'HE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

THE LONG TERM RELAXATION BEHAVIOUR

OF SPRING MATERIALS

4th Progress Report

CHROMIUM VANADIUM AND SILICON CHROMIUM SPRINGS

by

M O'Malley, B.Sc.

Report No 363

OCTOBER 1983

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SUMMARY

As a continuing build up of information for the Association's data base on the long term relaxation behaviour of spring materials, silicon chromium and standard chromium-vanadium springs have been tested.

The work indicates that both materials have good ambient temperature relaxation resistance, but for extended service at elevated temperatures the maximum recommended operating temperature for both materials would appear to be 200°C, provided that the springs are lowly stressed.

The work has also shown that the elevated temperature relaxation resistance of the standard chromium-vanadium steel is superior to that of the low chromium-vanadium which had been tested previously.[2]

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1. INTRODUCTION AND MATERIALS INVESTIGATED

In order to expand the Association's database on the relaxation properties of spring materials, tests have been carried out on pre-hardened and tempered silicon-chromium and standard chromium-vanadium springs made from wire to the BS 2803 685A55 and 735A50 grades respectively. This brings the number of materials tested to date as 14, the full list being as follows:-

BS 5216 NS1 (2), HD3 (1), M4 (1), and M5 (2)
BS 2803 G2 (1)
Oteva 60 (2)
BS 2056 En58A (1)
17/7PH (2), (3)
Inconel 600 (2)
Monel K500 (2)
Copper-beryllium (2)
BS 4659 BH13 (3)
BS 2803 685A55
BS 2803 735A50

The chemical composition, tensile and torsional properties, and spring designs for the 685A55 and 735A50 are given in Tables I-IV respectively.

2. TEST METHOD AND RESULTS

Both sets of springs were relaxation tested using standard nut and bolt techniques at the following combinations of stress and temperature.

Stress level (N/mm^2)	Test Temperature (^oC)
400, 600, 800	Ambient, 200, 250

The test stresses and temperatures were chosen as being representative of service applications for these materials. Five springs of each material were tested at each combination of stress and temperature.

The elevated temperature tests were carried out for a total test time of 3700 hours, and the springs were re-load tested at 13 discrete time intervals during the course of testing. The ambient temperature tests are still continuing, although data are only present in this report for a maximum test period of 3000 hours.

The results of the tests are shown graphically in figures 1-6. For each combination of stress level and test temperature, the data were analysed using standard linear regression techniques to produce logarithmic relationships of the form:-

$$Rel = c \ln t + d \qquad \text{............. (i)}$$

Where Rel = relaxation (%)

t = time (hours)

c and d are constants which depend on the material, stress level and temperature under test.

For each combination of material, stress and temperature, the derived relationship was found to be statistically significant at the 99.9% level. The values of c, d and the 95% confidence increments for all the test results are presented in Table V.

Using the derived relationships, it was possible to predict the mean levels of relaxation which the springs would experience over service durations of 10,000 and 20,000 hours respectively (i.e. approximately 1 and 2 year periods). These determined mean levels are given in Table VI.

3. DISCUSSION OF RESULTS

From an examination of Figures 1-3, it is apparent that the chromium vanadium springs have good relaxation resistance at ambient temperature, but at elevated temperatures their relaxation resistance over extended periods of time is poor. If the ambient temperature and $200^{\circ}C$ results for this material are compared with those obtained previously for a low chromium vanadium steel[2] (see Table 1 below), it can be seen that the ambient temperature relaxation behaviour of the two materials is fairly similar, but at $200^{\circ}C$ the 735A50 springs have superior properties to the low chromium vanadium springs. However, as the 735A50 springs are made from wire of a large diameter and lower tensile strength than the Octeva 60 springs, the difference in relaxation properties at $200^{\circ}C$ may be a result of a wire size and/or a tensile strength effect.

The results obtained for the silicon chromium springs indicate that this material has good relaxation resistance at ambient temperature and at the $200^{\circ}C$ test temperature provided that, in this latter case, it is not highly stressed.

At the higher stress levels and at higher temperatures, the relaxation resistance for these springs is poor.

TABLE 1 COMPARISON OF RELAXATION BEHAVIOUR OF 735A50 AND LOW CHROMIUM VANADIUM SPRINGS

Test Temperature °C	Stress Level N/mm²	% Relaxation			
		735A50		Oteva 60*	
		300 hours	2000 hours	300 hours	2000 hours
Ambient	400	1.1	1.6	0.8	1.2
	800	2.5	3.6	2.2	3.1
200	400	5.6	6.8	14.4	16.4
	800	12.3	14.2	18.6	21.2
Wire Diameter (mm)		3.17		2.51	
Rm after LTHT (N/mm²)		1660		1755	

* Values taken from previous SRAMA report [2]

4. CONCLUSIONS

1. The data obtained for all test conditions for both materials could be best described by the standard logarithmic time relaxation relationships. All the derived relationships were significant at the 99.9% level.

2. Both materials has very good ambient temperature relaxation resistance, although the 735A50 was slightly inferior to the 685A55.

3. From the results obtained in this work, the maximum recommended services conditions to limit the level of relaxation to approximately 10% for springs operating under static loading over extended periods of time at 200°C would be 600 N/mm^2 for 685A55 and 400 N/mm^2 for 735A50.

5. RECOMMENDATIONS

1. A large amount of data has now been accummulated on the long term relaxation behaviour of spring materials. This data should be drawn together in a summary report for ease of reference and to pinpoint any important omissions that have been made with regard to materials which have not been tested.

2. Further testing should be carried out on the materials covered to date to include operating conditions of lower temperature and stress, as most of the materials have been tested at the maximum operating temperatures recommended as a result of short term testing. In particular, the chromium-vanadium should be tested at temperatures of 100 and 150°C as these are the temperatures normally encountered by this material during operation as engine value springs.

3. In order to assist in the prediction of relaxation behaviour for springs of differing wire size to those tested to date, work should be carried out to assess the effects, if any, of wire diameter and tensile strength on the relaxation behaviour of springs.

4. The ambient temperature testing which is still continuing must be reported in a further report.

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. O'Malley, M. "The long term relaxation behaviour of spring materials. 2nd progress report." SRAMA Report No 349.

3. O'Malley, M. "The long term relaxation behaviour of spring materials. 3rd progress report." SRAMA Report No 360.

TABLE I CHEMICAL COMPOSITIONS

Material	Composition (%)						
	C	Si	Mn	Cr	V	S	P
685A55 Specified	0.5-0.6	1.2-1.6	0.5-0.8	0.5-0.8	-	0.025 max	0.03 max
685A55 Actual	0.51	1.60	0.77	0.60	-	0.020	0.018
735A50 Specified	0.46-0.54	0.1-0.35	0.6-0.9	0.8-1.1	0.15 min	0.035 max	0.035 max
735A50 Actual	0.53	0.26	0.80	1.03	0.16	0.015	0.014

TABLE II TENSILE PROPERTIES

Material	Rm N/mm^2	L of P N/mm^2	$Rp_{0.05}$ N/mm^2	$Rp_{0.1}$ N/mm^2	$Rp_{0.2}$ N/mm^2
685A55 Specified	1720-1870	-	-	-	-
685A55 As rec'd	1790	1085	1655	1685	1700
685A55 After LTHT 400°C for ½ hr	1800	1395	1715	1725	1725
735A50 Specified	1655-1805	-	-	-	-
735A50 As rec'd	1660	1480	1565	1580	1585
735A50 After LTHT 400°C for ½ hr	1660	1435	1560	1575	1585

TABLE III TORSIONAL PROPERTIES

Material	Modulus G N/mm^2	L of P N/mm^2	0.1 Proof stress N/mm^2	0.2% Proof stress N/mm^2
685A55 As rec'd	7.78×10^4	795	1030	1100
685A55 After LTHT of 400°C for ½ hr	7.79×10^4	945	1095	1145
735A50 As rec'd	7.85×10^4	740	1015	1085
735A50 After LTHT of 400°C for ½ hr	7.92×10^4	805	1030	1075

TABLE IV SPRING DESIGNS

	685A55	735A50
Wire Diameter (mm)	3.3	3.17
Mean Coil Diameter (mm)	23.1	22.19
Total Coils	5.5	5.5
Active Coils	3.5	3.5
Free Length+ (mm)	41.6	38.4
Solid Stress (N/mm^2)	1255	1170
End Type	Closed and Ground	
LTHT	400°C for 30 mins	

\+ After LTHT, end grinding and prestressing

TABLE V ANALYTICAL CONSTANTS FOR TIME RELAXATION RELATIONSHIPS

Material	Test Temperature (^{o}C)	Stress Level (N/mm^2)	R = clnt + d		95% confidence increment (%)
			c	d	
735A50	Ambient	400 600 800	0.261 0.262 0.558	-0.376 -0.041 -0.655	0.5 0.8 1.1
	200	400 600 800	0.635 0.748 1.000	2.039 3.500 6.555	0.9 0.9 1.0
	250	400 600 800	1.607 2.066 2.406	1.880 3.989 8.121	2.1 2.9 2.8
685A55	Ambient	400 600 800	0.229 0.225 0.288	-0.635 -0.075 -0.202	0.5 0.8 0.7
	200	400 600 800	0.399 0.511 0.631	1.984 2.796 5.694	0.5 0.7 0.8
	250	400 600 800	1.068 1.313 1.478	1.752 2.747 6.246	1.3 1.7 1.7

TABLE VI PROJECTED 10,000 AND 20,000 HOUR MEAN RELAXATION LEVELS

Material	Temperature (^{o}C)	Stress Level (N/mm^2)	Projected Relaxation (%)	
			10,000 hours	20,000 hours
735A50	Ambient	400 600 800	2.0 2.4 4.5	2.2 2.6 4.9
	200	400 600 800	7.9 10.4 15.8	8.3 10.9 16.5
	250	400 600 800	16.7 23.0 30.3	17.8 24.5 32.0
685A55	Ambient	400 600 800	1.5 2.0 2.5	1.6 2.2 2.7
	200	400 600 800	5.7 7.5 11.5	5.9 7.9 11.9
	250	400 600 800	11.6 14.8 19.9	12.3 15.8 20.9

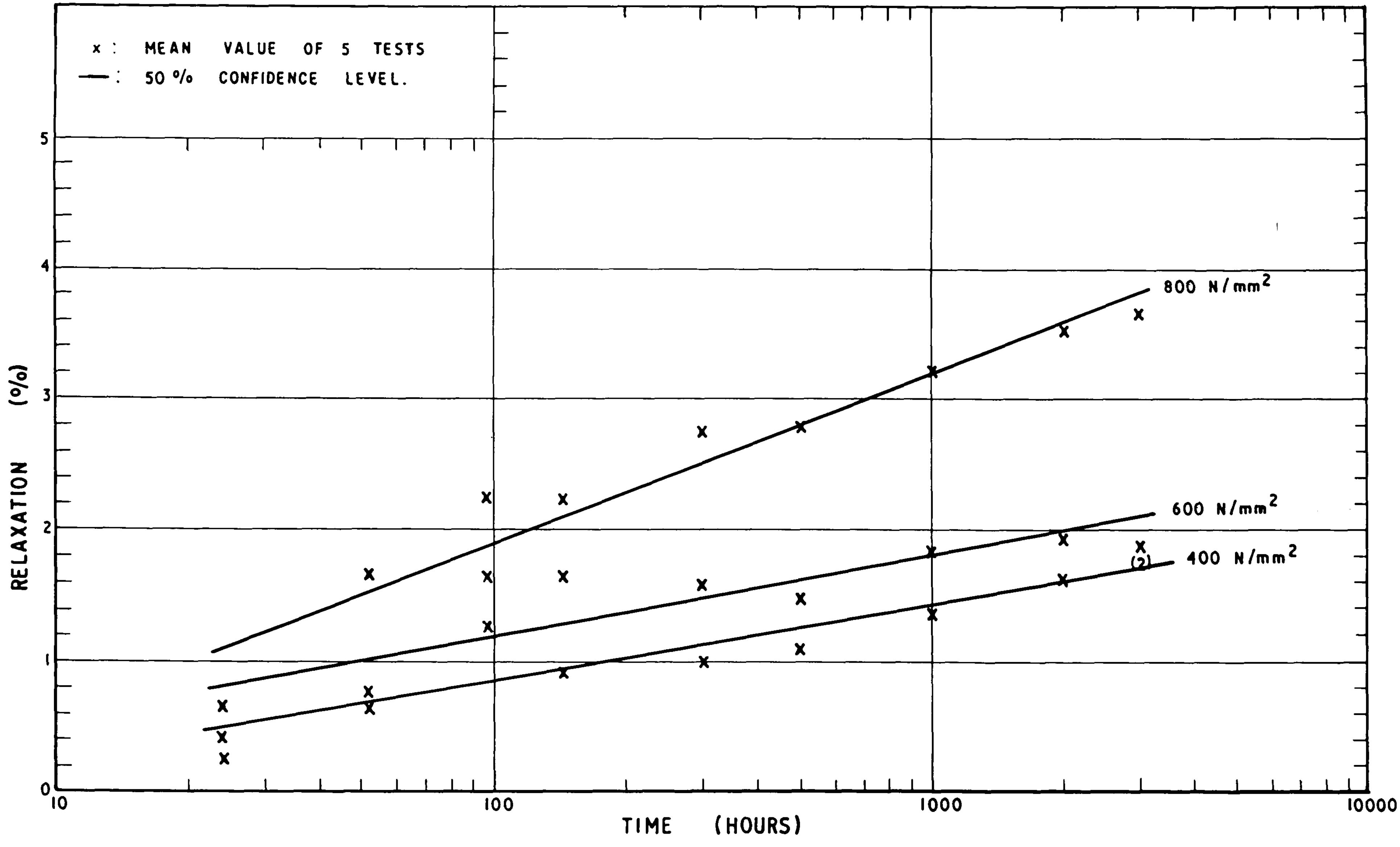

FIG. I. TIME RELAXATION OF 735A50 SPRINGS AT AMBIENT TEMPERATURE.

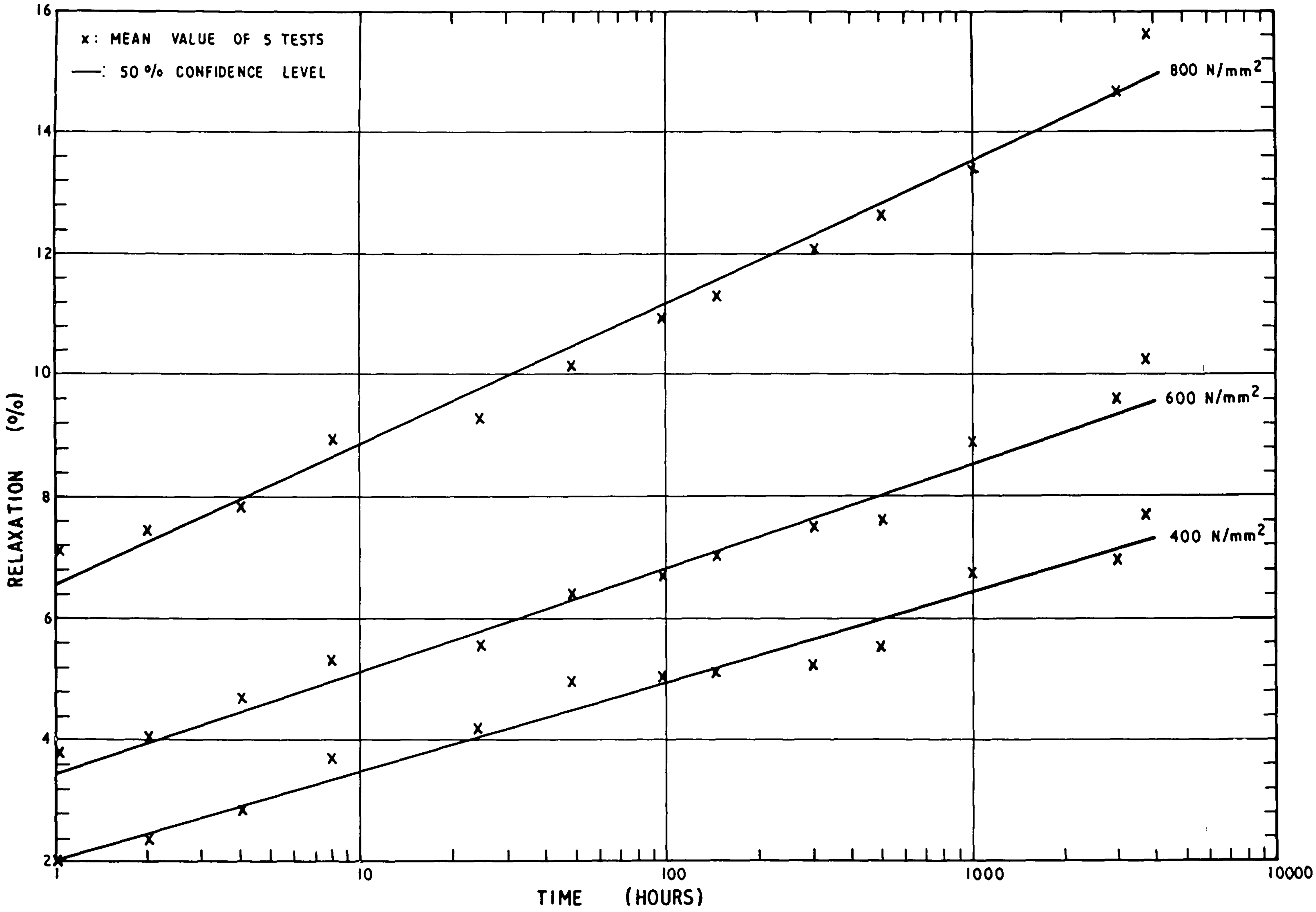

FIG. 2. TIME RELAXATION OF 735A50 SPRINGS AT 200°C.

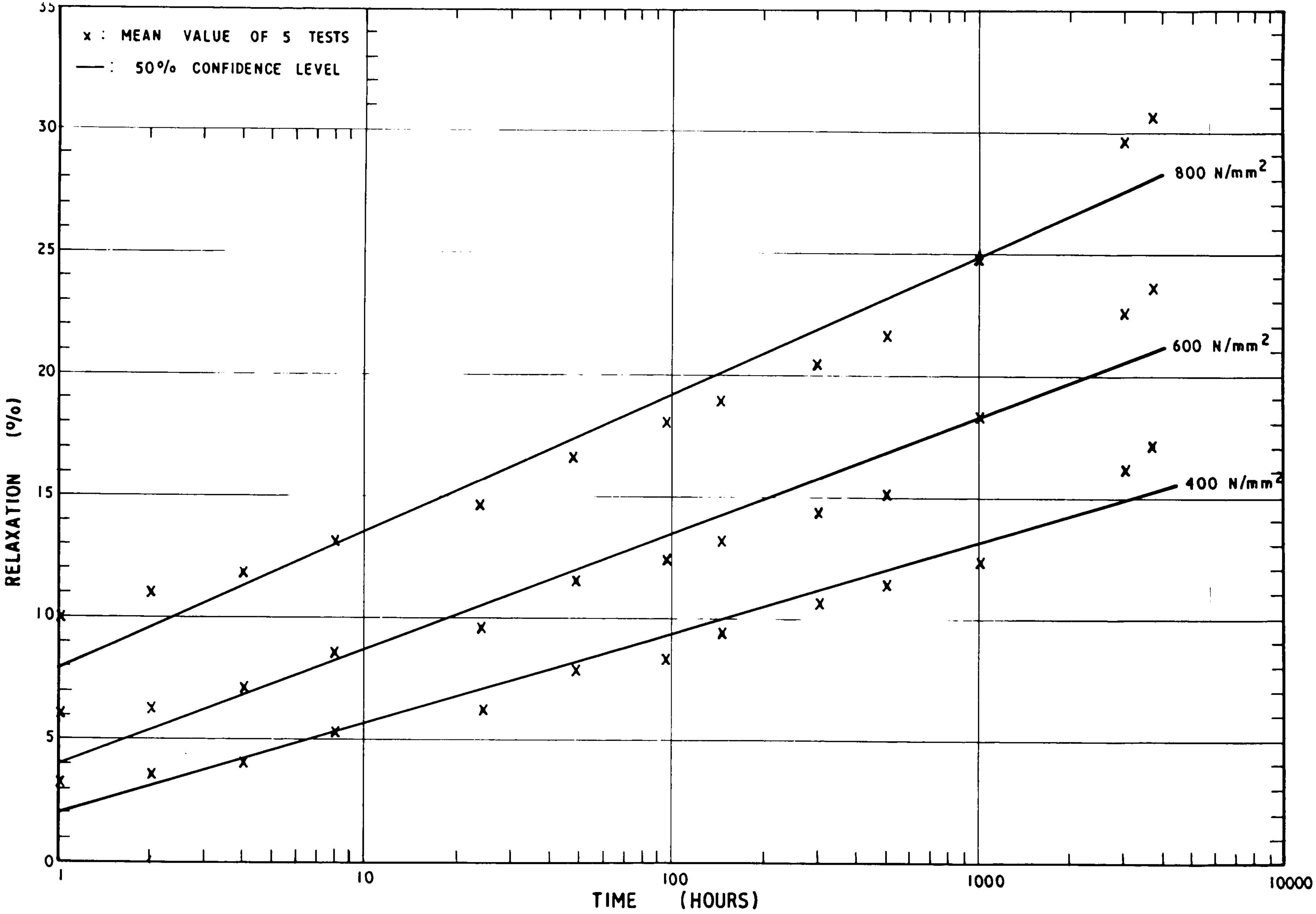

FIG. 3. TIME RELAXATION OF 735A50 SPRINGS AT 250°C.

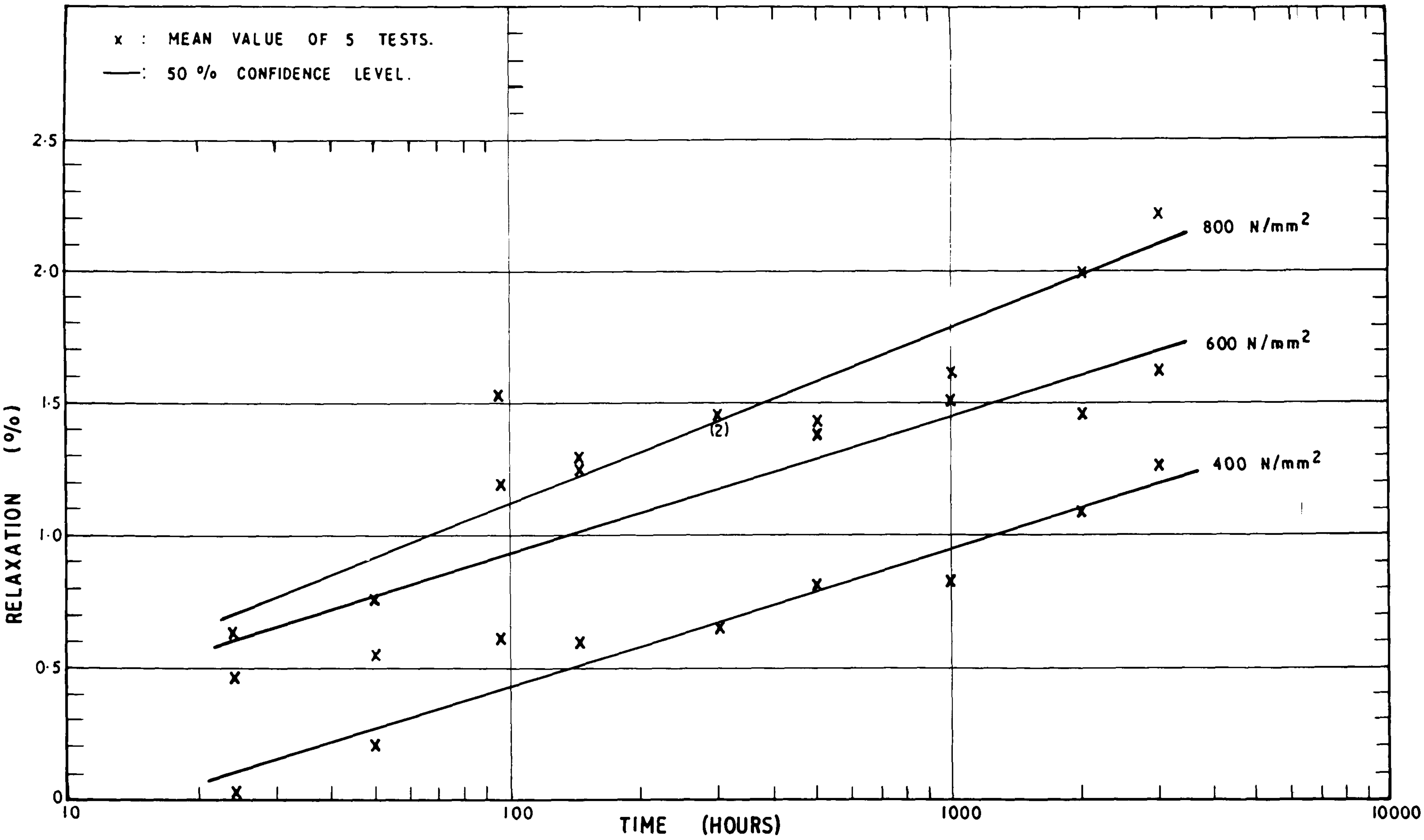

FIG. 4. TIME RELAXATION OF 685A55 SPRINGS AT AMBIENT TEMPERATURE.

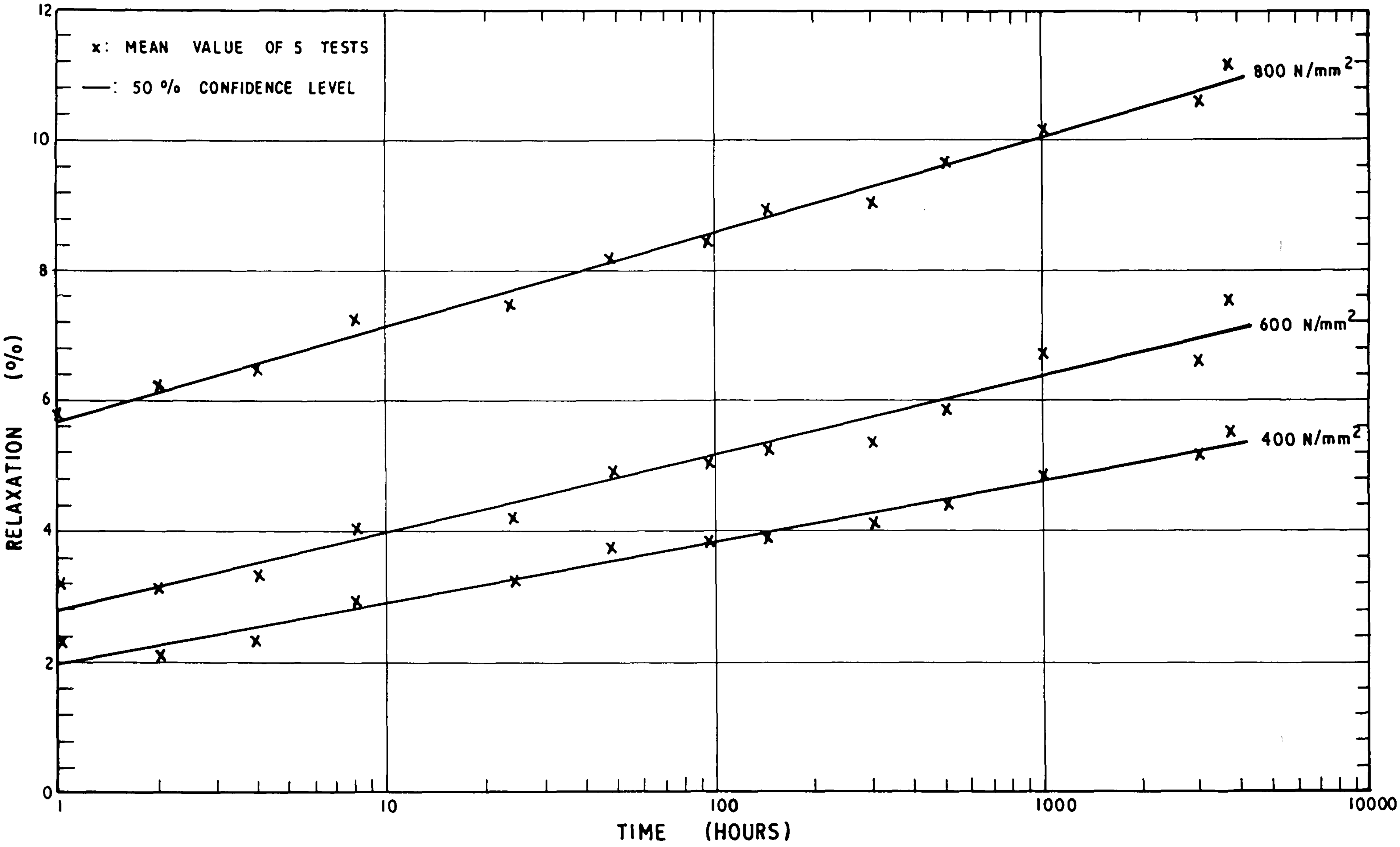

FIG. 5. TIME RELAXATION OF 685A55 SPRINGS AT 200°C.

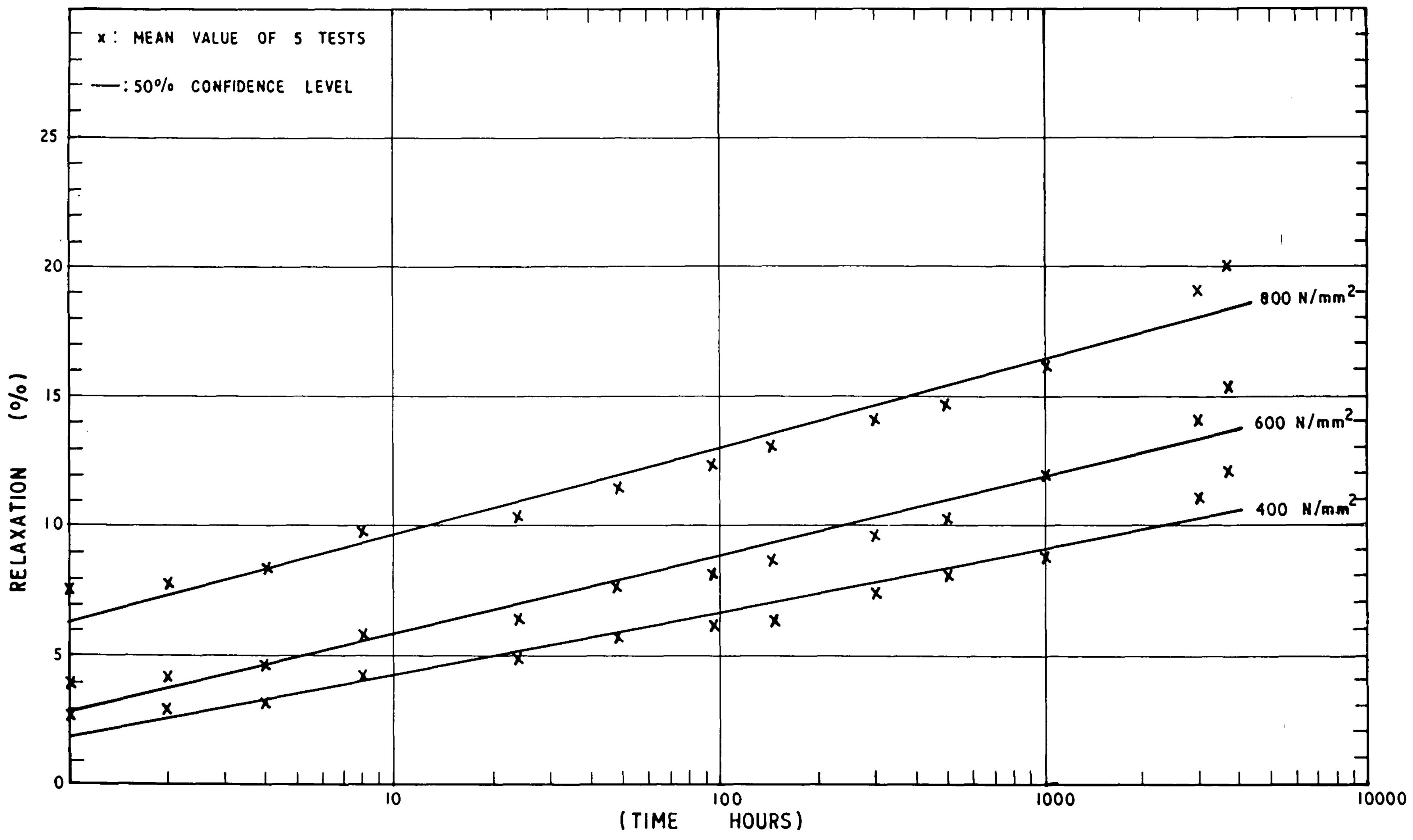

FIG. 6. TIME RELAXATION OF 685A55 SPRINGS AT 250°C.