THE SPRING RESEARCH ASSOCIATION

DESIGN DATA FOR TORSION SPRINGS

by

M. R. Southward, B.Sc.

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SUMMARY

In order to produce design data, torsion springs manufactured from three materials: BS 1408B Range 2; BS 2056, En 58A; and BS 2803 were investigated. Springs of four indices were made from two different wire diameters to determine the effect of spring index and wire diameter on the maximum operating stress. Springs of each material were subjected to various low temperature heat treatments and their influence on the stress properties was examined.

The maximum operating torque for each spring was determined by increasing the load until permanent set occurred.

The figures show the relationship between the maximum operating stress, expressed as a percentage of the tensile strength of the wire, and the heat treatment to which the springs were subjected. From the results it was concluded that the maximum operating stress was independent of spring index and, for all materials tested, an improvement in the maximum operating stress was achieved by a suitable low temperature heat treatment of the springs after coiling.

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1. INTRODUCTION

A helical torsion spring is a helical spring which is loaded by a torque acting about its axis. Normally it should be used so that under load the number of coils tends to increase and their diameter reduce. The material of the spring is stressed in bending by a moment which is identical in magnitude to the applied torque.

The purpose of this investigation was to determine the maximum working stresses which can be applied to torsion springs and to present this information in the form of design data. Data have been produced for three commonly used spring materials, and the influence of spring index and low temperature heat treatment on the maximum recorded working stresses has been examined.

2. MATERIAL AND SPRING DESIGN

The three materials selected for the investigation were:- a patented cold drawn steel spring wire to BS 1408B Range 2; an oil-hardened and tempered steel wire to BS 2803; and an austenitic stainless steel wire to BS 2056, En 58A.

Details of the spring designs are given in Table I. Torsion springs made from BS 1408B Range 2 and BS 2056, En 58A, materials were supplied by a spring manufacturer. The springs manufactured from BS 2803 material, which was only available in wire of 1.22 mm diameter, were produced at Headquarters on a Carlson hand coiling machine.

Tensile tests were carried out on wire in the 'as-received' condition; the results are given in Table II. Of the materials tested, only the 1.22 mm diameter wire of En 58A steel did not meet the specified tensile strength requirements.

3. EXPERIMENTAL PROCEDURE

The tests were carried out on an Amsler torsion testing machine fitted with specially designed jigs to support the torsion springs (See Fig. 1). The magnitude of the applied torque and the angular deflection of the torsion spring could be recorded from scales fixed to the machine.

A torque was applied to each spring until permanent set occurred. From the magnitude of the torque, the maximum working stress was calculated from the formula below:

$$\sigma = \frac{32M}{\pi d^3}$$

where σ = maximum bending stress
M = applied torque
d = wire diameter

For each design of spring, a batch of five springs was tested and the results expressed as a percentage of the measured tensile strength of the material.

Springs of each index from 1.22 mm diameter wire were subjected to heat treatment at different temperatures, as shown in Table III. The springs manufactured from 2.34 mm diameter wire were given the low temperature heat treatment which had yielded the best results with the 1.22 mm diameter wire.

The procedure for testing springs in the unwind direction was, in all other respects, identical to that described above. These tests were performed on batches of three. Wherever possible, the springs were given the heat treatment which the previous work had shown to be the most suitable.

4. RESULTS

From the torque which produced permanent set in each spring, the maximum bending stress was calculated and expressed as a percentage of the measured tensile strength. The results are presented in the form of figures showing the effect of heat treatment on the maximum bending stress (expressed as percentage tensile strength) for each of the different materials.

Figs. 2 to 4 show the results obtained with 1.22 mm diameter wire made from the three different materials tested. Fig. 5 shows the results for springs of 2.34 mm wire made from BS 1408B Range 2 and BS 2056, En 58A. Figs. 6 and 7 show the results obtained with springs in the unwind direction. Fig. 8 shows the recommended maximum working stresses for non-heat treated torsion springs of the materials investigated.

5. DISCUSSION

The figures showing the results obtained for springs tested in the wind-up direction indicate that, in the large majority of cases, there is no significant difference in the results obtained for springs of different indices subjected to any one heat treatment. The few results that are significantly different do not appear to form part of a general pattern and may be disregarded. Thus, no curvature correction factor is necessary and it was decided to combine all the results obtained for springs of different indices in any one heat treated condition. The mean and 2σ limits have been calculated and are marked on the figures.

Figure 2, for 1.22 mm wire to BS 1408B Range 2 indicates that differences in heat treatment had no significant effect on the results, except between 250°C and 350°C, and also between 280°C and 350°C. It was decided, therefore, to heat treat the 2.34 mm diameter wire of the same material to 280°C for half-an-hour. The results obtained are shown in Fig. 5. No significant difference was found in the results obtained for springs of the different wire diameter, either with or without heat treatment.

Figure 3, for En 58A, also shows no significant differences in the results obtained with the different heat treatments and it was decided to heat treat the 2.34 mm diameter wire at 450°C for two hours. The results obtained are shown in Fig. 5. With this material, there were no significant differences in the results obtained for springs of different wire diameter subjected to the same heat treatment. There were, however, significant differences in the results obtained for the untreated springs. Permanent set occurred at a lower torque in the springs of 1.22 mm diameter wire than in those of 2.34 mm diameter.

Figure 4, for BS 2803, differs from those for the preceding two materials in that it shows significant differences in the results obtained with different heat treatments. The best results were obtained with a heat treatment of 250°C for 30 minutes.

Figures 6 and 7 both show the results obtained with springs tested in the unwind direction. In general, heat treatment appears to improve the maximum working stress. Smaller index springs seem to exhibit better properties than larger ones before heat treatment, but acquire the same properties on being subjected to the same heat treatment. The reason for this difference may be that stresses in the spring that have arisen during manufacture are relieved by the low temperature heat treatment.

6. CONCLUSIONS

1. The torque at which permanent set occurred was independent of spring index; hence, no correction factor is necessary for torsion springs.

2. Maximum working stress, expressed as a percentage of tensile strength, was independent of wire diameter.

3. A low temperature heat treatment was found to improve the maximum working stress.

4. Recommended maximum working stresses for the three materials investigated, with and without heat treatment, can be calculated by multiplying the tensile strength by the factors shown in the table below:

MATERIAL	No L.T.H.T.	With L.T.H.T.
BS 1408	0.72	1.00
En 58A	0.65	1.03
BS 2803	0.78	1.43

The corresponding values for springs tested in the unwind direction were very much lower.

5. The types of low temperature heat treatment recommended are:

BS 1408	220°C - 280°C	for half-an-hour
En 58A	400°C - 500°C	for two hours
BS 2803	200°C - 250°C	for half-an-hour

TABLE I SPRING DESIGNS

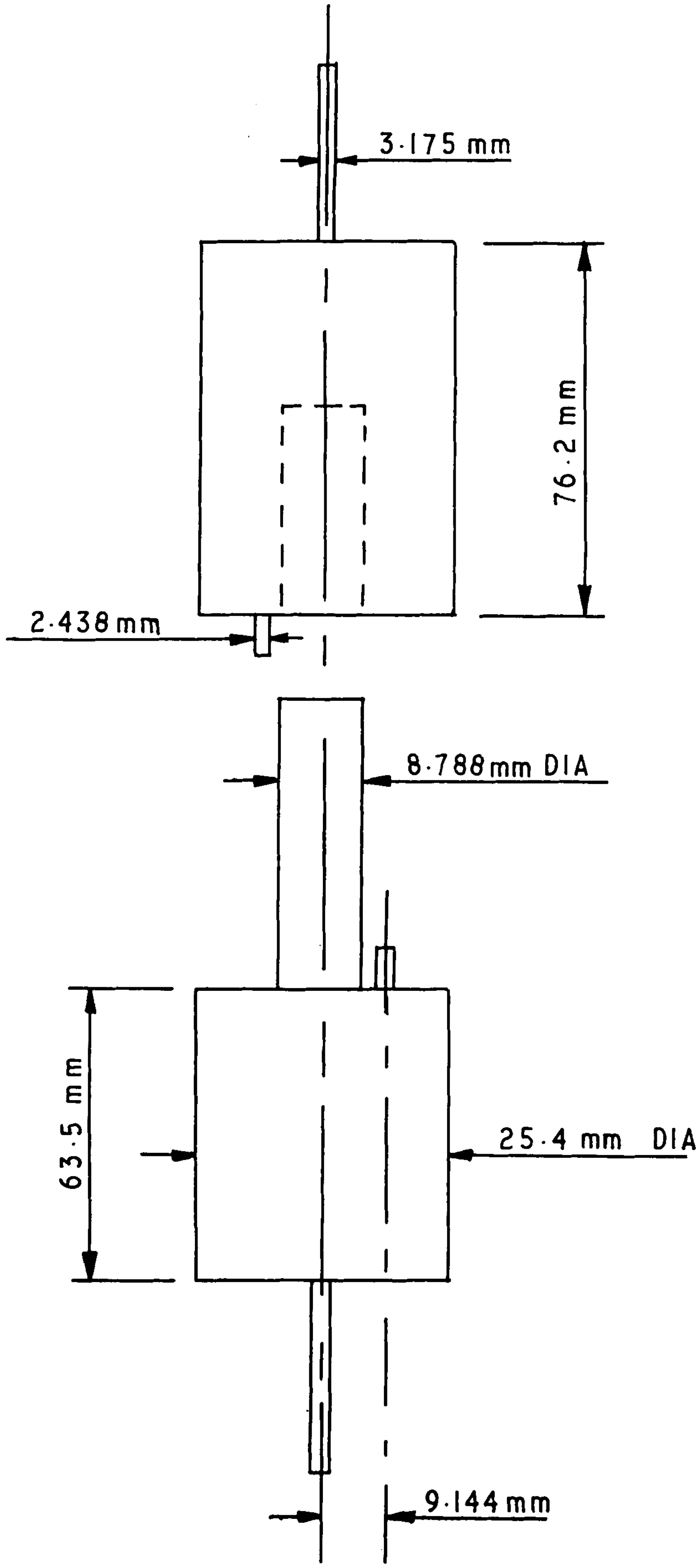
Wire diameter (mm)	1.22 and 2.34
Number of coils	8
Spring indices	3, 6, 10 and 15
Straight legs	180° apart

TABLE II TENSILE TEST RESULTS

MATERIAL	DIAMETER WIRE (mm)	TENSILE STRENGTH (N/mm^2)
BS 1408	1.22 2.34	2085 1668
En 58A	1.22 2.34	1606 1637
BS 2803	1.22	1930

TABLE III LOW TEMPERATURE HEAT TREATMENTS

MATERIAL	TEMPERATURE (°C)	TIME (mins)
BS 1408	220, 250, 280 or 350	30
En 58A	400, 450 or 500	120
BS 2803	200, 250, 300, 350, 400 or 450	30



THIS JIG WAS DESIGNED FOR A TORSION SPRING MANUFACTURED FROM 1·22 mm DIA. WIRE TO A SPRING INDEX OF 10

FIG. 1 TEST JIG FOR TORSION SPRINGS

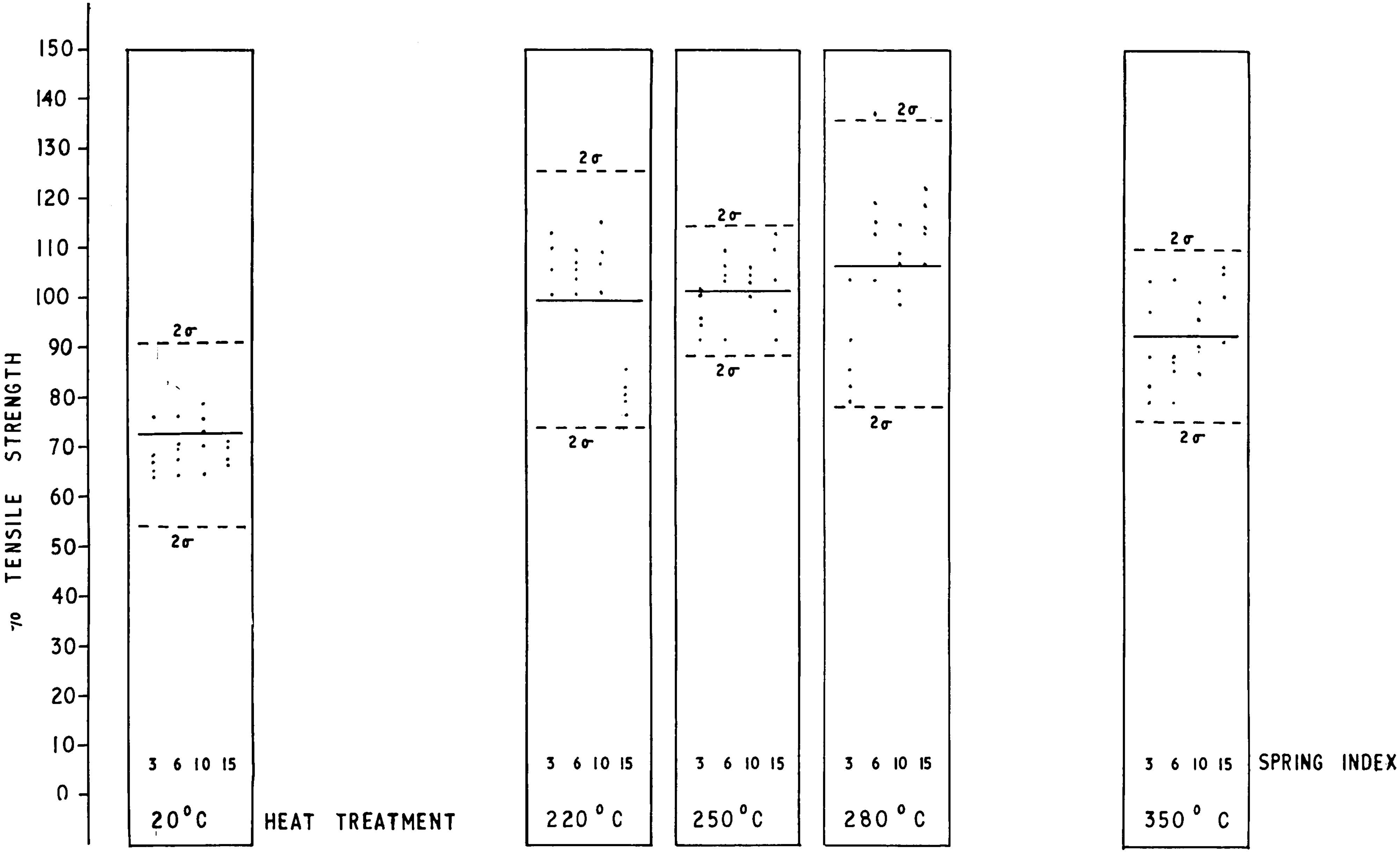


FIG. 2 MAXIMUM BENDING STRESS, EXPRESSED AS A PERCENTAGE OF TENSILE STRENGTH, AGAINST HEAT TREATMENT FOR BS 1408 B RANGE 2 USING 1·22 mm DIA.

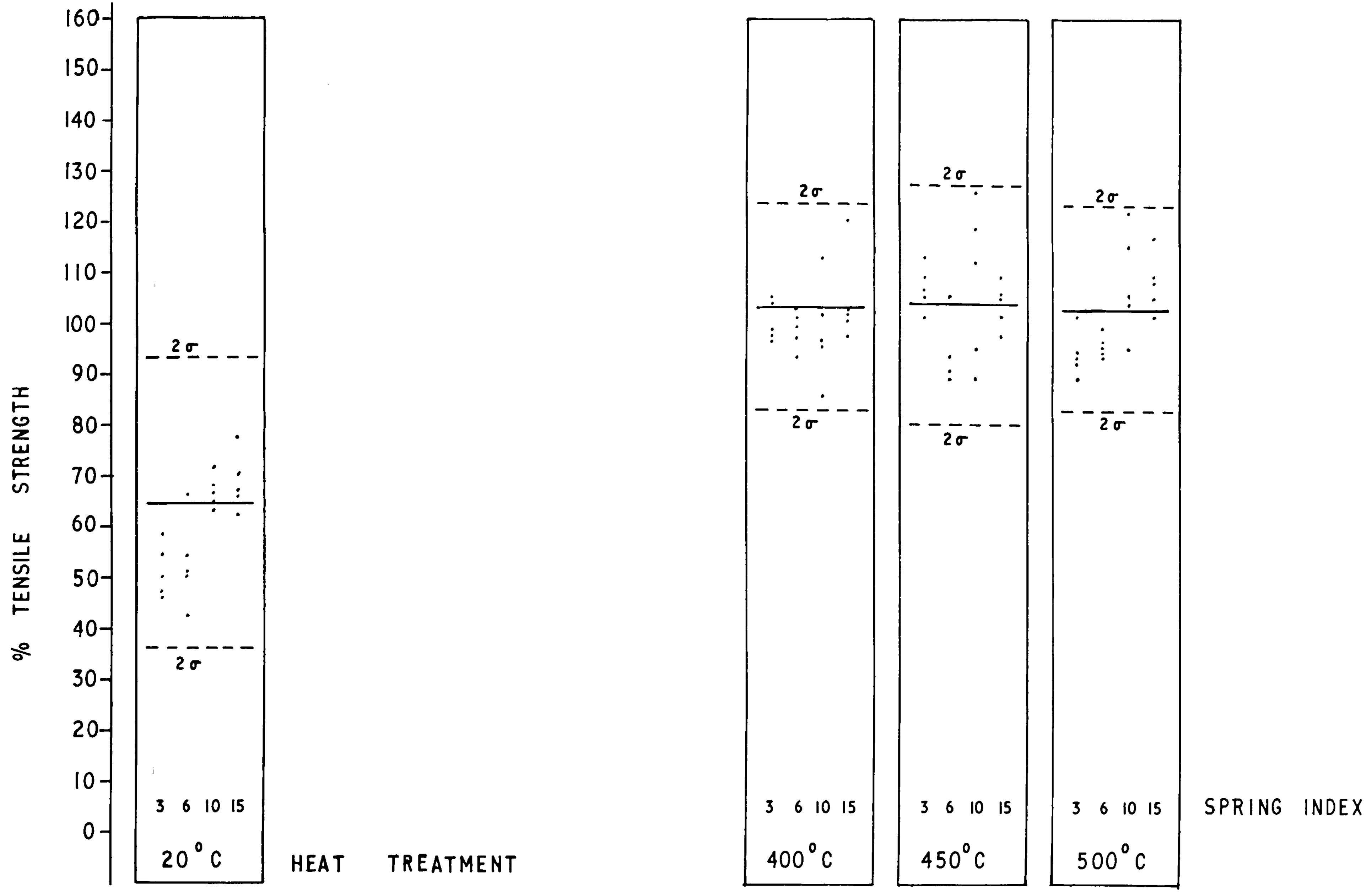


FIG. 3 MAXIMUM BENDING STRESS, EXPRESSED AS A PERCENTAGE OF TENSILE STRENGTH, AGAINST HEAT TREATMENT FOR BS 2056, En 58A, USING 1·22 mm DIA. WIRE.

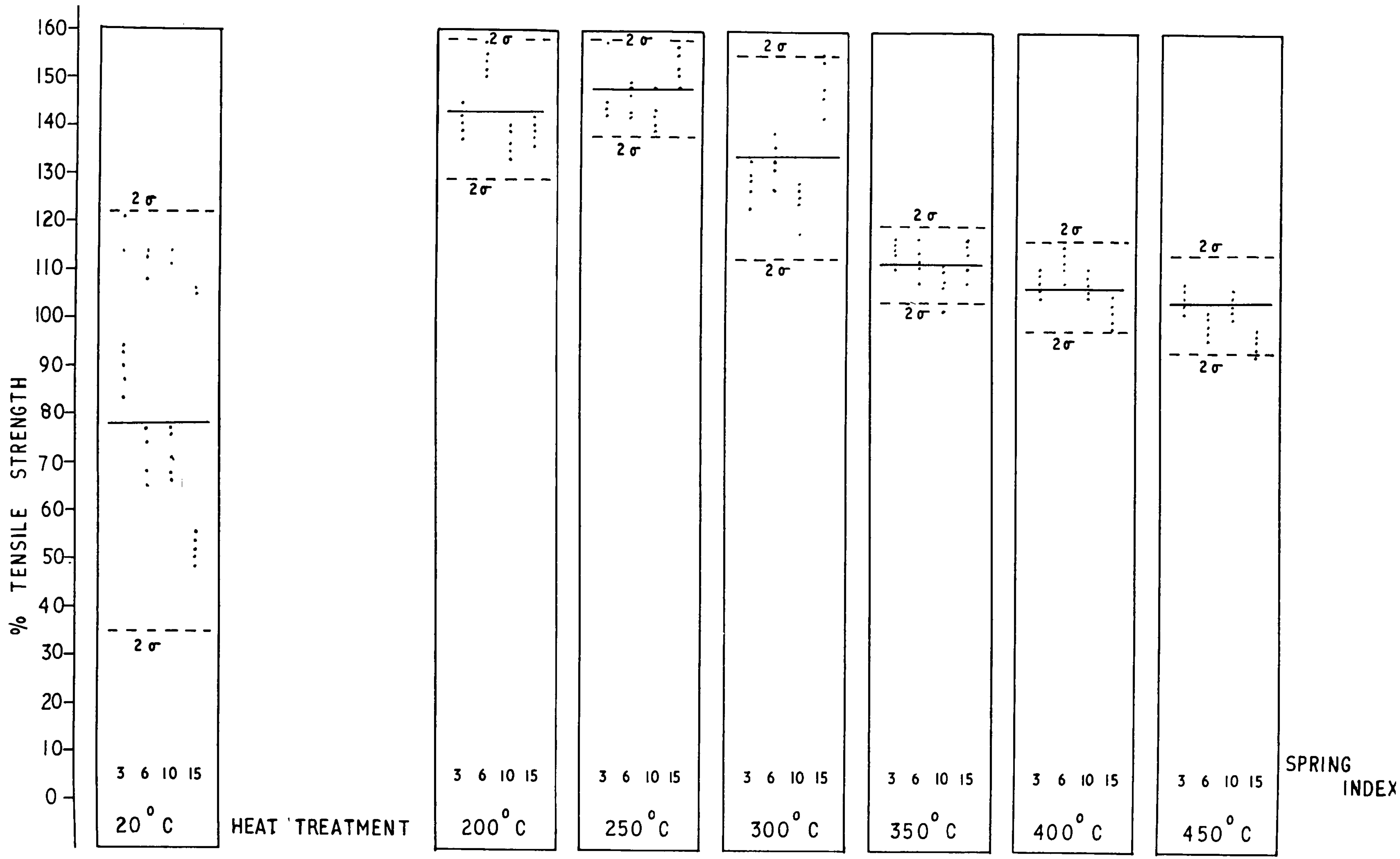


FIG. 4 MAXIMUM BENDING STRESS, EXPRESSED AS A PERCENTAGE OF TENSILE STRENGTH, AGAINST HEAT TREATMENT FOR BS 2803 USING 1·22 mm DIA. WIRE.

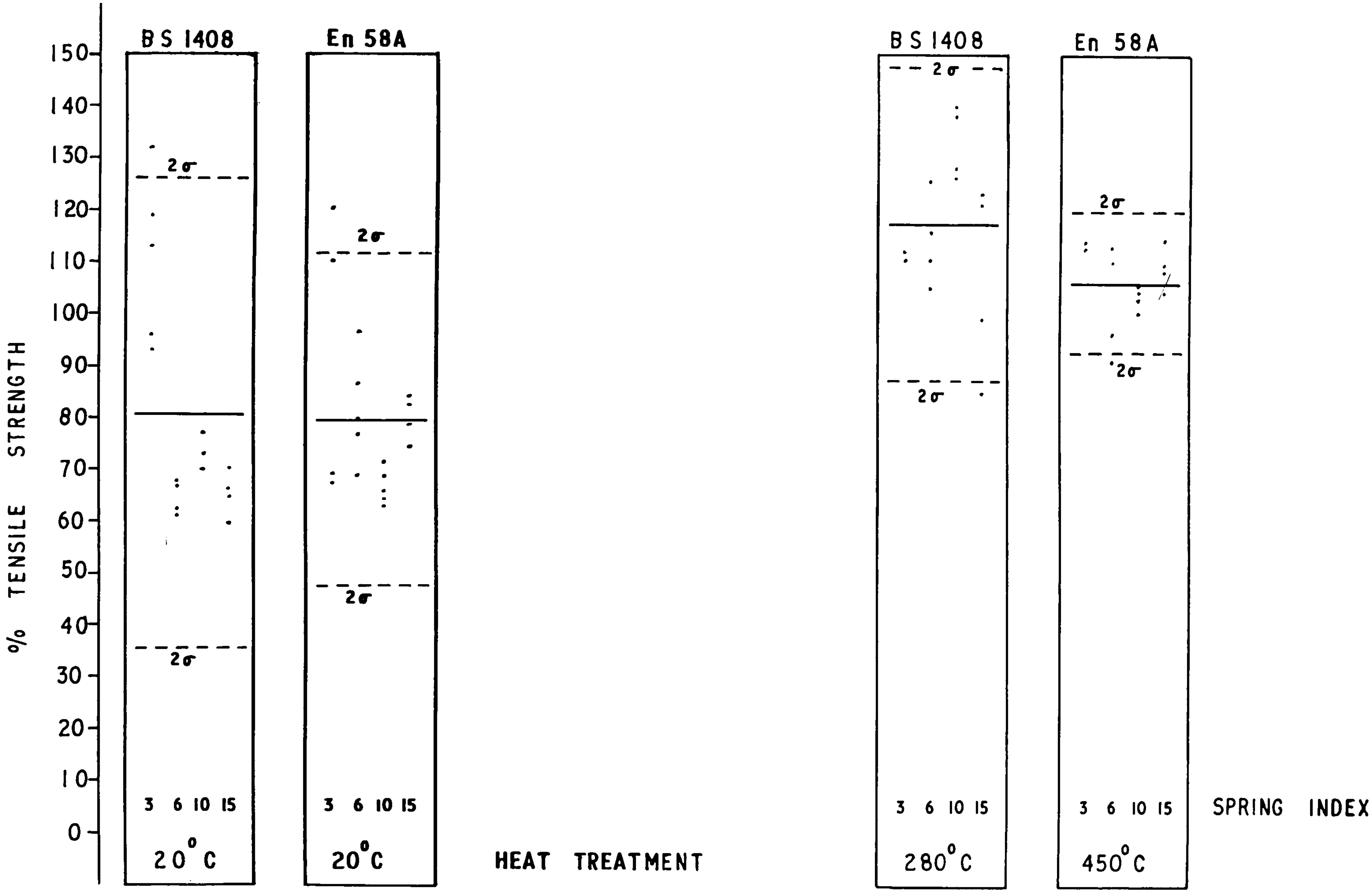


FIG. 5 MAXIMUM BENDING STRESS, EXPRESSED AS A PERCENTAGE OF TENSILE STRENGTH, AGAINST HEAT TREATMENT FOR BS 1408 B RANGE 2 & BS 2056, En 58A, USING 2·34 mm DIA. WIRE

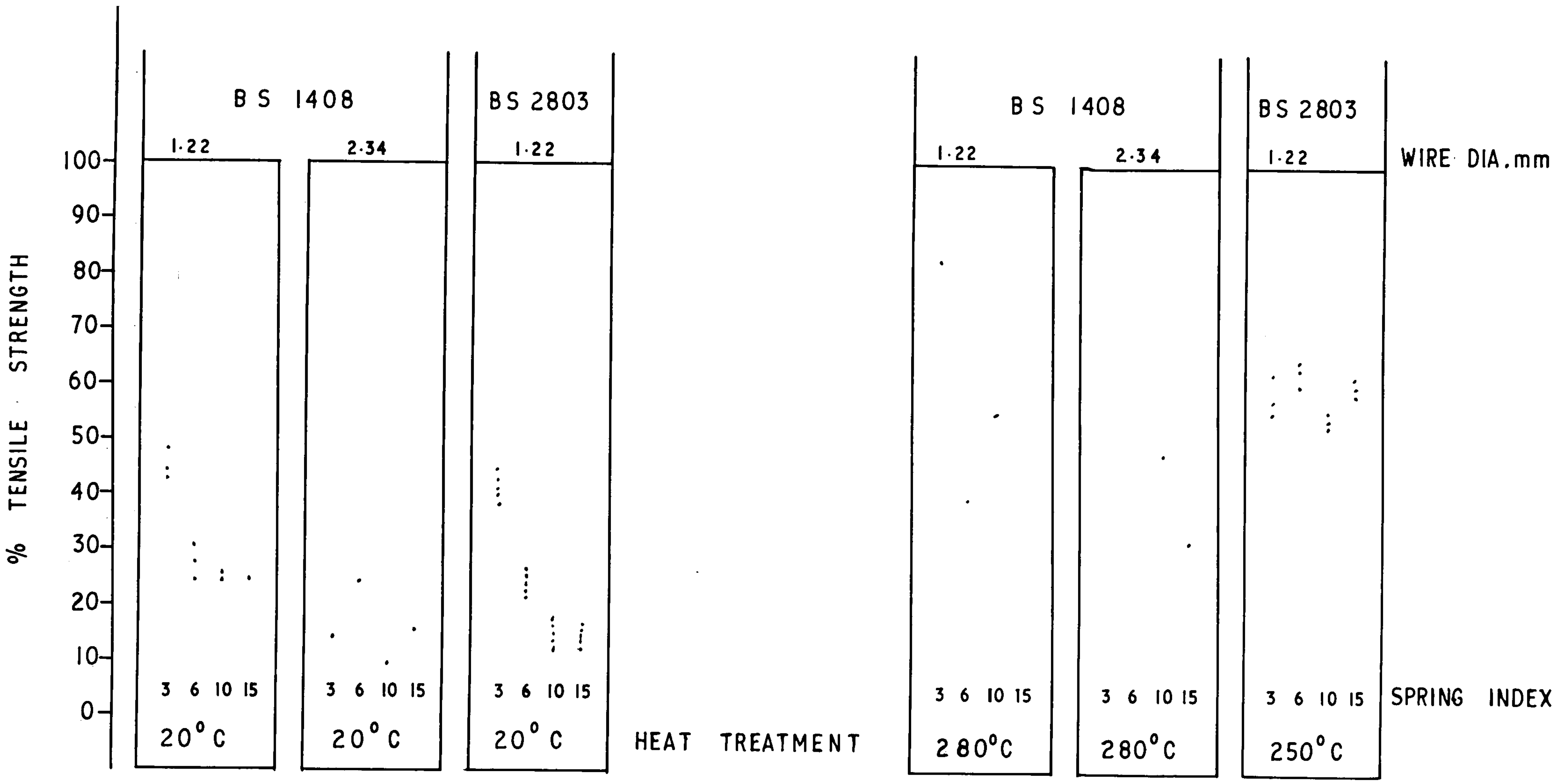


FIG. 6 MAXIMUM BENDING STRESS, EXPRESSED AS A PERCENTAGE OF TENSILE STRENGTH, AGAINST HEAT TREATMENT FOR BS 1408 B RANGE 2 & BS 2803 IN THE UNWIND DIRECTION.

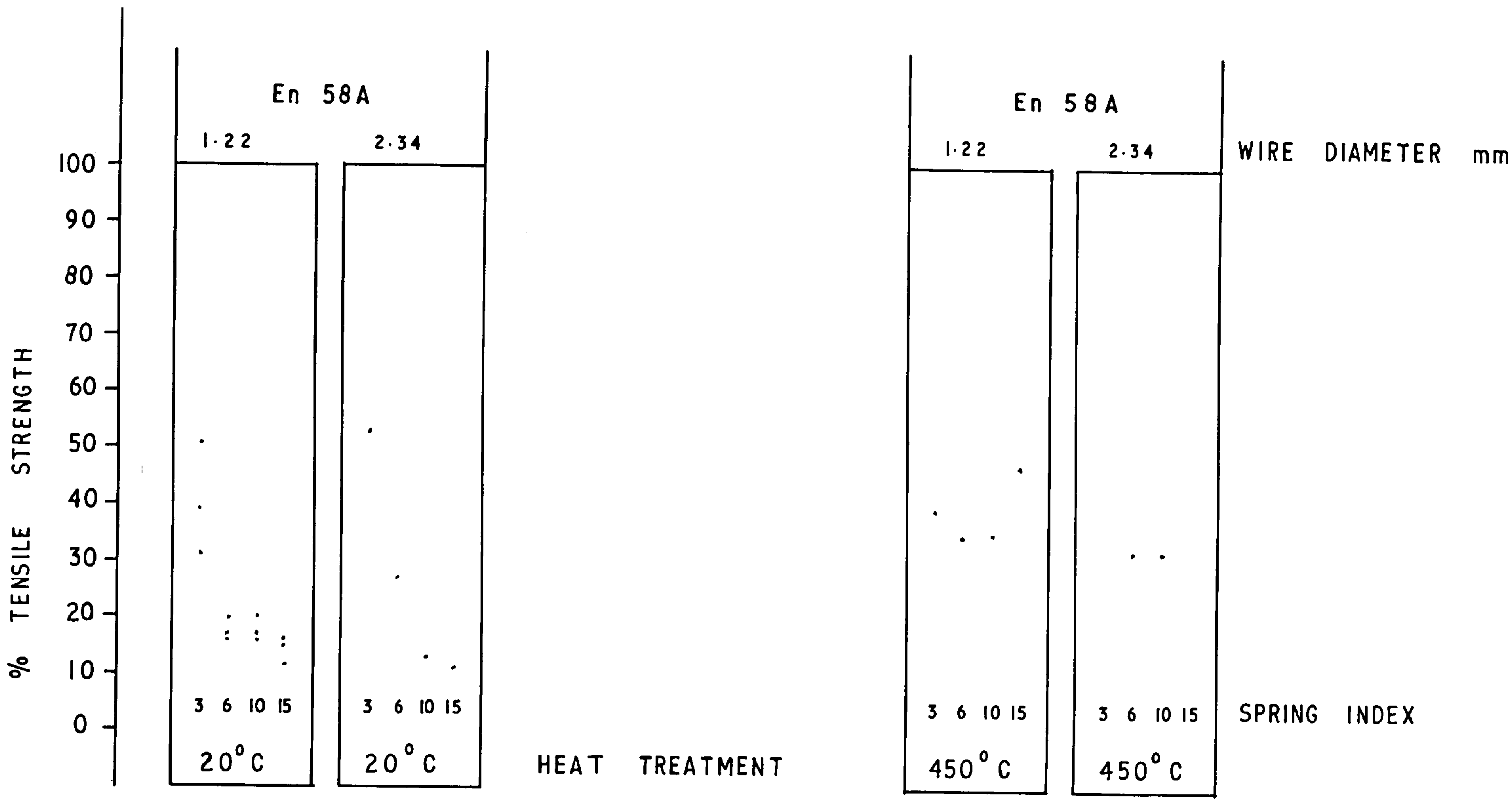


FIG. 7 MAXIMUM BENDING STRESS, EXPRESSED AS A PERCENTAGE OF TENSILE STRENGTH. AGAINST HEAT TREATMENT FOR BS 2056, En 58A, IN THE UNWIND DIRECTION.

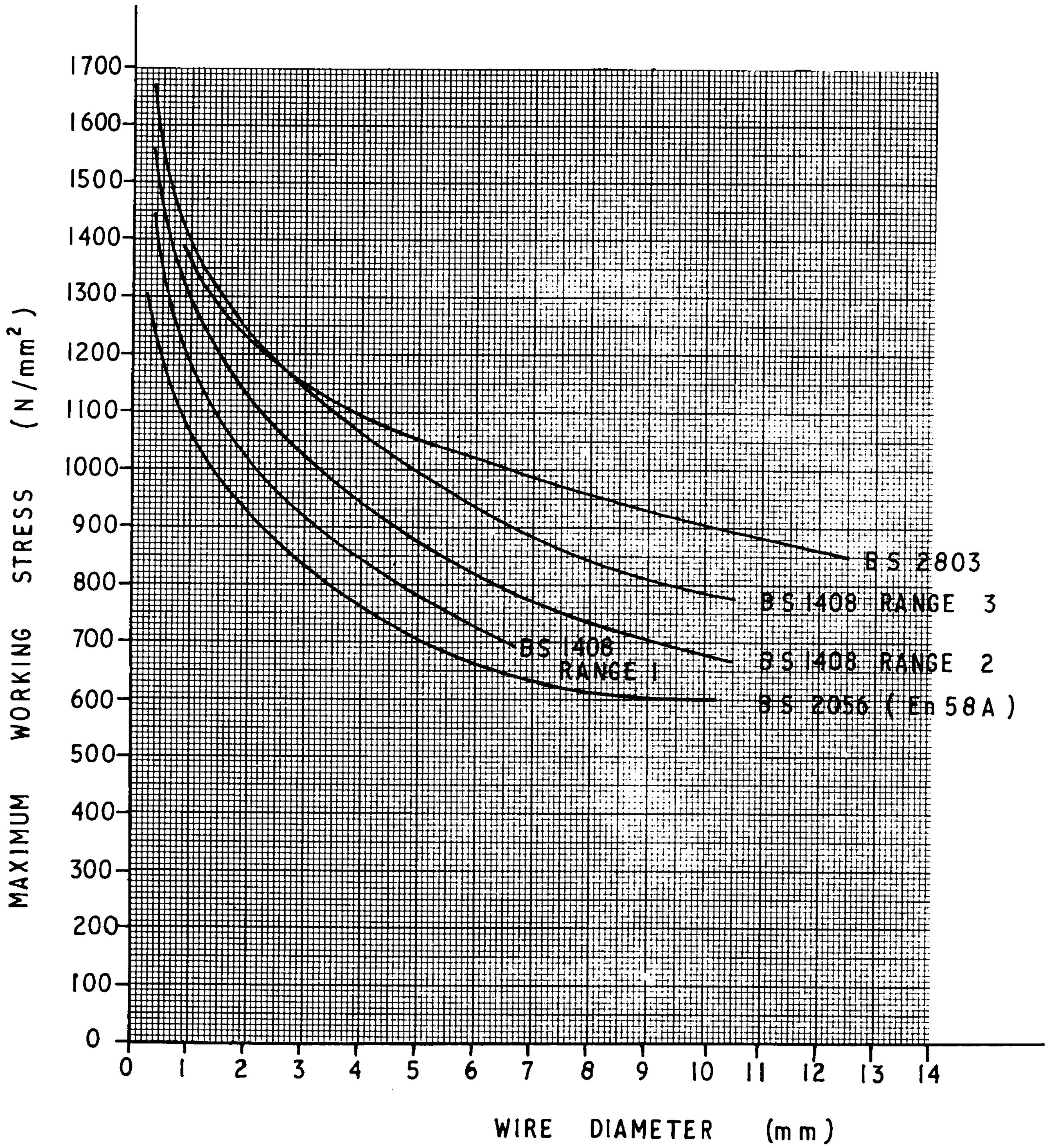


FIG. 8 GRAPH SHOWING MAXIMUM WORKING STRESS AGAINST WIRE DIAMETER FOR NON — HEAT TREATED SPRINGS