THE COIL SPRING FEDERATION RESEARCH ORGANISATION

The Stress-Temperature Relaxation Properties of Springs made from Oil Tempered and Patented Hard Drawn Wires

Report No. 115

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SUMMARY

The effects of temperature and stress on the relaxation properties of compression springs made from oil tempered wire to B.S.2803 Grade I, EN.49D Range 2 and EN.49C Range 2 wire to B.S.1408 have been determined.

Springs made from the oil tempered wire had better resistance to relaxation than those made from the patented hard drawn wires.

A comparison has been made with American published data.

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THE STRESS-TEMPERATURE RELAXATION PROPERTIES OF SPRINGS MADE FROM OIL TEMPERED AND PATENTED HARD DRAWN WIRES

by G.B. Greves, A.Met., A.I.M.
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1. INTRODUCTION

When helical compression springs are deflected a fixed amount and subjected to prolonged exposure at elevated temperatures there is a tendency to settle. This causes a reduction in stress. The degree of settling is dependent upon the temperature and initial stress applied.

A survey of the stress temperature relaxation properties of spring materials has recently been carried out by the C.S.F.R.O.(1) and from this it was clear that very little published data concerning British materials existed. A programme of work is now in hand to provide the necessary information on spring materials in regular use in the U.K.; this report is the first of a series on the subject.

2. COMPOSITION AND MECHANICAL PROPERTIES

The cast analyses of each coil of wire from which the test springs were made is shown in Table I below:-

Table I Chemical composition of test springs

Specification	Wire Dia. (ins)	Cast Analysis % C	% Mn	% Si	% S	% P.	% Cu
B.S.1408 EN.49D Range 2	0.104	0.74	0.48	0.16	0.015	0.024	
B.S.2803 Oil tempered Grade 1	0.104	0.64	0.75	0.23	0.013	0.023	
B.S.1408 EN.49C Range 2	0.144	0.82	0.64	0.24	0.027	0.010	0.02

The mechanical properties of each batch of wire were determined in the "as received" condition and after a low temperature heat treatment of 350°C for 30 minutes. The effects of prestressing in torsion were determined on wires which had received this low temperature heat treatment. This work has already been reported(2) but certain data are reproduced here for convenience.

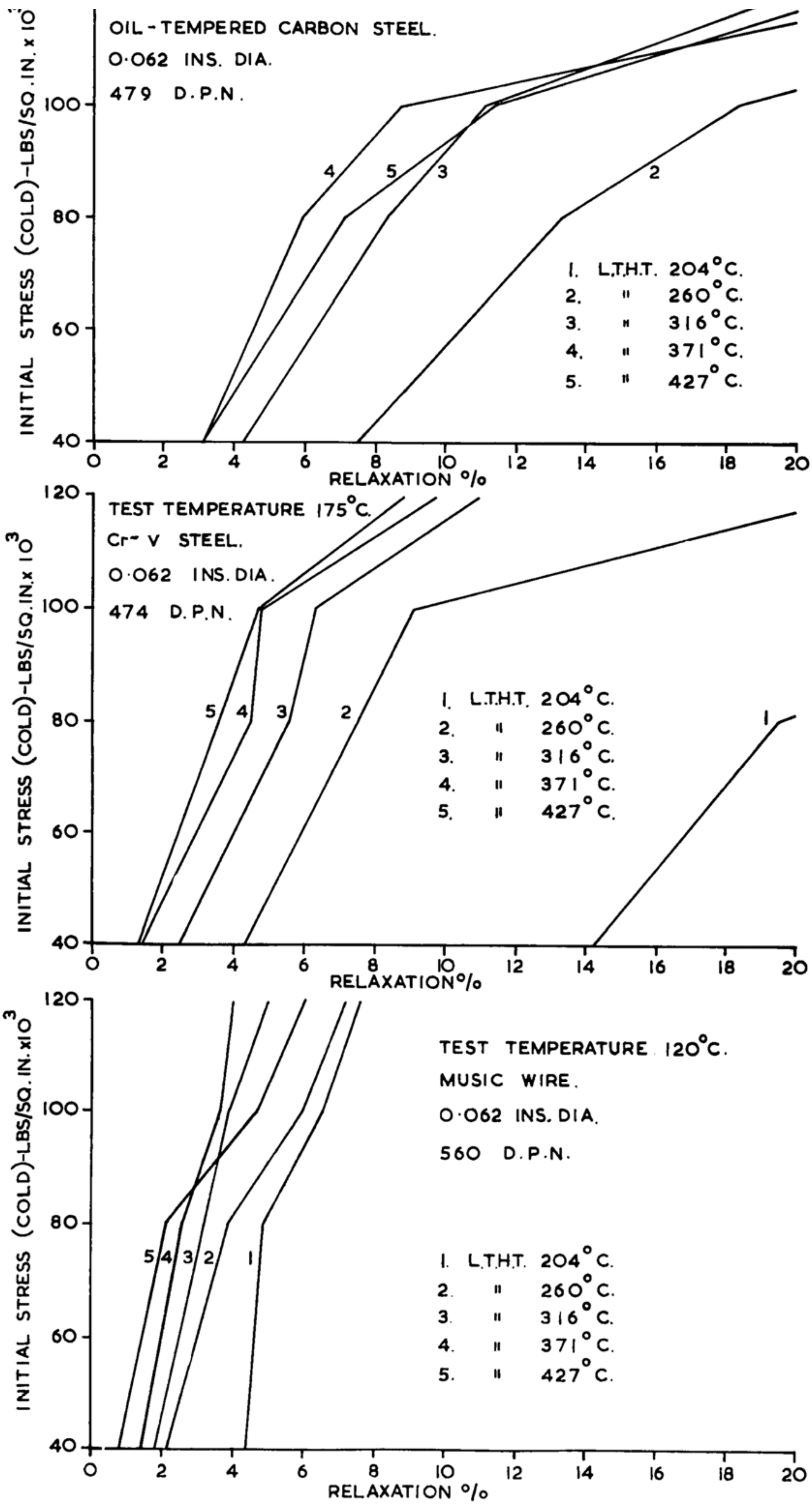

FIG. 1. STRESS TEMPERATURE RELAXATION OF SPRING MATERIALS AFTER VARIOUS

$$P = \frac{q \pi d^3}{8Dk}$$

where q = torsional stress (lbs/sq.in.)

P = load (lbs.)

D = Mean diameter of spring (ins.)

d = Wire diameter (ins.)

k = Sopwith correction factor

$$= \frac{C + 0.2}{C - 1}$$

and $c = D/d$

The outside diameter of each spring was measured by vernier calipers to ± 0.001 in. and from this the mean diameter was calculated.

All the stress calculations in this investigation were carried out using room temperature values of rigidity modulus, no correction was made for the decrease in modulus with increasing temperature. The actual stress or load on the springs at test temperature were, therefore, lower than the calculated values according to the following relationship.

$$P_t = P_r \frac{Gt}{Gr}$$

where P_t = Load at test temperature

P_r = Load at room temperature

G_t = Rigidity modulus at test temperature

G_r = Rigidity modulus at room temperature

If it is desired to know the actual load or stress on the springs at the test temperature, the corrected values may be obtained by applying the above relationship.

Calculations were also made to examine the effect of the following variables during the relaxation determinations:

(a) Change in stress due to thermal expansion of the spring material
(b) Change in stress due to thermal expansion of the Monel bolt
(c) Change in stress due to creep of the Monel bolt

These calculations demonstrated that the errors involved were negligible.

4.2 Load Tests

The loaded height was determined by loading the springs on two modified load testing machines of 40 lbs. (Fig. 1) and 220 lbs. capacity. The modifications consisted of the addition of a 2 in. micrometer dial gauge (reading to 0.001 in.) which was attached to an adjustable screw through the upper bracket of the machine and which bore onto a small flat plate attached to the central plunger. A sensitive electric buzzer was incorporated which operated immediately the upper platen made electrical connection with the spring. By adjusting the dial gauge to zero height when the platens were closed the free height and compressed height necessary to produce the desired load were noted.

Where low loads and deflections were encountered a correction was made to the load readings to allow for the rate of the dial gauge spring.

4.3 Relaxation Tests

Each spring was loaded on a $\frac{3}{4}$ in. diameter Monel bolt, nut and washer assembly and compressed to the desired stress as shown in Fig. 2. The height of the compressed springs was measured by dial gauge calipers reading to 0.001 inches. After loading, the assemblies were placed in a high temperature air-circulating oven in which the temperature was controlled to an accuracy of $\pm$ 1°C. and soaked for a period of 72 hours. A time of 72 hours in the case of carbon and low alloy steels had previously been found sufficient to allow practically all the relaxation to occur(3). After this period the springs were allowed to cool before unloading. The new free height and load at the original compressed height were measured. From these measurements the percentage loss in load was calculated.

The procedure described above was repeated for each spring material investigated and for a number of temperature levels.

5. RESULTS

The percentage loss in load calculated from the load deflection tests for each quality investigated is shown for a range of temperatures and stress levels in Figs. 3, 4, 5 and 6.

For all three spring qualities, at a number of points on the curves considerable scatter occurs, consequently the best possible smooth curves have been drawn.

6. DISCUSSION OF RESULTS

Of the three British spring wires examined the springs made from oil tempered wire appeared to have superior stress temperature relaxation resistance and at the lower stresses compared favourably with Zimmerli's(4) oil tempered material. At the higher stresses, however, Zimmerli's results were superior, this may be due to the higher low temperature heat treatment employed.

Based on a figure of 5% load loss the springs made from oil tempered wire and EN.49D quality wire withstood stresses of 50,000 to 55,000 lbs/sq.in. when subjected to a temperature of 150°C. The EN.49C wire on the other hand when tested at 150°C could only be stressed to 37,000 lbs/sq.in. before exceeding the 5% stress relaxation loss. At temperatures above 150°C the oil tempered material showed a marked superiority over the EN. 49D and EN.49C hard drawn qualities as would be expected. Again the EN.49D material resisted relaxation better than the EN.49C hard drawn wire.

Comparing Zimmerli's data for hard drawn wire springs with that obtained for EN.49D, the former appeared to have better resistance to relaxation, again this may be due in part to the higher low temperature heat treatment employed. It is not known whether this American data[4] was obtained from springs in the prestressed or unstresed condition. If, in fact, the data was obtained from unstressed springs this might well explain the differences between the British and American results as it is possible that unstressed springs possess better resistance to stress temperature relaxation.

7. CONCLUSIONS

(i) Oil tempered carbon steel wire springs show superior resistance to stress temperature relaxation than springs made from EN.49D and EN.49C patented hard drawn steel wire after a similar low temperature heat treatment.

(ii) There is evidence to suggest that for the materials investigated a somewhat higher low temperature heat treatment may be advantageous from the point of view of resistance to relaxation at temperature.

(iii) Based on a value of 5% relaxation the oil tempered wire springs could be used at temperatures up to 150°C and stresses up to 55,000 lbs/sq.in. At a similar temperature EN.49D could be stressed to 50,000 lbs/sq.in. and the EN.49C hard drawn wire quality springs to 37,000 lbs/sq.in. before exceeding 5% relaxation.

8. RECOMMENDATIONS

(i) The programme should be continued on Continental and other British spring wires with a view to assessing their stress temperature relaxation properties.

(ii) Due to the amount of scatter experienced with these results it is desirable that with subsequent investigations a larger number of tests be carried out at each level of stress and temperature.

(iii) Investigations on the effect of various low temperature heat treatments should be carried out to optimise them with respect to the maximum resistance to stress temperature relaxation.

(iv) A limited number of stress relaxation tests should be conducted on unstressed springs to determine whether such springs resist relaxation better than those which have been prestressed.

(v) The effect of "heat loading" on the resistance of springs to stress-temperature relaxation should be studied.

9. REFERENCES

1. G.B. Graves — C.S.F.R.O. Report No. 113 "The Relaxation and Creep of Springs at Elevated Temperatures: A Literature Survey".

2. J.W. Mee — C.S.F.R.O. Report No. 114 "The Mechanical and Fatigue Properties of Helical Compression Springs made from Patented Hard Drawn and Oil Tempered Wires".

3. F.P. Zimmerli, W.P. Wood, G.D. Wilson. Trans. A.S. Steel Treating 1933, Vol. 21, pp. 796-806 "Load Losses in Small Helical Springs".

4. F.P. Zimmerli & W.P. Wood — Trans. S.A.E. 1954, Vol. 62 "Effect of Temperature on the Endurance Limit and Relaxation of Spring Materials".

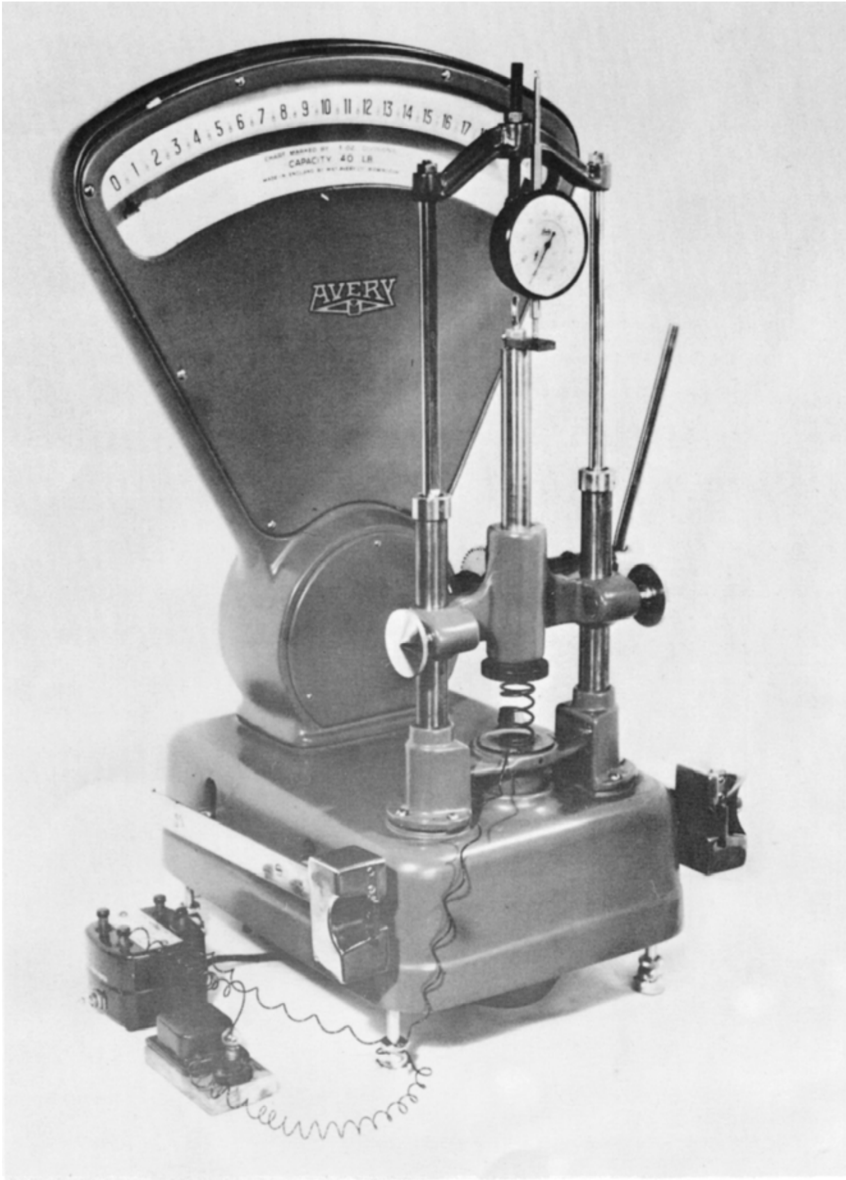

FIG. I

40 LB. SPRING LOAD TESTER SHOWING DIAL GAUGE METHOD OF MEASURING SPRING DEFLECTION

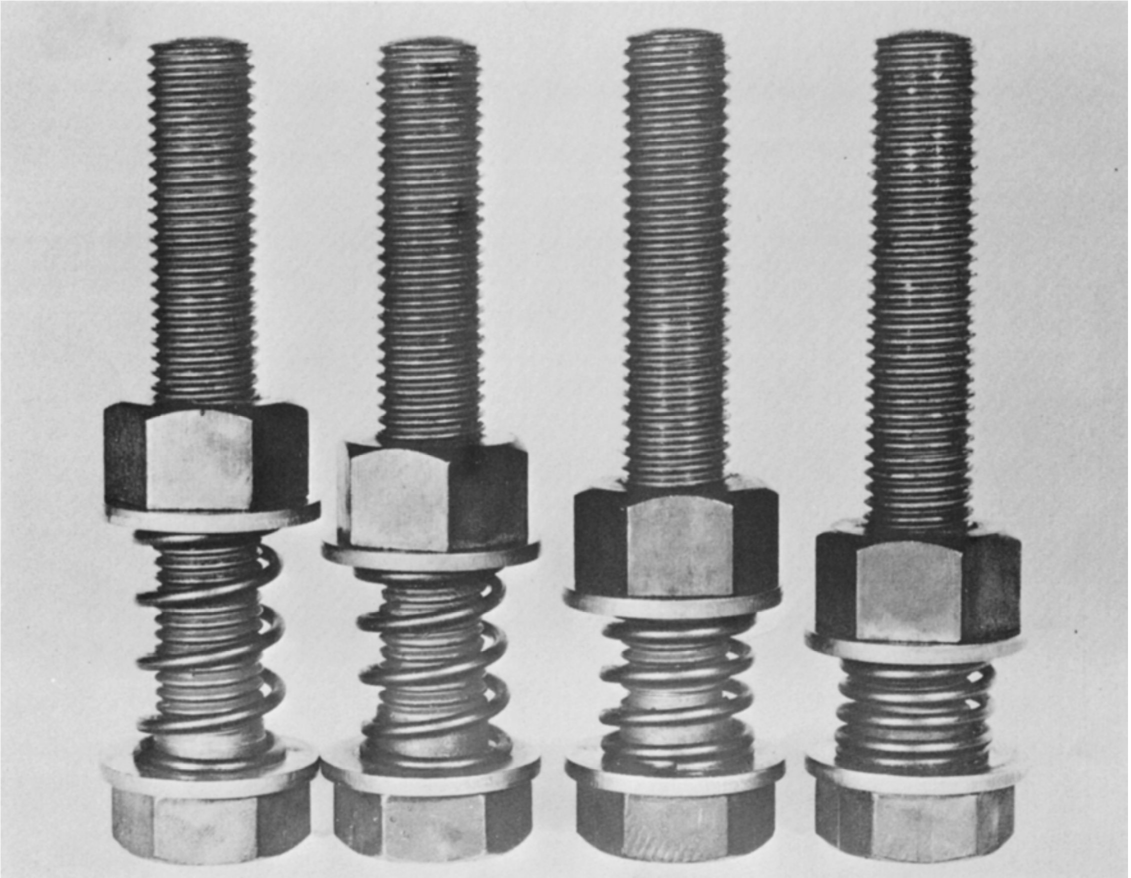

FIG. 2 MONEL BOLT ASSEMBLIES SHOWING A SERIES OF SPRINGS COMPRESSED TO THE DESIRED STRESS

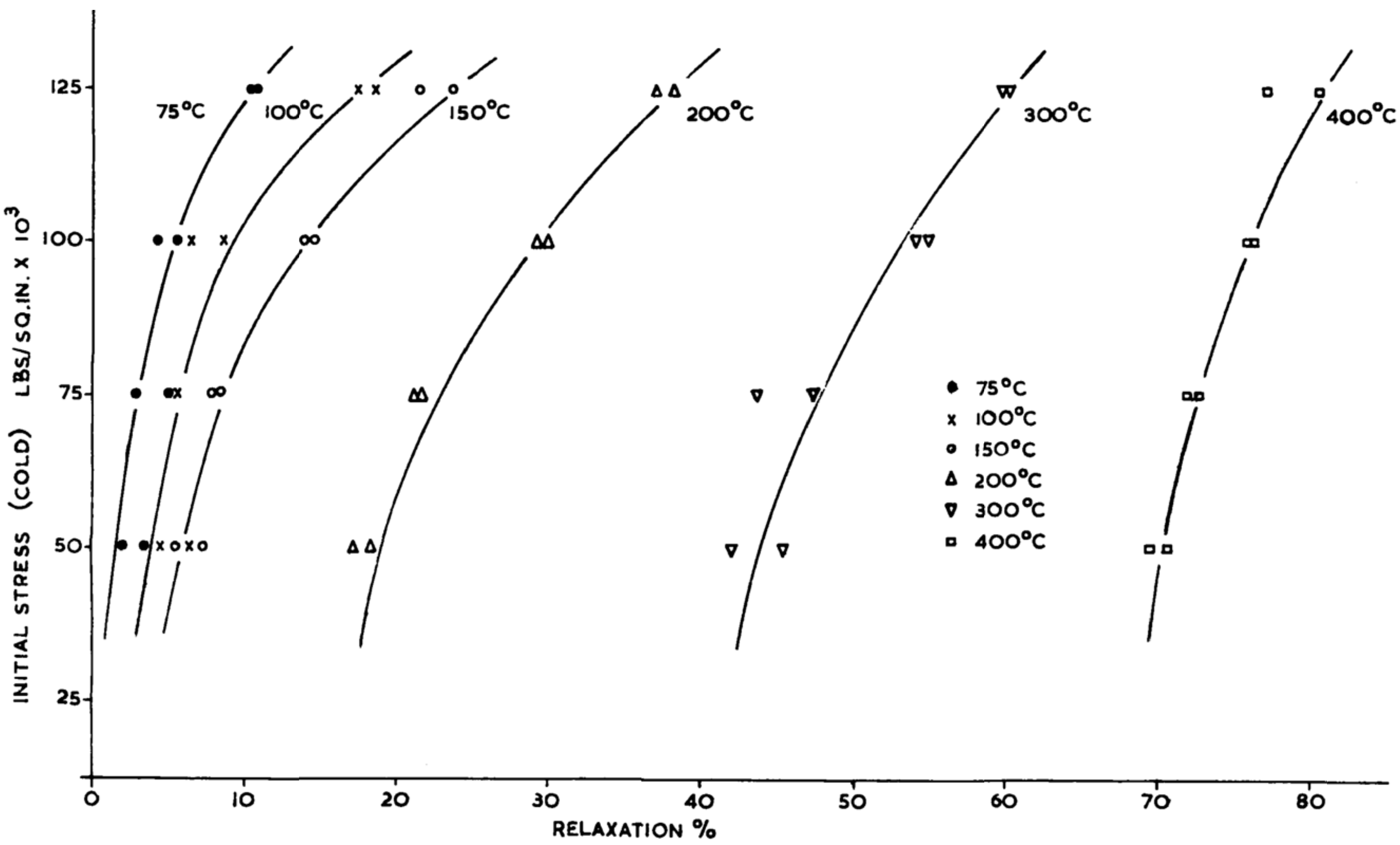

FIG.3 STRESS TEMPERATURE RELAXATION OF PATENTED HARD-DRAWN WIRE SPRINGS LOW TEMPERATURE HEAT TREATED AT 350°C FOR 1/2 HR.

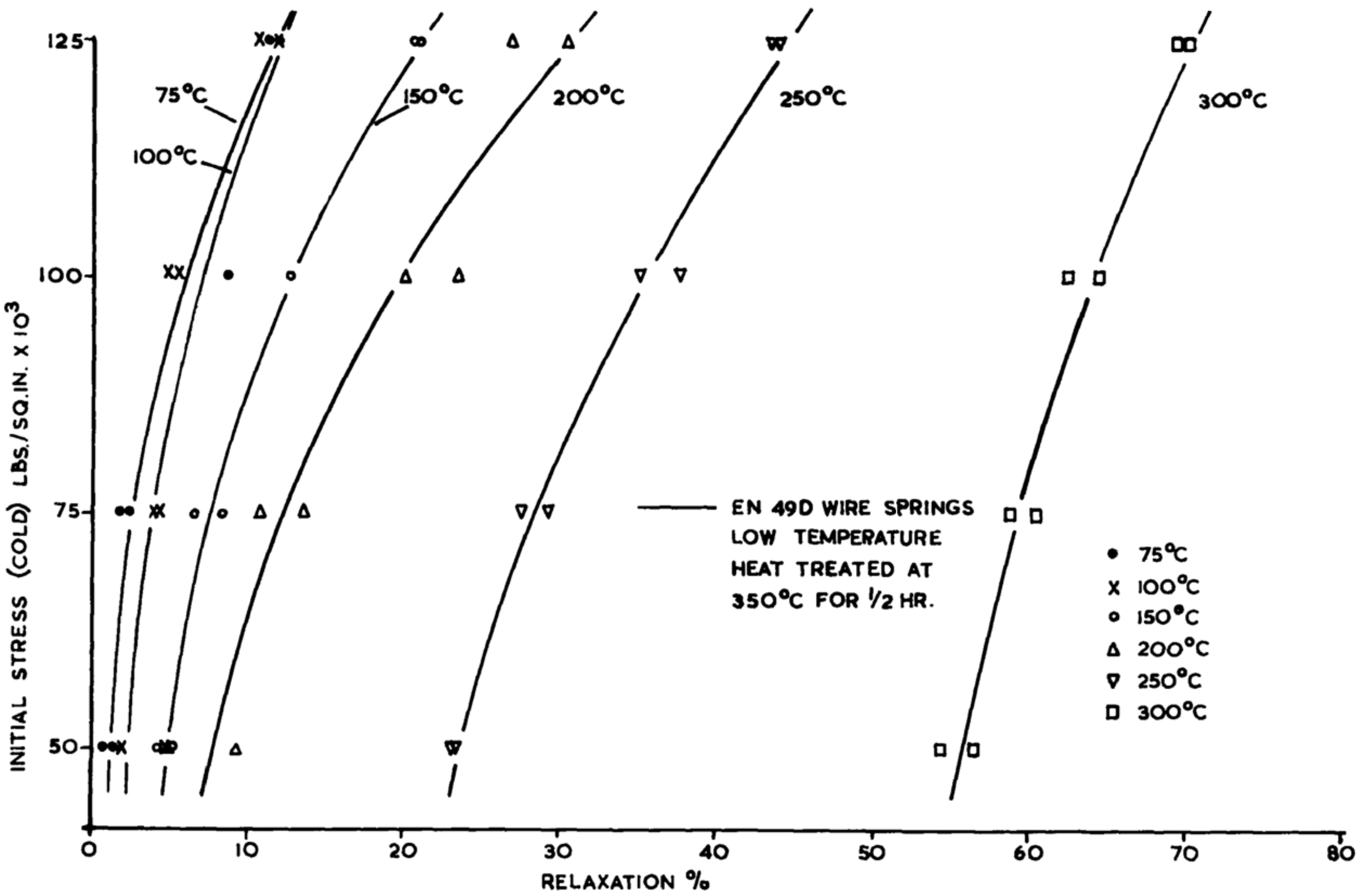

FIG.4 STRESS TEMPERATURE RELAXATION OF EN49D WIRE SPRINGS

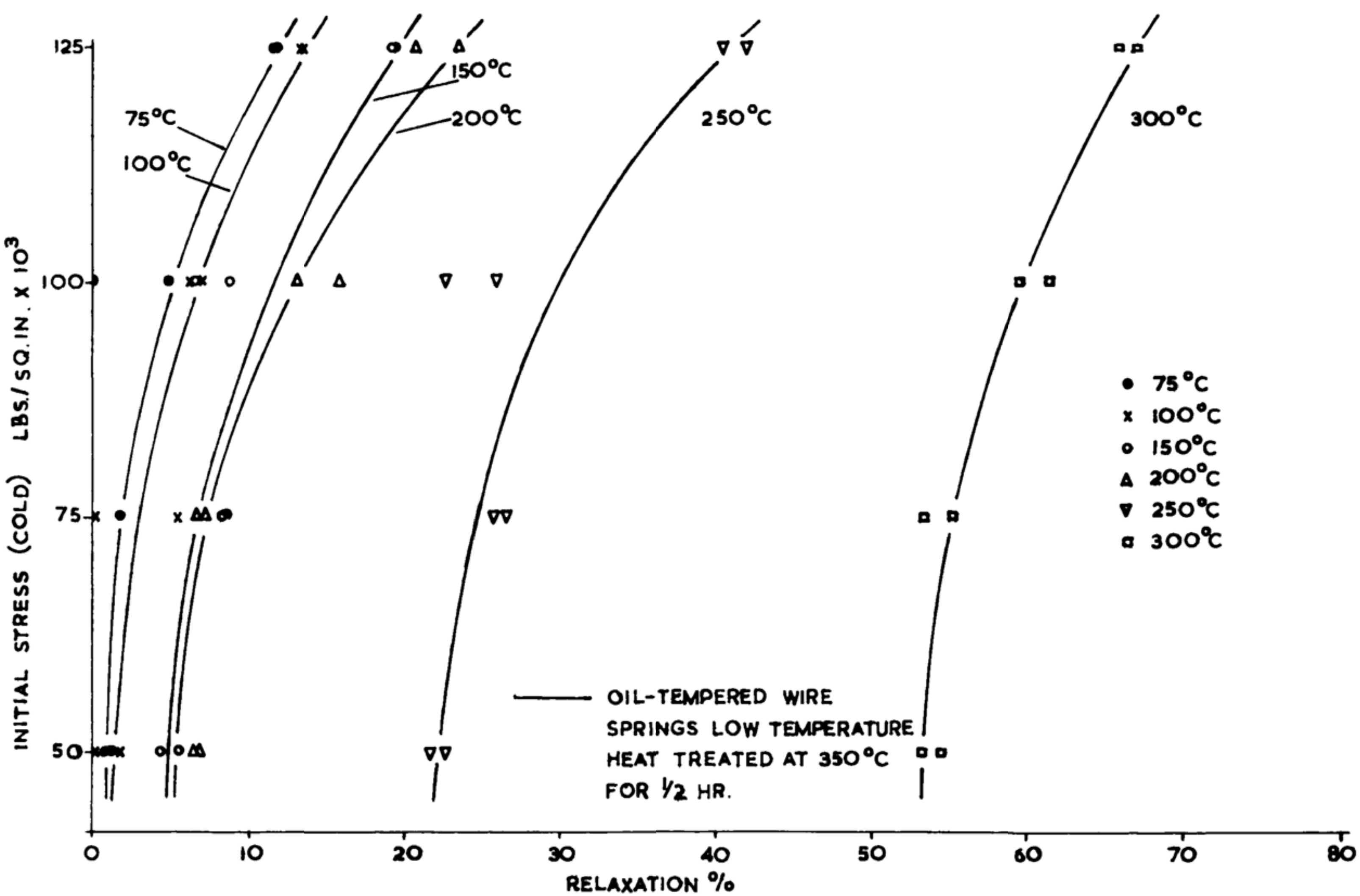

FIG. 5 STRESS TEMPERATURE RELAXATION OF OIL-TEMPERED WIRE SPRINGS

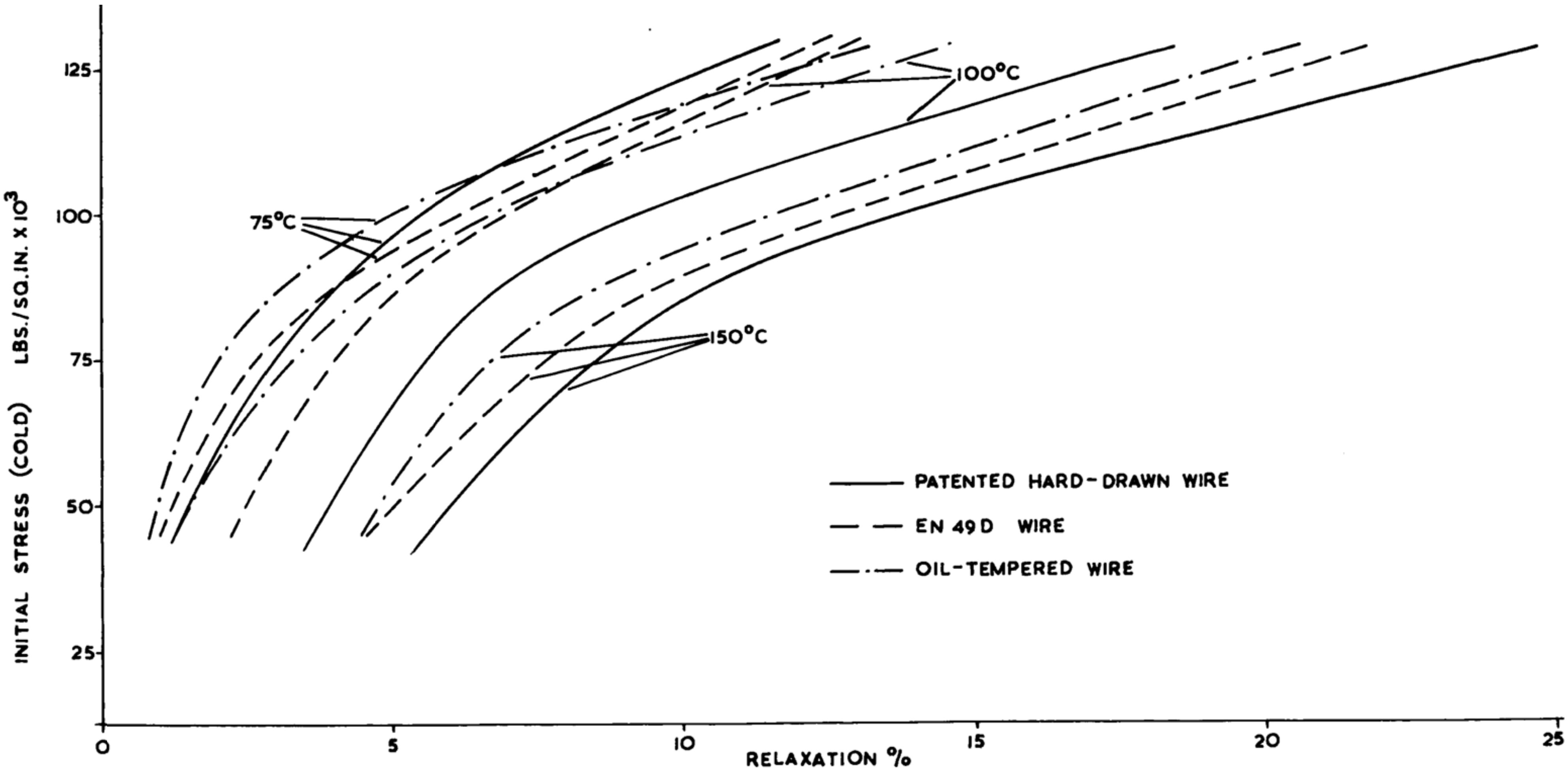

FIG.6 COMPARISON OF STRESS-TEMPERATURE RELAXATION PROPERTIES OF THREE SPRING WIRE QUALITIES