THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

HOT PRESTRESSING OF SPRINGS FOR AMBIENT TEMPERATURE SERVICE

FIRST PROGRESS REPORT

by

K. Brummitt B.Sc

Report No. 340

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Previous work on hot prestressing has indicated the benefits to be obtained on the stress-relaxation properties of spring materials when used at elevated temperatures. This work sets out to investigate the possibility that the process could be beneficial to springs operating at ambient temperatures.

Four materials, BS 5216 NS2, oil hardened and tempered BS 2803 grade 2, stainless steel En 58A to BS 2056 and a low Chrome Vanadium alloy were chosen and tested for physical properties and suitable springs made from them.

Short term tests were carried out on small samples at various temperatures to establish the approximate optimum prestressing temperature for each material and full scale tests carried out at these temperatures.

The full scale results show that considerable benefits can be obtained for three of the four materials, the stainless steel wire being unaffected, with the amount of relaxation being reduced by between 30 and 53 percent. This benefit was conferred after hot-prestressing the BS 5216 NS2 at 200°C, the BS 2803 at 250°C and the low Chrome Vanadium alloy at 300°C.

The present series of springs will be retested after increasing periods of time to monitor the relationship established between relaxation and time.

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SUMMARY

Hot prestressing is an established technique for reducing the amount of relaxation encountered when springs are used at elevated temperatures. The work reported here set out to determine whether hot prestressing would provide a worthwhile benefit in terms of increased relaxation resistance at room temperature. Four materials representing a reasonable cross section of materials commonly used for light springs, were used in this investigation. These were, a patented hard drawn wire to BS 5216 NS2, an oil hardened and tempered wire to BS 2803 grade 2, a low chrome vanadium alloy steel wire and a stainless steel wire of the 302S25 type. A range of hot prestressing temperatures were investigated for each type of wire and in most cases it was found possible to obtain realistic benefits from hot prestressing. This was not, however, true for the 302S25 where no benefit was obtained from the hot prestressing process. Having established that the technique was viable further tests were made to provide relaxation data for hot prestressed springs at ambient temperatures for each of the wire qualities investigated. Data is presented for the four materials at initial stresses up to 1000 N/mm^2 for time periods of up to 2000 hours.

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CONTENTS

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1. INTRODUCTION

The loss of load bearing ability in a spring is normally thought of as a high temperature phenomena but it can also be a problem at ambient temperature especially over long term periods. The technique of hot prestressing to reduce relaxation in springs has become well established in recent years although the additional cost over normal cold prestressing has limited its use to applications where maintenance of load bearing ability is critical. As there is no fundamental change in the dominant creep mechanism between ambient temperature and elevated temperature relaxation it seemed reasonable to suppose that hot prestressing could be used to combat room temperature relaxation. Since recent tests at SRAMA[1] have shown that relaxations of around 8% in six months are quite possible at ambient temperatures it was felt that the reduction of ambient temperature relaxation would be a useful field of investigation.

2. MATERIALS

Four spring wires were used for this investigation, these being chosen as a cross section of light spring materials used for essentially static applications. The wires used were a static quality patented hard drawn wire to BS 5216 NS2 in 2.8 mm dia., an oil hardened and tempered carbon steel wire to BS 2803 grade 2 in 2.8 dia. a stainless steel wire of the En 58A type to BS 2056 also in 2.8 mm dia. and a low chrome vanadium alloy steel wire in 2.5 mm dia. The chemical analysis and mechanical properties of these wires are shown in Tables I and II. These wires were used to produce springs to the designs shown in Table III. All the springs were given a normal LTHT (Table IV) before the hot prestressing operation.

3. HOT PRESTRESSING

The springs were individually hot prestressed using a pneumatically operated machine developed for this purpose at SRAMA. This machine has been described in previous reports[2]. The springs were heated to temperature using a Wild Barfield toolroom air circulating furnace and held at temperature for at least 15 minutes before hot prestressing. The springs were placed in the machine, compressed solid and held for 2 seconds before being quenched into water while still compressed. In the initial tests a range of prestressing temperatures was examined for each material, in each case the minimum temperature was 100°C but the maximum temperature varied from 250°C for the NS2 to 500°C for the En 58A. For comparison purposes during the initial stage of relaxation testing (see Section 4 below), cold prestressed and un-prestressed springs were also used. The amount of set down produced by each prestressing temperature is given in Table V.

4. RELAXATION TESTS

Relaxation tests were carried out using the normal cramp test which has been described in previous reports[3]. Initially, a range of hot prestressing temperatures were investigated and three springs were tested at a stress of 800 N/mm^2 for each material and temperature.

These initial tests were run for 2×10^3 hours after which those tests giving unpromising results were discontinued and promising temperatures selected for a more detailed set of tests at stresses of 950 (1000 N/mm^2 for the low Cr-V springs), 800 and 600 N/mm^2 with ten springs at each test stress. The results of these tests can be seen in Fig. 5.

5. DISCUSSION

The preliminary tests on hot prestressed springs show that, for <u>three</u> of the four test materials investigated, a considerable benefit in terms of relaxation performance can be obtained by using hot prestressing (See Table VI). However, little advantage is gained unless the deformation (set down) is greater than that achieved with normal cold prestressing.

For the fourth material used in the investigation (En 58A) there was no improvement in the relaxation resistance on hot prestressing (see Table VI). This may well be due to the fact that, as En 58A has inherently superior relaxation properties as compared with the other three materials (see Table VI), then the benefits gained on hot prestressing are negligible.

On a practical level the problems facing the introduction of hot prestressing for ambient temperature components are cost, but the cost of hot prestressing will be less than that of hot setting which is an alternative method currently used to reduce relaxation. To satisfy the most critical applications the only other solution would be to up grade the steel quality by turning to more highly alloyed materials. The increased material costs however could quite possibly be greater than the increase due to hot prestressing.

Another factor which needs to be considered is the distortion of the spring on hot prestressing, but this is not unique to this particular case. It has been previously found that for elevated temperature service higher hot prestressing temperatures would be useful but would introduce an unacceptable level of distortion. It is therefore necessary to compromise and select the conditions of hot prestressing (temperature and stress) such that the required dimensional tolerances on free length and squareness can be achieved.

6. CONCLUSION

1. It is possible to improve the room temperature relaxation properties of three of the materials investigated (and therefore presumably the majority of materials used for light spring manufacture) by hot prestressing.

2. No benefit is gained in the ambient temperature relaxation resistance of En 58A by hot prestressing.

3. Suitable temperatures for hot prestressing the materials tested are

BS 5216 NS2	200°C
BS 2803	250°C
Low CrV alloy steel	300°C

8. 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. Hood, A.R. 'The Effect of Order of Hot Prestressing and Shot Peening on the Fatigue and Relaxation Properties of Low Cr-V Valve Springs'. SRAMA Report No. 317, 1979.

3. Graves, G.B. 'The Stress Temperature Relaxation and Creep Properties of Some Spring Materials'. SRA Report No. 143, 1963.

4. Brummitt, K. Unpublished Work.

5. 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, 1979.

TABLE I CHEMICAL COMPOSITION OF WIRES

Material	%C	%Mn	%Si	%S	%P	%Cr	%Ni	%V
BS 5216 NS2	0.69	0.46	0.18	0.024	0.015			
BS 2803 G2	0.62	0.75	0.24	0.015	0.017			
BS 2056 En58A	0.08	0.68	0.50	0.003	0.028	17.5	8.4	
Low CrV	0.70	0.51	0.19	0.015	0.016	0.54		0.23

TABLE II MECHANICAL PROPERTIES OF WIRES

Material and Condition	Tensile Properties					Torsional Properties		
	Rm N/mm^2	L of P N/mm^2	$Rp_{0.05}$	$Rp_{0.01}$	$Rp_{0.2}$	L of P	0.1%PS	0.2%PS
BS 5216 NS2 As received	1670	415	855	1055	1250	370	655	755
BS 2803 G2 As received	1615	840	1435	1460	1475	610	920	980
BS 2056 En58A As received	1475	570	970	1105	1240	235	555	560
Low CrV As received	1780	720	1640	1690	1705	765	1050	1130

TABLE III SPRING DESIGN DATA

Material	Wire Dia. (mm)	Coil Dia. (mm)	Free Length* (mm)	Active coils	Total coils
BS 5216 NS2	2.8	22.4	44	3.5	5.5
BS 2803 G2	2.8	22.4	43	3.5	5.5
BS 2056 En58A	2.8	22.4	44	3.5	5.5
Low CrV	2.5	22	44.5	3.5	5.5

* Free length after LTHT and cold prestress

TABLE IV LOW TEMPERATURE HEAT TREATMENTS

Material	Treatment after Coiling
BS 5216 NS2	250°C for 30 mins
BS 2803 G2	375°C for 30 mins
BS 2056 En58A	500°C for 30 mins
Low CrV	400°C for 30 mins

TABLE V LOSS IN FREE LENGTH ON PRESTRESSING

Prestressing Temperature	Mean Free Length (mm)			
	BS 5216 NS2	BS 2803 G2	Low CrV	BS 2056 En58A
As coiled 20°C	49.6	49.3	49.3	48.7
Cold scragged 20°C	43.9	42.8	45.5	43.7
100°C	44.1	42.8	54.6	44.1
150°C	42.5	42.0	44.4	43.7
200°C	41.1	40.9	43.4	43.5
250°C		39.8	42.4	43.1
300°C		38.8	41.5	42.9
350°C			39.5	42.4
400°C			39.3	41.9
450°C				41.4

All four materials have had the appropriate LTHT

TABLE VI COMPARISON OF RELAXATION BETWEEN COLD PRESTRESSED AND HOT PRESTRESSED SPRINGS

Material	LTHT	Hot Prestressing Temperature /°C	% Relaxation after 2000 hours at a stress of 800 N/mm^2				% Reduction in Relaxation
			Cold Prestressed+		Hot Prestressedx		
			%	σ	%	σ	
BS 5216 NS2	250°C/ ½ hour	200	2.1	0.173	1.47	0.211	30
BS 2803 G II	375°C/ ½ hour	250	2.9	0.265	1.39	0.351	52
BS 2056 En 58A	500°C/ ½ hour	450	1.4	0.361	1.59	0.765	NIL
Low Cr-V	400°C/ ½ hour	300	2.7	0.851	1.26	0.295	53

+ Mean of 3 samples

x Mean of 10 samples

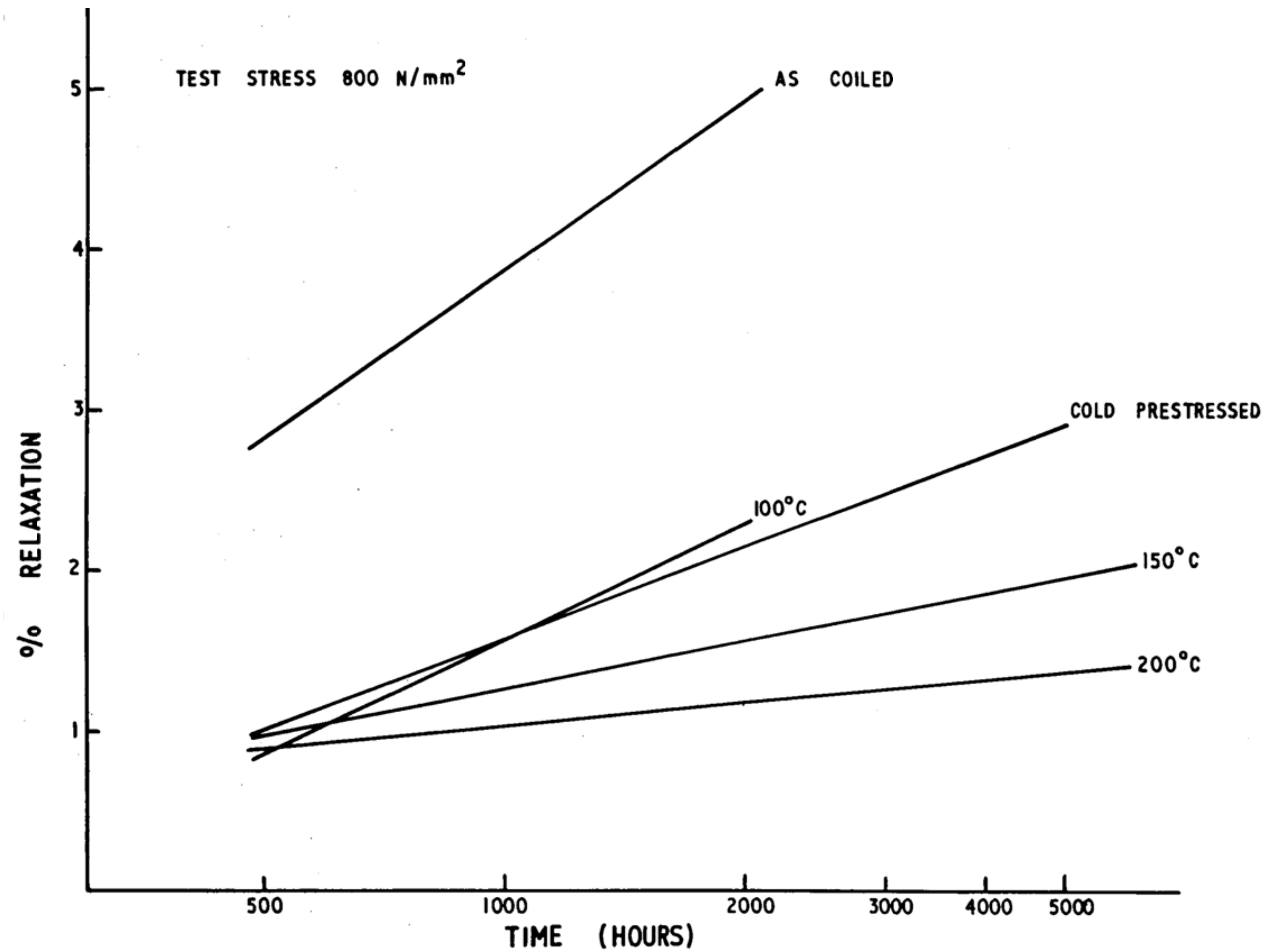

FIG. 1. EFFECT OF PRESTRESSING TEMPERATURES ON ROOM TEMPERATURE RELAXATION OF BS 5216 NS 2 SPRINGS.

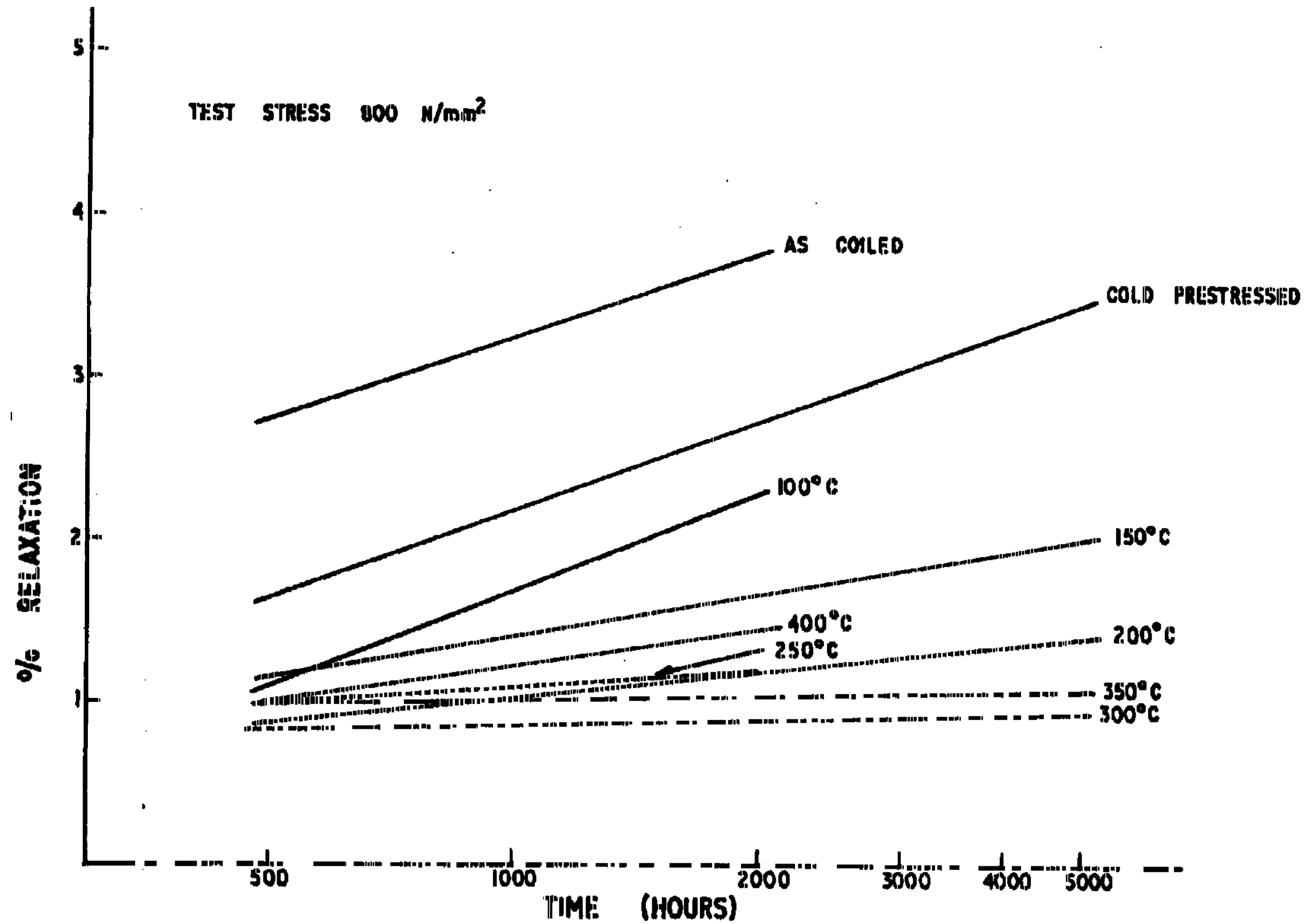

FIG. 2. EFFECT OF PRESTRESSING TEMPERATURES ON ROOM TEMPERATURE RELAXATION OF LOW Cr-V SPRINGS.

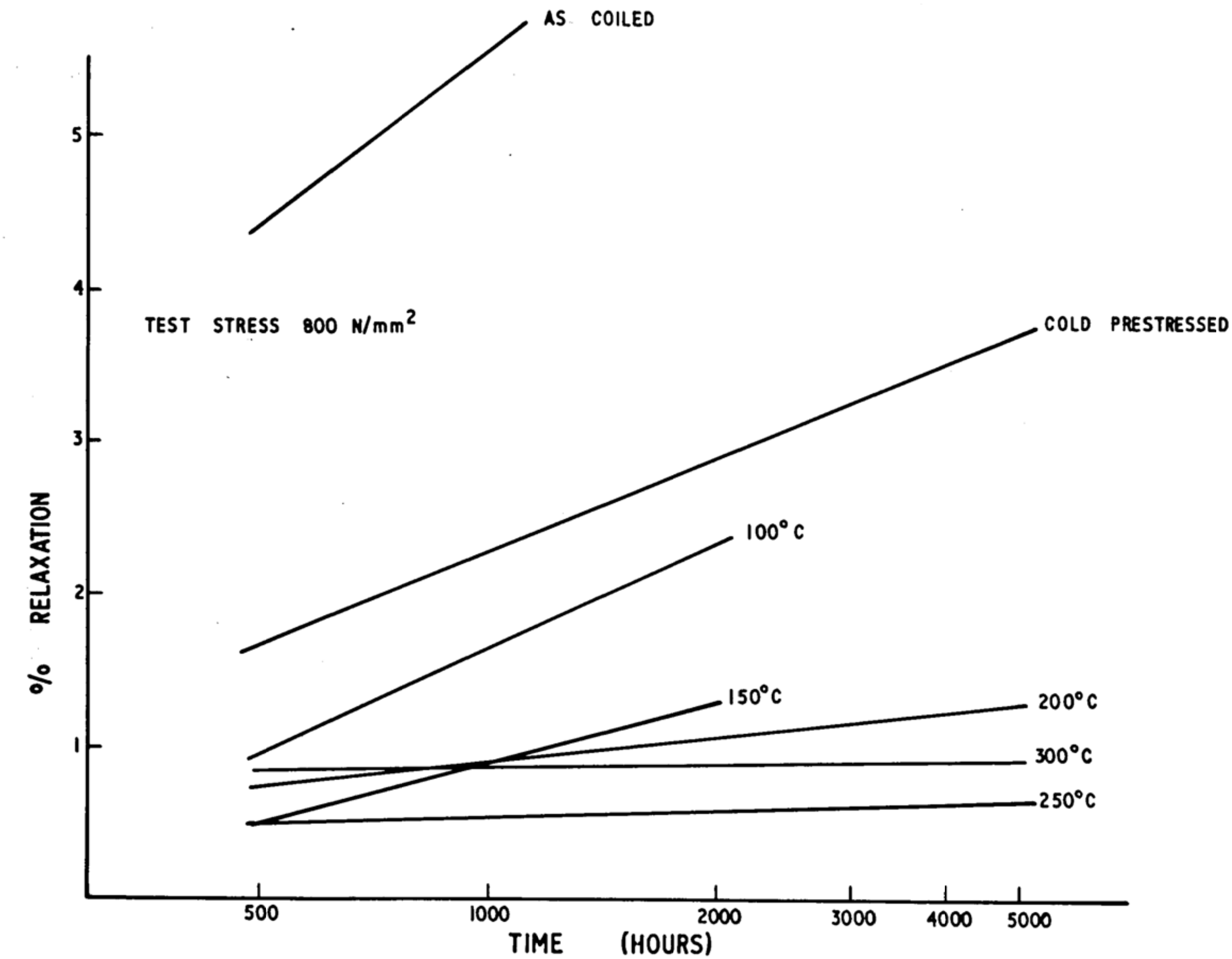

FIG. 3. EFFECT OF PRESTRESSING TEMPERATURES ON ROOM TEMPERATURE RELAXATION OF BS 2803 GII SPRINGS.

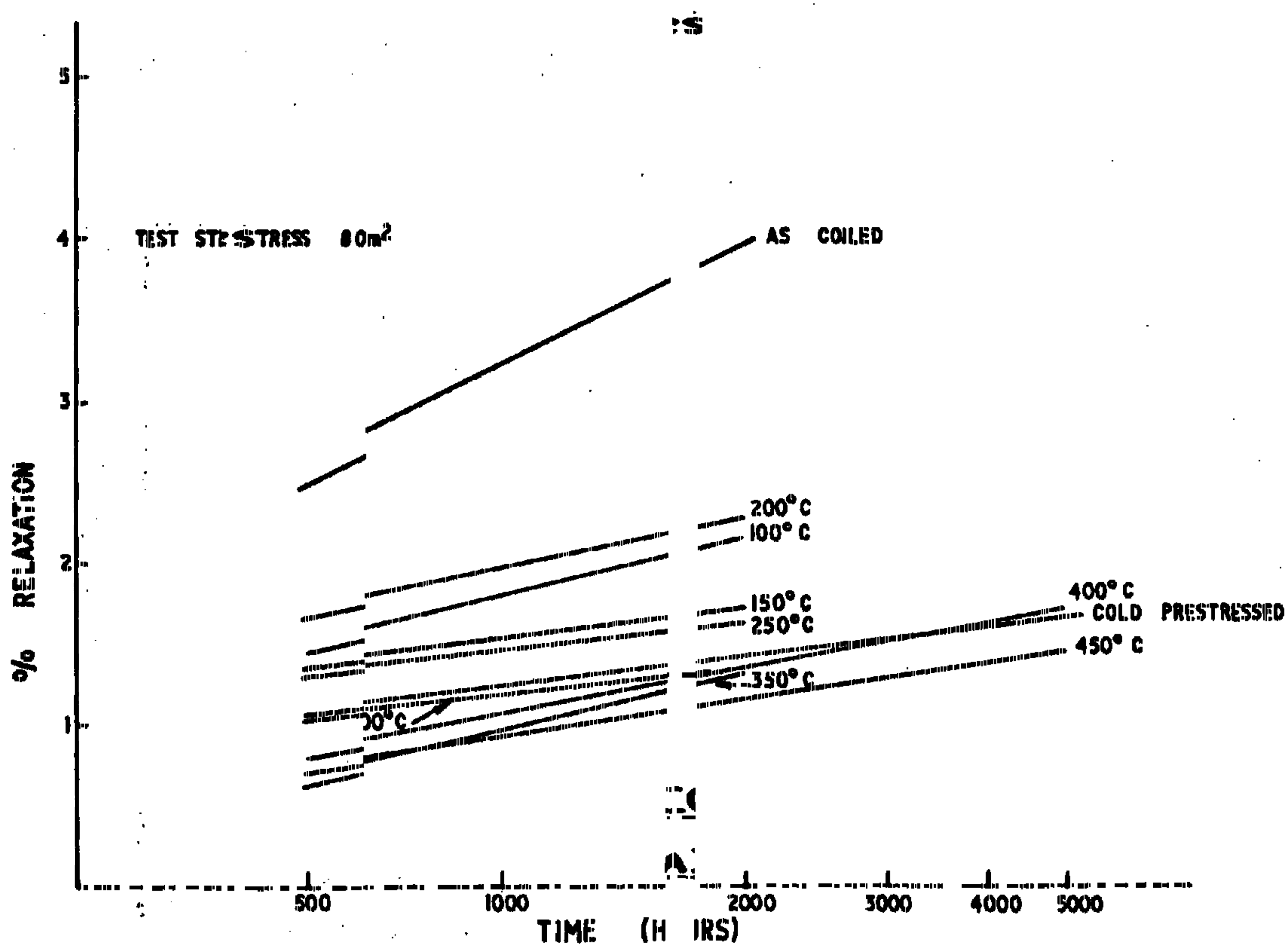

FIG. 4. EFFECT OF PRESTRESSING TEMPE TURES ON ROOM TEMPERATURE RELAXATION F En 58 A SPRING

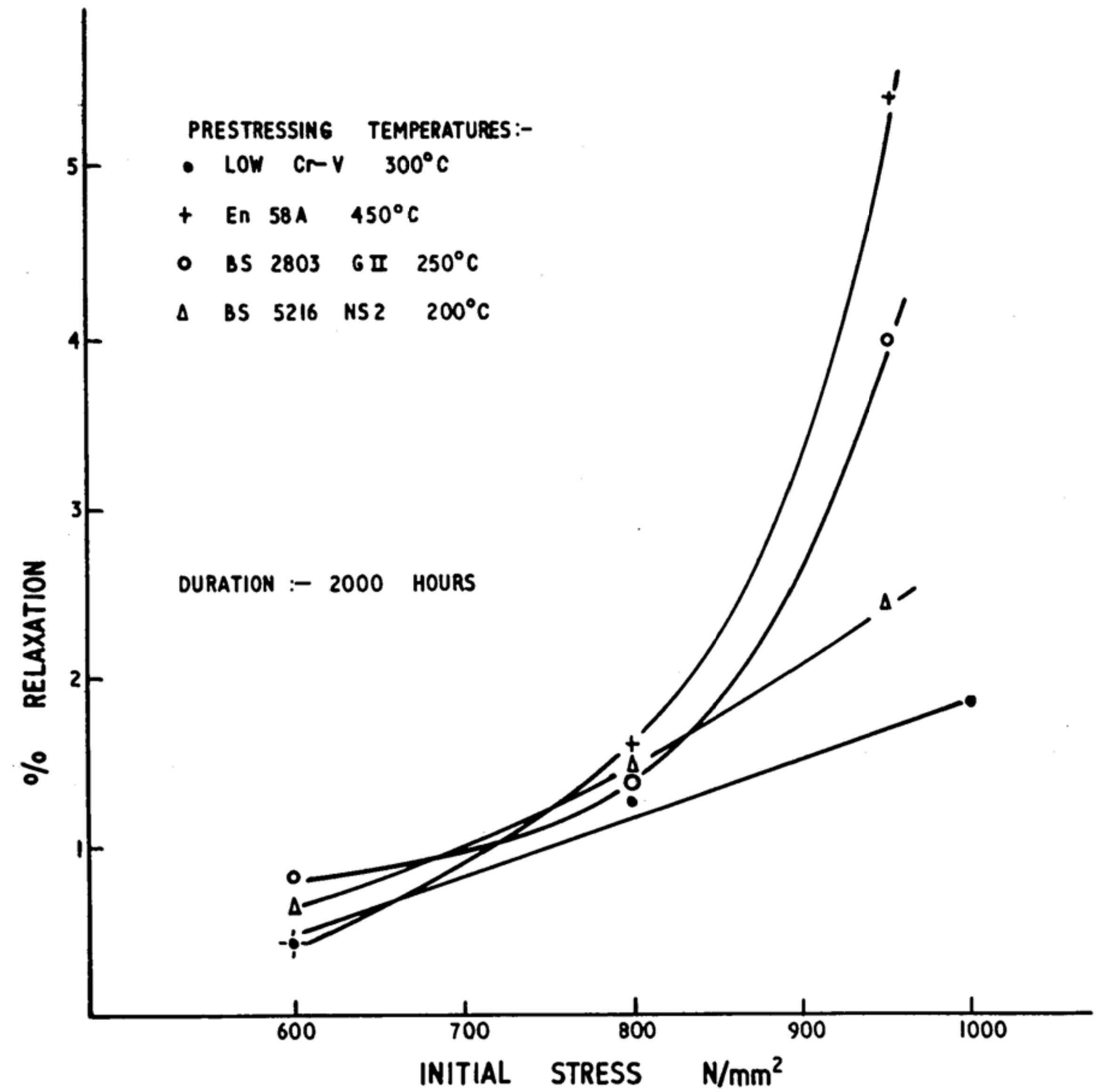

FIG. 5. STRESS RELAXATION AT ROOM TEMPERATURE (20°C)