THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

AN INVESTIGATION INTO THE EFFECT OF SPINNER STRAIGHTENING WIRE

by

M.R. Southward B.Sc.

Report No. 310

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SUMMARY

Previous work by the Association involved coiling trials to ascertain the effect of roller and spinner straightening upon coiling tolerances. This work showed that spinner straightening of wire results in a greater improvement in coiling tolerances than did roller straightening.

The next step in this program of work was to investigate the effect of spinner strightening on the static and fatigue performance of the wire, and the results of this investigation are reported here. The tensile test data shows that the straightening of the wire in general reduces the proof stresses which recover after a suitable low temperature heat treatment.

The change in surface finish of the wire was recorded with a talysurf and the general conclusion was that spinner straightening improved the surface finish.

The fatigue performance of spings manufactured from spinner straightened and roller straightened wire was compared and no significant differnce in fatigue performance was recorded.

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1. INTRODUCTION

The spring industry normally uses one of two methods for the straightening of wire. The first of these employs a device, consisting of two series of rollers, one mounted vertically, the other horizontally and situated between the swift and the feed roller of an autocoiling machine.

The second method is spinner straightening, which uses only one set of fixed dies which rotate at high speed around the axis of the wire. This device is normally used to produce straight lengths of wire for wire forms or torsion springs where straight legs are required. As far as is known, it has not been attached to an autocoiling machine for the production of compressions springs.

The Association has tested these two devices separately and in combination for their effect upon free length variability of compression springs(1). The conclusion then was that spinner straightening improved coiling tolerances by a greater degree than roller straightening, but that the spinner dies had a tendency to mark the wire. Consequently the objective of this investigation was to examine the changes brought about in the wire during spinner straightening. This involved passing wire of different materials and diameters through the spinner device and measuring any change in material properties and surface condition. Fatigue tests were also undertaken to investigate whether the changes in surface condition produced by straightening were in any way harmful.

2. MATERIAL AND SPRING DESIGN

Two materials were used in this investigation, a patented cold drawn spring steel wire to BS 1408 and an austenitic stainless wire to BS 2056. Various wire sizes were employed for each material.

The spring design selected for fatigue tests is as follows:

Material : BS 1408 B Range 3

Wire diameter : 2.03 mm

Mean coil diameter : 11.5 mm

Total number of coils : 7.5

Number of active coils : 5.5

Free length (after grinding and prestressing) : 30 mm

Solid stress : 1300 N/mm^2

3. PROCEDURE

3.1 Wire Straightening

The spinner straightening device was sited between a Torrington 115A autocoiling machine and a free running swift. The power supply to the spinner head was connected in series with micro switches, attached to the coiling machine and actuated by the spring "cut off" cam follower. This ensured that power was supplied to the spinner device only when a spring was being coiled.

To enable straight lengths of wire to be collected, the coiling point assembly was removed and the coiling machine set for maximum wire length. The equipment was then switched on and a sample of wire checked for degree of straightness. This was repeated several times with adjustments being made to the spinner head until the straightest possible length of wire was achieved. Wire samples were then collected of the straightened wire and the as received wire. The whole procedure was repeated for each wire sample.

In order to determine the relativity of rotational speed of the spinner head to speed of the wire passing through, the coiling speed was varied for two wire samples.

3.2 Testing of Wire

Tensile Testing.

Four lengths of each wire sample were selected, two of which were subjected to a suitable low temperature heat treatment, and all wire samples were tested to determine tensile strength and proof stresses.

Torsion Testing.

Once again four lengths of wire were selected, two of which were heat treated, and each sample of wire was tested in the clockwise direction to determine the maximum torques. Since the spinner head also rotated in a clockwise direction tests on selected wire samples were repeated in the anticlockwise direction.

Surface Condition.

It was only possible to test certain wires due to the machine limitations on diameter of test specimens. The items of equipment used for testing were:

a) Linear talysurf

b) Rotary talysurf

c) Talyrond

The latter method was to measure ovality in the wire.

Fatigue Testing.

Springs were coiled to the same spring design from as received and straightened wire then subjected to a low temperature heat treatment. The springs for each condition were divided into batches of ten. First one batch from each type was tested at an initial stress of 100 N/mm^2 and a maximum stress of 800 N/mm^2 until failure or 10,000,000 cycles were reached. This was followed by a second test for another two batches of springs at the same initial stress but at a maximum stress of 700 N/mm^2.

4. RESULTS

The dies in the spinner head were adjusted for each wire sample in order to obtain the straightest possible length of wire. A visual indication to the degree of distortion of the wire when passing through the head is shown in Fig. 1. The maximum distortion occurs at the 'lead in' end of the head.

Tensile test data has been separated into table I for the carbon steel wire and table II for the stainless steel wire.

No results have been tabulated for the torsion tests as no differences could be detected in maximum torque for the as received wire, compared with the spinner straightened wire. Also there was no difference for varying wire speeds and different directions of twisting.

Numerical results of the surface roughness for the samples are shown in table III while a visual indication is given by Figs. 2 and 3 for round the wire and Figs. 4 and 5 for along the wire. The cross sectional profile of the wire is depicted in Figs. 6, 7 and table III.

The fatigue test results have been collated in table IV. These show spring life in number of cycles to failure or whether they survived 10,000,000 cycles, at which point they were then removed from the fatigue machine.

5. DISCUSSION

5.1 Tensile Test Data

This data has been divided to enable the results for each material to be analysed separately.

Table I contains the results for the carbon steel wires and will be considered first. Straightened wire samples numbers 2, 3 and 4 all originate from the as received sample number 1, but they have been passed through the spinner head at three different wire speeds. Considering only the proof stresses for these straightened wires without any LTHT shows no significant difference, similarly for the tensile strengths though there is an indication that a higher wire speed may increase tensile strength. Comparison of these values with the as received wire shows a suppression of proof stresses with straightening and virtually no change in tensile strength. A suitable low temperature heat treatment of the wire samples enabled the as drawn properties to be retained.

Wire samples numbers 10 and 11 originate from sample number 9 but have been passed through the spinner head without and with a lubricant respectively. Comparison of these three sets of results shows a much greater suppression of proof stresses for the non lubricated wire but both wires recover after being subjected to a suitable low temperature heat treatment. The tensile strength of the wire appears independent of lubrication.

Analysing all the data for the carbon steel wire indicates a general trend of spinner straightening depressing proof stresses without affecting tensile strength. But after a suitable low temperature heat treatment there is little difference in tensile properties in the two wire conditions. The exceptions are two larger wire diameters that appear unaffected by the spinner straightening process.

The tensile data for the stainless steel wire is shown in table II. Once again a sample of wire was passed through the spinner head at different wire speeds. This showed no change in tensile strength but a larger suppression of proof stresses at the slower speed occurred. A suitable low temperature heat treatment eliminated this difference but still indicated a slight reduction of proof stresses for spinner straightened, but no change in tensile strength.

Comparing all the wire samples in table II shows a considerable variation in tensile strength for both conditions of wire, but all these variations are reduced by a suitable low temperature heat treatment. Similarly proof stresses which are reduced by straightening recover after a low temperature heat treatment. Also the larger wire size does appear to be affected by spinner straightening which is contrary to the result obtained with carbon steel wire.

5.2 Torsion Test Data

These tests measured only the maximum torque for each wire sample. The results showed no difference due to direction of testing or speed of wire through the spinner head. Also there was no difference between the as received wire and the straightened wire, whether the wire was lubricated or not. Even a suitable LTHT had no significant effect upon the results.

5.3 Surface Condition

Due to the difficulties of measuring the surface condition of small diameter specimens only the larger wire samples used in this investigation were sent for testing. The numerical values (centre line average) attributed to the surface condition are shown in table III. A pictorial indication of surface conditions is given by the rotary surface profiles for 180° in Figures 2 and 3, all being recorded with a magnification of 2000 in the vertical direction and 50 in the horizontal direction. The linear profiles are depicted in Figures 4 and 5 being recorded with magnifications of 2000 in the vertical direction and 10 in the horizontal. The readings of centre line average using the rotary talysurf were recorded at differing positions around the circumference of the wire and show a large variation. With one exception straightened wire appears to have a slightly improved surface condition over the as received wire. The results for the linear surface condition indicate the same possible trend but with less definition. Also included in table III are the results from the talyrond examinations where the cross section of the wire is depicted by Figs. 6 and 7. This shows considerable ovality of some wire samples but no indication of a difference between the two wire conditions. Unfortunately it was impossible to extend the scope of the research into larger wire diameters owing to the limitations of the spinning device.

5.4 Fatigue Testing

In total 40 springs were tested until either failure when their life was measured in number of cycles or they reached 10,000,000 cycles and were removed from the machine and the data recorded in table IV. The results for the highest stress level indicate considerable variation for each condition of wire but no significant difference between the averages. As these lives were comparatively short a second test was initiated at a lower maximum stress level, the initial stress remaining as before. These results showed more survivors for the as received wire but no significant difference in the average life of the failed springs. Examination of the broken springs produced from spinner straightened wire, detected a marking of the wire, caused by the spinner head, at 1½ coils from one end, which was in fact the point of failure for these springs.

6. CONCLUSIONS

1. Spinner straightening of carbon steel wire or stainless steel wire reduces proof stresses without affecting tensile strength for the majority of wire samples.

2. Tensile properties for both conditions of wire are the same after subjecting them to a suitable low temperature heat treatment.

3. The maximum torsional strength for both materials is unaffected by spinner straightening.

4. Speed of wire through the spinner head has no significant affect upon tensile or torsional properties for the speed range considered.

5. The surface condition shows a slight improvement after straightening but more data is necessary before a definite trend can be discovered.

6. The fatigue life of a spring manufactured from the spinner straightened wire is similar to that for non straightened, but further tests are necessitated due to marking on the wires by the spinner head.

7. REFERENCE

Southward, M.R. The effect of roller and spinner straightening on the free length variability of springs made on an auto-coiling machine. SRAMA Report No. 269.

TABLE I. TENSILE TEST DATA FOR CARBON STEEL WIRE

Sample No.	Wire Condition	Wire speed m/s	Wire diameter mm	Heat treatment	Tensile strength N/mm^2	Proof Stress N/mm^2		
						0.2%	0.1%	0.05%
1	As received	-	1.22	-	1900	1800	1695	1475
	As received	-	1.22	225°C/½hr	1950	-	1925	1850
2	Spinner	0.58	1.22	-	1825	1550	1400	1250
	Straight	0.58	1.22	225/½	1900	-	1875	1800
3	Spinner	0.90	1.22	-	1850	1575	1400	1250
	Straight	0.90	1.22	225/½	1950	-	1925	1875
4	Spinner	1.21	1.22	-	1900	1600	1400	1225
	Straight	1.21	1.22	225/½	1975	-	1950	1900
5	As received	-	2.64	-	1650	1275	1100	925
	As received	-	2.64	225/½	1750	1625	1525	1400
6	Spinner	0.57	2.64	-	1650	1275	1100	950
	Straight	0.57	2.64	225/½	1750	1650	1600	1500
7	As received	-	2.03	-	1775	1450	1300	1100
	As received	-	2.03	225/½	1925	-	1875	1800
8	Spinner	0.57	2.03	-	1750	1425	1250	1125
	Straight	0.57	2.03	225/½	1875	-	1800	1700
9	As received	-	1.22	-	2125	-	2025	1925
	As received	-	1.22	225/½	2125	2100	2025	1950
10	Spinner	0.57	1.22	-	2100	1900	1675	1475
	Straight	0.57	1.22	225/½	2125	-	2075	2000
11	Spinner	0.57	1.22	-	2075	1825	1575	1350
	Straight	0.57	1.22	225/½	2200	2150	2125	2050

TABLE II. TENSILE TEST DATA FOR STAINLESS STEEL WIRE.

Sample No.	Wire Condition	Wire speed m/s	Wire diameter mm	Heat treatment	Tensile strength N/mm^2	Proof Stress N/mm^2		
						0.2%	0.1%	0.05%
21	As received	-	1.22	-	1975	1775	1600	1400
	As received	-	1.22	450°C/2hr	1925	1825	1650	1475
22	Spinner	0.57	1.22	-	1850	1500	1300	1125
	Straight	0.57	1.22	450/2	1950	1775	1625	1450
23	As received	-	2.03	-	1775	1550	1275	1025
	As received	-	2.03	450/2	1900	1775	1575	1375
24	Spinner	0.57	2.03	-	1725	1375	1150	875
	Straight	0.57	2.03	450/2	1900	1625	1375	1150
25	Spinner	0.91	2.03	-	1750	1450	1250	1050
	Straight	0.91	2.03	450/2	1900	1625	1375	1125
26	As received	-	1.62	-	1725	-	1575	1375
	As received	-	1.62	450/2	1900	1800	1650	1500
27	Spinner	0.57	1.62	-	2050	1825	1600	1400
	Straight	0.57	1.62	450/2	1900	1825	1600	1400

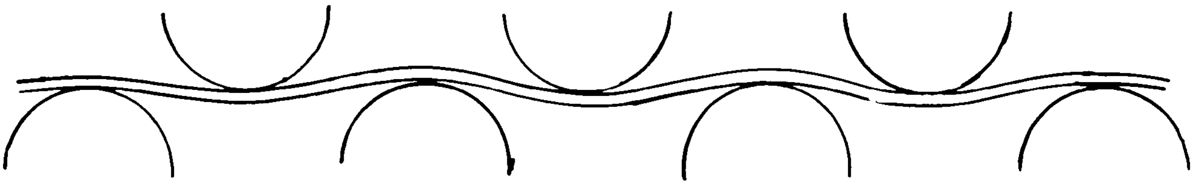
TABLE III SURFACE CONDITION DATA

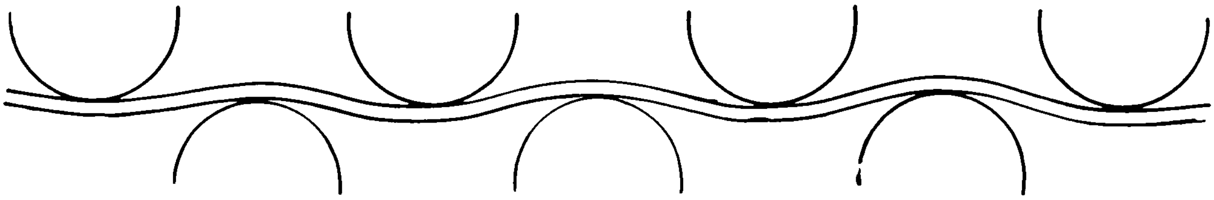
Material	Wire Diameter mm	Rotary Talysurf CLA value (μmm)						Linear Talysurf CLA value (μmm)			Wire Ovality on Diameter mm
BS 1408(AR)	2.64	380	405	455	535	510	685	355	355	250	0.008
(SS)	2.64	280	430	510	180	430	255	305	355	430	0.016
BS 1408(AR)	2.03	865	685	710	990	1040	965	1090	860	1145	0.032
(SS)	2.03	760	510	785	710	635	460	760	760	780	0.030
En58A (AR)	2.03	380	255	280	535	510	380	660	305	280	-
(SS)	2.03	710	330	480	635	510	330	255	255	405	0.014
En58A (SS)	1.62	330	330	430	305	585	230	685	685	560	-
En58A (SS)	1.22	180	305	460	460	280	255	585	685	510	-
BS 1408(SS)	1.22	510	535	455	455	635	480	710	610	735	

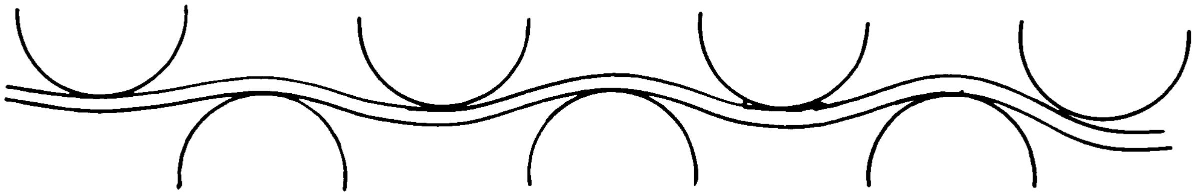
TABLE IV FATIGUE DATA

Fatigue Life Number of cycles X10^3			
Max stress 800 N/mm^2		Max stress 700 N/mm^2	
As received wire	Spinner Straight wire	As received wire	Spinner Straight wire
270	225	2079	423
234	198	774	2772
234	270	2214	3501
207	234	Unbroken	405
261	171	Unbroken	459
225	324	Unbroken	Unbroken
216	198	Unbroken	Unbroken
288	117	Unbroken	4941
198	342	375	Unbroken
		7263	1926

FIG. 1 PROFILES OF SPINNER HEAD


CARBON STEEL WIRE DIAMETER 1·63 mm


CARBON STEEL WIRE DIAMETER 2·03 mm


STAINLESS STEEL WIRE DIAMETER 2·03 mm


CARBON STEEL WIRE DIAMETER 2·64 mm

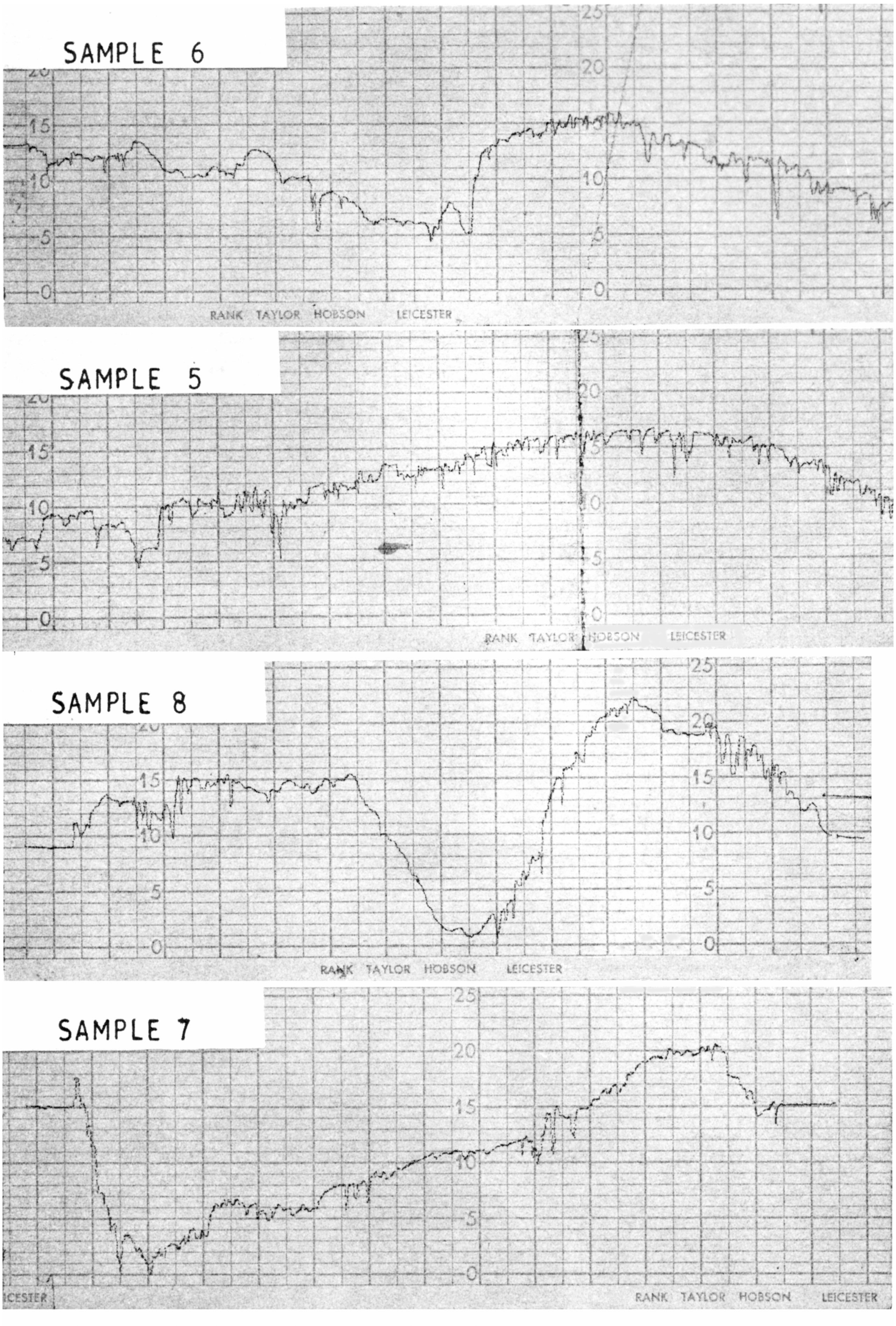


FIG. 2 Typical surface profile for the semi circumferences of carbon steel wires

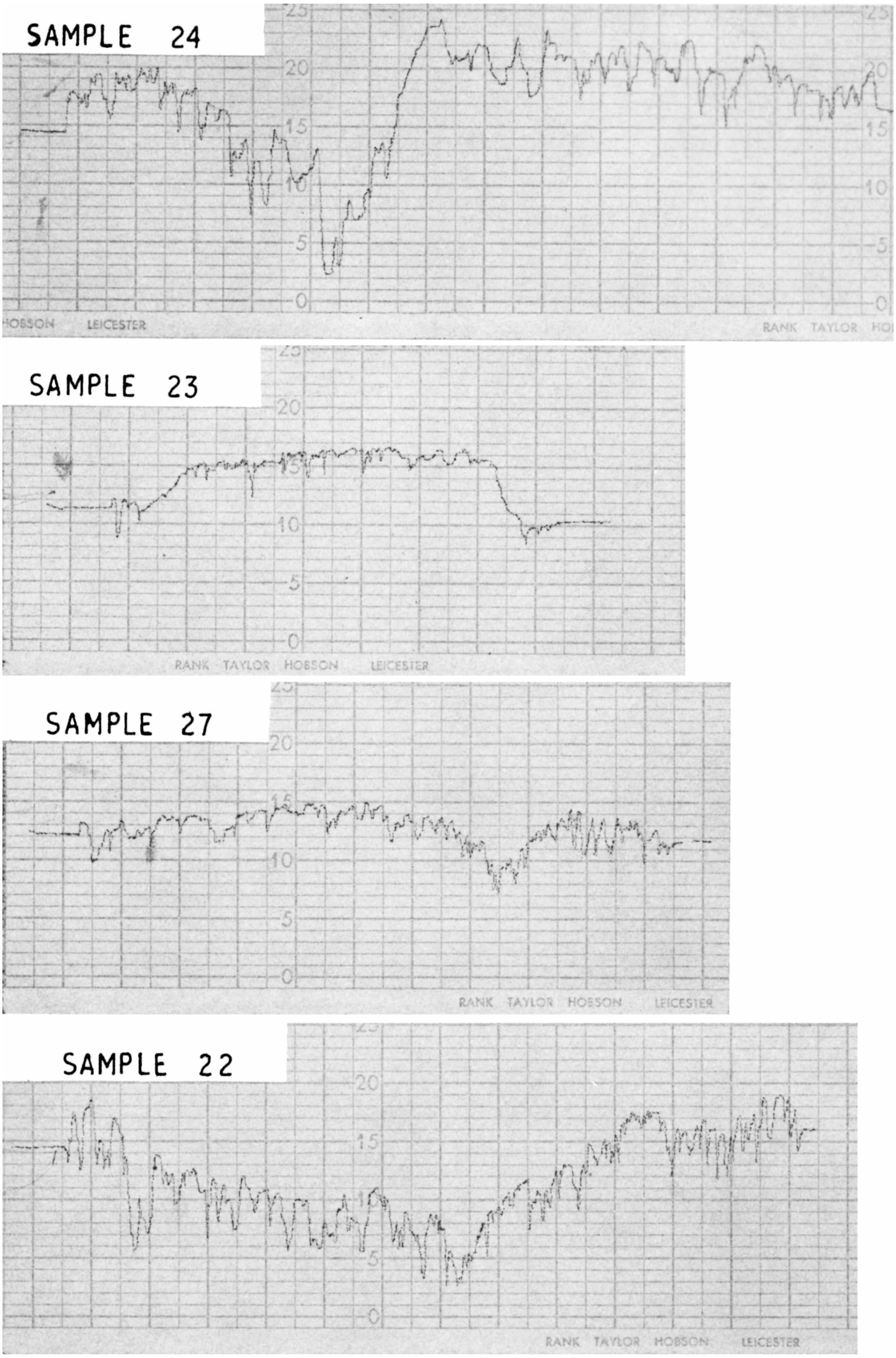


FIG. 3 Typical surface profiles for the semi circumference of stainless steel wire

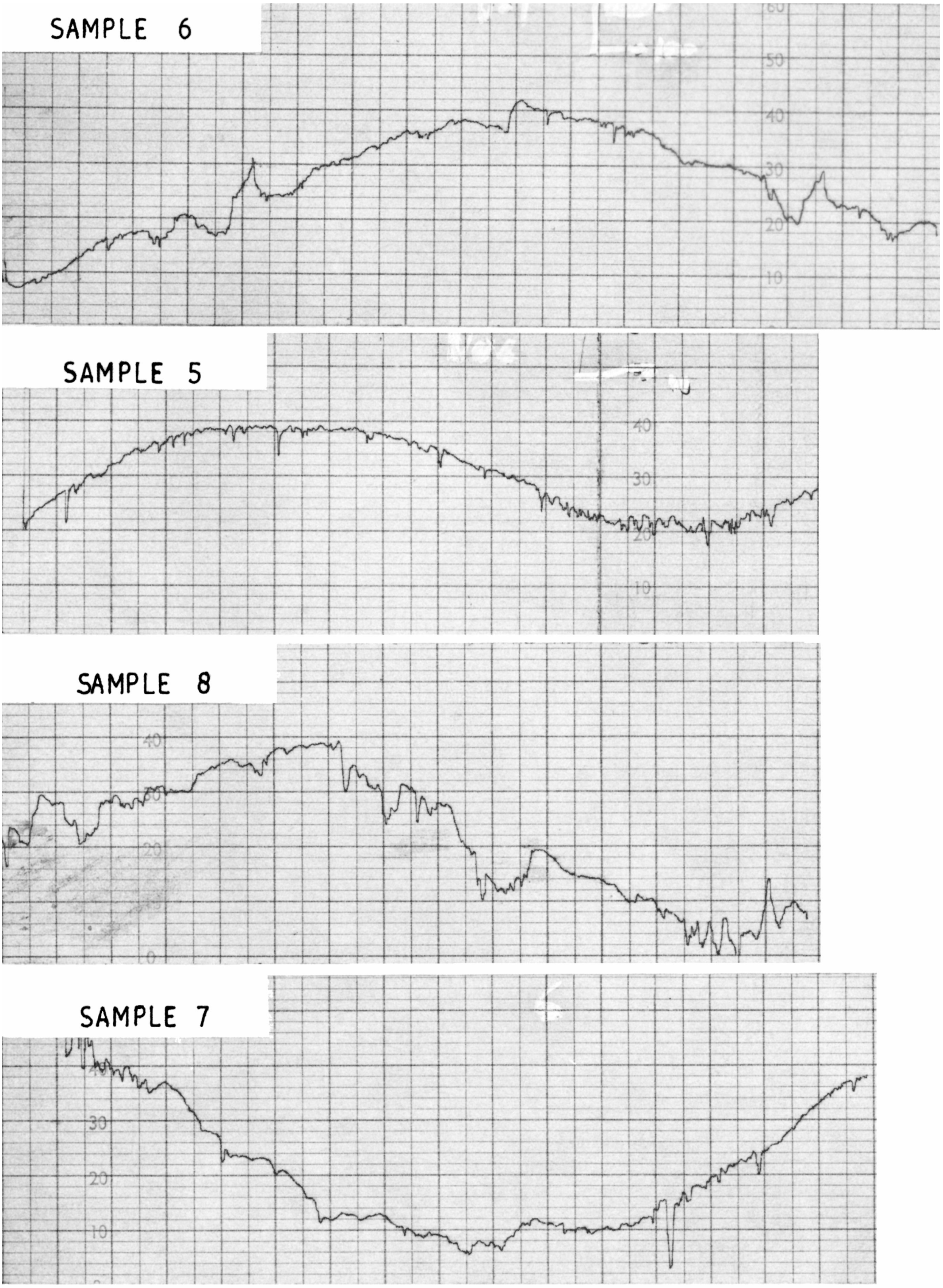


FIG. 4 Typical surface profiles along samples of carbon steel wire

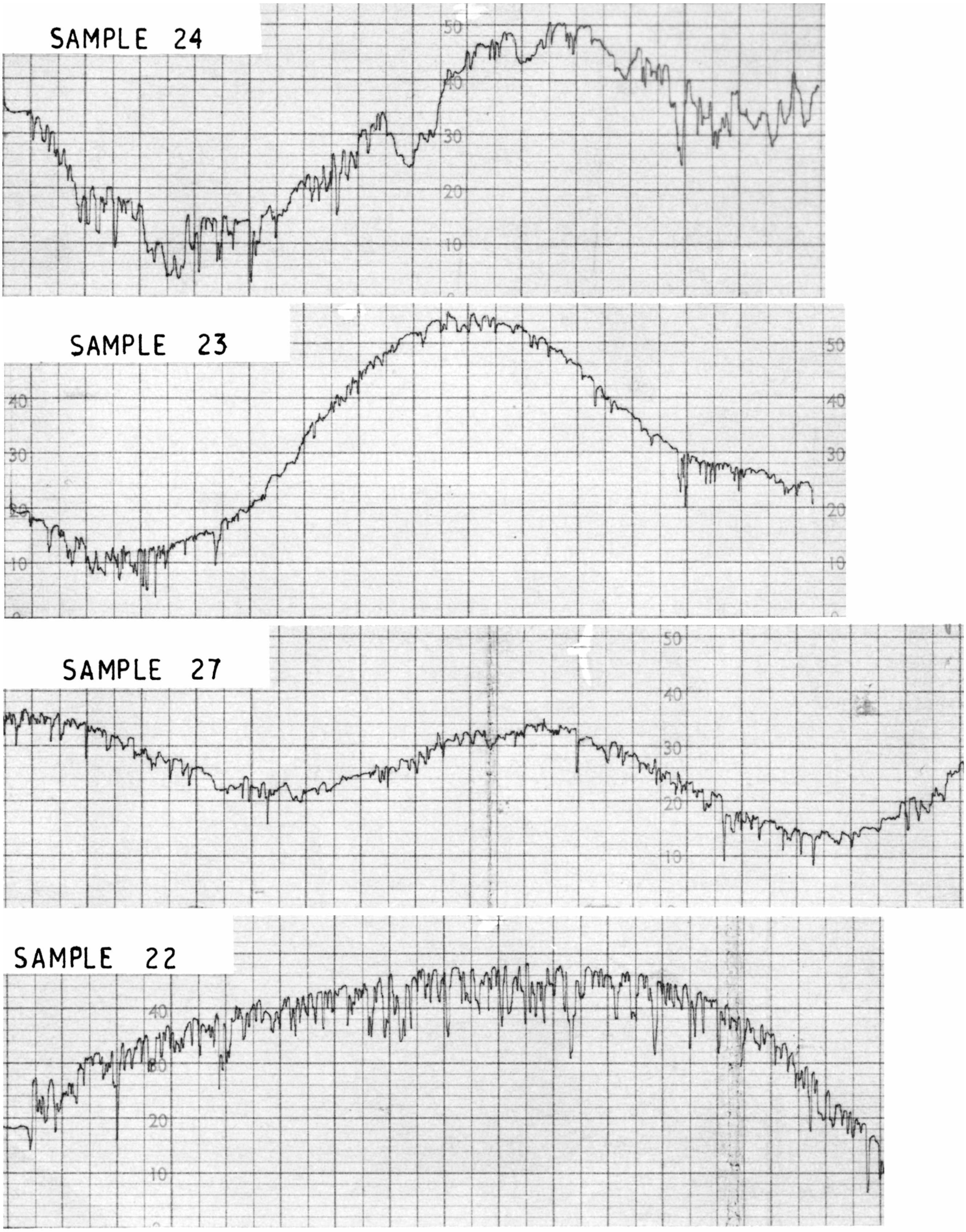


FIG. 5 Typical surface profiles along samples of stainless steel wire

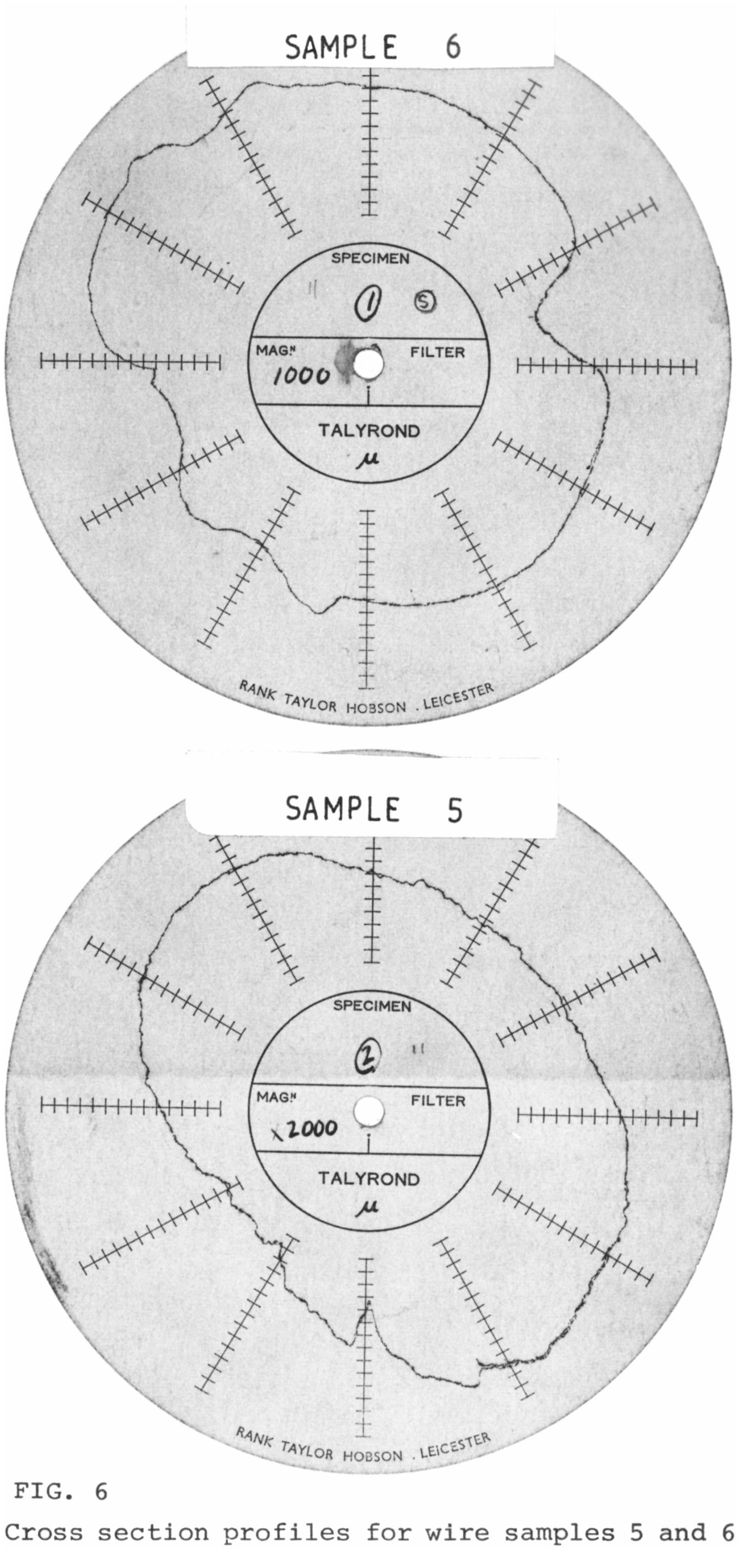
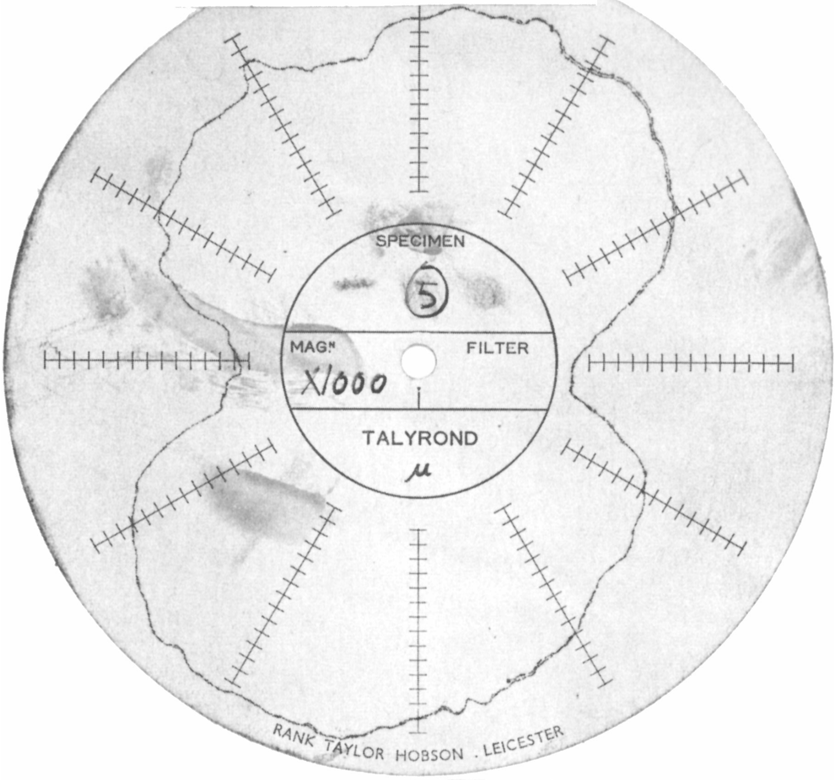


FIG. 6

Cross section profiles for wire samples 5 and 6

SAMPLE 8



SAMPLE 7

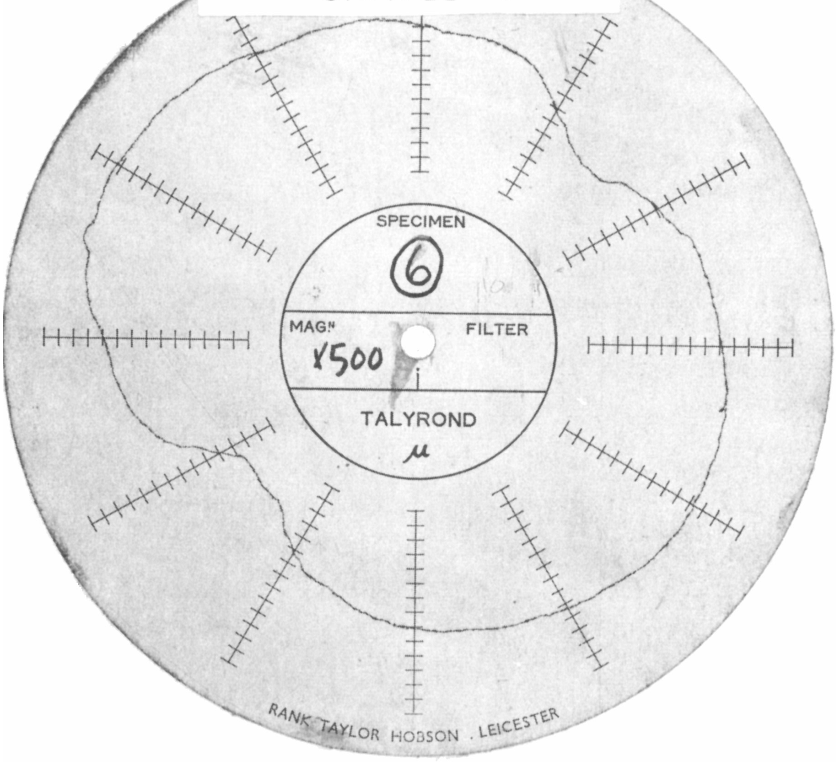


FIG. 7
Cross section profiles for wire samples 7 and 8