THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

THE LONG TERM RELAXATION BEHAVIOUR OF SPRING MATERIALS

3rd Progress Report

by

M O'Malley B.Sc.

Report No 360

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SUMMARY

The work indicates that of the materials tested to date[1,2], 17/7PH and BH 13 have by far the best ambient temperature relaxation resistance, and so should find increasing usage for applications where relaxation resistance is a prime requirement.

Below a temperature of 250°C, 17/7PH has excellent relaxation resistance; above this temperature there is a marked deterioration in the relaxation resistance of the material.

BH 13 tool steel springs have excellent relaxation resistance at ambient temperature and at elevated temperatures below 300°C provided that they are not highly stressed.

This continuation of previous work has shown that it is possible to produce statistically significant logarithmic time relaxation relationships for BH 13 tool steel and 17/7PH stainless steel springs.

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1. INTRODUCTION

Over the past few years the Association has carried out a programme of work examining the long term relaxation behaviour of a variety of spring materials in order to produce reliable information for the spring designer and user.[1,2] This programme has been extended to include a further range of materials.

2. MATERIALS INVESTIGATED

The work was carried out using springs made from BH 13 tool steel and a 17/7PH stainless. As 17/7PH is finding increasing usage in spring applications, it was decided to carry out a very comprehensive series of tests to enable a full picture of its relaxation properties to be developed.

The chemical compositions and spring designs for the two materials are given in Tables I and II.

3. EXPERIMENTAL METHOD

Relaxation tests were carried out using the standard nut and bolt technique. The test conditions are detailed in Table I as follows:

Table I TEST CONDITIONS

Material	Test Temperatures (°C)	Test Stresses (N/mm^2)
BH 13	Ambient 250, 300, 350	600, 800, 1000
17/7PH	150, 200, 275, 300, 350	400, 600, 800, 1000

The particular test temperatures and stresses for the BH 13 springs were chosen as being representative of current service applications. For the 17/7PH material the choice of test conditions was based on two considerations. Firstly, as 17/7PH has been shown to have very good relaxation resistance at 250°C (2) (which is the maximum recommended service temperature for austenitic stainless steels), tests were carried out above this temperature to determine the point at which the relaxation resistance deteriorated. Also, as very little data is available for 17/7PH as wide a range of test temperatures as possible were used.

The elevated temperature tests were allowed to continue for a maximum of 3000 hours. The ambient temperature tests are still running.

4. RESULTS AND DISCUSSION

The results of the tests are shown in Figures 1-8. The results for the 17/7PH springs tested at 150 and 200°C are not included as the levels of relaxation experienced by these springs were less than 1%. The results were statistically analysed using linear regression techniques to determine the significance of the relationship between time and relaxation for each combination of material and test condition. The majority of the results were found to fit the logarithmic time relaxation relationship derived by the Association:-

$$R = c \ln t + d$$

where R = relaxation (%)

t = time (hours)

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

The values of c and d are given in Table III together with 95% confidence limits.

The results for the 17/7PH tested at 150°C and 200°C could not be fitted to the logarithmic relationship due to the very low levels of relaxation obtained.

A further discussion of the statistical analysis of the test data is presented in the appendix.

Predicted mean levels of relaxation for durations of 10,000 hours and 20,000 hours are given in Table IV for the two test materials.

Examining all the tests results for 17/7PH it is obvious that at temperatures below 250°C this material has excellent relaxation resistance. Above this temperature the relaxation resistance is still good at low stress levels, but at higher stress levels there is a marked deterioration in the relaxation resistance.

The BH 13 has good relaxation resistance at ambient temperature and at 250°C and 300°C for the two lower stress levels tested. However at the higher stress level (1000N/mm^2) and at 350°C the level of relaxation experienced by the springs was rather high.

5. CONCLUSIONS

1. The logarithmic time relaxation relationships which were produced were significant to the 99.5% level and can be used to predict long term relaxation levels for the materials and service conditions to which they relate.

2. 17/7PH has excellent relaxation resistance at temperatures below 250°C. Above this temperature a marked deterioration in relaxation resistance occurs.

3. BH 13 springs have excellent relaxation resistance at ambient temperature.

4. At temperatures of 250°C and 300°C BH 13 springs have good relaxation resistance provided that they are not highly stressed.

6. RECOMMENDATIONS

The work should be extended to cover other spring materials. In order to assess the assumption that the period variation in relaxation observed was a reflection of the changes in ambient temperature during the testing period(see appendix), it is suggested that, in future, the ambient temperature should be measured at each load testing operation.

7. REFERENCES

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

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

APPENDIX

It was noticed that, for most of the test results, the mean values were not randomly scattered around the regression line, but appeared to be periodically situated around this line. The data was reanalysed using polynomial regression techniques. It was found that the data could best be described by a 5th order polynomial expression between relaxation and logarithmic time of the form:-

$$R = a + b x + c x^2 + d x^3 + e x^4 + f x^5 \quad \ldots\ldots\ldots\ldots \text{(i)}$$

Where R = relaxation (%)

x = lnt

t = time (hours)

a-f are constants depending on the material and test conditions.

The statistical significance of this relationship was higher than that for the standard logarithmic time relaxation relationship. Also, the data for the five sets of tests results which did not fit the standard logarithmic time relaxation relationship (ie for the 17/7PH at 150°C and 200°C) could be fitted to this form of polynomial relationship.

The reason for this periodic variation in the results is unclear at the present moment in time, and it is possible that this variation is a reflection of the ambient temperature changes occuring during the testing period.

It must be pointed out that although this polynomial relationship is of academic interest, for practical prediction purposes the standard logarithmic relationship is quite adequate since where it is not possible to determine a statistically significant logarithmic time relaxation relationship the level of relaxation experienced is very low.

TABLE I CHEMICAL COMPOSITION OF MATERIALS USED IN THE INVESTIGATION

Material		Composition (%)									
		C	Si	Mn	S	P	Cr	Mo	V	Ni	Al
BS 4659 BH13	specified	0.32-0.42	0.85-1.15	0.4 max	-	-	4.75-5.25	1.25-1.75	0.9-1.1	-	-
	actual	0.39	1.04	0.38	0.006	-	5.10	1.26	0.89*	-	-
17/7PH	specified	0.09 max	1.0 max	1.0 max	0.025 max	0.035 max	16.0 18.0	- -	- -	6.5-7.75	0.75-1.5
	actual	0.05	0.38	0.63	0.010	0.020	17.9	-	-	7.5	0.75

* This variation is within the limits set on the method of analysis, and so the material is deemed to comply with the specification.

TABLE II SPRING DESIGN DETAILS

	BS 4659-BH13	17/7PH
Wire diameter (mm)	3.25	2.64
Mean coil diameter (mm)	24.26	18.48
Spring index	7.46	7
Active coils	3.5	3.5
Total coils	5.5	5.5
Free length (after end grinding and prestressing) (mm)	38.1	36.71
End type	closed and ground	
Solid stress (N/mm^2)	-	1485
Material hardness (HV)	470	-

TABLE III ANALYTICAL CONSTANTS FOR TIME RELAXATION RELATIONSHIPS

Material	Test Temperature (°C)	Stress level (N/mm²)	R = clnt + d		95% confidence increment (%)
			c	d	
BS 4659 BH13	Ambient	600	0.183	-0.359	0.8
		800	0.189	-0.322	0.7
		1000	0.183	-0.136	0.8
	250	600	0.244	2.722	0.6
		800	0.301	3.508	0.4
		1000	0.479	5.903	1.6
	300	600	0.322	2.762	1.0
		800	1.300	3.384	0.7
		1000	0.684	6.553	1.0
	350	600	1.192	2.450	1.8
		800	1.537	3.568	2.1
		1000	1.683	7.554	1.8
17/7PH	275	400	0.535	-1.332	0.7
		600	0.608	-1.426	0.5
		800	0.789	-1.865	0.4
		1000	1.297	-2.688	1.0
	300	400	0.739	-0.471	0.9
		600	0.735	-0.060	1.0
		80C	0.893	-0.275	1.5
		1000	1.339	0.645	1.5
	350	400	2.010	-1.675	1.5
		600	2.278	-1.985	1.1
		800	2.695	-1.825	1.2
		1000	2.959	1.902	1.3

TABLE IV PROJECTED 10,000 AND 20,000 HOUR MEAN LEVELS OF RELAXATION

Material	Temperature (^oC)	Stress Level (N/mm^2)	Projected Relaxation (%)	
			10,000 hour	20,000 hour
BS 4659 BH13	ambient	600 800 1000	1.3 1.4 1.6	1.5 1.6 1.7
	250	600 800 1000	5.0 6.3 10.3	5.1 6.5 10.6
	300	600 800 1000	5.7 7.4 12.9	6.0 7.7 13.3
	350	600 800 1000	13.4 17.7 23.1	14.3 18.8 24.2
17/7PH	275	400 600 800 1000	3.6 4.2 5.4 9.3	4.0 4.6 6.0 10.2
	300	400 600 800 1000	6.3 6.7 7.9 13.0	6.9 7.2 8.6 13.9
	350	400 600 800 1000	16.8 19.0 23.0 29.2	18.2 20.6 24.9 31.2

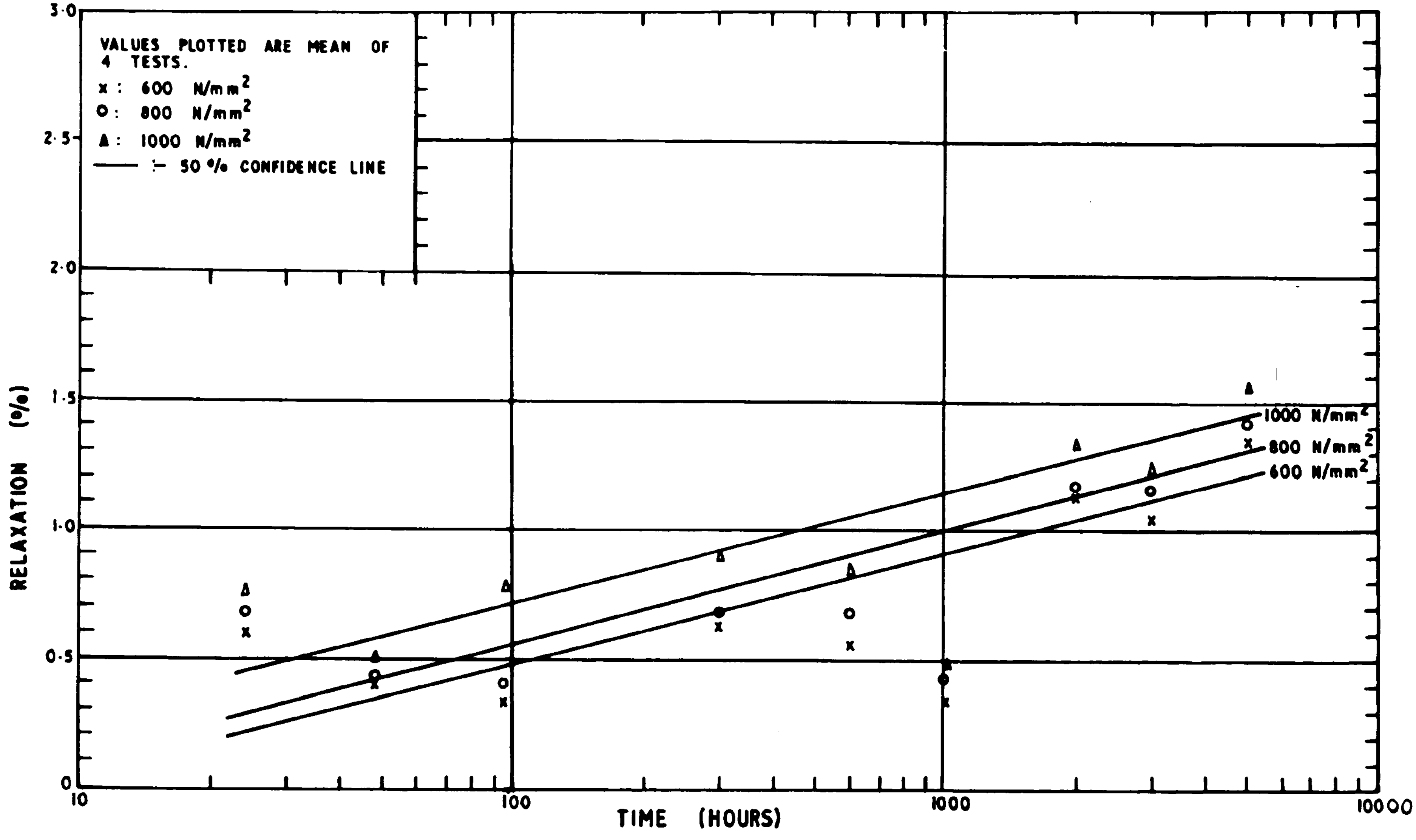

FIG. I TIME RELAXATION OF BS 4659 BH 13 SPRINGS AT AMBIENT TEMPERATURE.

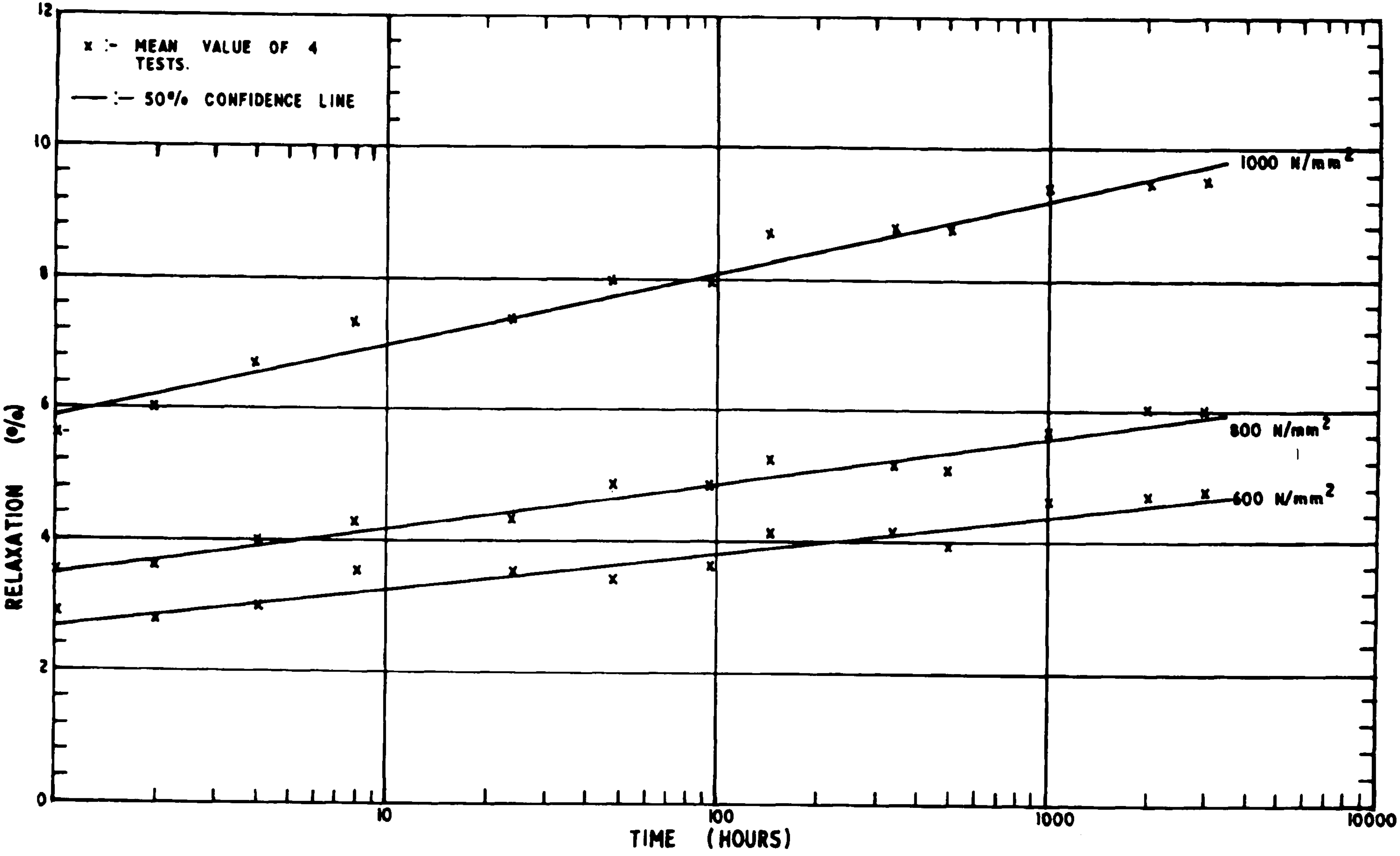

FIG. 2. TIME RELAXATION OF BS 4659 BH 13 SPRINGS AT 250° C.

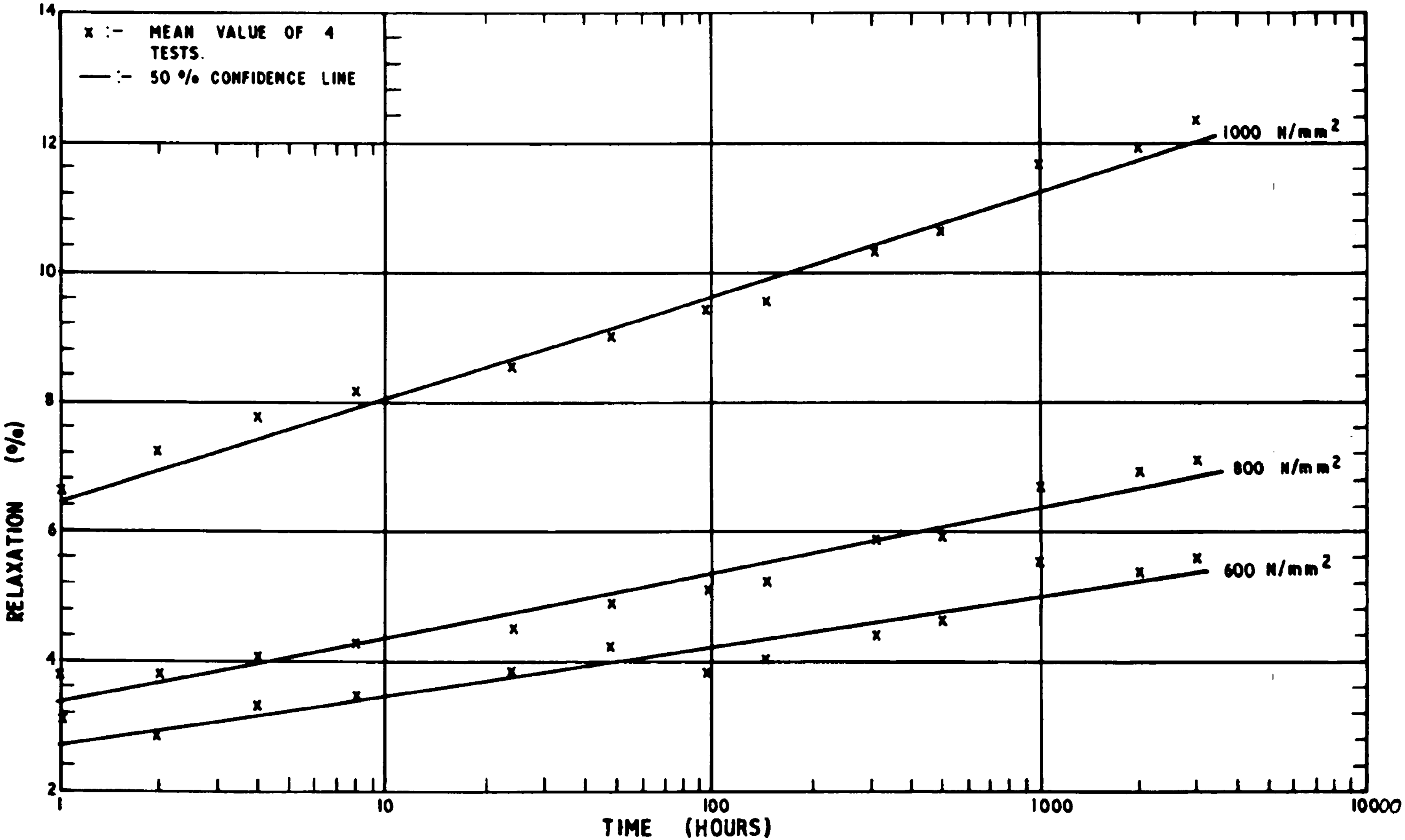

FIG. 3. TIME RELAXATION OF BS 4659 BH 13 SPRINGS AT 300° C.

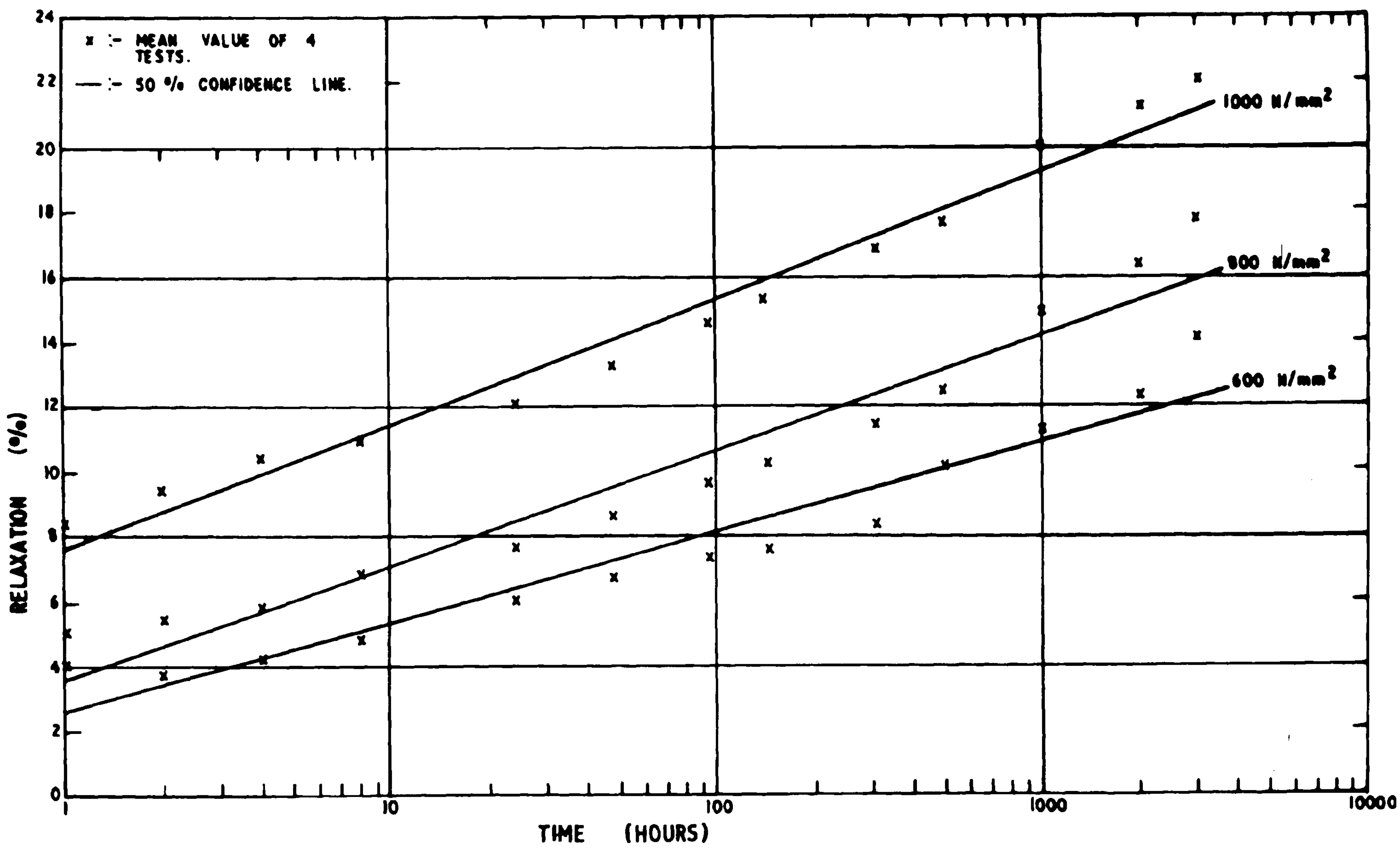

FIG. 4 TIME RELAXATION OF BS 4659 BH 13 SPRINGS AT 350° C.

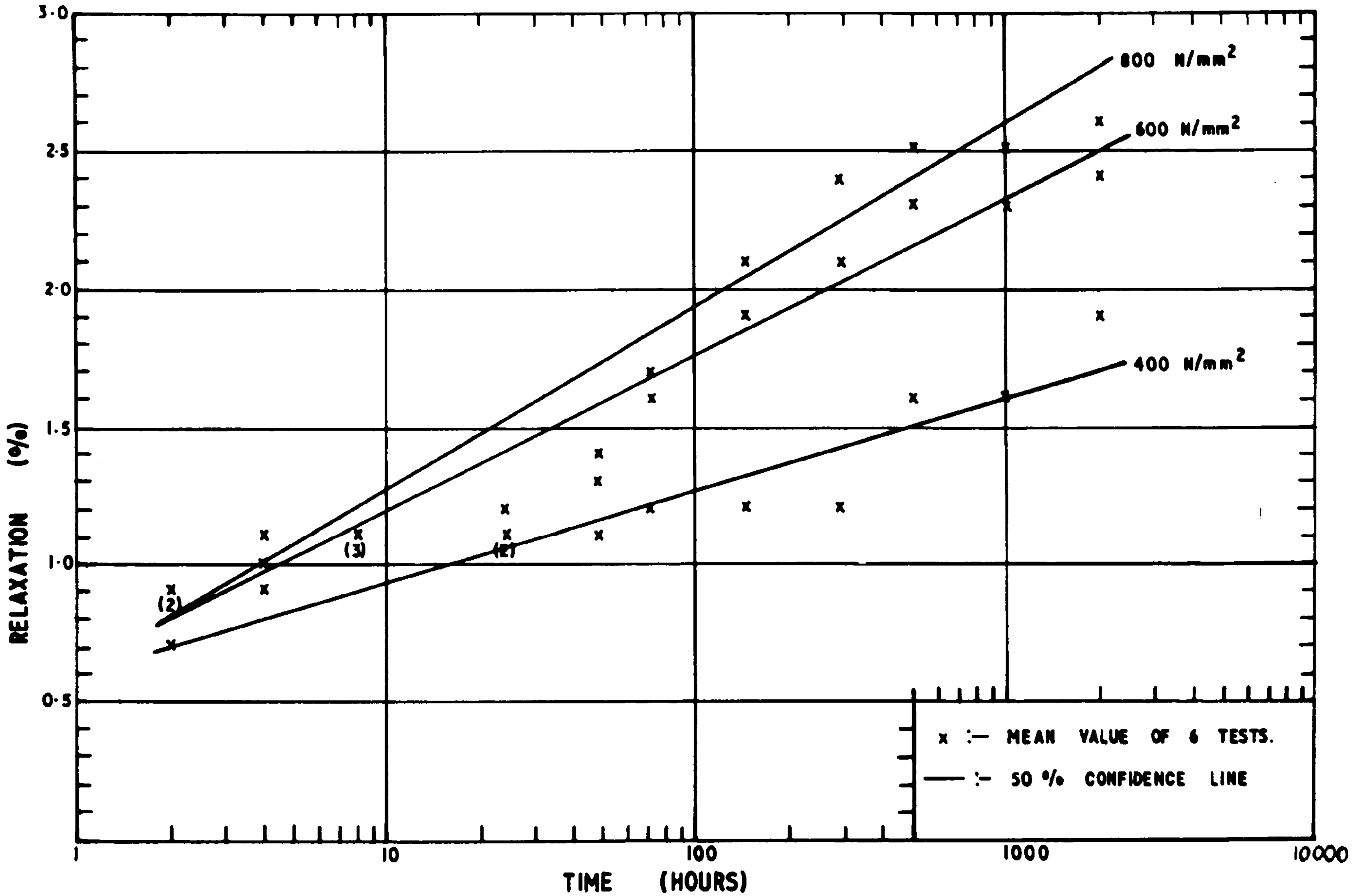

FIG. 5. TIME RELAXATION OF 17/7 PH SPRINGS AT 250°C. (TAKEN FROM REPORT No. 349)

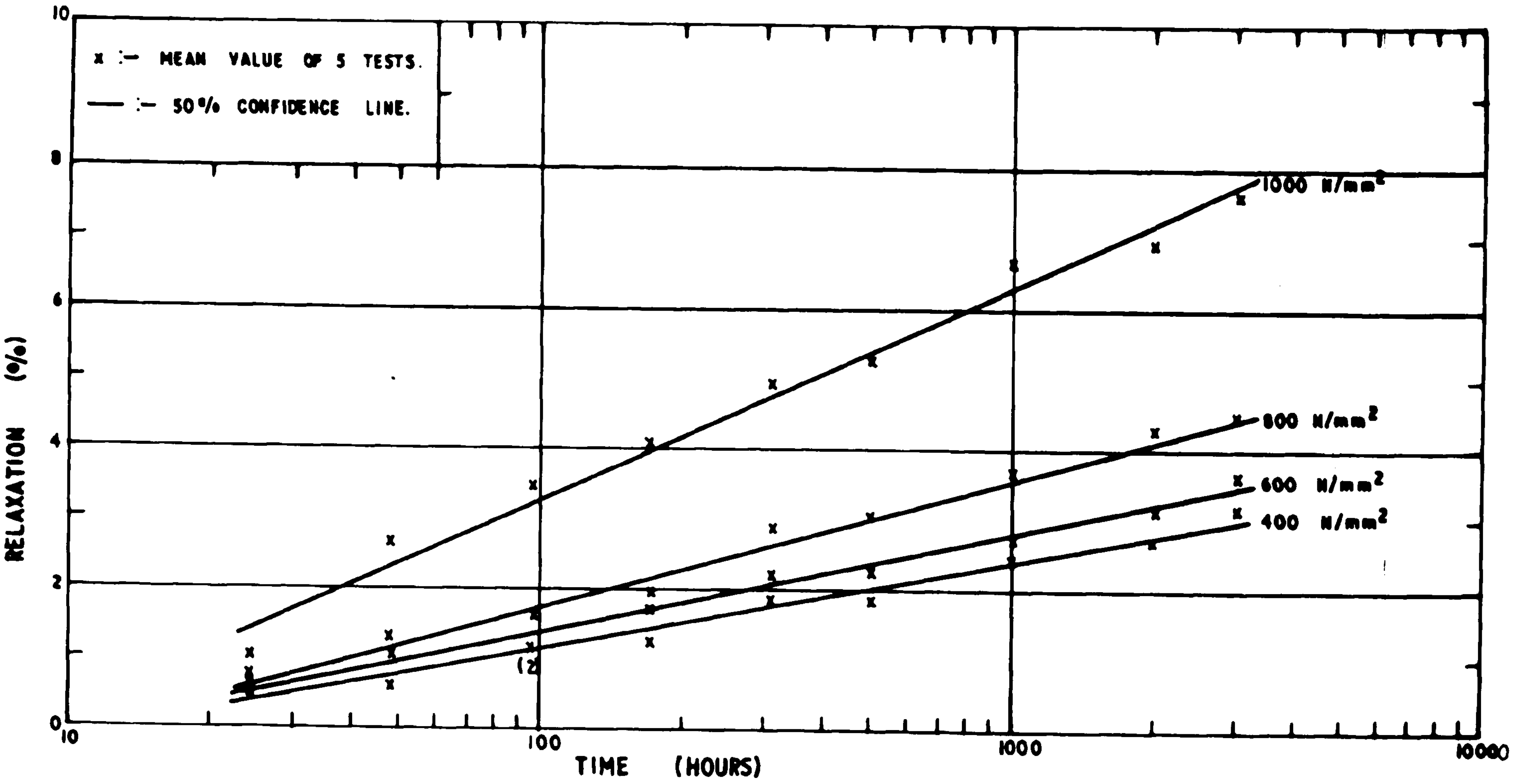

FIG. 6. TIME RELAXATION OF 17/7 PH SPRINGS AT 275°C.

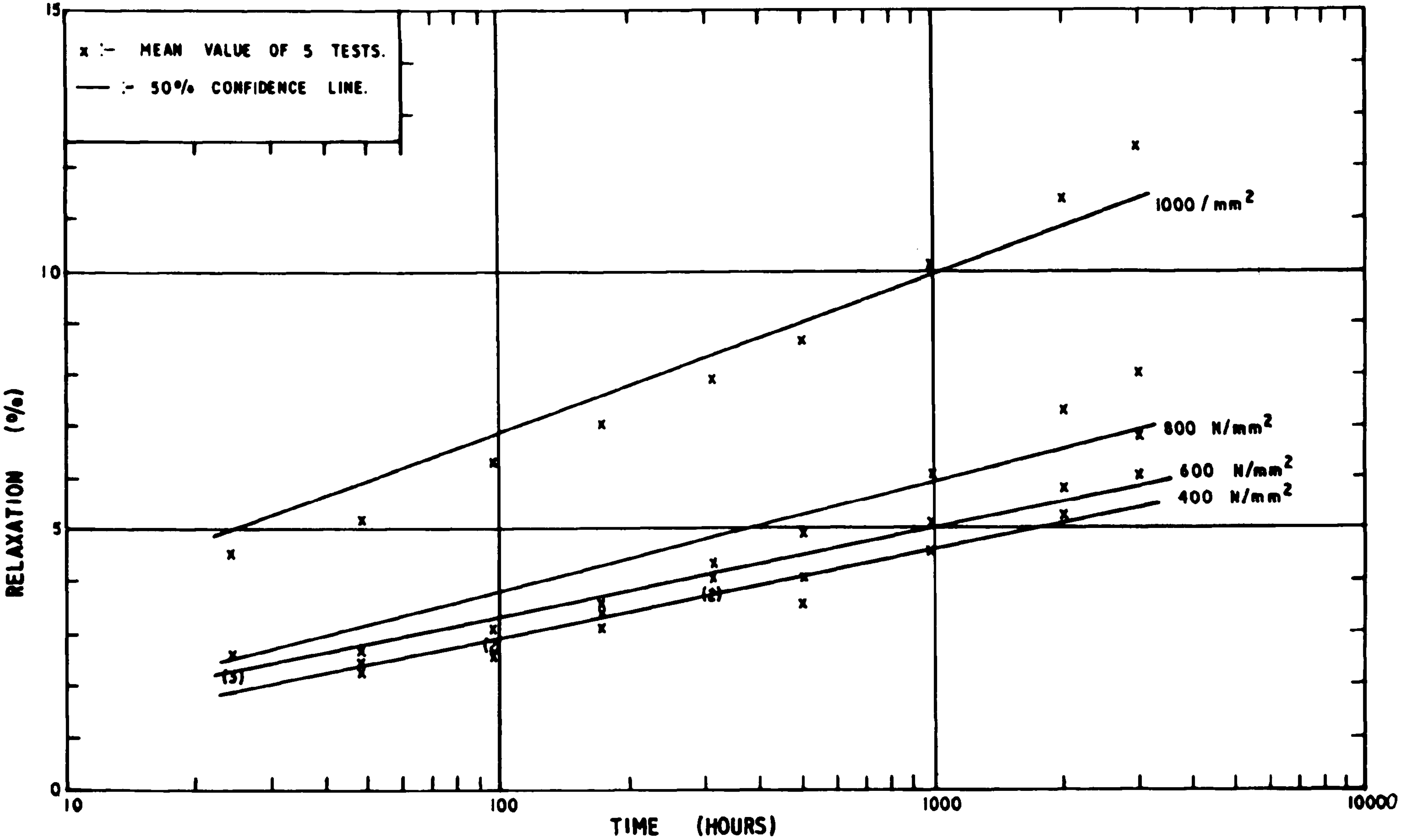

FIG. 7 TIME RELAXATION OF 17/7 PH SPRINGS AT 300° C.

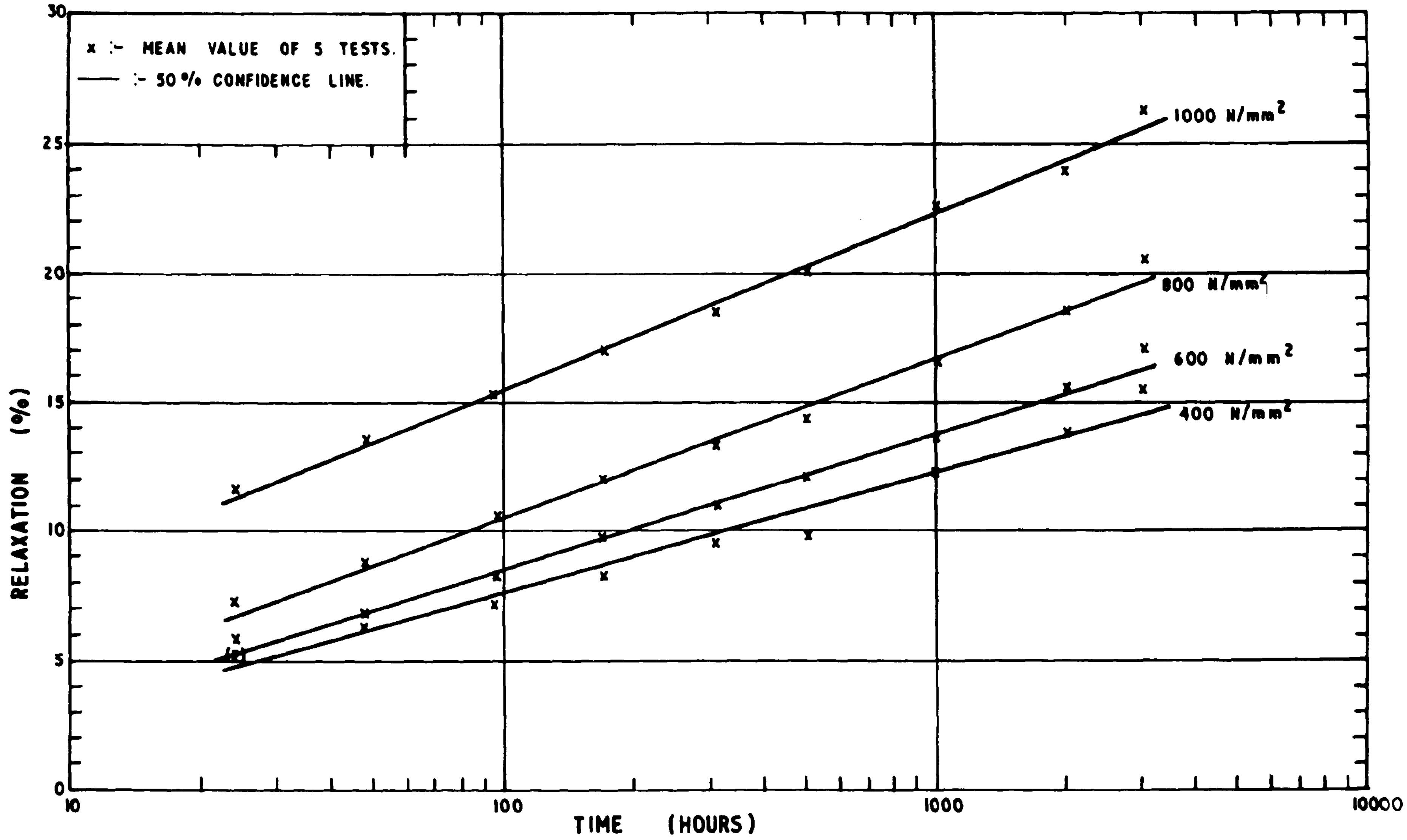

FIG. 8 TIME RELAXATION OF 17/7 PH SPRINGS AT 350° C.