THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

THE RELAXATION BEHAVIOUR OF HELICAL EXTENSION SPRINGS

by

M.R. Southward, B.Sc.

Report No. 276

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SUMMARY

The Association recently investigated the fatigue behaviour of extension springs formed with two different types of end loop. In this investigation, the same springs were employed in order to study the relaxation behaviour. Tests were performed at two temperatures with both springs subjected to a low temperature heat treatment and with springs without treatment. The relaxation and initial tension in these springs were measured after certain intervals to record any alteration. The results indicate no difference in relaxation between springs with different end loops and that, even after 1000 hours, the highly stressed springs were still relaxing whilst for the less highly stressed springs, relaxation had ceased. The effect of the low temperature heat treatment was to reduce the initial tension and also the level of relaxation in the spring. This resulted in little loss of initial tension in heat treated springs tested at 100°C but a great loss in non-heat treated springs at the same temperature. Comparison of the extension and compression results indicated greater relaxation in the compression spring compared with the extension spring

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1. INTRODUCTION

Small extension springs find widespread use, particularly in the field of electronic and electrical components. The fatigue behaviour of such springs has been described in a previous SRAMA Report, No. 272. The object of this programme of work is to examine their relaxation behaviour at room and elevated temperatures.

In order to maintain the level of initial tension produced by coiling, such springs are often not stress relieved after coiling and looping. In this investigation, therefore, tests were carried out using springs both with and without a low temperature heat treatment.

Most information published on the relaxation data for carbon steel springs relates to compression springs and gives the relaxation obtained after 72 hours. The present work will determine if any additional relaxation occurs when the springs are stressed for much longer periods, as well as examining differences in performance between compression and extension springs.

2. SPRING DESIGN AND MANUFACTURE

The springs used for this project were similar to those used in the previous investigation into stresses in the end loops of extension springs, being manufactured from 0.66 mm diameter wire to BS 1408C Range 3[1]. In the previous work, all the springs had been given a low temperature heat treatment of 250°C for half an hour after coiling and looping. In the present work, however, half of the springs were tested without any heat treatment. For purposes of comparison, compression springs made from the same material were coiled to a spring index of 8, so that their solid stress was the same as the maximum working stress of the heat treated tension springs. Details of all the spring designs are given in the table below.

TABLE I SPRING DESIGNS

	Tension Springs			Compression Springs
Wire diameter (mm)	0.66	0.66	0.66	0.66
Mean coil diameter (mm)	2.64	5.28	7.92	5.28
Spring index	4	8	12	8
Total coils	20	11	5	9.5
Active coils				7.5
Free length (mm)				22.0
English loops	19.4	17.4	18.8	
German loops	16.5	15.2	18.8	

3. PROCEDURE

The maximum corrected working stresses for the extension springs were measured by load testing the springs beyond their elastic limit and, from the load deflection curves, determining the load and hence the stress at which the curves deviated from a straight line. The values obtained are shown in Table II which is given below:

TABLE II INITIAL TENSION AND MAXIMUM WORKING STRESSES OF EXTENSION SPRINGS

Spring Index	As Coiled			After L.T.H.T.		
	Uncorrected Initial Tension Stress (N/mm^2)	Corrected Maximum Working Stress (N/mm^2)	Corrected Maximum Working Stress % of Rm	Uncorrected Initial Tension Stress (N/mm^2)	Corrected Max. Working Stress (N/mm^2)	Corrected Max. Working Stress % of Rm
4	45	1180	47.8	30	1495	60.5
8	125	790	32.0	70	1290	52.1
12	65	670	27.3	35	1220	49.3

Relaxation tests were carried out for each design of spring at room temperature and at a temperature of 100°C. The tests were continued for a period of 1000 hours and measurements were made at intervals during this test period. Springs which had been given a low temperature heat treatment were subjected to four test stresses corresponding to 80, 60 40 and 20% of the maximum working stress. The non-heat treated springs were tested at the two lower stress levels only. Triplicate tests were performed for each test condition.

The procedure adopted for each spring was as follows:- The length of the spring was determined at the load corresponding to the required test stress. The spring was placed on a jig that enabled the spring to be held at this test stress, but to be easily removed for subsequent measurement. The jig containing the spring was kept either at room temperature or maintained at a temperature of 100°C in an oven. After the first test period (and after cooling to room temperature in the case of the elevated temperature tests) the loss in load of the spring was determined by measuring the loads at three lengths shorter than the test length and using these data to calculate the load at the test length. The spring was replaced on its test jig and measurements repeated after intervals of 6, 12, 28, 52, 116, 284 and 1000 hours for the elevated temperature tests and after intervals of 16, 40, 104, 272, 1000 and 5000 hours for the room temperature tests.

4. RESULTS

The percentage relaxation was calculated for each spring after every time interval. Comparison of the results for any one temperature showed that for each spring design there was no significant difference between the results from English loop and German loop springs. Consequently, all results are presented as an average of the results from both types of spring.

Figures 1 - 3 show the effect of applied stress and time on the relaxation of each design of extension spring, low temperature heat treated and tested at 100°C: Figs. 4 - 6 show these results for the non-heat treated springs. All the room temperature tests for both the heat treated and non-heat treated springs are contained in Figures 7 - 9. The results for the compression springs are shown in Fig. 10 for the tests at 100^{o}C and Fig. 11 for the room temperature tests.

The effect upon initial tension of maintaining an extension spring at a stress is depicted in Fig. 12 for the 100^{o}C tests and Fig. 13 for the room temperature tests. The trend indicated by these two figures occurred for each spring design; the results shown, however, are for one design only.

Finally, Fig. 18 enables a comparison to be made of the relaxation behaviour of the different spring designs and indicates how the applied stress and the spring index affect the relaxation behaviour of the extension springs.

5. DISCUSSION

From the data in Table II it is apparent that, where a spring has not been stress relieved after coiling, the maximum operating stress is generally about 55 - 60% of that attainable after heat treatment, which more than compensates for the drop in initial tension.

Figs.1 - 3, which relate to the low temperature heat treated springs tested at 100^{o}C, each show the results for a different spring design. All these figures show the same trend, in that at the highest stress level, relaxation is 'log-linear' and continues to increase up to 1000 hours, whereas at the lower stress levels relaxation has almost ceased by this time. Although the difference in test stress levels are equal, there is generally a great increase in relaxation when stress is increased from 60% to 80% of the maximum working stress.

Differences in the relaxation at the lower stress levels were difficult to measure accurately because of the very small changes in load that occurred, which were approximately equal to the sensitivity of the load testing machine. In such cases, therefore, a single curve has been drawn for two or more of these stress levels.

Figs. 4 - 6 show the relaxation of non-low temperature heat treated springs tested at 100°C; also included in these figures is a line indicating the percentage relaxation for the same test stress level of the low temperature heat treated springs. The reason for such a large difference in these results is that the low temperature heat treatment has already reduced the internal stress in the wire and therefore lessened the relaxation that occurs when additional thermal energy is applied.

There is little difference in the relaxation occurring at the two stress levels, indicating that, as found in previous work on compression springs[2], only a very low stress at elevated temperature is needed to cause a large loss in load.

The room temperature test results are shown graphically in Figs. 7 - 9, each figure relating to one spring design and including the results for both the low temperature heat treated springs and the non-heat treated springs. These relaxation values are lower than those encountered at 100°C, although they still follow the same trend, except for the non-heat treated springs - in this case there is a significant difference in the results for the two stress levels.

Figs. 12 and 13, for simplicity, depict the loss in initial tension for only one specific spring design, although the same trend was encountered with the other designs. Fig.12 shows how the initial tension in springs tested at 100°C altered with time. It can be seen that the loss in initial tension for the heat treated springs was small, whilst the loss for the non-heat treated springs was very considerable over the first few hours. In fact, the loss was much greater than that which occurred during the low temperature heat treatment. It would appear, therefore, that when tension springs are to be used at temperatures above ambient then the loss in initial tension and spring load can be minimised by stress relieving after coiling. Fig. 12 shows the room temperature results; here the loss in initial tension after stress relieving is greater than the amount lost during the relaxation tests. However, the stress relieving treatment has the effect of stabilizing the spring material so that only a negligible amount of further loss in load occurs during testing, while the non-stress relieved springs exhibited a loss in initial tension which was gradual but continued even after 5000 hours under load.

In order to obtain a comparison between the relaxation behaviour of compression and extension springs, compression springs were coiled to a design similar to that of one of the extension springs. The relaxation results for this spring are shown in Fig. 10 for the 100°C tests and Fig. 11 for the room temperature tests. These results show a similar trend to those of the extension spring in that, at the highest stress level, relaxation has not been completed after 1000 hours, and generally, the relaxation values are higher than those of extension springs.

To enable a comparison to be made of relaxation results obtained with the different spring designs, Fig. 14 was constructed. This graph of stress against percentage relaxation shows both the room temperature and 100°C results and indicates how relaxation increases slightly with changes in stress at low stresses but is greatly influenced with changes in high stresses. Moreover, comparison of the data for the three spring indices shows that, at both room temperature and at 100°C, the relaxation for a given stress level was least for the index 4 springs and greatest for the index 12 springs.

6. CONCLUSIONS

1. With the most highly stressed springs the relaxation was still increasing after 1000 hours, although it levelled off for the two lowest stressed springs after this time.
2. Subjecting springs to a low temperature heat treatment reduces the relaxation in the springs and, at the higher temperature, the difference was greater.
3. Heat treatment reduces the amount of initial tension in a spring but decreases the loss in tension during relaxation.

7. REFERENCES

1. Southward, M.R., An investigation into the stress encountered in two types of end loop formation in extension springs. SRAMA Report No. 272

2. Bayliss, M.S., A further study of the effects of warm coiling using electrical resistance heating. SRAMA Report No. 275.

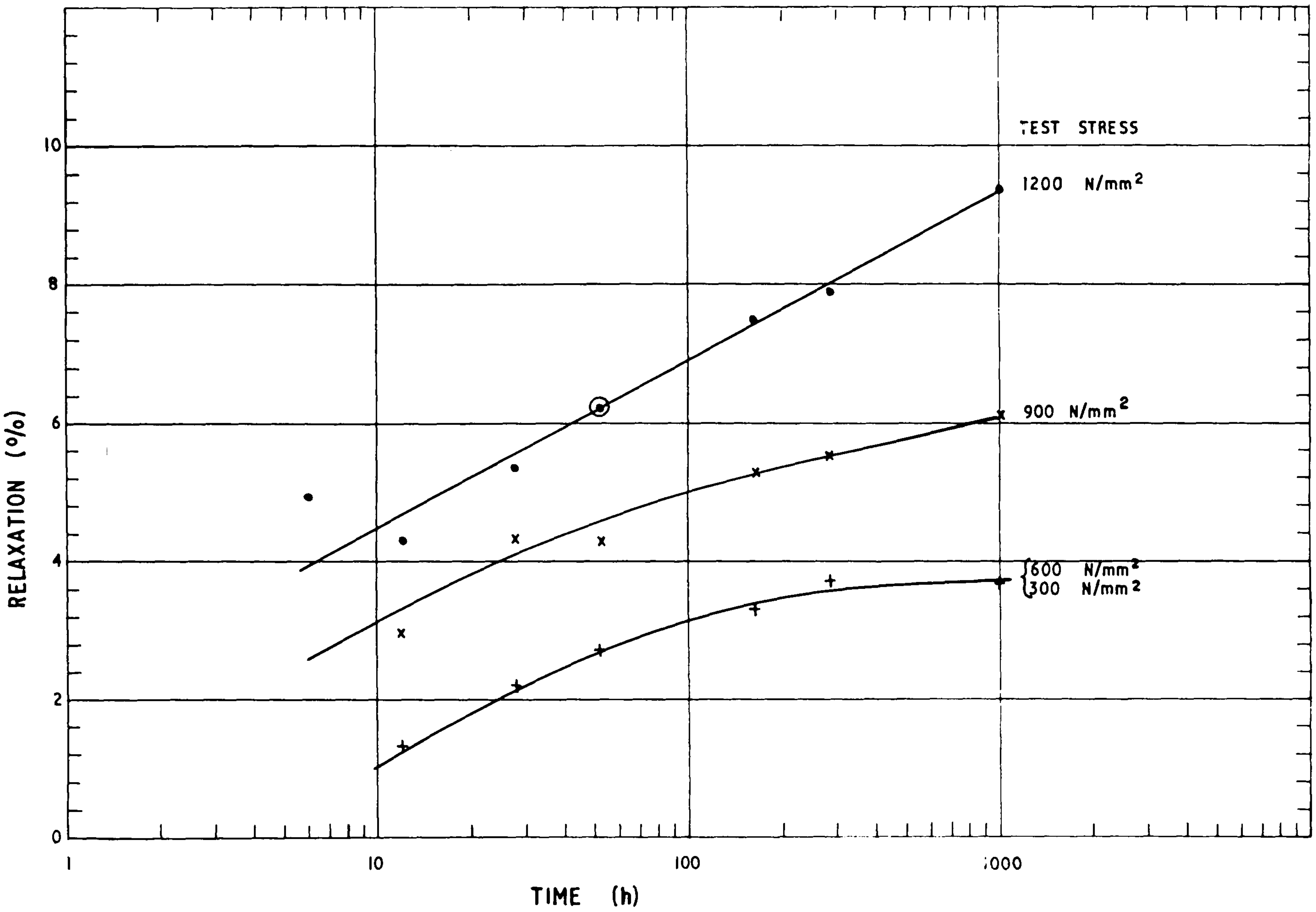

FIG. 1 RELAXATION OF INDEX 4 TENSION SPRINGS, STRESS RELIEVED, AT 100° C.

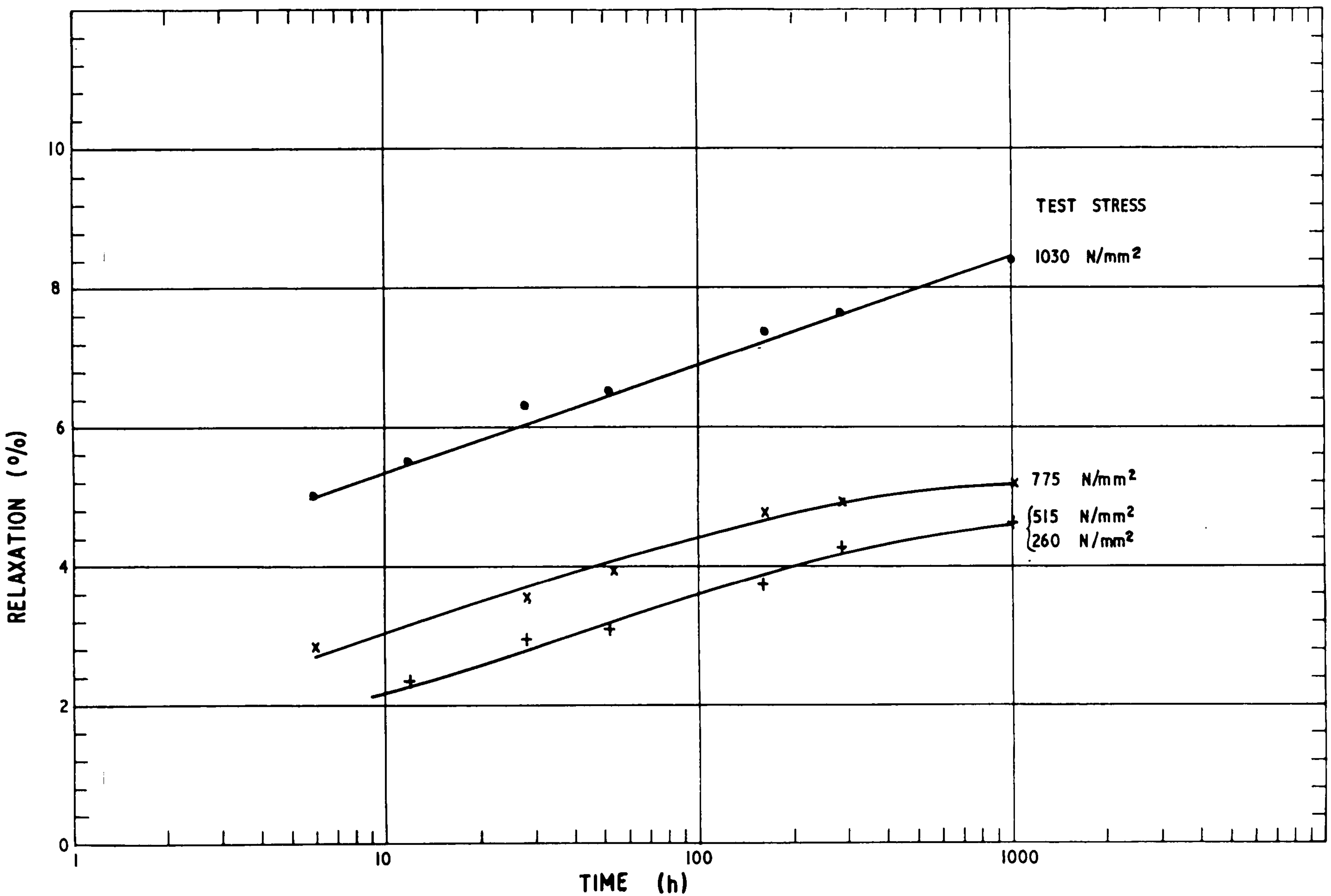

FIG. 2 RELAXATION OF INDEX 8 TENSION SPRINGS, STRESS RELIEVED, AT 100°C.

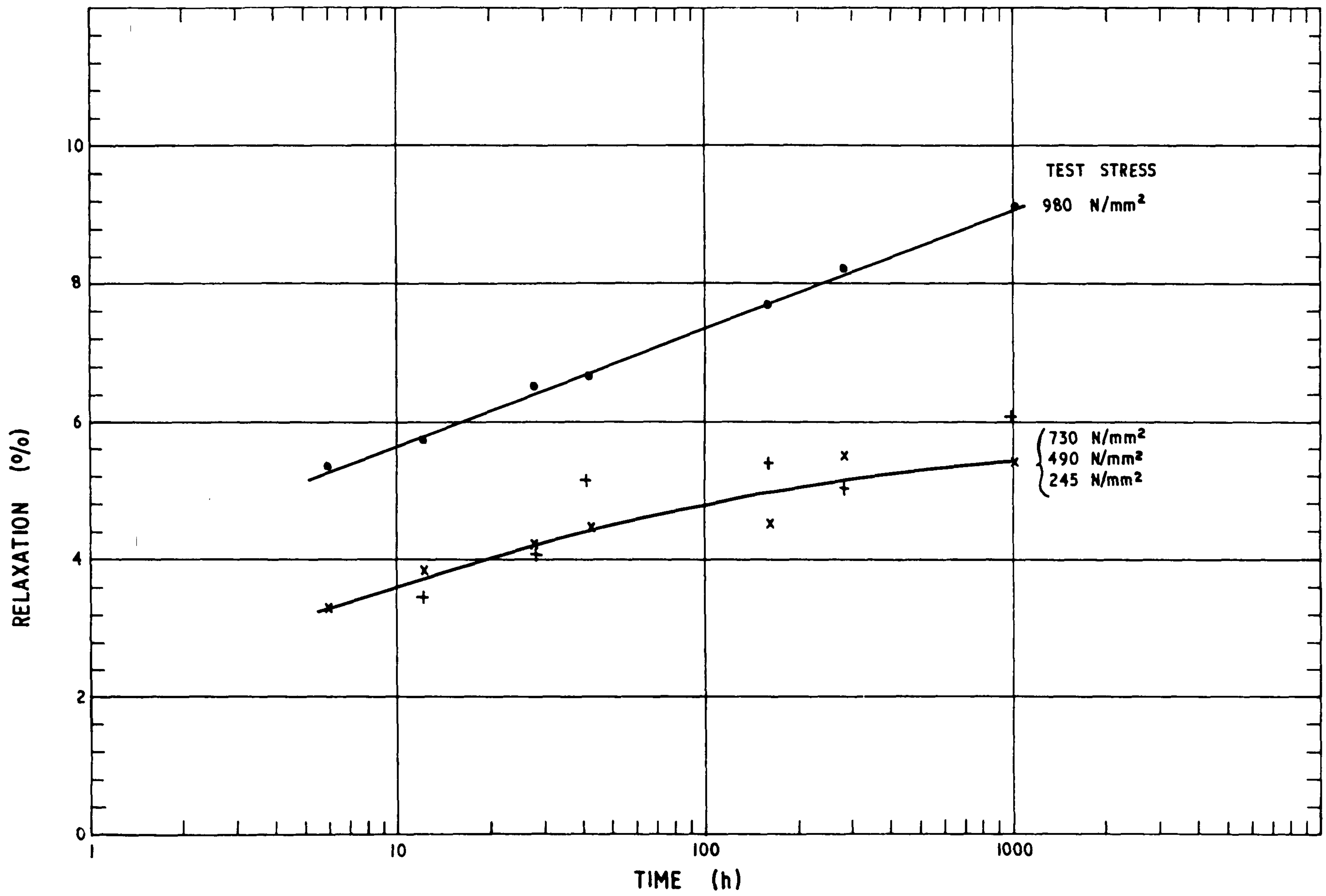

FIG. 3 RELAXATION OF INDEX 12 TENSION SPRINGS, STRESS RELIEVED AT 100°C.

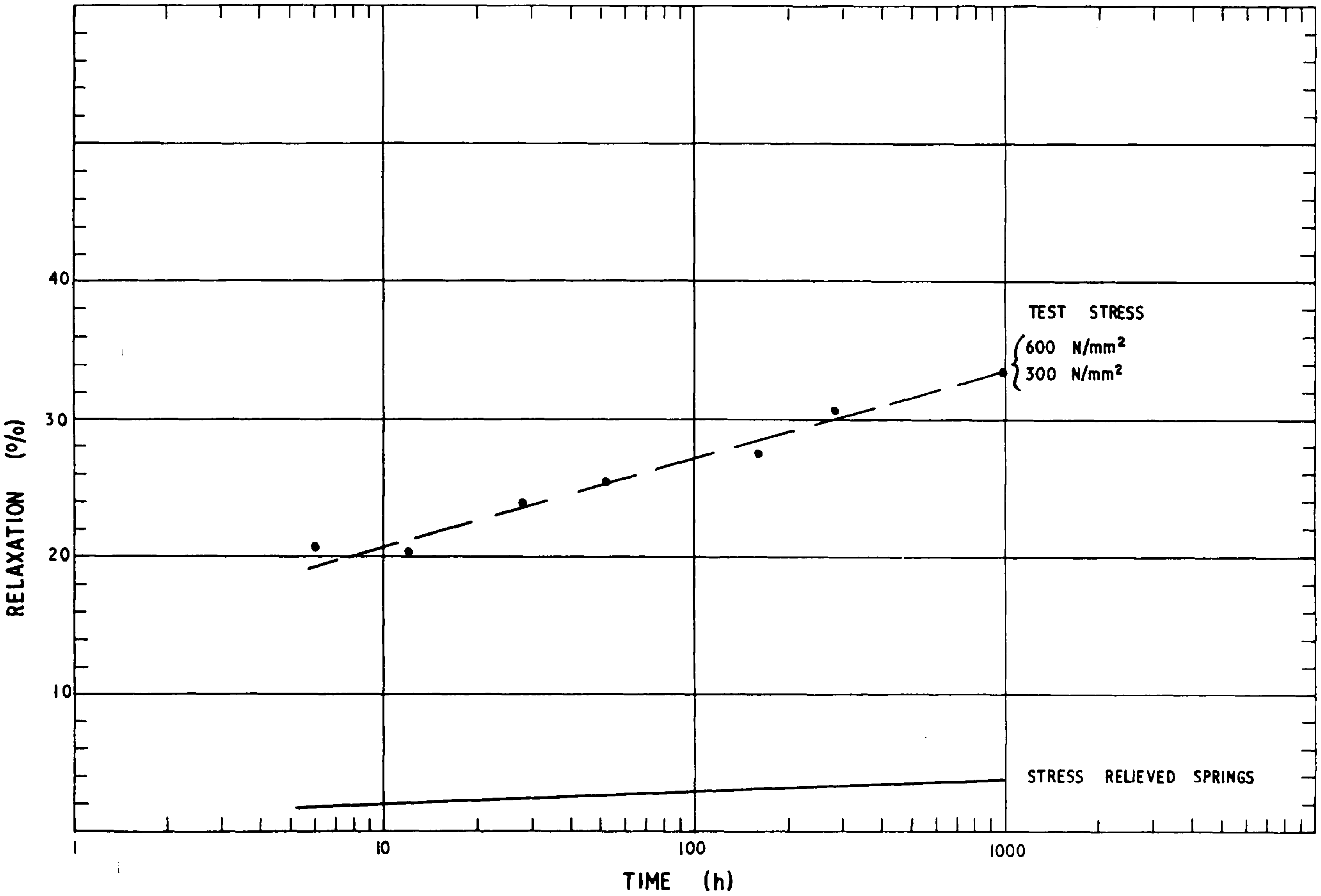

FIG. 4 RELAXATION OF INDEX 4 TENSION SPRINGS, (No L.T.H.T.) AT 100°C

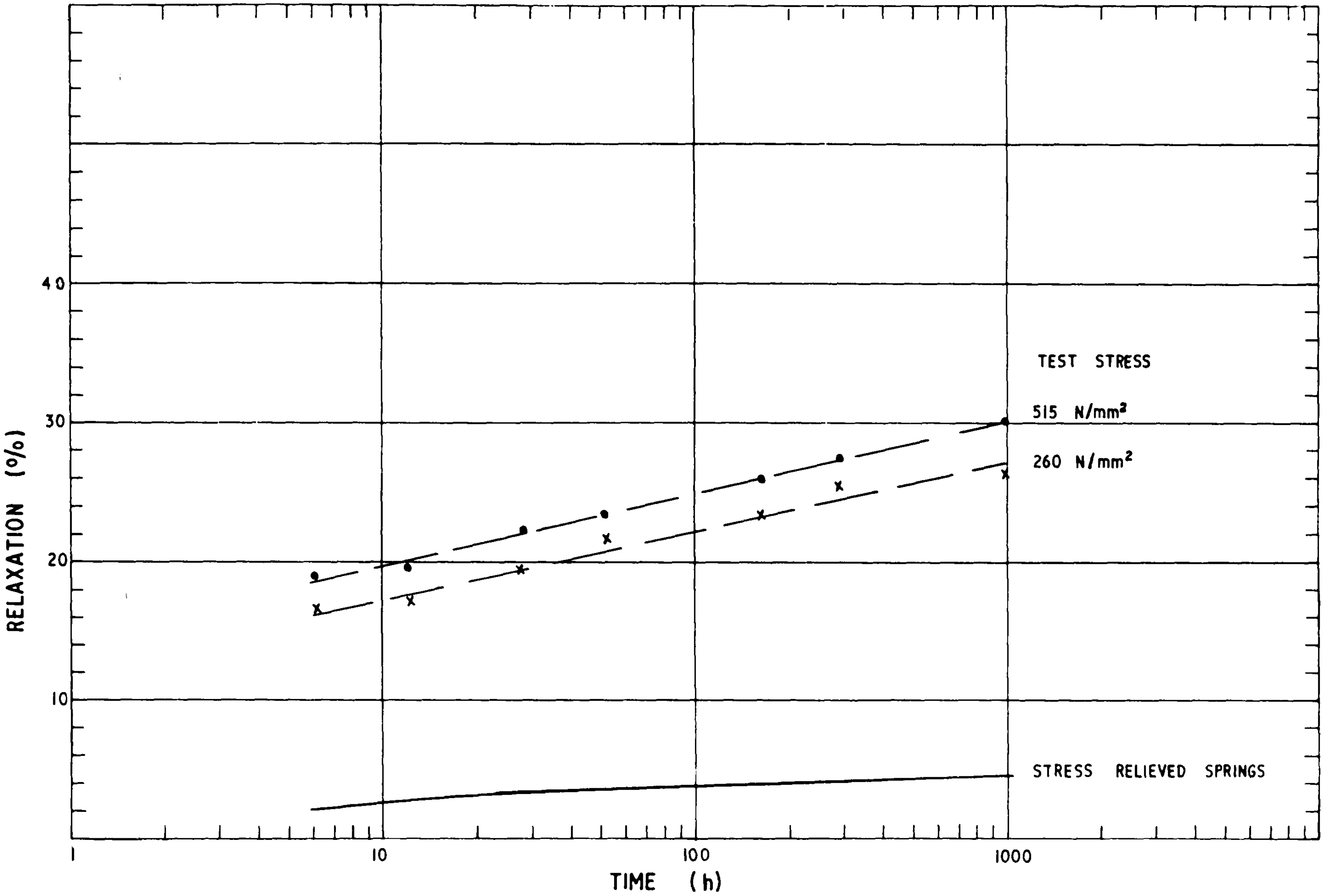

FIG. 5 RELAXATION OF INDEX 8 TENSION SPRINGS (No. LTHT.) AT 100°C.

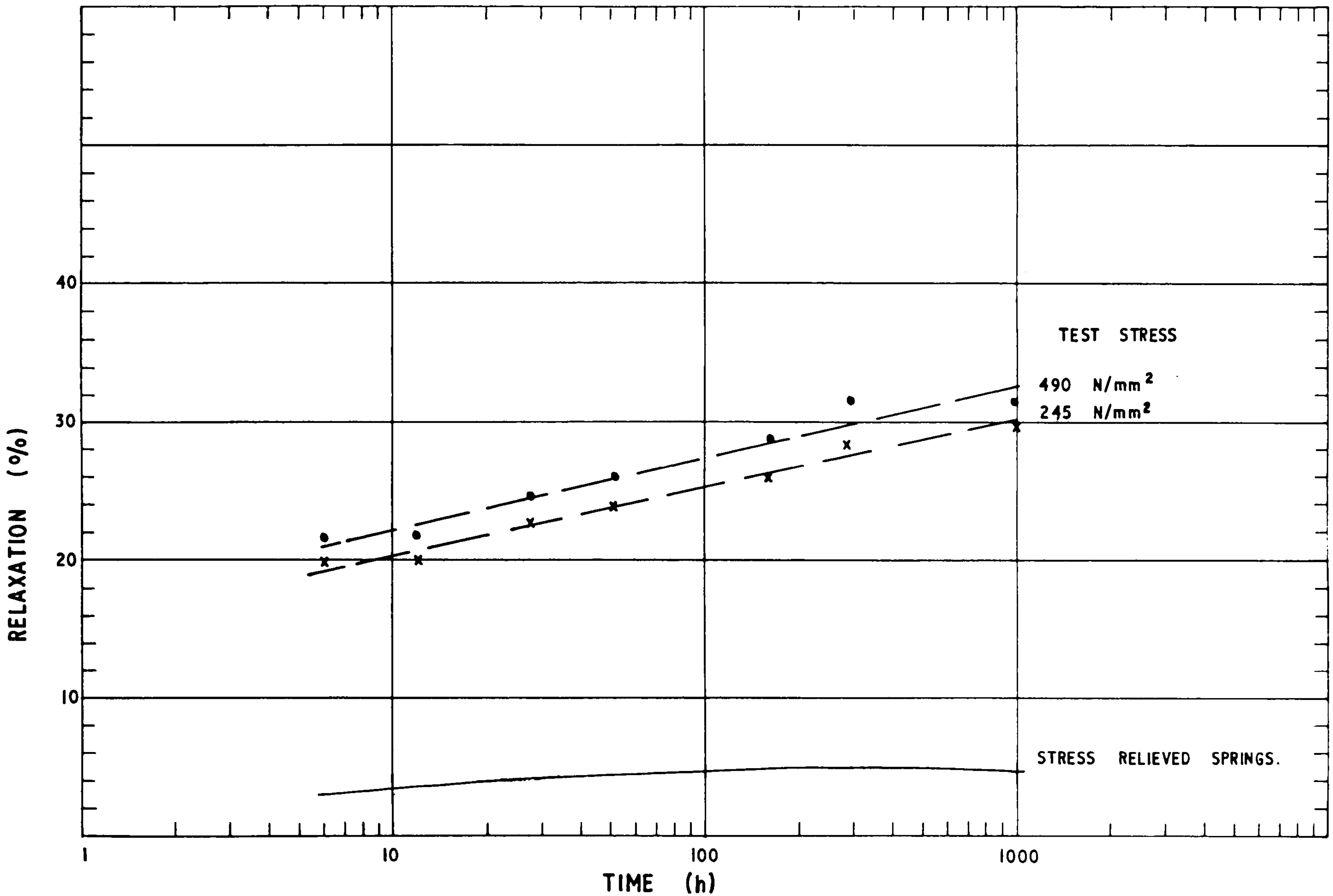

FIG. 6 RELAXATION OF INDEX 12 TENSION SPRINGS (No L.T.H.T.) AT 100° C.

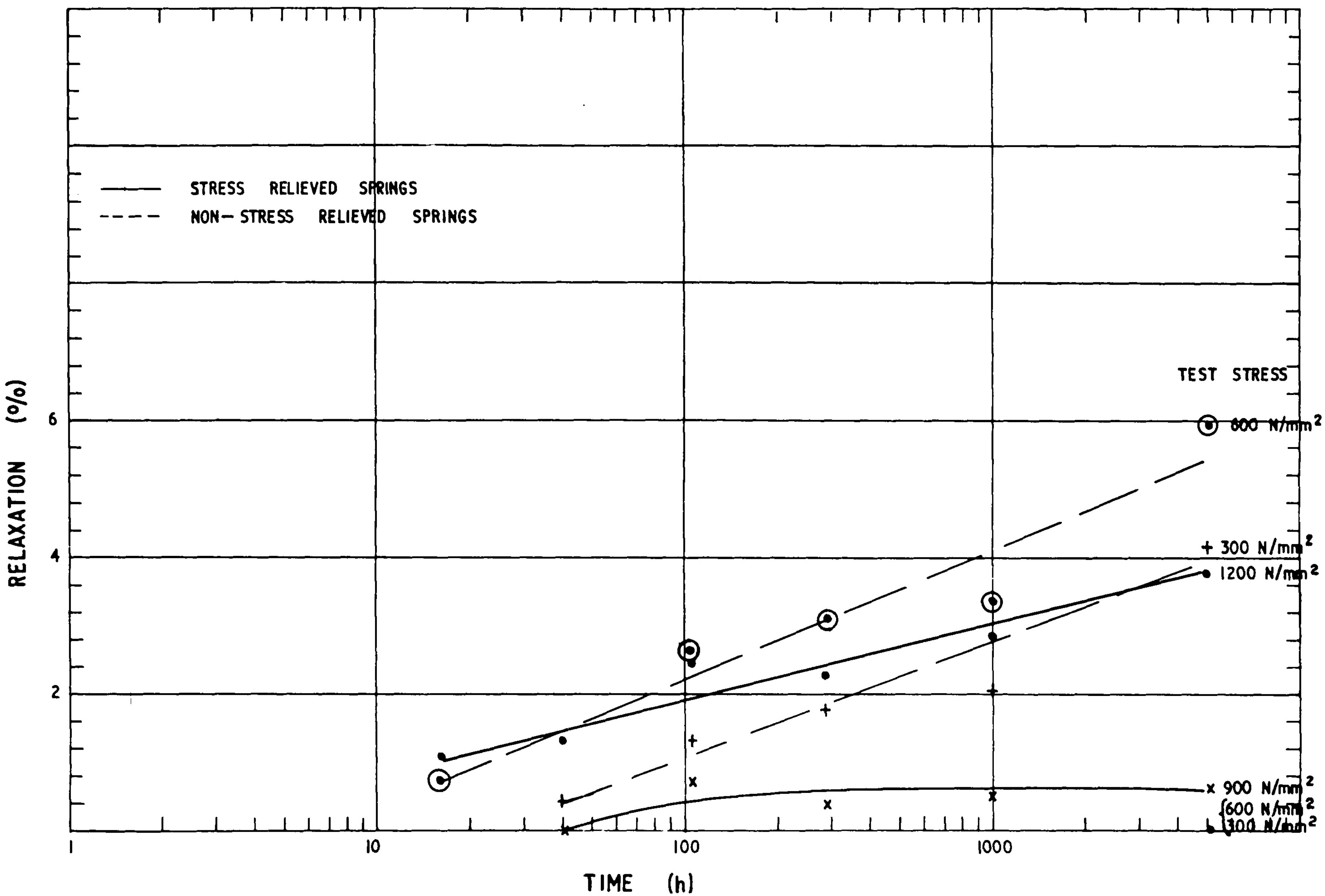

FIG. 7 RELAXATION OF INDEX 4 TENSION SPRINGS AT ROOM TEMPERATURE.

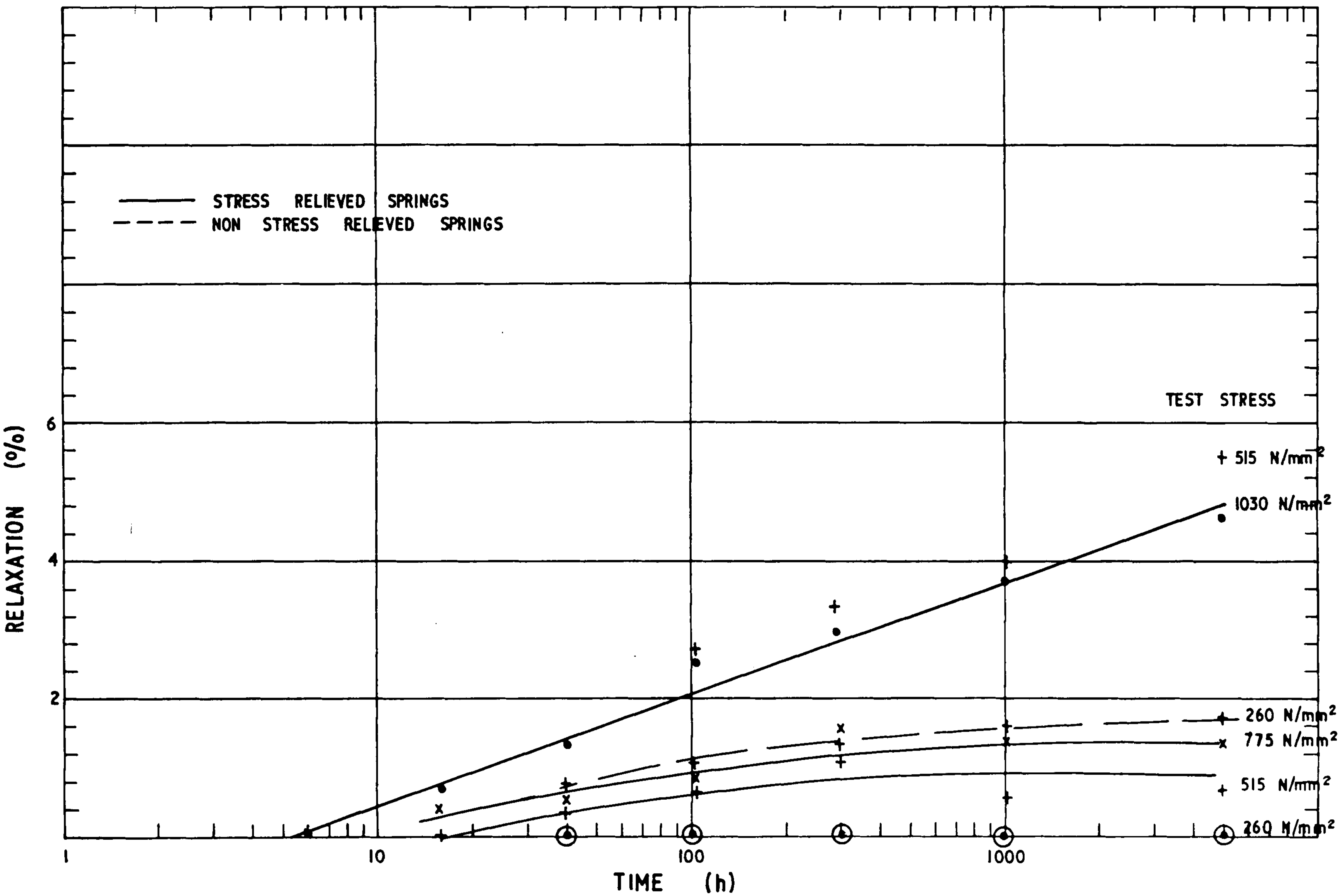

FIG. 8 RELAXATION OF INDEX 8 TENSION SPRINGS AT ROOM TEMPERATURE.

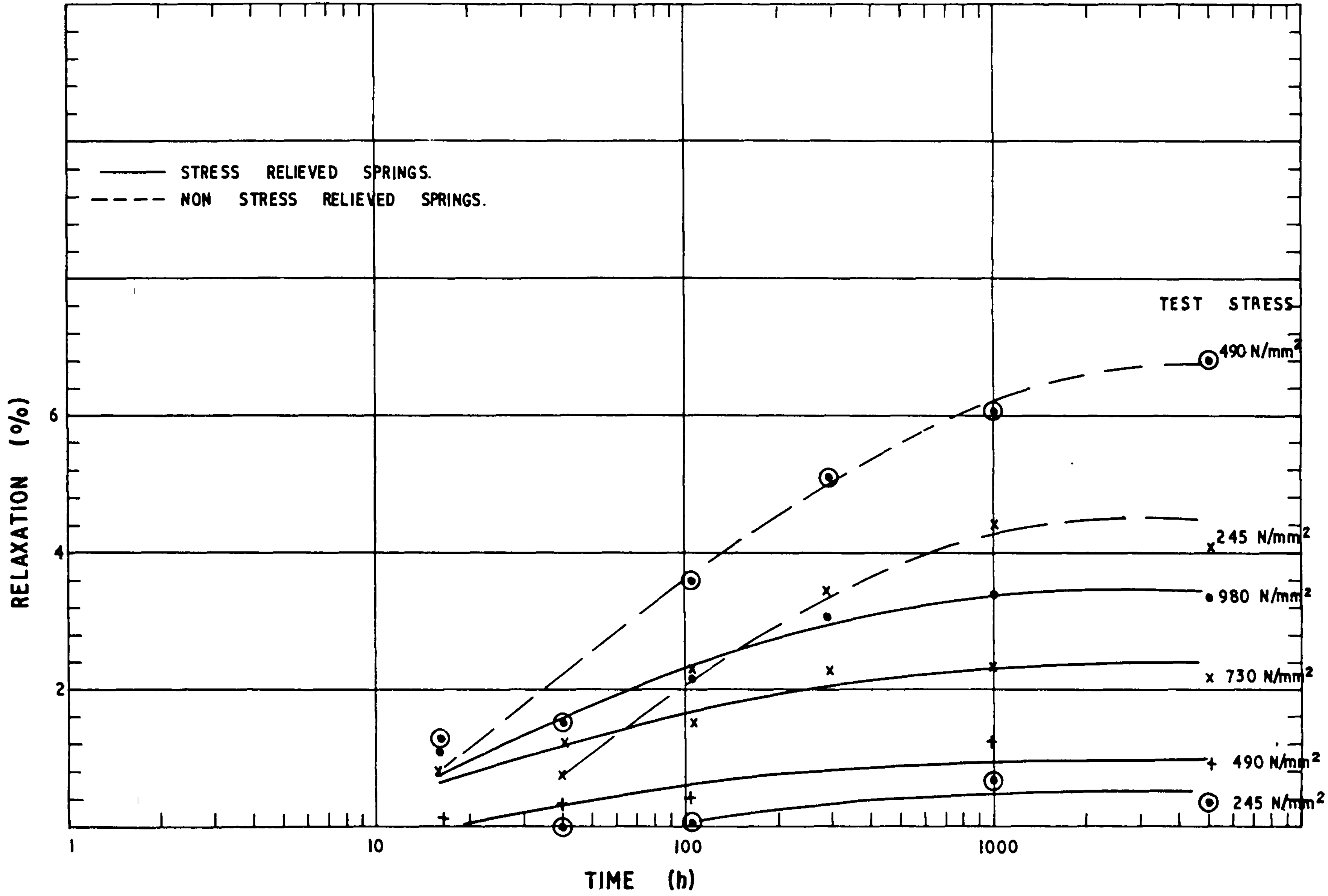

FIG. 9 RELAXATION OF INDEX 12 TENSION SPRINGS AT ROOM TEMPERATURE.

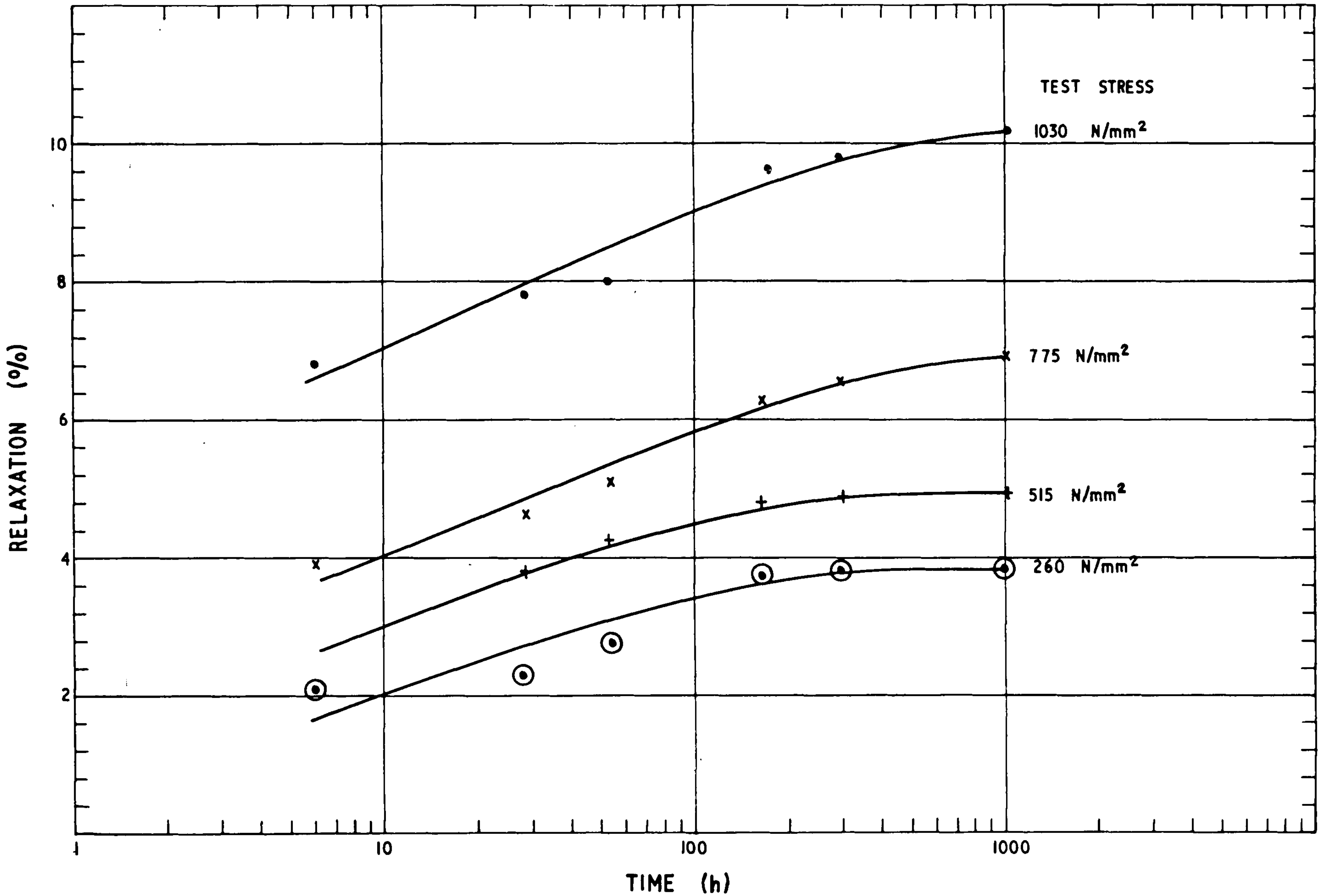

FIG. 10 RELAXATION OF COMPRESSION SPRINGS AT 100°C.

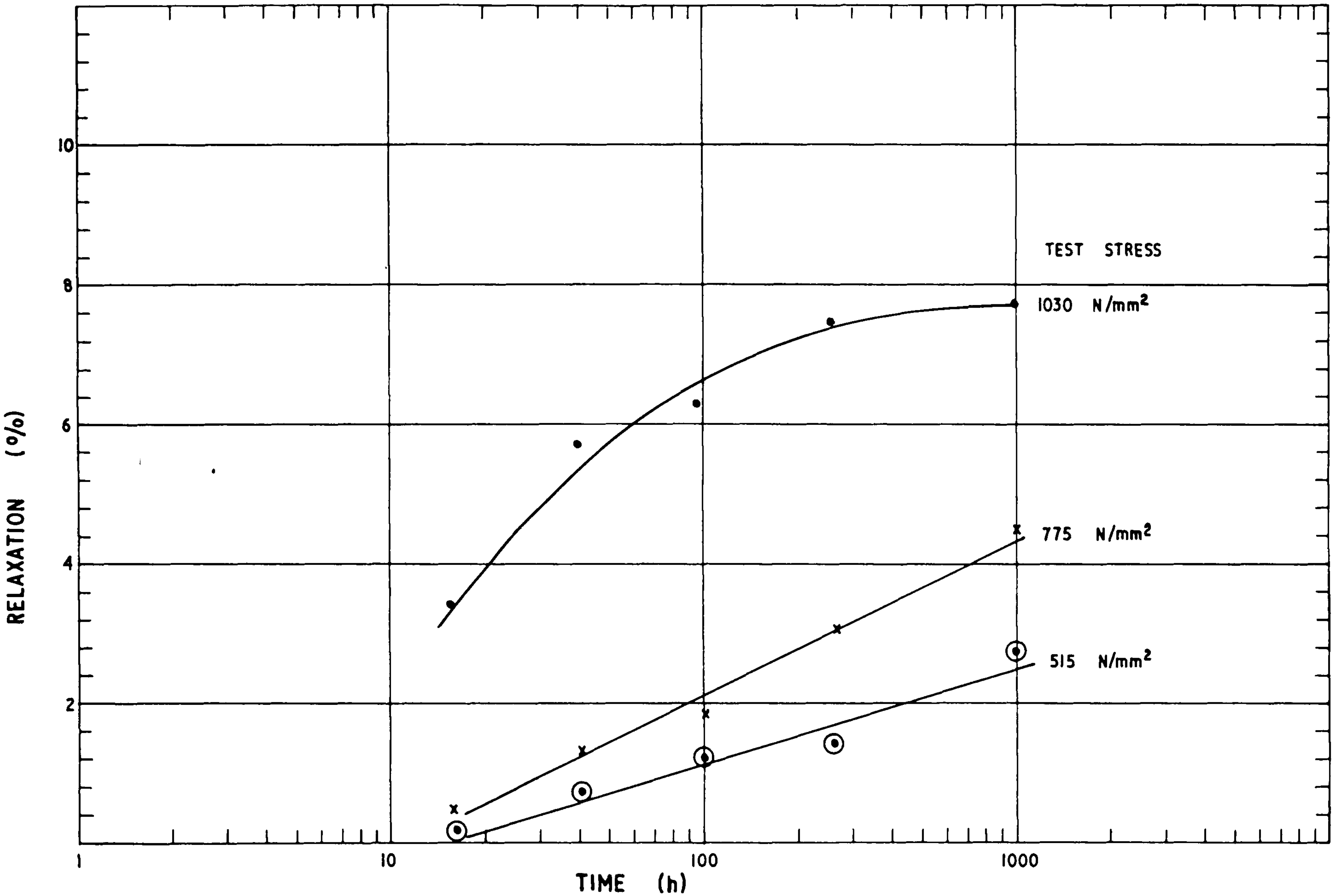

FIG. 11 RELAXATION OF COMPRESSION SPRINGS AT ROOM TEMPERATURE.

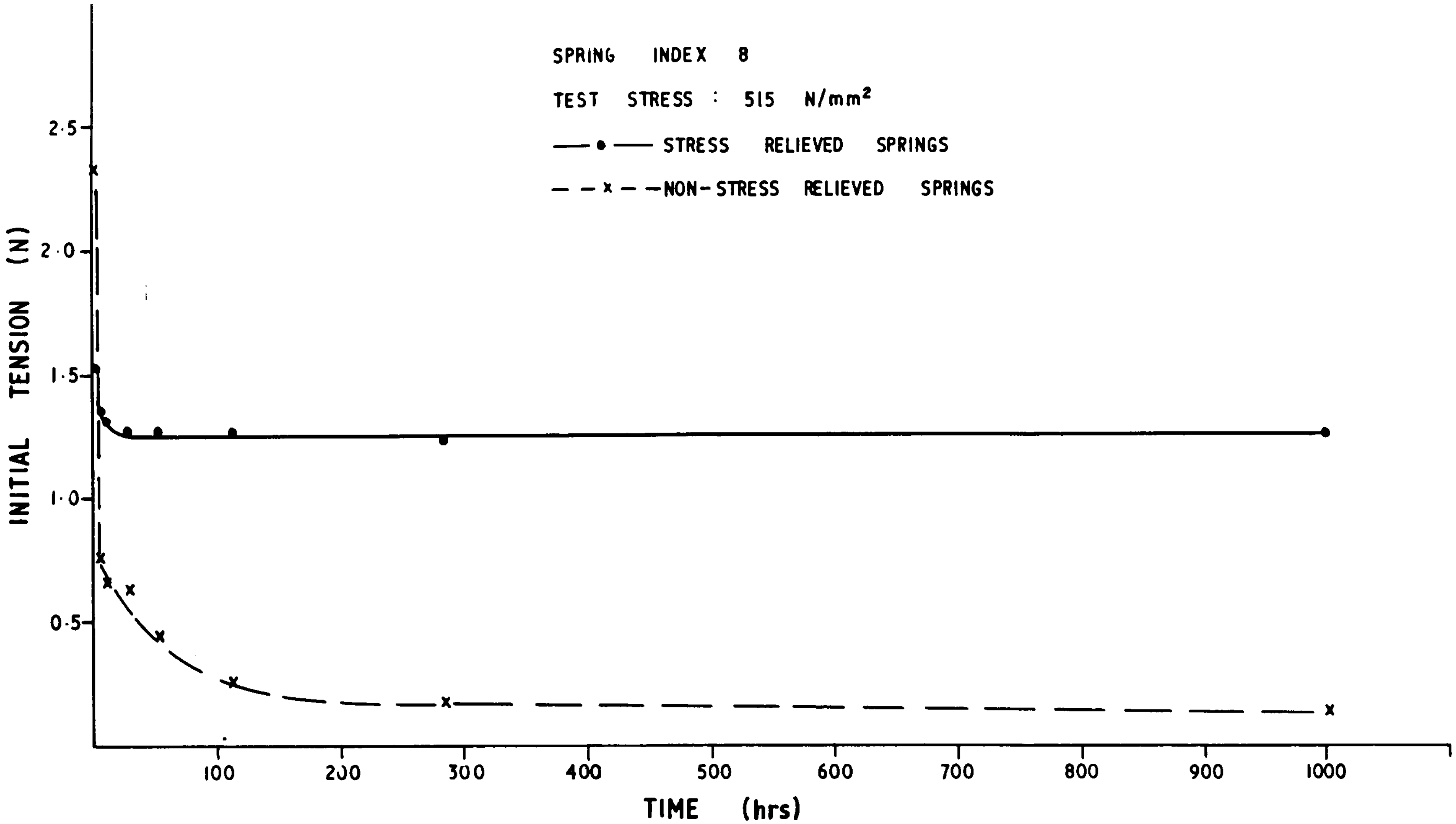

FIG. 12 EFFECT OF TIME ON INITIAL TENSION IN SPRINGS AT 100° C.

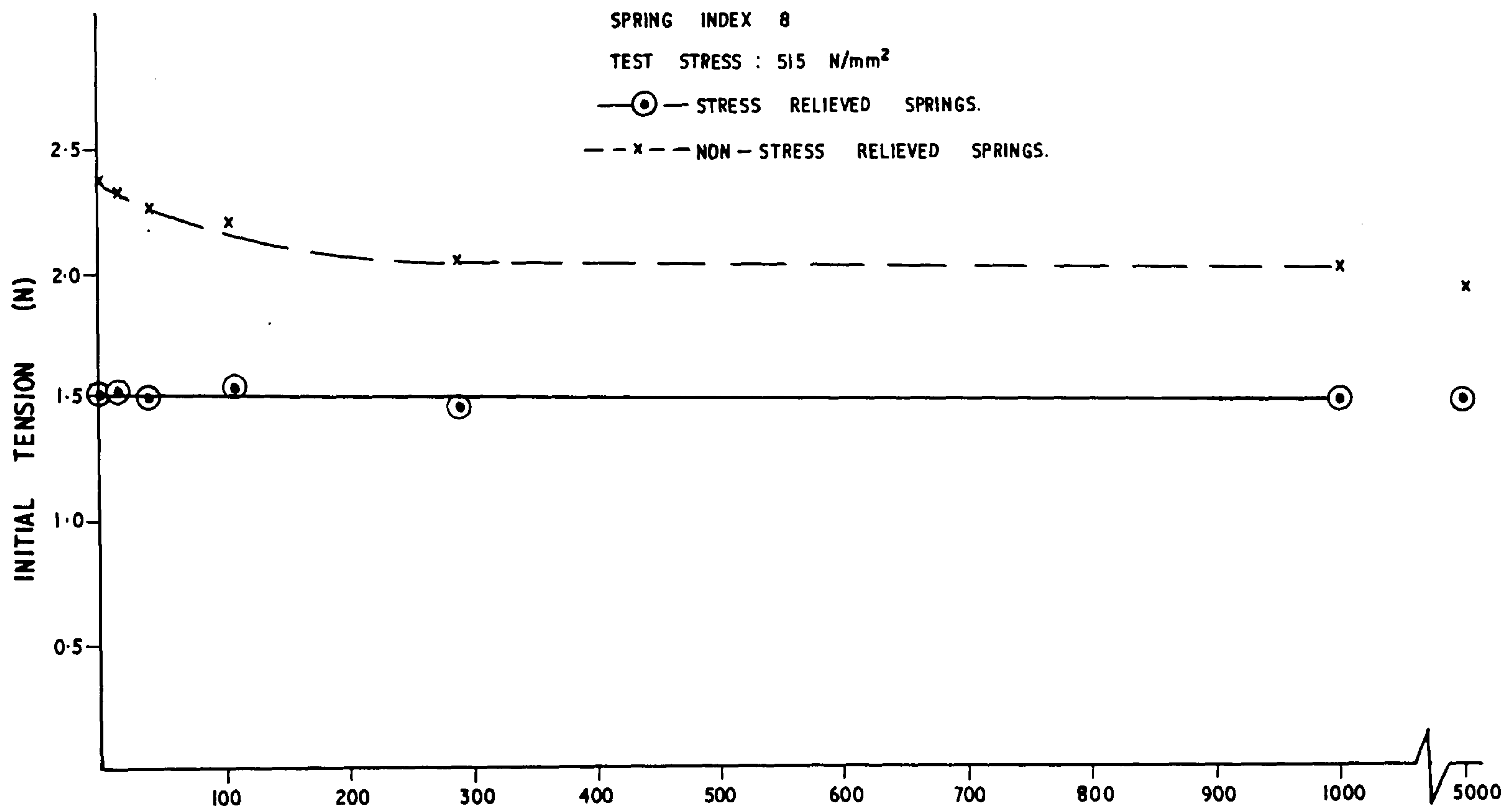

FIG. 13 EFFECT OF TIME ON INITIAL TENSION IN SPRINGS AT ROOM TEMPERATURE.

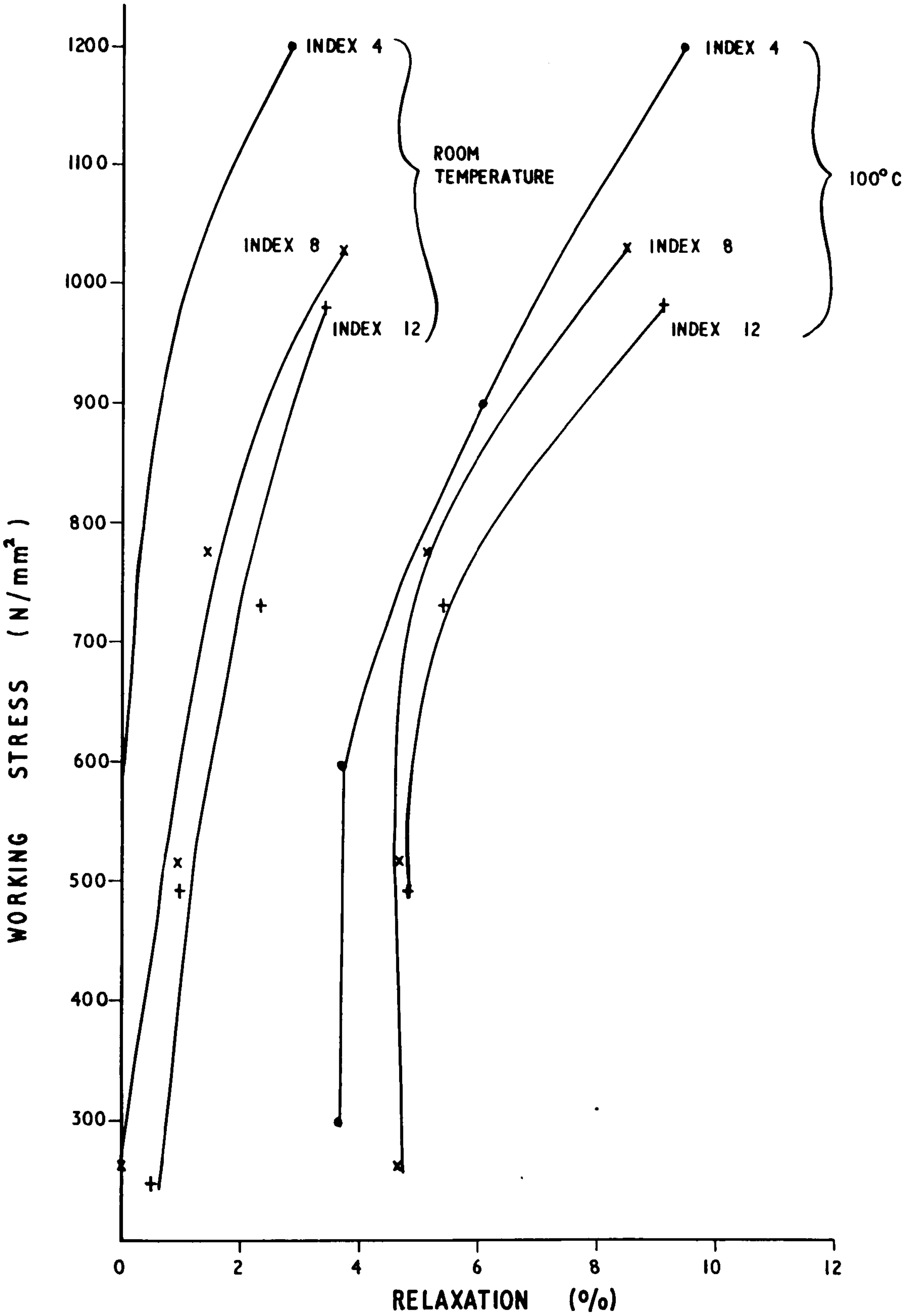

FIG. 14 SUMMARY OF RELAXATION DATA AT 1000 HOURS FOR STRESS RELIEVED TENSION SPRINGS.