THE SPRING RESEARCH ASSOCIATION

THE EFFECT OF ROLLER STRAIGHTENING ON THE FREE LENGTH VARIABILITY OF SPRINGS MADE ON AN AUTOCOILING MACHINE

by

I. B. R. Elliott, C.Eng., M.I.Prod.E.

Report No: 207

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SUMMARY

A series of experimental coiling trials was undertaken in order to compare the variability of spring dimensions when coiling with and without roller straighteners.

Statistical analysis of the data obtained from spring free length measurement showed that the use of roller straighteners, when coiling the spring design selected, caused a 24% reduction in the variability of the free lengths. There was a slight, but significant, increase in mean free length. This was 0.004 in (0.33%).

The use of roller straighteners enabled the coiling tolerance to be brought within the British Standard Specification.

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CONTENTS

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1. INTRODUCTION

Roller straighteners are usually fitted to autocoiling machines so as to provide a means of automatically straightening wire before coiling. Often spring wire will already have been straightened as part of the manufacturing process and therefore it is sometimes the practice not to use rollers as straighteners but as guides only.

This report describes an experiment which was conducted to ascertain whether or not the use of roller straighteners is worthwhile, by examining the difference in coilability of un-roller straightened and roller straightened spring steel wire.

2. MATERIAL

A commonly used spring material was chosen for this investigation; this was 0.048 in diameter patented cold drawn spring steel wire to B.S. 1408C Range 2.

3. SPRING DESIGN

One spring design was used throughout the experiment as follows:-

Nominal wire diameter	0.048	in
Nominal free length	1.2	in
Nominal outside diameter	0.3	in
Total no. of coils	16	
Index	$5^1/4$	
Ends closed but not ground		

4. EXPERIMENTAL PROCEDURE

4.1 Experiment Design

It was suspected that the effect of roller straighteners on the free length variability might be small, therefore the repeatability of the results was checked by repetition of the experiment. This also increased the amount of data, thereby providing greater statistical significance to the end result. Repetition revealed the small drift effects which occurred due to changes in wire properties and tooling wear.

The experiment design was for 500 springs to be made for each of six coiling trials. The experimental order was as follows:-

RUN NO.	NO. MADE	ROLLERS
1	500	ON
2	500	OFF
3	500	ON
4	500	OFF
5	500	ON
6	500	OFF

4.2 Roller Adjustment

The rollers were the standard type as fitted by the Torin Corporation and consisted of sealed ball bearings in which central 'V' grooves had been machined around the periphery of the outer cases (Fig. 4). They were independantly adjustable for wire displacement and were in two series of seven; horizontally and vertically opposed.

For the first run the rollers were used. These were set on the wire by means of a lever operated loading device. The rollers were adjusted so that their displacement was approximately equal and sufficient just to cause the maximum wire straightening without producing any wave forms in the wire. The displacement was as shown in Fig. 5.

4.3 Wire Measurements

The curvature and dimensions of the free form of the wire were measured before and after straightening and are given below:-

INSPECTION OF WIRE

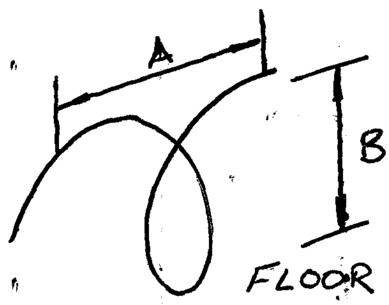
Un-Straightened

A Pitch: 3ft - 4ft approx.

B Height (dia. perpendicular to floor): 1½ ft

C Diameter: 2ft - 2½ft approx.

D Flatness (2ft coil, 2 turns): 1½ ft



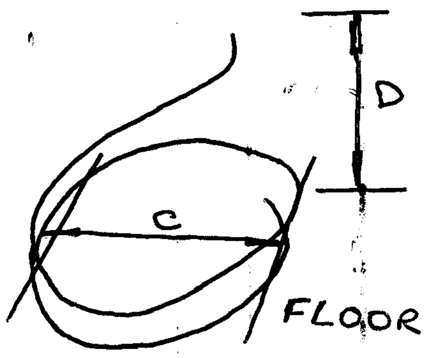
Straightened

A Pitch: 5ft - 7ft approx.

B Height: 2ft - 3ft

C Diameter: 3ft - 4ft approx.

D Flatness (3ft coil, 2 turns): 6 in



4.4 Coiling

The spring design was produced on a Torrington 115A auto-coiling machine equipped with a tungsten carbide coiling point.

The wire was coiled on an 8 in reel by the manufacturers. A free-running swift was used for the wire feeding arrangement.

Once the machine had been set to the operator's satisfaction, springs were coiled at a constant rate of approximately 20 per minute. For each run a batch comprising 500 springs was coiled applying the rollers where appropriate according to the experiment design. The last 10 consecutive springs in every 50 were collected and identified in sequential order, thus giving 10 sub-samples of 10 springs each.

5. STATISTICAL ANALYSIS

Having obtained the samples of 100 springs each, measurements of free length were made on a Nikon profile projector. The variances, standard deviations and means of free length were calculated for each run and for the data collectively for those runs (a) with and (b) without the use of rollers.

The F ratio test was applied to the overall variances to determine whether or not the difference between the variabilities (with and without roller straighteners) was significant. The Student t test was applied to the overall means to determine whether the difference between the mean free lengths was significant.

The root mean squares of the variances of the runs with rollers both 'on' and 'off' were found for the short term analysis. The F ratio test was applied so that the significance of the immediate effect of roller straighteners without the influence of drift could be found.

The British Standard 1726 tolerance equation gives a manufacturing tolerance for the spring design used of ± 0.024 in. 3σ limits have been used for comparison with this.

6. RESULTS

Run	Rollers	Mean (in)	Repeatability Test		
			$\pm\sigma$ (in)	$\pm 2\sigma$ (in)	$\pm 3\sigma$ (in)
1	ON	1.194	±0.0055	±0.0110	±0.0166
2	OFF	1.187	±0.0065	±0.0130	±0.0194
3	ON	1.197	±0.0062	±0.0124	±0.0186
4	OFF	1.197	±0.0070	±0.0140	±0.0211
5	ON	1.199	±0.0066	±0.0133	±0.0199
6	OFF	1.196	±0.0082	±0.0165	±0.0247

The data obtained from the investigation are given above and the overall effect of roller straighteners on spring coilability is shown below:-

Rollers	Mean (in)	Overall Tolerances		
		$\pm\sigma$ (in)	$\pm 2\sigma$ (in)	$\pm 3\sigma$ (in)
ON	1.197	±0.0065	±0.0130	±0.0195
OFF	1.193	±0.0086	±0.0172	±0.0258

Overall significance of difference between variabilities:
(F Test) 99% probability level

Overall significance of difference between means:
(t Test) Better than 99% probability level

Rollers	Mean (in)	Short Term Tolerances		
		$\pm\sigma$ (in)	$\pm 2\sigma$ (in)	$\pm 3\sigma$ (in)
ON	1.197	±0.0061	±0.012	±0.018
OFF	1.193	±0.0073	±0.015	±0.022

Short term effect of Roller Straighteners significant at the 95% probability level (F ratio test).

B.S. Tolerance

$$\pm (0.005 + 1\tfrac{1}{4}\% \text{ FL}) (1 + \frac{c}{25})$$

where FL (free length) = 1.2 in, c (spring index) = 5.25

B.S. Tolerance = ±0.024 in

The overall (long term) effect of the use of roller straighteners was to reduce the spring free length variability by 24%, that is, from ± 0.0258 in to ± 0.0195 in (3σ limits). This effect was significant at the 99% probability level.

The use of roller straighteners also caused a significant overall increase in mean free length of 0.004 in.

7. DISCUSSION

The use of Roller Straighteners may, besides straightening wire, further improve coiling tolerances due to the fact that the wire tension is kept approximately constant between the roller straighteners and drive rolls.

The effect of roller straighteners was ascertained by the analysis of the total data in two sets; one with the use of roller straighteners and one without. By this method it was found that the reduction in free length variability obtained with the use of roller straighteners was highly significant. Reciprocation of the experimental runs and the analysis of the short term variability eliminated the influence of drift on the accuracy of determination of the effect of roller straighteners on coilability.

The use of roller straighteners brought the coiling tolerance well within that of British Standard 1726 and caused a small, but significant, increase in free lengths. This was from a mean of 1.193 in to a mean of 1.197 in.

8. CONCLUSIONS

1. The use of roller straighteners caused a highly significant reduction in free length variability of 24%, i.e. from $\pm$0.028 in to $\pm$0.0195 in.

2. The use of roller straighteners caused a slight increase in the mean spring free length (0.004 in or 0.33%).

3. The free length tolerance specified by B.S. 1726 (0.024 in) for the spring design used was maintained only when using the roller straighteners.

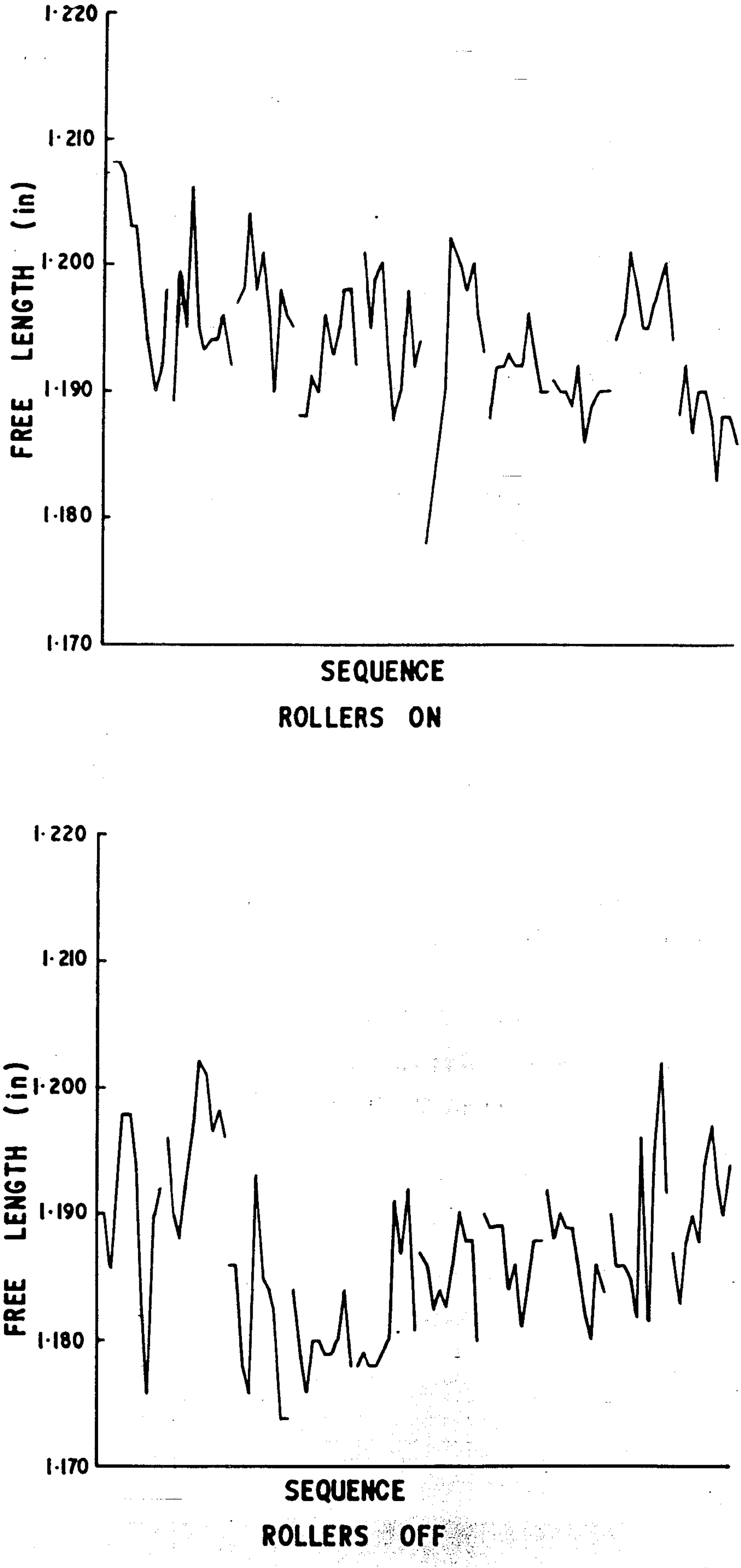


FIG. 1 SEQUENCE CURVES FOR RUNS 1 AND 2.

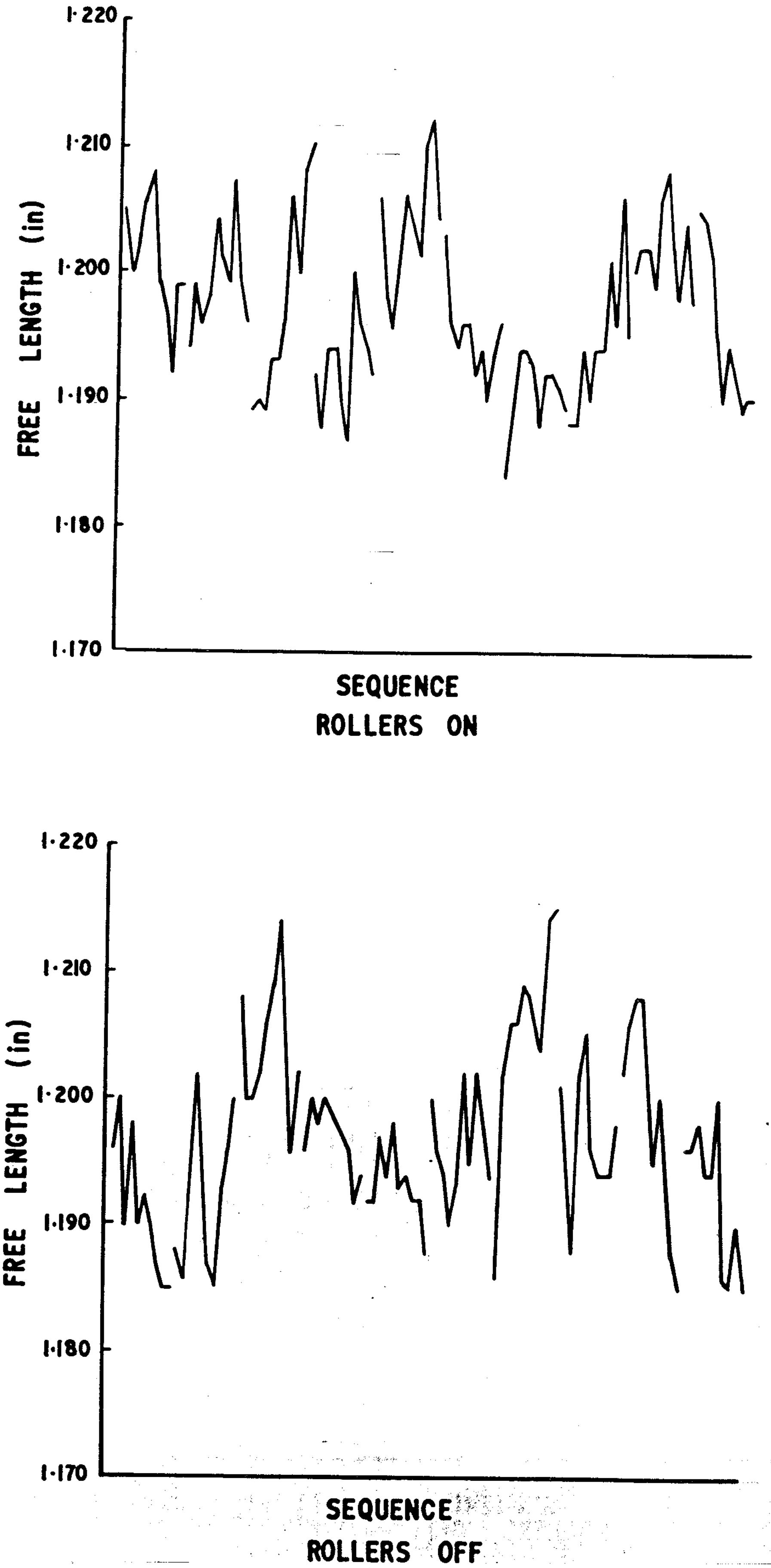
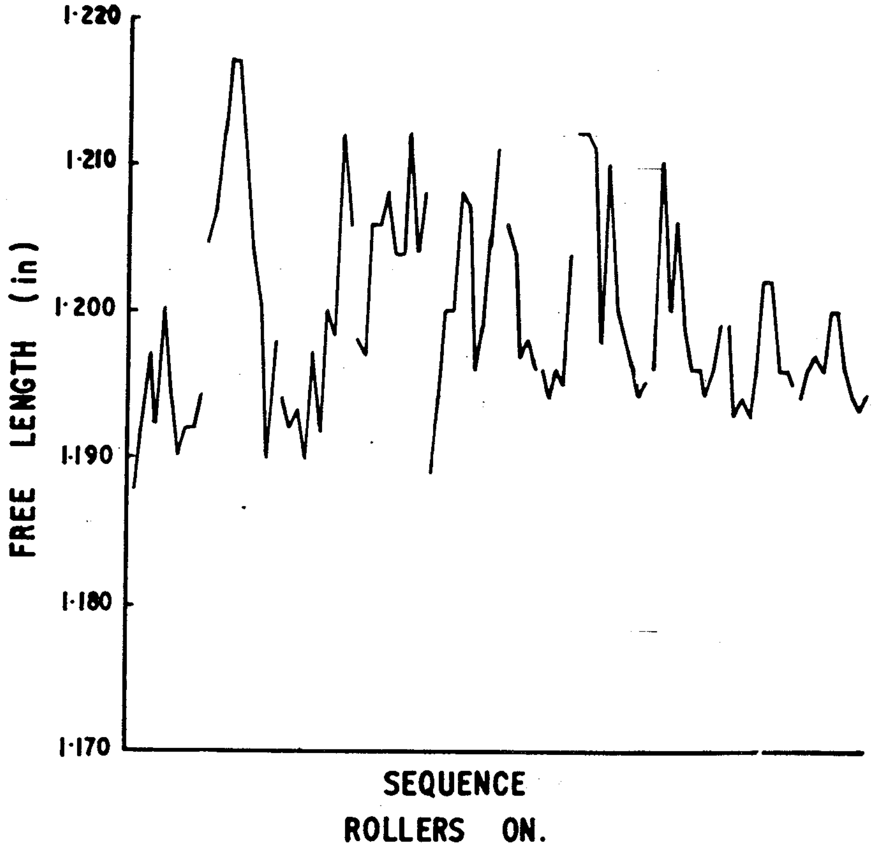


FIG. 2 SEQUENCE CURVES FOR RUNS 3 AND 4



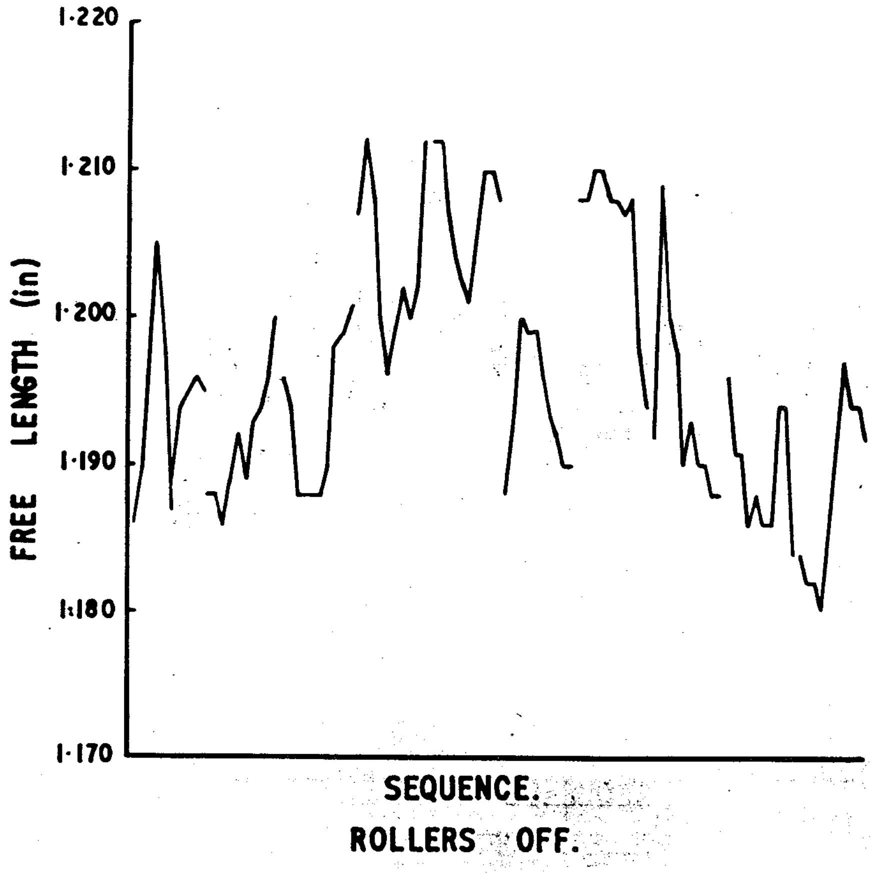


FIG. 3 SEQUENCE CURVES FOR RUNS 5 AND 6.

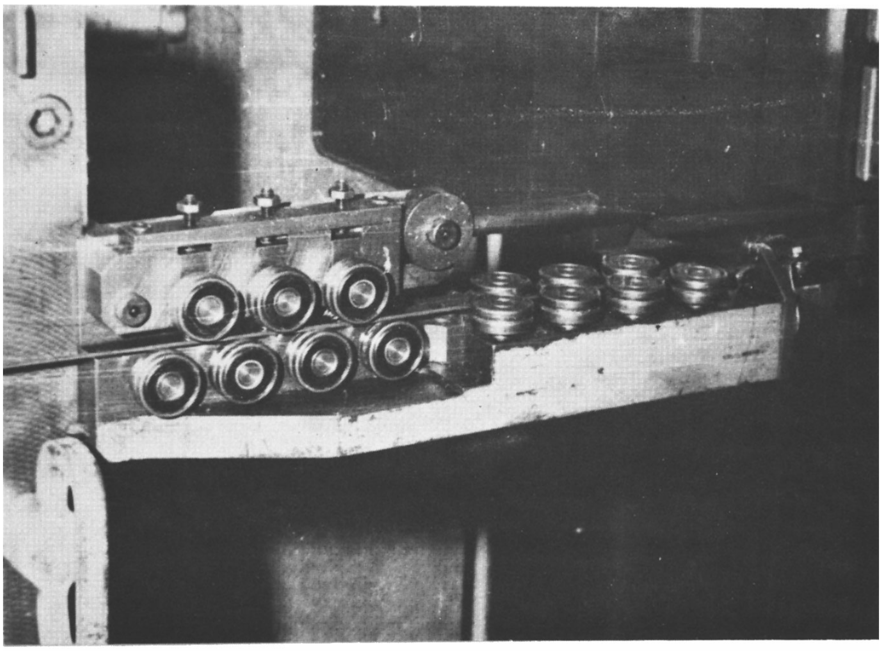


FIG. 4. THE ROLLER STRAIGHTENERS

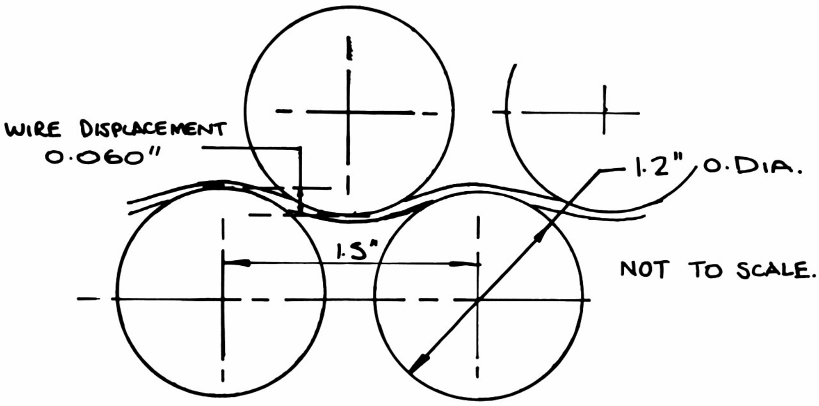


FIG. 5. WIRE DISPLACEMENT THROUGH ROLLERS