THE SPRING RESEARCH ASSOCIATION

END GRINDING OF SPRINGS

Progress Report No. 1

PRELIMINARY INVESTIGATION

by

G. C. Bird, B.Sc.

Report No. 237

November 1974

THE SPRING RESEARCH ASSOCIATION

Report No. 237

END GRINDING OF SPRINGS

Progress Report No. 1

PRELIMINARY INVESTIGATION

SUMMARY

A preliminary study has been made of the end grinding of helical springs, in an attempt to discover the effect of different variables on the efficiency of the grinding process and to determine the factors responsible for the deterioration of both springs and the wheels as grinding proceeds.

For this initial investigation, three types of wheel of different hardnesses were used on a Bennett SG1-14 Spring End Grinder. Springs of one particular design were ground using the three types of wheel at different grinding rates. Measurements of spring and wheel parameters were recorded at regular intervals during the grinding process until excessive distortion of the end coils made it impossible to grind further springs to an acceptable standard.

The results have shown that no single parameter can be used to define the performance of a grinding wheel. With all three wheels used, as the rate of grinding was increased, the number of springs which could be ground decreased and the rate of wheel wear increased. It was found that the pattern and amount of wheel loss differed considerably for each type of wheel.

The value of this preliminary work has been to reveal the difficulties involved in assessing grinding wheel performance and to give an indication of how future work on the project should be carried out in order to provide useful information on the selection of grinding wheels.

November 1974

CONTENTS

		Page No.
1.	INTRODUCTION	1
2.	GRINDING MACHINE	2
3.	GRINDING WHEELS	2
4.	SPRING DESIGN	2
5.	PROCEDURE	2
6.	RESULTS	4
7.	DISCUSSION OF RESULTS	4
	7.1 Effect of Table Speed	4
	7.2 Effect on Measured Spring Parameters	5
	7.3 Effect on Wheel Wear	5
	7.4 Effect of Tilting Top Grinding Wheel	6
8.	CONCLUSIONS	7
9.	COMPARATIVE GRINDING COSTS	7
10.	ACKNOWLEDGEMENTS	9
11.	TABLES	
	I Spring Design	
	II Rate of Metal Removal	
	III Rate of Wheel Wear	
	IV Ratios of Metal Removal/Wheel Wear	
	V Spring Hardness Measurements	
	VI Summary of Wheel Performance Data	
12.	FIGURES	
	1. Profile of Wheel A showing wheel wear - top wheel	
	2. Profile of Wheel A showing wheel wear - bottom wheel	

3. Profile of Wheel A showing wheel wear - top wheel tilted

4. Profile of Wheel B showing wheel wear - top and bottom wheels

5. Profile of Wheel C showing wheel wear - top and bottom wheels

END GRINDING OF SPRINGS

Progress Report No. 1

PRELIMINARY INVESTIGATION

by

G. C. Bird, B.Sc.

1. INTRODUCTION

At present there is no published information on the selection of grinding wheels for springs. Spring manufacturers rely on their own experience and advice from grinding wheel manufacturers. The choice of wheel, which can have a significant effect on both the cost and efficiency of the process, depends upon both the design and material of the springs.

This is the first investigation in a long-term project which will involve the study of many variables, such as: wheel matrix; table speed; frequency of dressing; spring material; and spring design. It is intended that the data collected will eventually form the basis of a report advising spring manufacturers on the selection of grinding wheels. Such a report would enable them to select the most suitable wheel for a particular spring design or a wheel that will serve as a good compromise for a range of spring designs.

This report describes a preliminary study of the grinding process itself, particularly the effect of certain variables on the efficiency of the process and the factors responsible for the deterioration of both the springs and wheels during the process. It must be pointed out that the wheels selected at this early stage were not necessarily the best for the springs to be ground; thus, the results obtained do not provide a "solution" to the problem of end grinding, but will simply be incorporated into the larger body of data collected during the course of the project. The "solution", it is hoped, will become evident at a later stage.

2. GRINDING MACHINE

The machine employed for all the tests was a Bennett SG1-14 Spring End Grinder, fitted with a pair of 14-inch diameter wheels, mounted horizontally. The wheel speed was constant at 1700 rpm, but the table speed was adjustable from $\frac{1}{3}$ rpm to 3 rpm. The table used incorporated 20 bushes, so that the rate of grinding could be varied between 400 and 3600 springs per hour. Attached to the machine was a D.C.E. Dust Extractor Unit, which was in continuous operation while the springs were being ground.

3. GRINDING WHEELS

Three different types of wheel were used and are referred to below as Wheels A, B and C. All the wheels were of the MA24 type, but varied in grades of hardness. Wheel A was the softest wheel, being grade L; Wheel B was a double-grade wheel having a core of grade N and a harder outer annulus of grade Q with a nominal thickness of $1\frac{1}{2}$ in; Wheel C was a single grade wheel of grade N.

4. SPRING DESIGN

The spring design was kept constant throughout the investigation and details are given in Table I. A wire diameter was selected which would ensure a high degree of wheel wear during the single-pass grinding of relatively few springs.

5. PROCEDURE

Before any springs were ground, both top and bottom wheels were dressed so that they were level across the surface. The gap between the wheels was then adjusted to enable a spring to be ground to the correct specification. A measured spring was ground and set aside for inspection later.

A batch of 100 springs was then ground, samples being taken at regular intervals to check that the solid length was still within the specification and the gap between the wheels being readjusted if necessary.

The profile of both the top and bottom wheels was determined by traversing the radius with a dial gauge and reading the change in height from the centre of the wheel. Readings were taken at $\frac{1}{4}$-inch intervals along three different radii. From the average of the three measurements obtained in both cases, profiles were drawn for the top and bottom heads.

A further batch of 100 springs was ground and the procedure repeated until wheel wear made it impossible to grind the springs to the dimensions required.

From each batch of 100 springs, twenty samples were examined and weighed to determine the average loss in weight of the springs resulting from the grinding process.

The investigation was carried out using the three sets of wheels at different table speeds, as indicated below:

Wheel type	Table speed (rpm)	Grinding rate (Springs/h)
A	2.4	2880
A	1.5	1800
A	0.8	960
A*	0.8	960
B	1.5	1800
B	0.8	960
C	1.5	1800
C	0.8	960

* For this condition, the top head was tilted.

6. RESULTS

Table II shows the average amount of metal removed, by grinding, from each batch of 100 springs, employing each combination of wheel type and table speed.

The weight of wheel lost per batch of 100 springs was calculated from the measured wheel profiles and Table III gives these values for each wheel type and table speed combination. To enable a comparison to be made between the different wheels, the ratio of metal removal to wheel wear has been calculated in each case, as shown in Table IV.

The standard springs ground at the beginning of each batch were measured afterwards to check the load and length specification. All of the springs were within the specification, indicating that the bodies of the springs had not been overheated during the grinding process. From a visual inspection of the distortion of the end coils, an assessment could be made of the maximum number of springs that could be ground satisfactorily. Hardness measurements around the end coil were taken on one sample from approximately every 200 springs to determine whether any softening of the material had occurred during the grinding process. These values are given in Table V.

Typical wheel profiles showing the distribution of wheel wear in the three different types of wheel used are shown in Figs. 1 - 3.

7. DISCUSSION OF RESULTS

7.1 Effect of Table Speed

For all three wheels, the use of different table speeds gave rise to considerable variation in the number of springs which could be ground satisfactorily. At the slowest speed (0.8 rpm) approximately 400 to 500 springs could be ground on all three wheels but, as the table speed was increased, the number declined rapidly. Using Wheel A, when springs were ground at a speed of 2.4 rpm only about 100 springs could be ground without excessive distortion occurring around the end coils.

7.2 Effect on Measured Spring Parameters

The use of different wheels and table speeds did not give rise to any differences in the free length and end squareness measurements. All of the springs ground were within BS 1726 Class B tolerances for end squareness and free length variation.

The major criterion for rejecting springs after grinding was the spread of the end coils; in the worst case the end coil tip projected more than 1 mm from the outside diameter of the spring. An arbitrary figure of 0.5 mm was set as the maximum acceptable level and was used to determine the number of springs that could be ground employing any one combination of wheel type and table speed. The results are given in Table VI.

The results of the hardness measurements show that, although the tip of the end coil becomes softer as the wheel wears or as the table speed is increased, beyond a point a quarter of the way round the circumference of the end coil, the hardness is not significantly reduced.

7.3 Effect on Wheel Wear

For all three types of wheel, the amount of wheel wear increased as the table speed was increased, although, as Figs. 1 - 3 show, the individual wheel profiles were markedly different. With the softest wheel, Wheel A, grit was removed from the wheel over a large proportion of the surface. Where a harder wheel was used, whether a double- or single-grade wheel, most of the wear occurred on the first

$1\frac{1}{2}$ inches of the wheel. On the double-grade wheel, there was no evidence of a step at the junction of the two rings of different hardnesses.

As would be expected, the amount of wear on Wheels B and C was markedly lower than that of Wheel A, as can be seen from Table III.

From the ratios of metal removal to wheel wear shown in Table IV, two general trends are apparent. Firstly, the efficiency of the process decreases as the table speed is raised, and secondly, the highest ratios are achieved after one or two hundred springs have been ground, probably because the wheel wear rate is higher as the sharp edges of the wheel are removed during the grinding of the first few springs.

An interesting observation can be made from Table VI: with one exception, the total amount of wear (measured by the depth lost at the edge of the wheel) on a particular type of wheel, after grinding the maximum number of springs, is virtually constant at all the table speeds. The reason for this is that, as the table speed is increased, the rate of wheel wear increases, but the number of springs which can be satisfactorily ground decreases.

7.4 <u>Effect of Tilting of Top Grinding Wheel</u>

The top head assembly of the Bennett SG1-14 grinding machine can be tilted to a maximum of 1 degree angular displacement, giving a difference of approximately 1/8 in between the loading and trailing edges of the wheel. As part of the investigation, using wheels of type A at a table speed of 0.8 rpm, the top head was tilted so that, when the springs were ground, the wheel gap at the point of entry was approximately equal to the free height of the unground springs. In this position, the initial pressure of the spring on the wheel would be reduced to a minimum. It was found that tilting the wheel reduced the rate of wheel wear considerably and increased the number of springs which could be ground satisfactorily.

8. CONCLUSIONS

The object of this preliminary investigation was to study methods of evaluating the performance of grinding wheels; this report has shown that, for the particular spring design employed, no single parameter can be used to define wheel performance. It is necessary to establish an acceptance standard for the ground springs and to compare different types of wheel by measuring the amount of wear and the number of springs that can be ground on each type.

In view of the rapid wear of the grinding wheels caused by the large wire diameter of the springs employed it may be desirable, before investigating different wheel abrasives or spring materials, to check the validity of the results obtained using a spring design of the same material but of smaller wire diameter.

9. COMPARATIVE GRINDING COSTS

On the basis of figures obtained from the preliminary investigation and approximate costs supplied by a Member Company, the comparative costs of grinding a batch of springs with different combinations of wheel type and table speed can be estimated. The figures used for this exercise are as follows:

No. of springs to be ground	2000
Time to dress and reset wheel	0.25 hour
Cost of wheels per set	£30.00
Cost of wheel per inch of usable depth	£ 7.50

Cost of direct labour/hour	£0.75
Cost of machine depreciation/hour (depreciation and maintenance)	£0.20
Cost of floor space/hour	£0.01
Cost of power consumption/hour	£0.04

Total operation cost/hour £ 1.00

From the data in Table VI, the time taken to grind the springs can be calculated:

Wheel type	Table speed (rpm)	No. of dressing operations	Dressing time (hrs)	Grinding time (hrs)	Total time (hrs)
A	0.8	4	1.00	2.08	3.08
A	0.8	5	1.25	2.08	3.33
A	1.5	6	1.50	1.11	3.61
A	2.4	20	5.00	0.69	5.69
B	0.8	5	1.25	2.08	3.25
B	1.5	8	2.00	1.11	3.11
C	0.8	5	1.25	2.08	3.25
C	1.5	8	2.00	1.11	3.11

From the time taken to grind the springs the labour cost can be calculated and added to the cost of the amount of wheel used, to give an estimate of the overall cost of grinding the springs:

Wheel type/ Table speed combination	Cost of grinding time (£)	Wheel cost (£)	Total cost (£)
A1	3.08	1.87	4.95
A2	3.33	1.83	5.16
A3	3.61	1.83	5.44
A4	5.69	1.81	7.50
B1	3.25	1.07	4.32
B2	3.11	1.68	4.79
C1	3.25	0.95	4.20
C2	3.11	0.87	3.98

The above figures show clearly that the cheapest method of grinding the springs is to employ the combination of wheel type and table speed which gives least wear. It should be borne in mind, however, that the figures are only intended to be comparative and that variations in the number of springs ground or the cost of labour may make significant differences to the total cost.

10. ACKNOWLEDGEMENTS

The Association would like to thank the following Member Companies for their invaluable assistance in the project:

Abrasive Products Limited
Bennett Tools Limited
Geo. Salter & Co. Limited
Universal Grinding Wheel Co. Limited.

TABLE I SPRING DESIGN

Wire diameter	3.5 mm
Mean coil diameter	25.3 mm
Total coils	6.5
Active coils	4.5
Spring rate	20.5 N/mm
Load at length of 32 mm	250 N ± 9N
Maximum solid length	22.6 mm

TABLE II RATE OF METAL REMOVAL

Weight of metal removed in grinding per 100 springs (grammes)

WHEEL A

Batches of springs ground	Table speed (rpm)			
	0.8*	0.8	1.5	2.4
0-100	167	181	178	203
101-200	180	214	177	211
201-300	207	242	194	201
301-400	240	262	215	212
401-500	-	244	-	-
501-600	-	257	-	-
601-700	-	210	-	-
701-800	-	219	-	-

* Top head tilted

WHEEL B

Batches of springs ground	Table speed (rpm)	
	0.8	1.5
0-100	156	178
101-200	162	189
201-300	220	199
301-400	240	270
401-500	245	-
501-600	251	-

WHEEL C

Batches of springs ground	Table speed (rpm)	
	0.8	1.5
0-100	309	266
101-200	530	276
201-300	309	264
301-400	243	-
401-500	191	-

TABLE III RATE OF WHEEL WEAR

Weight of wheel removed per
100 springs (grammes)

WHEEL A

<table>
<tr><th rowspan="2">Batches of springs ground</th><th colspan="4">Table speed (rpm)</th></tr>
<tr><th>0.8*</th><th>0.8</th><th>1.5</th><th>2.4</th></tr>
<tr><td>0-100</td><td>17.7</td><td>58.6</td><td>64.1</td><td>137.5</td></tr>
<tr><td>101-200</td><td>13.1</td><td>69.5</td><td>44.0</td><td>112.0</td></tr>
<tr><td>201-300</td><td>47.9</td><td rowspan="2">34.0</td><td>48.6</td><td>113.5</td></tr>
<tr><td>301-400</td><td>70.7</td><td>38.1</td><td>118.3</td></tr>
<tr><td>401-500</td><td>-</td><td rowspan="2">46.7</td><td>-</td><td>-</td></tr>
<tr><td>501-600</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>601-700</td><td>-</td><td rowspan="2">41.5</td><td>-</td><td>-</td></tr>
<tr><td>701-800</td><td>-</td><td>-</td><td>-</td></tr>
</table>

* Top head tilted

WHEEL B

<table>
<tr><th rowspan="2">Batches of springs ground</th><th colspan="2">Table speed (rpm)</th></tr>
<tr><th>0.8</th><th>1.5</th></tr>
<tr><td>0-100</td><td rowspan="2">11.8</td><td rowspan="2">33.7</td></tr>
<tr><td>101-200</td></tr>
<tr><td>201-300</td><td rowspan="2">10.0</td><td rowspan="2">60.1</td></tr>
<tr><td>301-400</td></tr>
<tr><td>401-500</td><td rowspan="2">22.6</td><td rowspan="2">-</td></tr>
<tr><td>501-600</td></tr>
</table>

WHEEL C

Batches of springs ground	Table speed (rpm)	
	0.8	1.5
0-100	12.9	18.1
101-200	9.7	14.4
201-300	15.6	26.5
301-400	13.1	-

TABLE IV RATIOS OF METAL REMOVAL/WHEEL WEAR

WHEEL A

Batches of springs ground	Table speed (rpm)			
	0.8*	0.8	1.5	2.4
0-100	9.4	3.1	2.8	1.5
101-200	13.7	3.1	4.0	1.9
201-300	4.3	7.1	4.0	1.8
301-400	3.4	7.7	5.6	1.8
401-500	-	5.2	-	-
501-600	-	5.5	-	-
601-700	-	5.0	-	-
701-800	-	5.3	-	-

* Top head tilted

WHEEL B

Batches of springs ground	Table speed (rpm)	
	0.8	1.5
0-100	13.2	5.3
101-200	13.7	5.6
201-300	23.0	3.3
301-400	23.0	3.6
401-500	10.8	-
501-600	11.1	-

WHEEL C

Batches of springs ground	Table speed (rpm)	
	0.8	1.5
0-100	24.0	14.7
101-200	54.8	19.2
201-300	19.8	10.0
301-400	18.5	-

TABLE V SPRING HARDNESS MEASUREMENTS

Figures given are in HV

WHEEL A

Table speed	No. of springs	Tip →					
0.8	1	435	466	498	447	447	441
0.8	200	347	362	401	441	429	438
0.8	500	305	300	381	466	460	460
0.8	700	303	404	438	418	438	450
1.5	200	278	356	435	450	460	476
2.4	200	318	391	480	480	457	483
0.8*	200	418	409	490	466	470	480
0.8*	400	362	306	423	325	441	457

* Top head tilted

WHEEL B

Table speed	No. of springs	Tip →					
0.8	200	329	360	444	453	469	470
0.8	400	296	264	450	412	365	444
1.5	200	323	394	463	460	450	473

WHEEL C

Table speed	No. of springs	Tip →					
0.8	200	360	383	435	420	453	487
0.8	400	343	391	441	441	381	463
0.8	500	335	303	369	343	457	444
1.5	200	289	391	457	460	438	463

TABLE VI SUMMARY OF WHEEL PERFORMANCE DATA

Wheel type	Table speed (rpm)	Maximum no. of springs ground	Total wheel wear at edge
A*	0.8	400	0.250 in
A	0.8	350	0.245 in
A	1.5	300	0.245 in
A	2.4	100	0.242 in
B	0.8	400	0.143 in
B	1.5	250	0.225 in
C	0.8	400	0.127 in
C	1.5	250	0.117 in

* Top head tilted

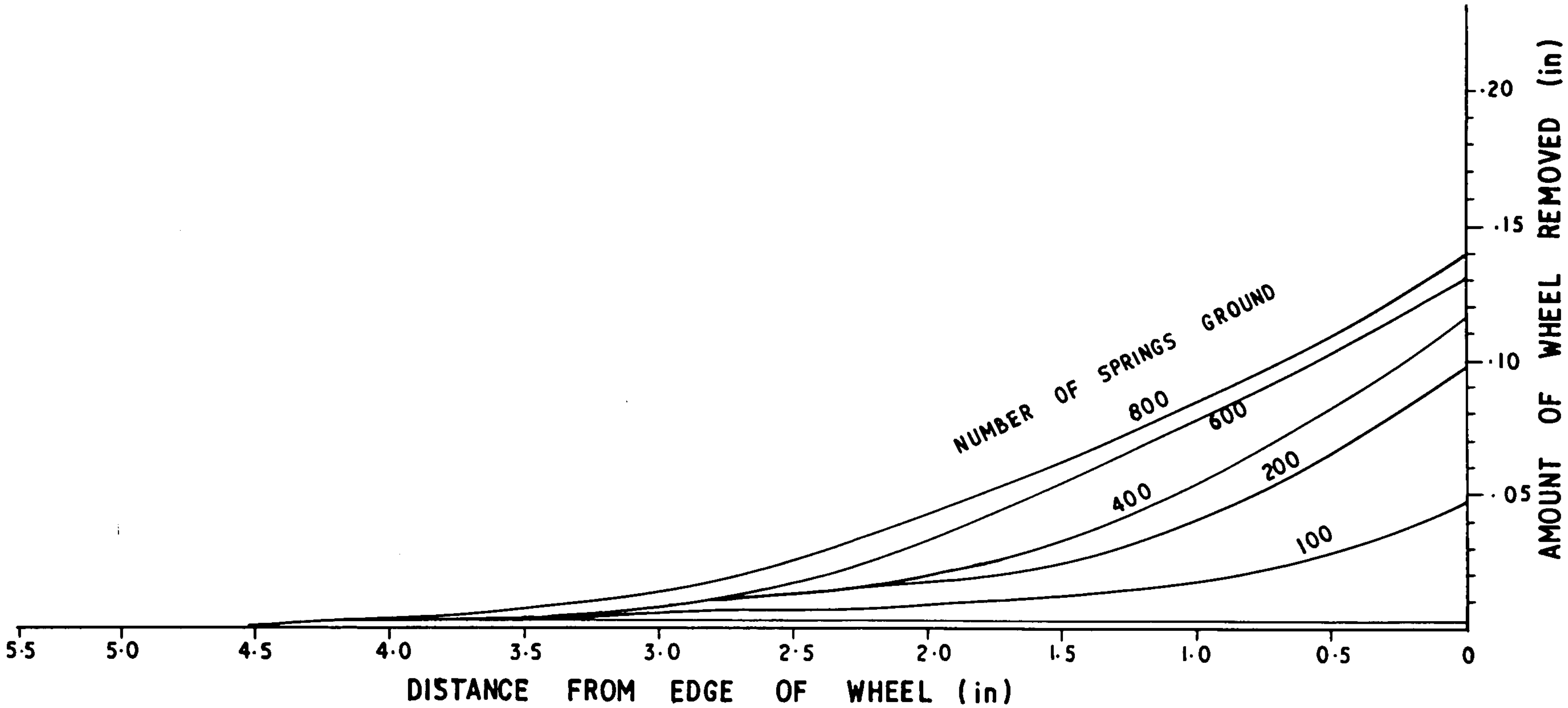

FIG. I WHEEL A TABLE SPEED 0·8 r.p.m. TOP WHEEL.

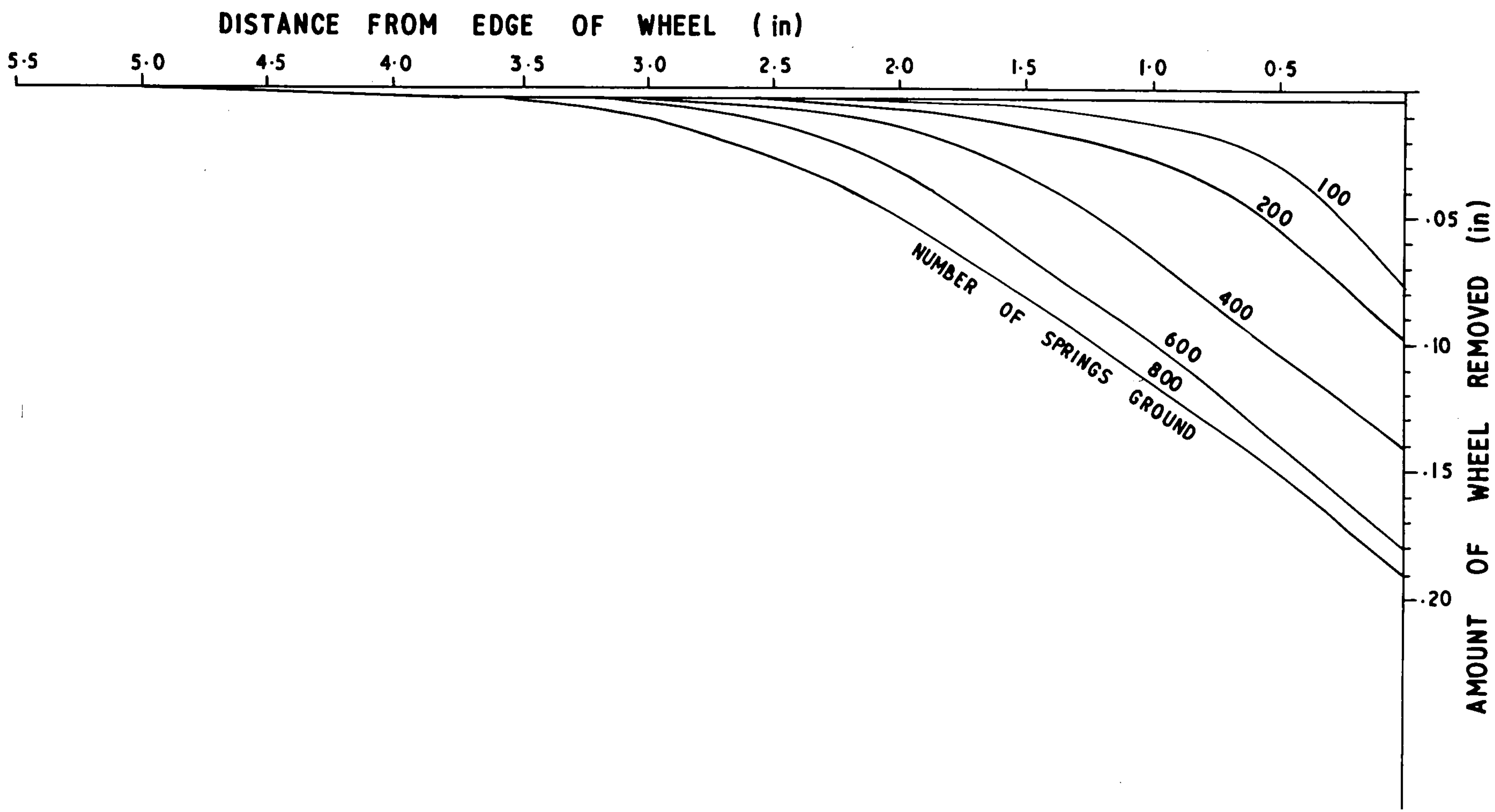

FIG. 2 WHEEL A TABLE SPEED 0·8 r.p.m. BOTTOM WHEEL.

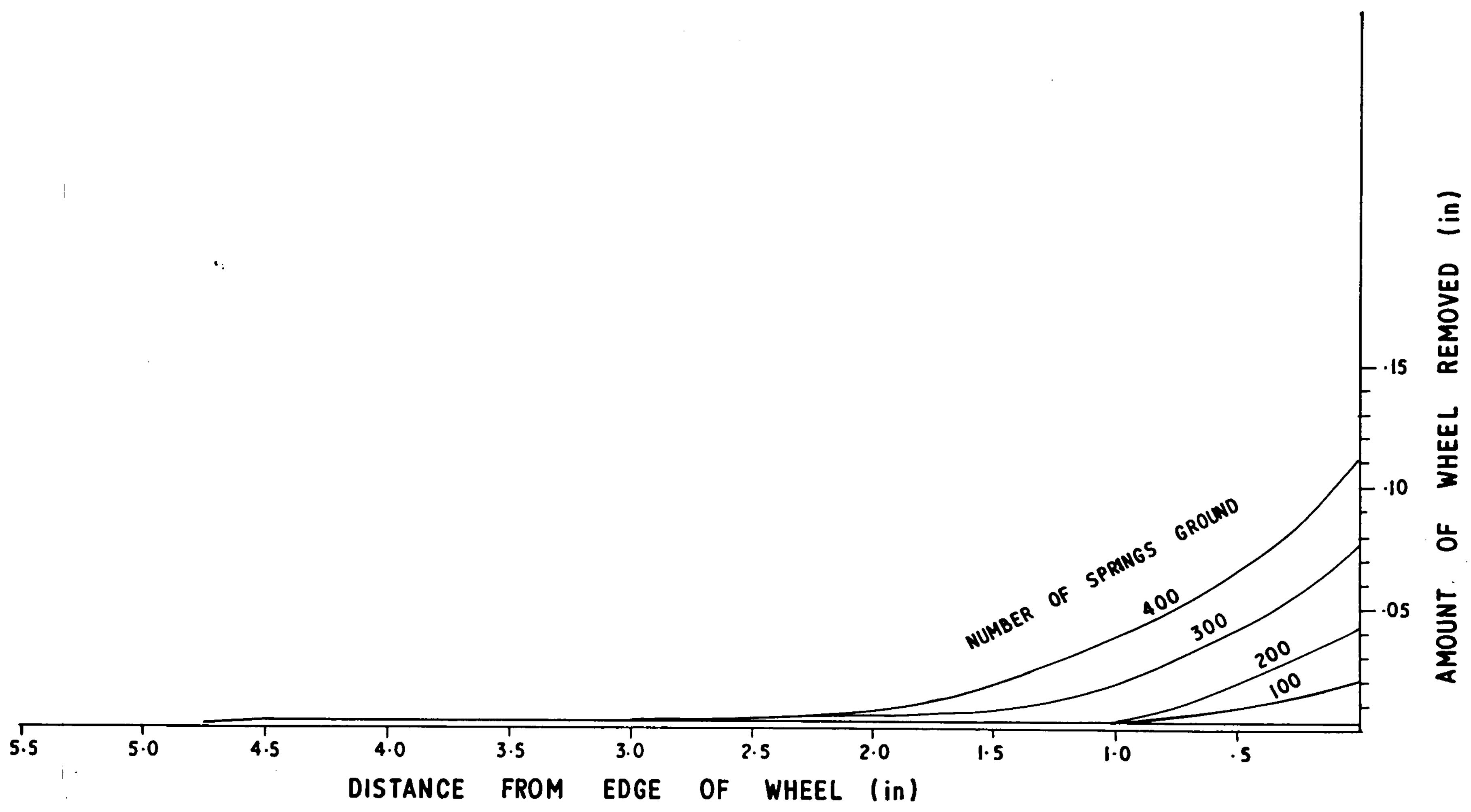

FIG. 3 WHEEL A. TABLE SPEED 0·8 r.p.m TOP WHEEL TILTED.

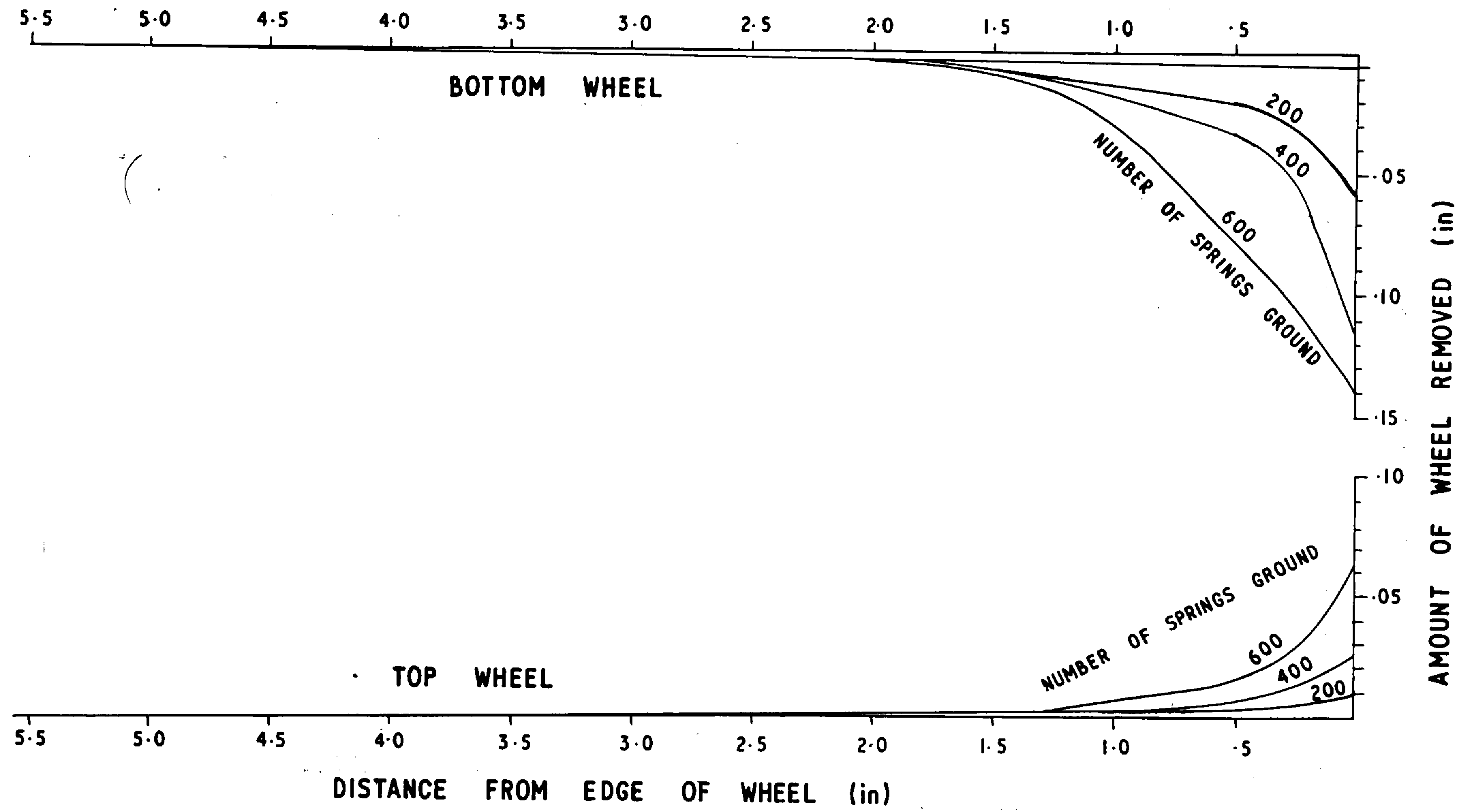

FIG. 4. WHEEL B. TABLE SPEED 0·8 r.p.m. BOTTOM AND TOP WHEELS

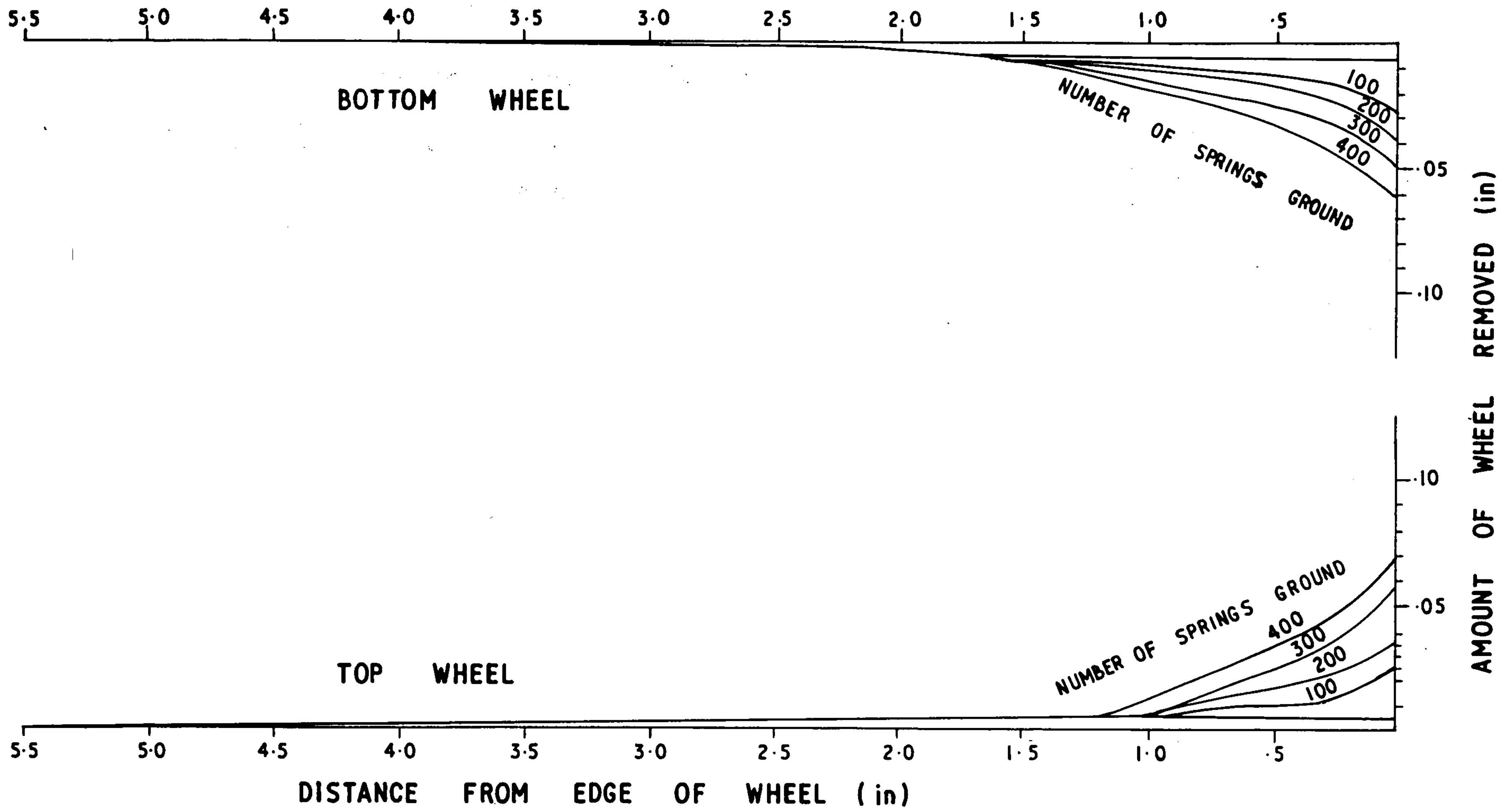

FIG. 5 WHEEL B TABLE SPEED 0·8 rpm TOP AND BOTTOM WHEELS.