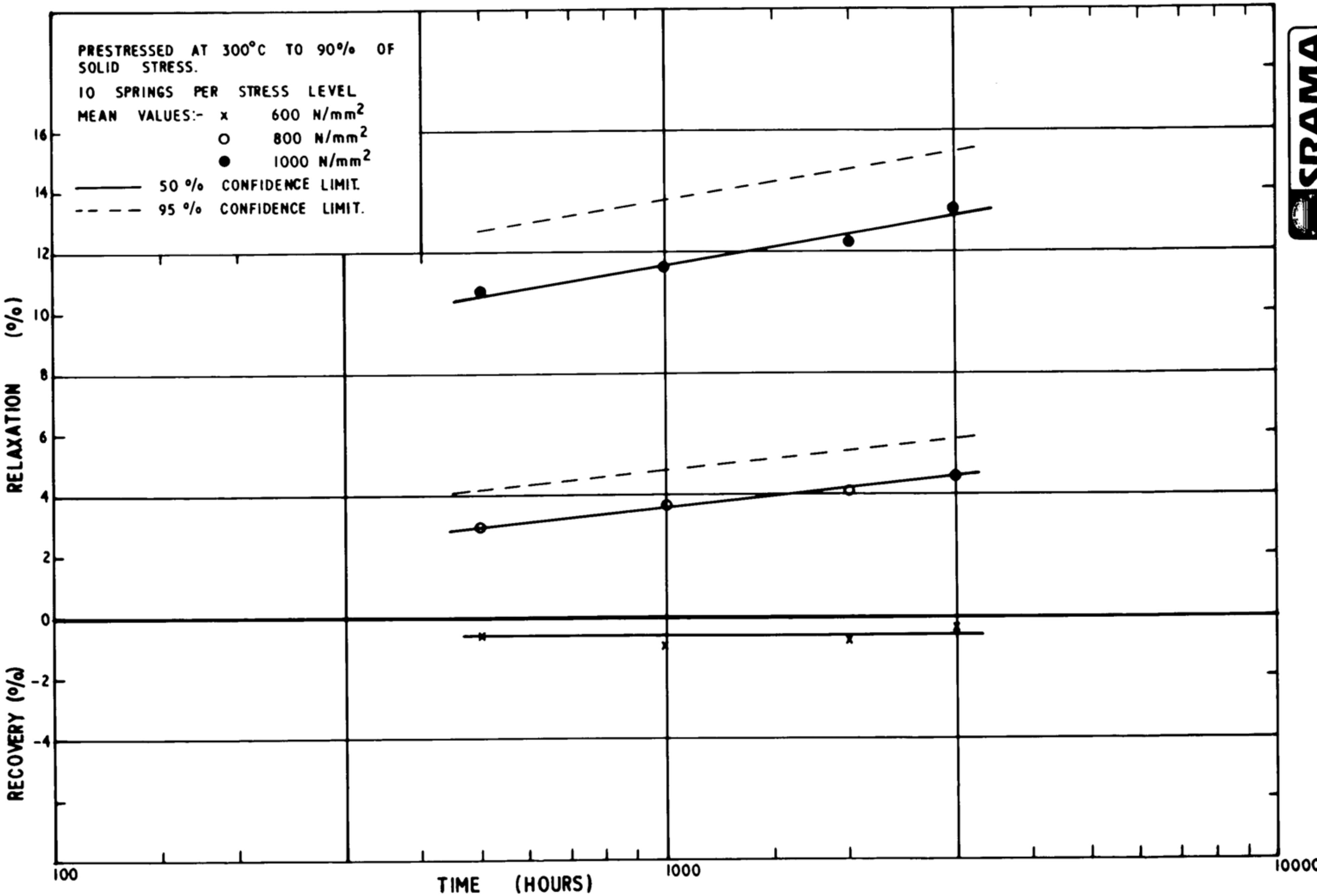

FIG. 10. LONG TERM RELAXATION AT 150°C OF HOT PRESTRESSED BS 5216 NS2 SPRINGS.

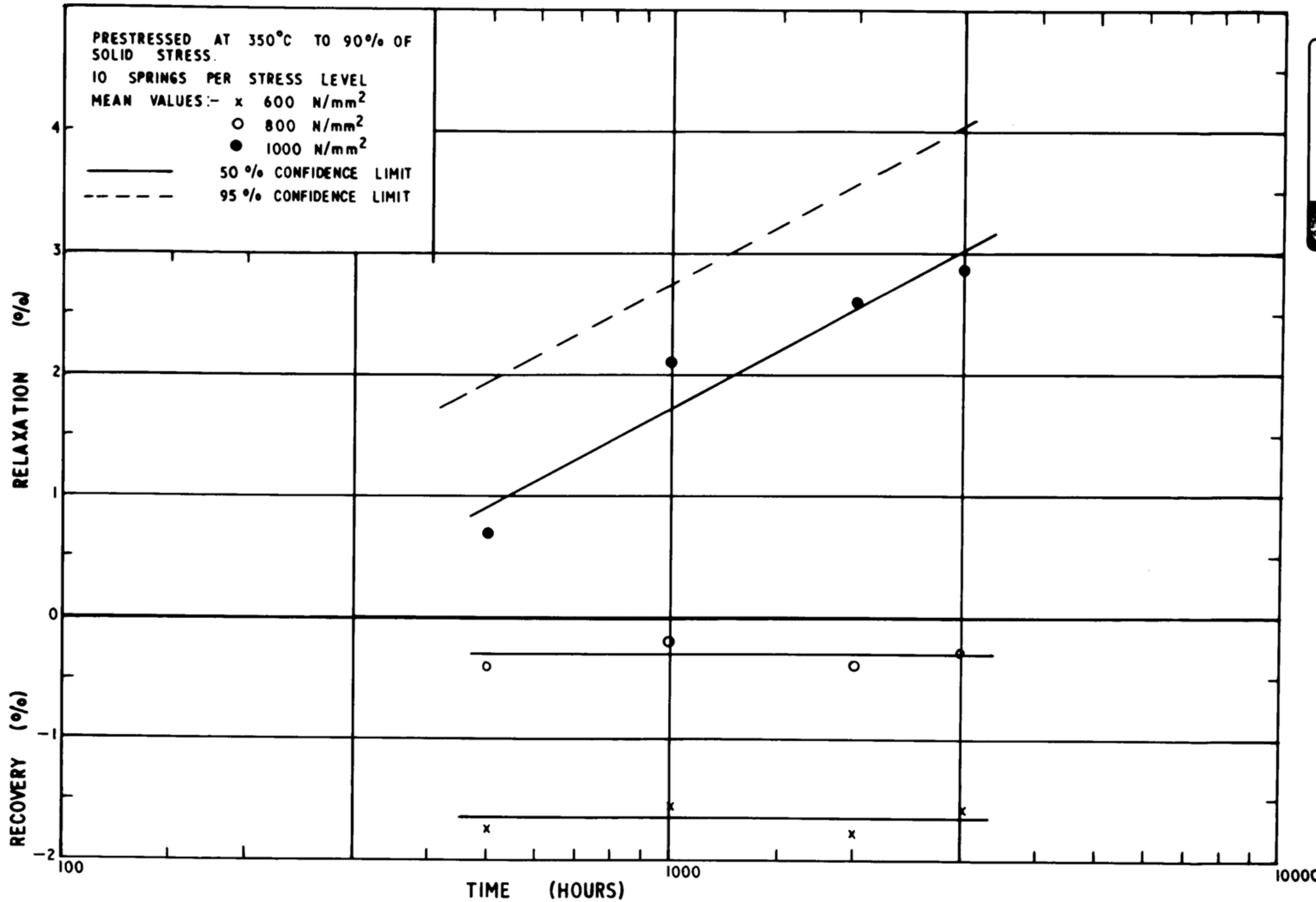

FIG. 11. LONG TERM RELAXATION AT 100°C OF HOT PRESTRESSED BS 2803 G2 SPRINGS.

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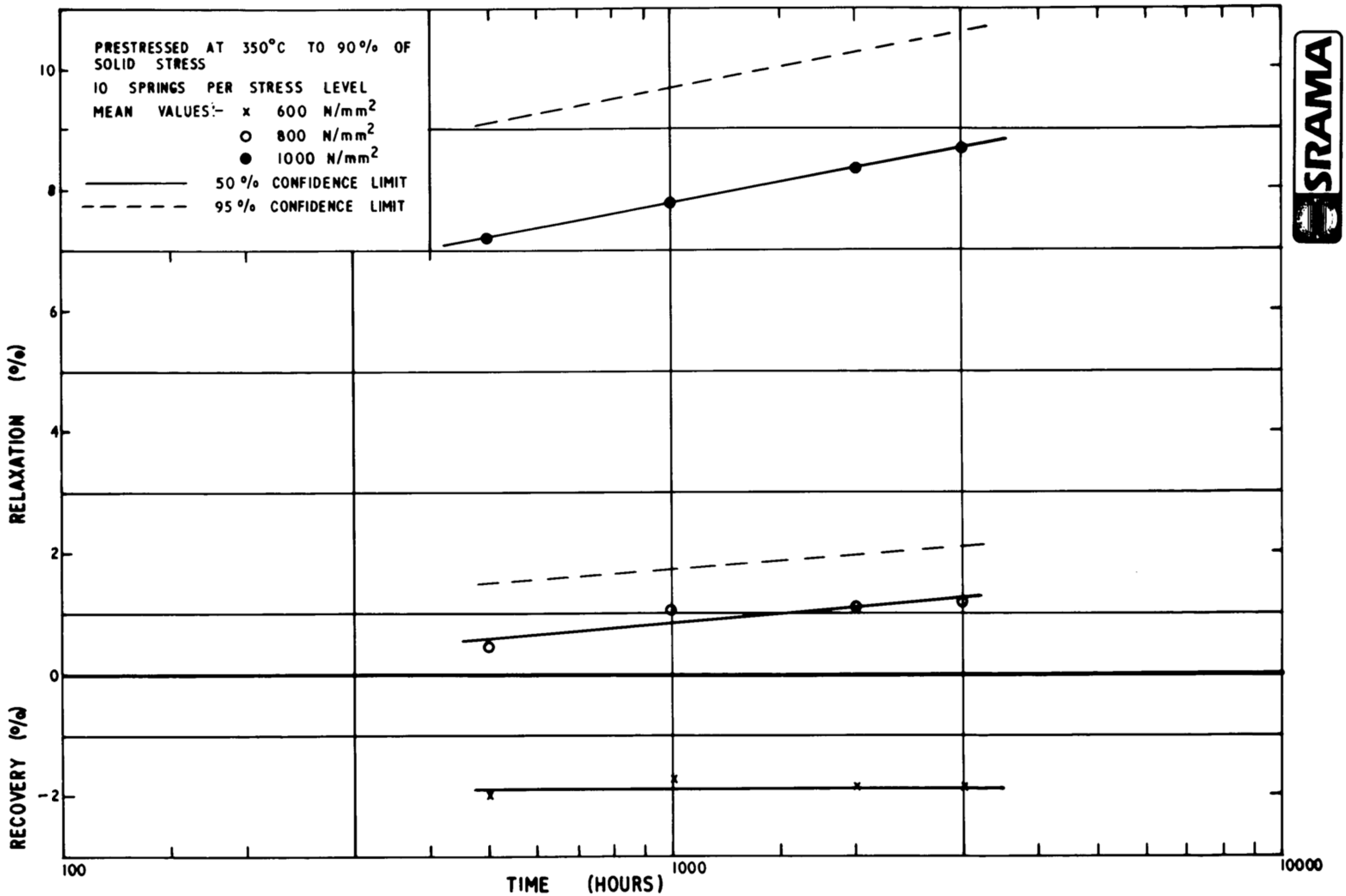

FIG. 12. LONG TERM RELAXATION AT 150°C OF HOT PRESTRESSED BS 2803 G2 SPRINGS.

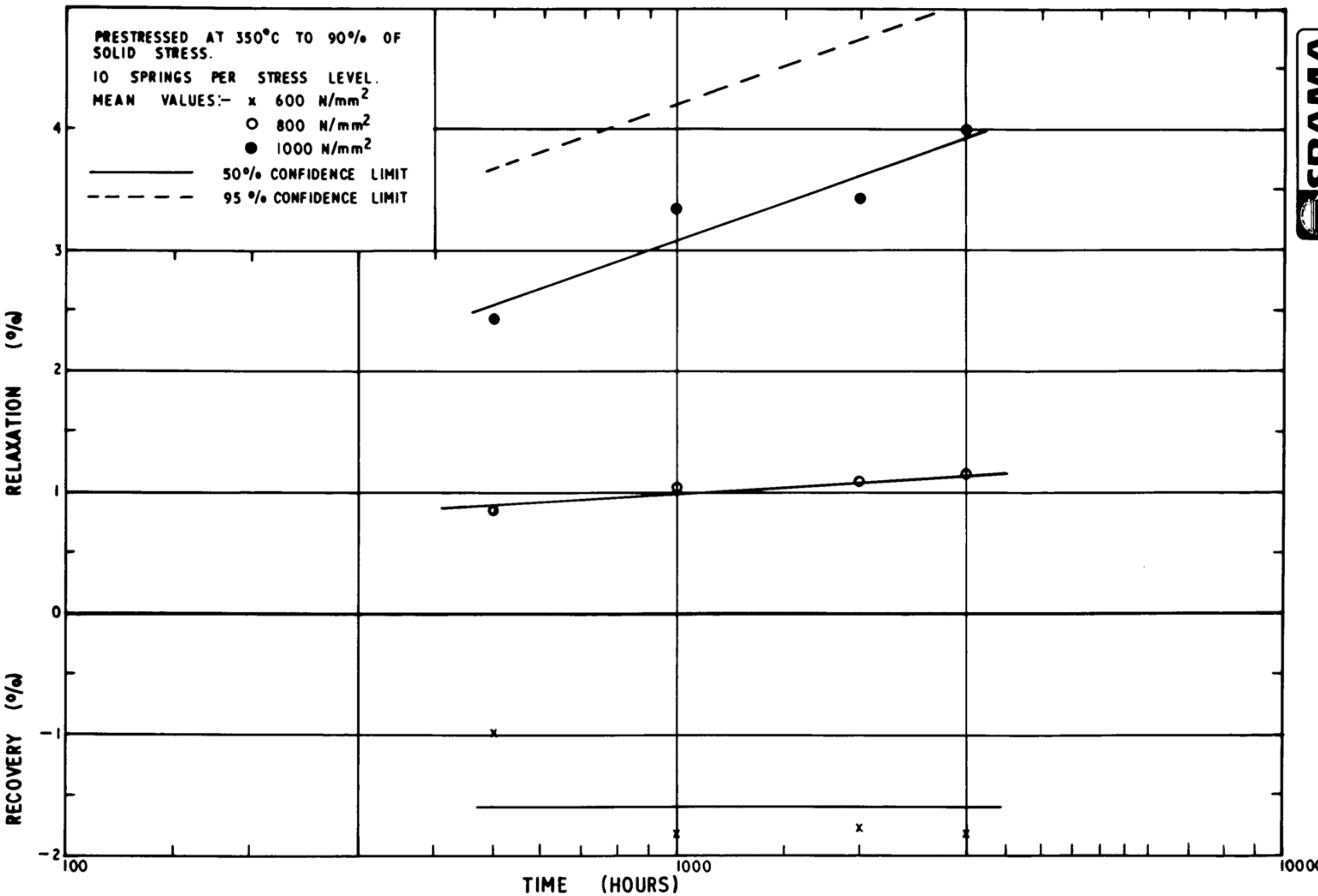

FIG. 13. LONG TERM RELAXATION AT 150°C OF HOT PRESTRESSED LOW Cr-V SPRINGS.

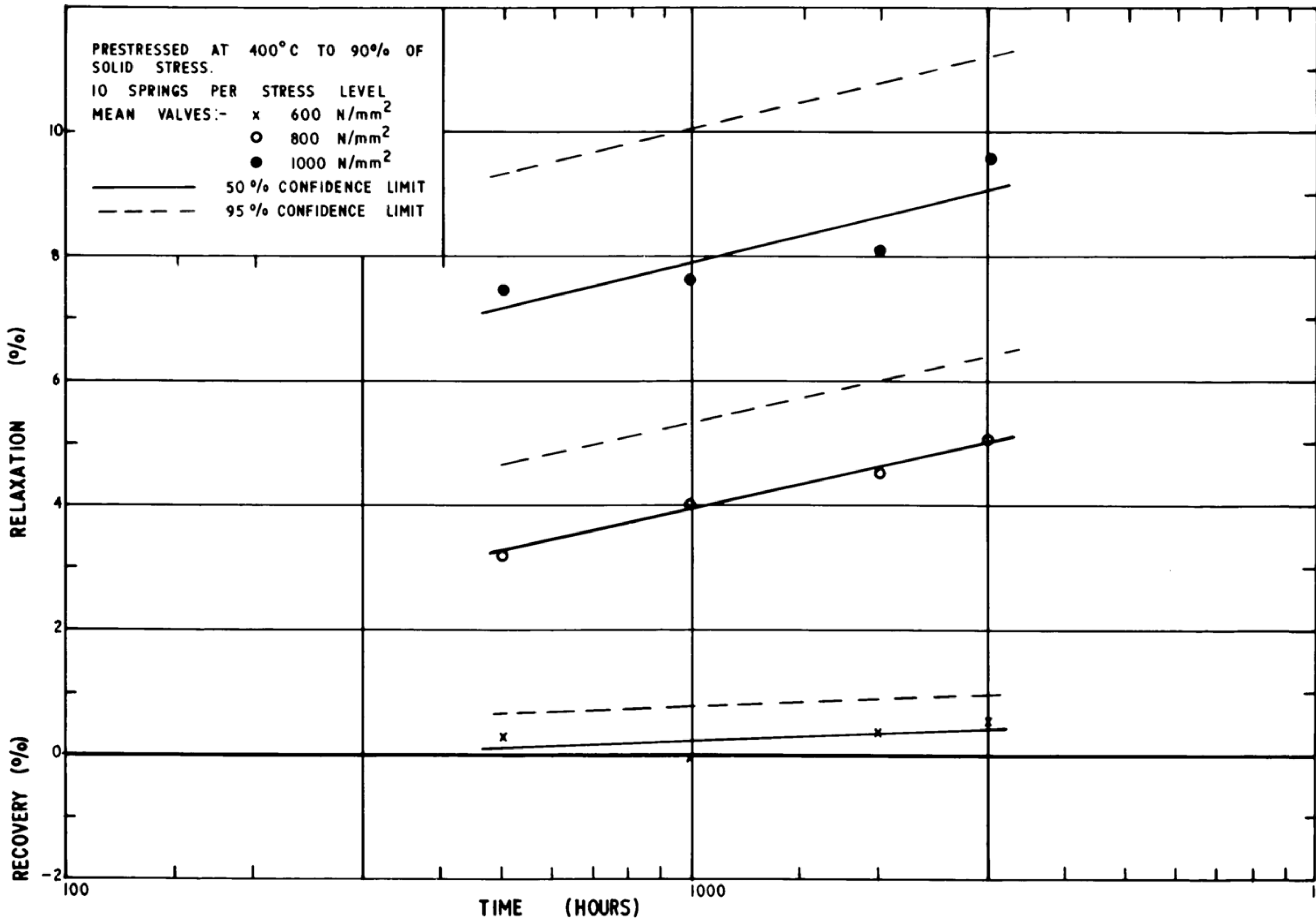

FIG. 14. LONG TERM RELAXATION AT 200°C. OF HOT PRESTRESSED LOW Cr-V SPRINGS.

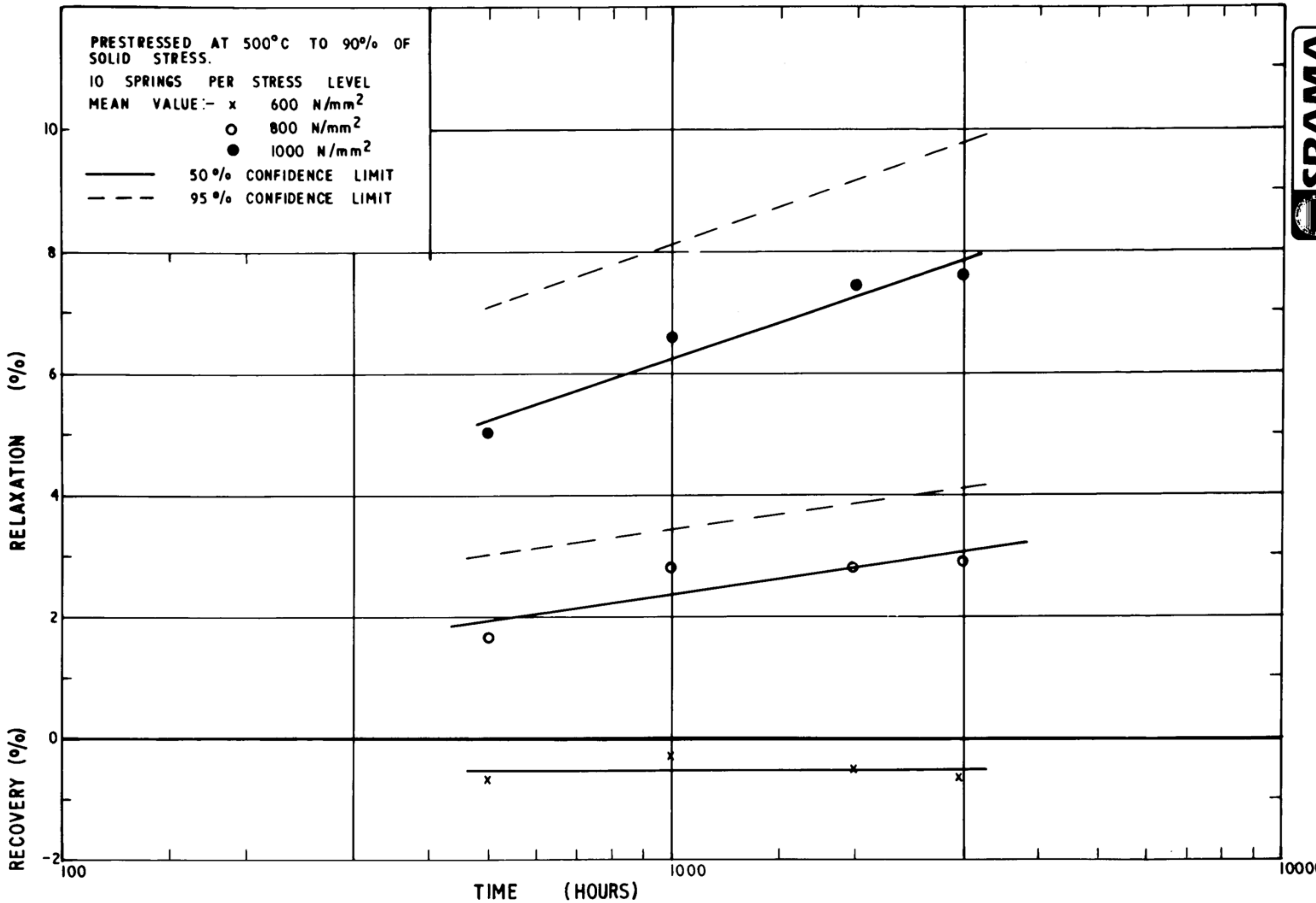

FIG. 15. LONG TERM RELAXATION AT 200°C OF HOT PRESTRESSED BS 2056 En 58 A SPRINGS.

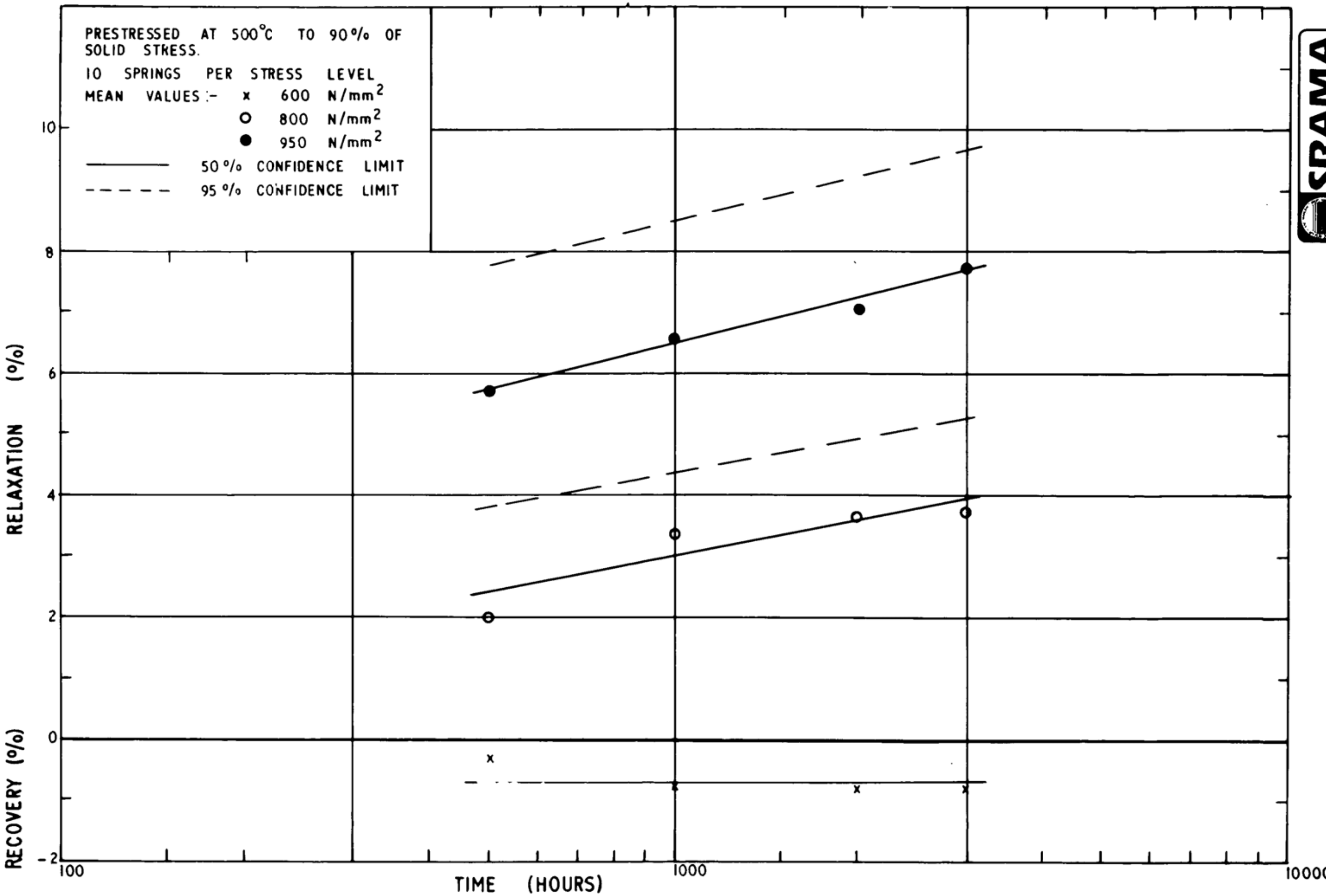

FIG. 16. LONG TERM RELAXATION AT 250°C OF HOT PRESTRESSED BS 2056 En 58 A SPRINGS.