THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

THE AMBIENT TEMPERATURE RELAXATION OF HEAVY SPRING MATERIALS

by

M. O'Malley B.Sc.

Report No. 352

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SUMMARY

Ambient temperature time relaxation tests have been carried out on heavy springs manufactured from En 47 and En 45 bar in order to assess such factors as material, hardness level and effects of hot setting on these springs. The results indicate that the relaxation behaviour of the En 45 and En 47 springs was very similar. A higher hardness level had the effect of improving the relaxation resistance slightly over short periods, but this improvement diminished with increasing time. The hot set springs had better relaxation resistance than non hot set springs of similar material and hardness level. The hot set springs experienced a maximum of approximately 1% relaxation after 9000 hours, while the non hot set springs experienced a maximum of over 2% after the same period of time.

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1. INTRODUCTION

The majority of springs operating under static loading conditions exhibit set down or relaxation, and a considerable amount of work has been carried out by the Assocation in examining the various types of relaxation behaviour for a large variety of spring materials. To date, however, this work has been limited to springs produced from wire of 4 mm diameter and under. As quite a large number of springs operating in static applications are produced from large diameter material, e.g. springs for relief values in the chemical and petroleum industries and for pipe hangers etc., it was felt that some indication of the level of relaxation experienced by heavier springs would be helpful. It was decided to examine the effects on the relaxation of heavy springs of such factors as material type and hardness level, and also the effects of hot setting.

2. MATERIALS INVESTIGATED

The investigation was carried out using 18 En 45 springs and 6 En 47 springs. The En 45 springs consisted of a batch of 12 springs with a hardness level of approximately 500 Hv (this was a higher hardness than anticipated) and a batch of 6 springs with a hardness of 520 Hv. The En 47 springs had a hardness of approximately 460 Hv. The springs were produced to the dimensions listed in Table I and were all cold prestressed to solid prior to relaxation testing in order to stabilise them.

3. HOT SETTING

Six of the batch of 12 lower hardness En 45 springs were hot set prior to relaxation testing. The hot setting process consisted of heating the springs to a temperature of 250°C for a period of one hour while they were held at a compressed length corresponding to a stress of approximately 90% of their solid stress. The percentage decrease in free length which occurred for each spring as a result of the hot setting process is given in Table II.

4. RELAXATION TESTING

Owing to the size of the springs used in this investigation, a test method was utilised whereby the springs could be load tested without stopping the tests or removing the springs from their test rigs. The test rig for each spring consisted of two large steel base plates with four matching holes drilled in them (one hole at each corner) and four threaded rods with nuts attached. The rods were put through the holes in one plate, the spring placed on this plate, the second plate was then placed onto the spring after first locating the holes with the rods, and the nuts loosely fastened down.

The spring was then compressed while in the test rig until the test load (P_0) was achieved, and held at this load while the nuts were tightened down. On removal of the load the spring was thus constrained at its test load by the base plate and nut arrangement. The load was then reapplied to the spring and a measurement made of the load (P_1) at a point at which the spring had been deflected through a further 10 mm from its test position. When further load testing after the set periods of time was necessary the loss in load was measured by compressing the spring to the deflection at which P_1 had originally been measured and noting the new load (P_2). Thus the necessity of removing the spring from the test rig each time a load test was carried out was eliminated.

Preliminary tests confirmed that, in all cases, load tests were within the linear portion of the load deflection curve and so the assumption could be made that, as the rate of the spring remains linear over the applied testing range even when relaxation occurs, then the difference between the two loads, P_1 and P_2, would be the same as the difference between the original test load (P_0) and the load which would have been measured if the spring had been taken out of the test rig and load tested after the time period had elapsed. The percentage relaxation can thus be calculated using:-

$$\% \text{ relaxation} = \frac{P_1 - P_2}{P_0} \times 100$$

Where P_0 = original load at test position (N)

P_1 = original load at test position - 10 mm (N)

P_2 = new load at test position - 10 mm (N)

5. RESULTS AND DISCUSSION

The springs were all relaxation tested at the same initial load (P_0) which produced a stress level of 740 N/mm^2 in the En 45 springs, but only produced a stress level of 720 N/mm^2 in the En 47 springs. This anomaly in test conditions was not discovered until after testing had commenced.

The results of the tests are shown in Figures 1 - 4. The results were analysed using standard regression techniques in order to produce statistically significant relationships for the time relaxation behaviour of the springs. Due to the near horizontal nature of the results for the hot set springs, the regression was not statistically significant. The results for the other three sets of springs were found to comply with a logarithmic time relaxation relationship of the form:

$$\% \text{ relaxation} = c \ln t + d$$

Where t = time (hours)

c and d are constants which depend on the material and conditions under test.

Best fit and 95% confidence lines were calculated for each of the four sets of springs and these are shown in Figures 1 - 4, and the values of c and d and the 95% confidence increments are given in Table III. Although the regression for the hot set springs was not statistically significant, it was still possible to calculate the values of c and d for the near horizontal line, and to determine a 95% confidence increment.

It can be seen from examination of Figures 1 and 2, that there is essentially no difference in the ambient temperature relaxation resistance of large size En 45 and En 47 springs. Unfortunately, due to the difference in hardness and test stress levels for these two sets of springs, it is not possible to make a direct comparison between them.

It would appear from examination of Figures 2 and 3 that a higher hardness level results in a very slight improvement (approximately 0.5%) in relaxation resistance; but this benefit appears to diminish over extended periods of time and the relaxation level of the higher hardness springs approaches that of the lower hardness springs.

The hot set springs have better relaxation resistance than the cold prestressed springs of the same hardness. The hot set springs exhibited either recovery or low levels of relaxation (a maximum of about 1% relaxation after 9000 hours). Even though there did seem to be a slight increase in the relaxation of these hot set springs with increasing time, even after 9000 hours some of the springs were still experiencing about 2% recovery. This reduction in relaxation for hot set springs is consistent with results previously obtained by the Association[1,2] for various materials using small test springs.

6. CONCLUSIONS

1. The time relaxation behaviour of heavy springs at ambient temperature complies with the logarithmic relationship derived for light springs.

2. En 47 heavy springs exhibit similar relaxation resistance to En 45 springs.

3. Higher hardness material appears to be more resistant to ambient temperature relaxation than similar material of a lower hardness level, but this improvement decreases with increasing time.

4. Hot setting improves the relaxation resistance of En 45 heavy springs at ambient temperature.

7. RECOMMENDATIONS

The tests should be allowed to continue in order to assess whether:

1. The higher hardness material will continue to exhibit better relaxation resistance than the lower hardness material.

2. The hot set springs continue to experience recovery.

8. REFERENCES

1. Graves, G. B. "The Stress Temperature Relaxation and Creep Properties of Some Spring Materials". SMRA Report No. 143

2. Graves, G. B. "The Stress Relaxation Properties of Nimonic 90 and Inconel X750 Helical Compression Springs". SMRA Report No. 152.

TABLE I SPRING DESIGN DATA

		En 47	En 45 normal hardness	En 45 normal hardness (hot set)	En 45 high hardness
Free length (mm)	nominal	254	254	254	254
	actual	255	259	260	260
Bar diameter (mm)	nominal	20	20	20	20
	actual	20.35	20.125	20.1	20.1
Mean coil diameter (mm)	nominal	152	152	152	152
	actual	154.9	152.8	152.6	152.6
Spring index	nominal	7.6	7.6	7.6	7.6
	actual	7.61	7.59	7.59	7.59
Total coils	nominal	5 1/2	5 1/2	5 1/2	5 1/2
	actual	5 1/3	5 1/2	5 1/2	5 1/2
Hardness (Hv)	nominal	450	450	450	520
	actual	463	497	506	520

TABLE II CHANGE IN FREE LENGTH DUE TO HOT SETTING OF EN 45 SPRINGS

Spring No.	Free length (mm)		% decrease in free length.
	Before hot-setting	After hot-setting	
1	259.4	246.5	5.0
2	260.6	250.5	3.9
3	258.9	246.3	4.9
4	261.3	250.5	4.1
5	260.7	248.0	4.9
6	259.3	247.5	4.6

TABLE III STATISTICAL CONSTANTS FOR LOGARITHMIC TIME RELAXATION RELATIONSHIPS

Material	R = c lnt + d		95% Confidence increment (% relaxation)
	c	d	
En 47	0.381	-1.859	1.58
En 45 normal hardness	0.262	-1.018	1.27
En 45 high hardness	0.378	-2.211	1.38
En 45 hot set	0.143	-1.670	2.14

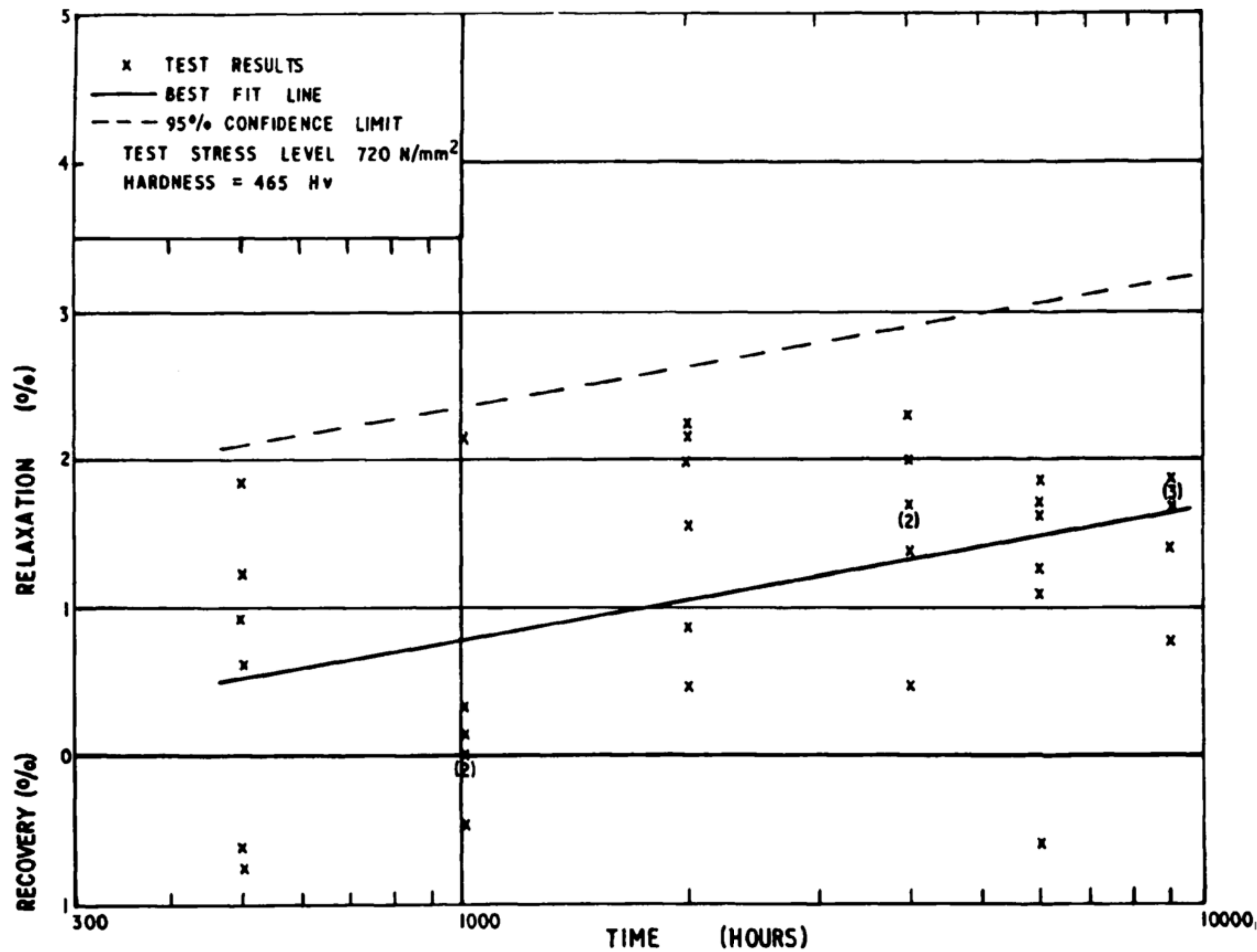

FIG. 1. TIME RELAXATION RESULTS FOR En 47 SPRINGS.

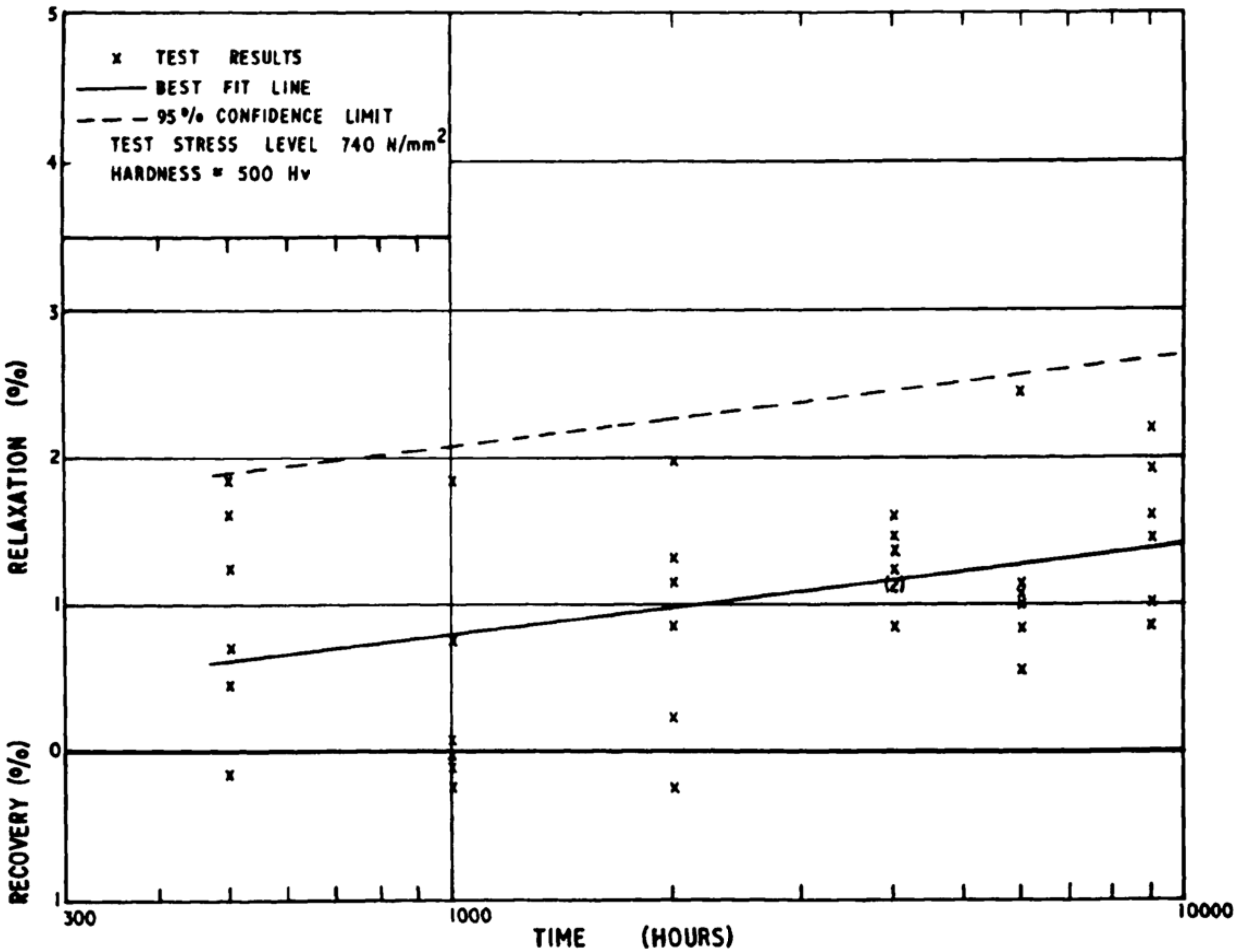

FIG. 2. TIME RELAXATION RESULTS FOR NORMAL HARDNESS En 45 SPRINGS.

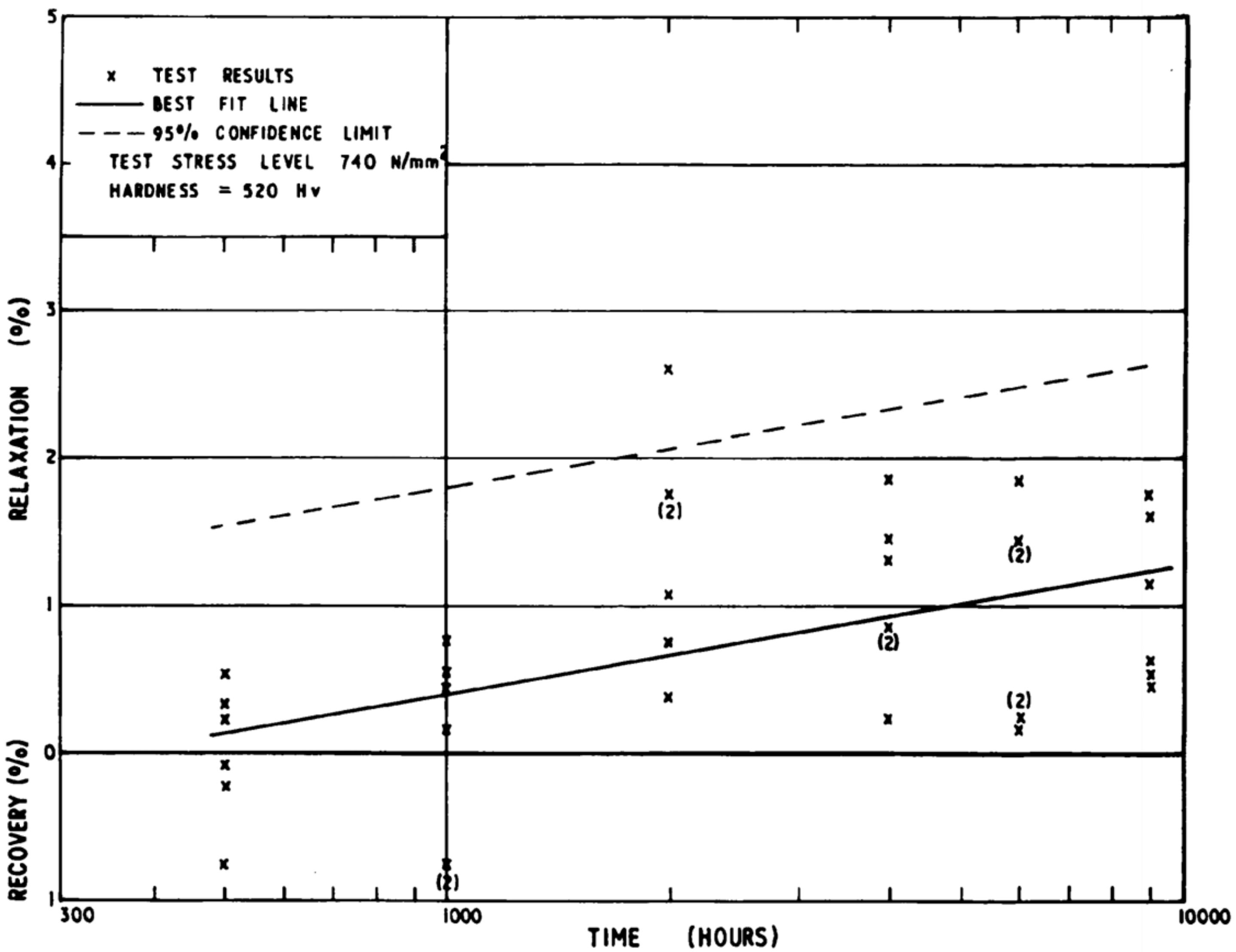

FIG. 3. TIME RELAXATION RESULTS FOR HIGH HARDNESS En 45 SPRINGS.

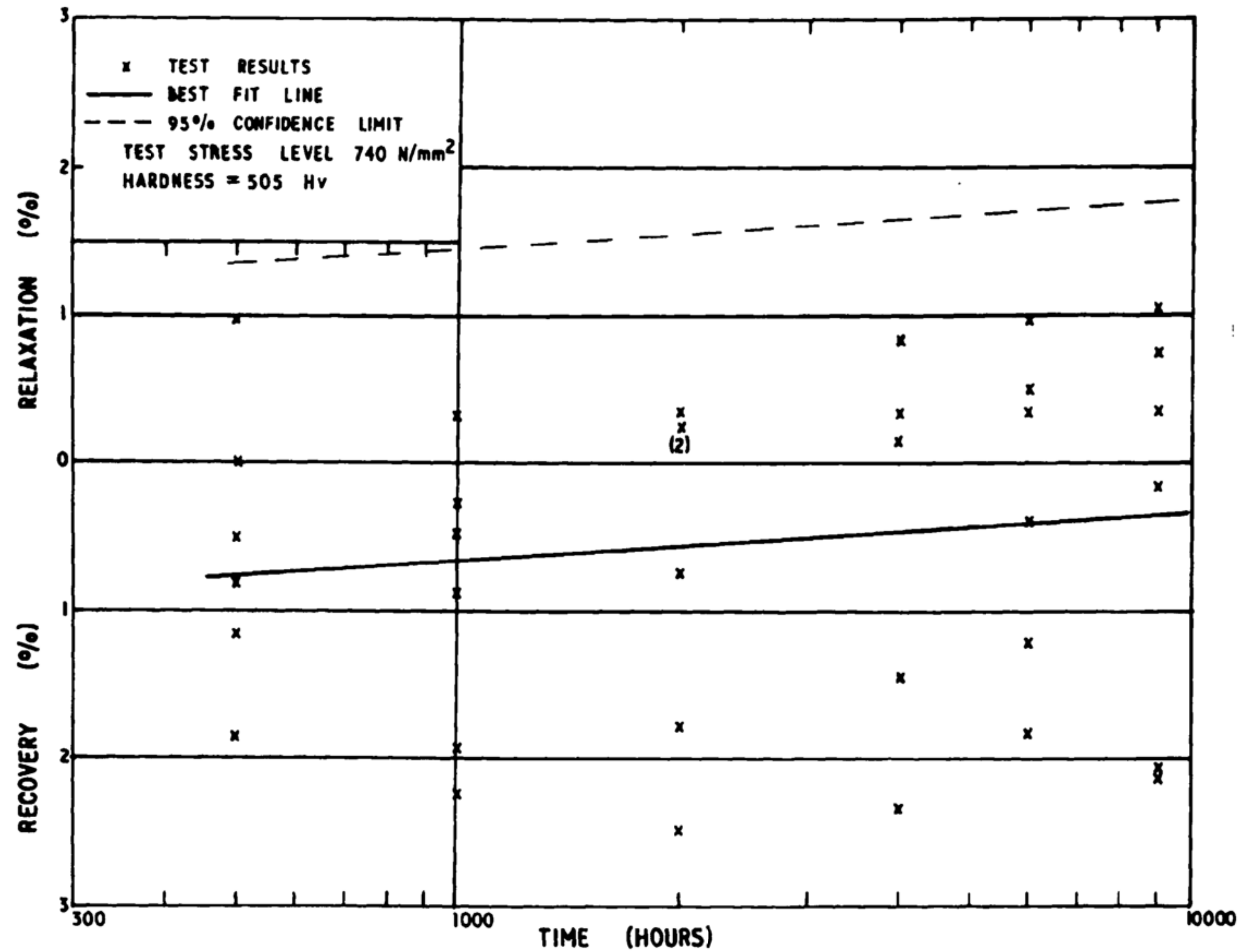

FIG. 4. TIME RELAXATION RESULTS FOR HOT SET NORMAL HARDNESS En 45 SPRINGS.