THE SPRING RESEARCH ASSOCIATION

SPRING COMPARATOR

A SIMPLE BUT ACCURATE DEVICE

FOR LOAD TESTING SPRINGS

by

A. H. WILKINSON, B.Sc.

Report No. 202

June, 1972

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SUMMARY

A device has been invented which is capable of accurate load, length and rate testing of springs on a production basis. In principle, it applies the same load to two springs and detects the difference in length between them. One spring would be calibrated and the other would be under test. Normally the calibrated spring would be one from the batch of springs being tested.

An important feature is that it is possible to measure the load/deflection characteristics of a spring over its full deflection range in one operation. Inspection can be undertaken either by reading a dial gauge or by setting electrical contacts to accept or reject springs if they are outside the required tolerance band.

As the speed of response is very high, the device is suited to automation.

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1. INTRODUCTION

The present system of load testing a spring involves the use of an instrument which deflects the spring and indicates the load and deflection on two separate dials. The deflection is usually controlled by means of a lever. This system has the advantage that it is simple and reliable, but it is not particularly suited to measurement of spring rate. The 1971 Research Programme, therefore, included a project to develop a machine for measuring rate directly. During this work a device was invented which did not in fact satisfy the requirement of being able to measure rate directly but it was shown to have certain important advantages over conventional equipment.

The working part of the device has been manufactured and tested, but a complete prototype has not yet been made. A Provisional Patent Specification, 4785/72, has been filed.

2. DESCRIPTION

A diagram of the device is shown in Fig. 1. In principle it applies the same load to two springs and detects the difference in length between them. One spring would be of known characteristics (a calibrated spring) and the other would be under test. The calibrated spring would normally be one from the batch of springs to be tested. Its characteristics would first be determined by normal load testing methods.

Inspection can be undertaken in two ways, either

(a) On a go/no go gauge principle where electrical contacts are set to the tolerance required. These would operate red lights which would indicate that the test spring is outside the required tolerance band; or

(b) By reading a dial gauge.

3. USES OF THE SPRING COMPARATOR

3.1 To Measure Free Length

The instrument is first set to zero by operating the lever without any springs in position. This causes the plungers to come into contact with the table. The dial gauge is set to zero and the free length tolerances are set by adjusting the contact gaps to suit, using the dial gauge to measure the gaps.

For example:

If the required free length is equal to the free length of the calibrated spring $\pm$ 0.005 in, the gaps are each set to 0.005 in. It is not essential for the free length of the calibrated spring exactly to equal the required free length as the contact gaps need not be set equal.

It is then only a matter of placing a test spring in position and operating the lever which brings the comparator down to just touch the two springs. If the test spring is outside the required tolerance band a red light will indicate this. The dial gauge will show half the difference in free length between the two springs.

A unique feature of this device is that measurement of the 'effective free length' of a spring is possible. The difference between the free length and 'effective free length' is shown in Fig. 2. In this case the stop is adjusted so that both springs are just compressed (by about 5% of their maximum deflection) when the lever is operated. The tolerances are set and the instrument operated as for measurement of free length.

3.2 To Measure Length at a Particular Load

The procedure is very similar to the measurement of free length. The stop is adjusted so that the nominal load applied to each spring is equal to the required load.

3.3 To Measure Load at a Particular Length

The instrument is first set to zero as described under section 3.1. The stop is adjusted so that the mean spring length of the two springs being compared is equal to the required length.

When testing springs the dial gauge reading is interpreted as follows:

Difference in load between the two springs at the required length = 2 x dial gauge reading x mean spring rate (see Appendix).

Example:

Suppose a comparator is designed to suit spring loads up to 200 lbf and to measure length differences to an accuracy of $\pm$ 0.001 in.

If dial gauge reading = 0.010 in
and mean spring rate = 100 lb/in
then load difference = 2 x 0.010 x 100 = 2 lbf

If it is desired to operate the device on a production basis, the contact gaps can be adjusted to the required limits.

Note that the accuracy of measurement is about ± 0.15 lbf assuming that the spring rates of the batch of springs vary by about ± 5% (see Appendix).

3.4 <u>To Measure the Complete Load/Length Curve</u>

This test is particularly suited to springs which have non linear load/deflection characteristics.

Fig. 3 shows the type of tolerance band which can be set. The contact gaps are set to the required tolerances and springs are tested by deflecting them to solid. The red lights would indicate springs which have characteristics outside the required range.

3.5 <u>To Measure Rate</u>

The contact gaps cannot be used to set tolerances for this measurement. It is not necessary in this case to set the instrument to zero.

With the two springs in position, the lever is operated and the springs are compressed to a nominal length 0.050 in longer than that at which the rate measurement is required. The dial gauge reading is noted. The springs are then compressed a further 0.1 in exactly (this can easily be controlled by means of stops or slip gauges) and the dial gauge reading is again noted. The difference between the two readings multiplied by 2000 equals the percentage difference in rate between the two springs e.g. a dial gauge reading of 0.002 in indicates a rate difference of 4%.

Note that if length difference is measured to an accuracy of ± 0.001 in, then the rate difference measurement is accurate to about ± 1.2% (this figure varies according to the rate difference) which is very accurate over a 0.1 in range (see Appendix).

The sensitivity can be increased by increasing the range.

4. DISCUSSION

In order to test the feasibility of this technique, the working part of a spring comparator was made (see Fig. 4) and tested using it in conjunction with a conventional drill stand. Rolling bearings were used at all pivot points and the results were quite successful in that the speed of response was very high and friction within bearings was negligible. It was observed, however, that it would be necessary to manufacture the instrument and control its motion to close tolerances if the desired accuracy was to be achieved. The examples given in the Appendix are based on being able to measure spring length to an accuracy of ± 0.001 in. It is expected that this accuracy would be achieved using an instrument for testing springs of engine valve spring size and that in general the accuracy of measurement would be related to the size of the instrument.

The accuracy of measurement is, of course, limited by the accuracy to which the calibrated spring can be measured and this would normally involve using a conventional load testing machine. It is, however, anticipated that very careful procedure for setting up and measurement would result in much better accuracy than during a normal production run. Also, springs could be calibrated by an external body possessing accurate equipment or by testing the spring within the component in which it is intended to be used.

The testing of tension springs could be accommodated by fitting hooks to the plungers and lifting instead of lowering the Comparator.

5. CONCLUSIONS

This instrument has a number of advantages over conventional load testing equipment. These are summarised below:-

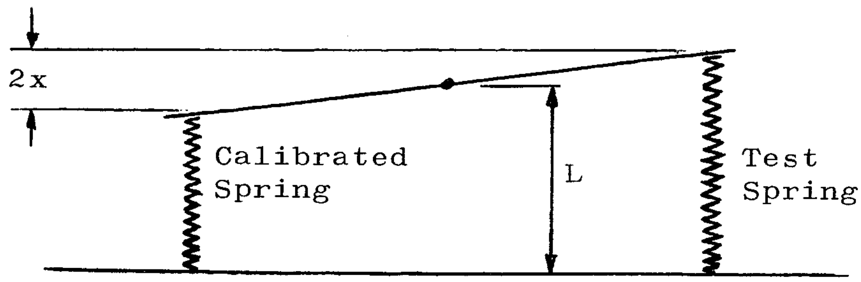
1. It is possible to measure the load/deflection characteristics of a spring over its full range in one operation.
2. The response time is very quick and therefore ideally suited to either inspection on a production basis or to automation.
3. If manufactured to fairly close tolerances it could be extremely accurate.
4. The basic design and construction are very simple.

A possible disadvantage is that it is necessary to provide a calibrated spring.

APPENDIX

Calculations

1. Load at a Particular Length



	Calibrated Spring	Test Spring
Rate	R_1	R_2
Deflection	Y_1	Y_2
Load at Length L	P_1	P_2

Dial gauge reading = X

Applied load = $P_1 + R_1X = P_2 - R_2X$

$\therefore \quad P_2 - P_1 = X(R_1 + R_2)$

$\therefore$ Load difference = 2 x dial gauge reading x mean spring rate

Accuracy of measurement

Example: Dial gauge reading = 0.010 ± 0.0005 in
Mean spring rate = 100 lbf/in
Test spring rate = 100 lbf/in $\pm$ 5%

$\therefore$ Mean spring rate = 100 lbf/in $\pm$ $2\frac{1}{2}$%
Load difference = 2 x 0.010 x 100 = 2 lbf

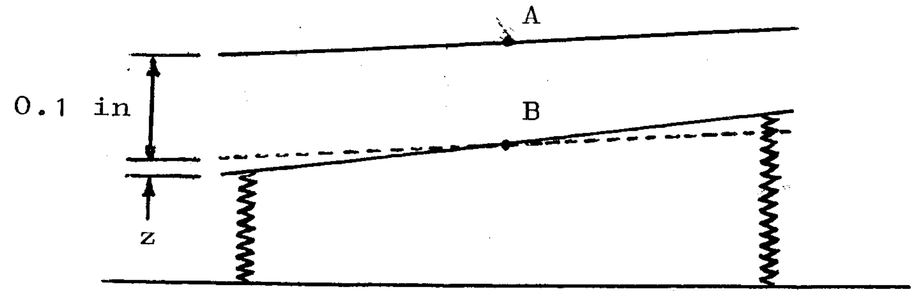
Error due to mean spring rate error = $\pm$ $2\frac{1}{2}$% of 2 lbf
= $\pm$ 0.05 lbf

Error due to dial gauge reading error = $\pm$ 2 x 0.0005 x 100
= $\pm$ 0.1 lbf

$\therefore$ Total possible error = $\pm$ 0.15 lbf

Hence load difference = 2 lbf $\pm$ 0.15

2. <u>Rate</u>



Difference between dial gauge readings at positions A and B = Z

As the load on the calibrated spring always equals the load on the test spring, the load difference for the two deflections is the same for each spring.

	Calibrated Spring	Test Spring
Rate	R_1	R_2

Load difference = $R_1 (0.1 + Z) = R_2 (0.1 - Z)$

$\therefore \quad R_2 - R_1 = 10Z (R_2 + R_1)$

$\therefore \quad \frac{\text{Rate difference}}{\text{Mean spring rate}} = 20Z \doteq \frac{\text{Rate difference}}{\text{Calibrated spring rate}}$

$\therefore$ Percentage difference in rate

$\doteq$ 2000 x difference between dial gauge readings

<u>Accuracy of measurement</u>

Example: Let dial gauge reading be accurate to $\pm$ 0.005 in.

Let rate difference = 5% of calibrated spring rate.

Calibrated spring rate = mean spring rate $\pm$ $2\frac{1}{2}$%

Error due to the calibrated spring rate not being equal to the mean spring rate = $2\frac{1}{2}\%$ of 5% = 0.125%

Error due to dial gauge reading error = 2000 x .0005 = 1%

$\therefore$ Total error = 1.125%

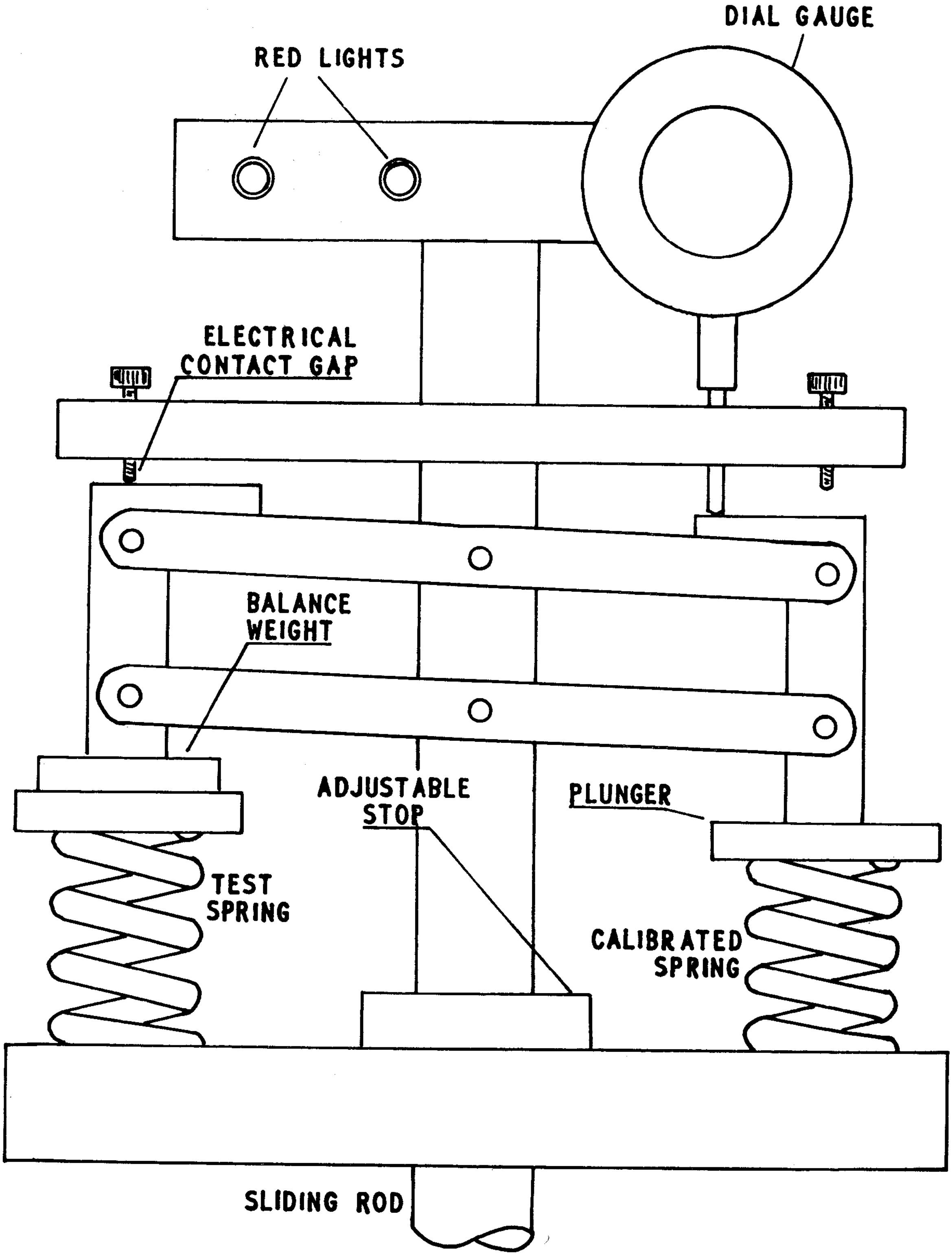


FIG. 1 SPRING COMPARATOR

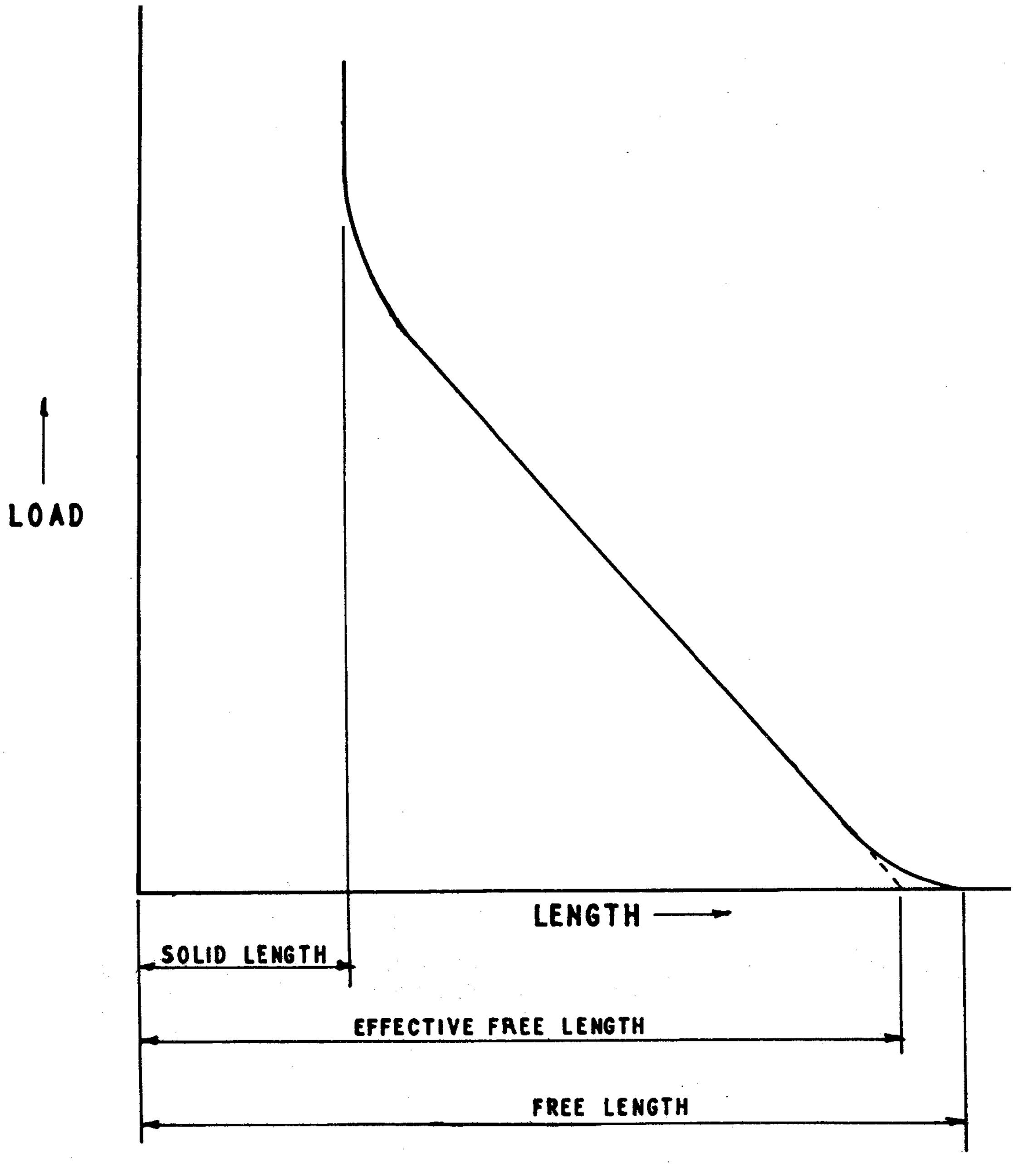


FIG. 2 LOAD/LENGTH DIAGRAM

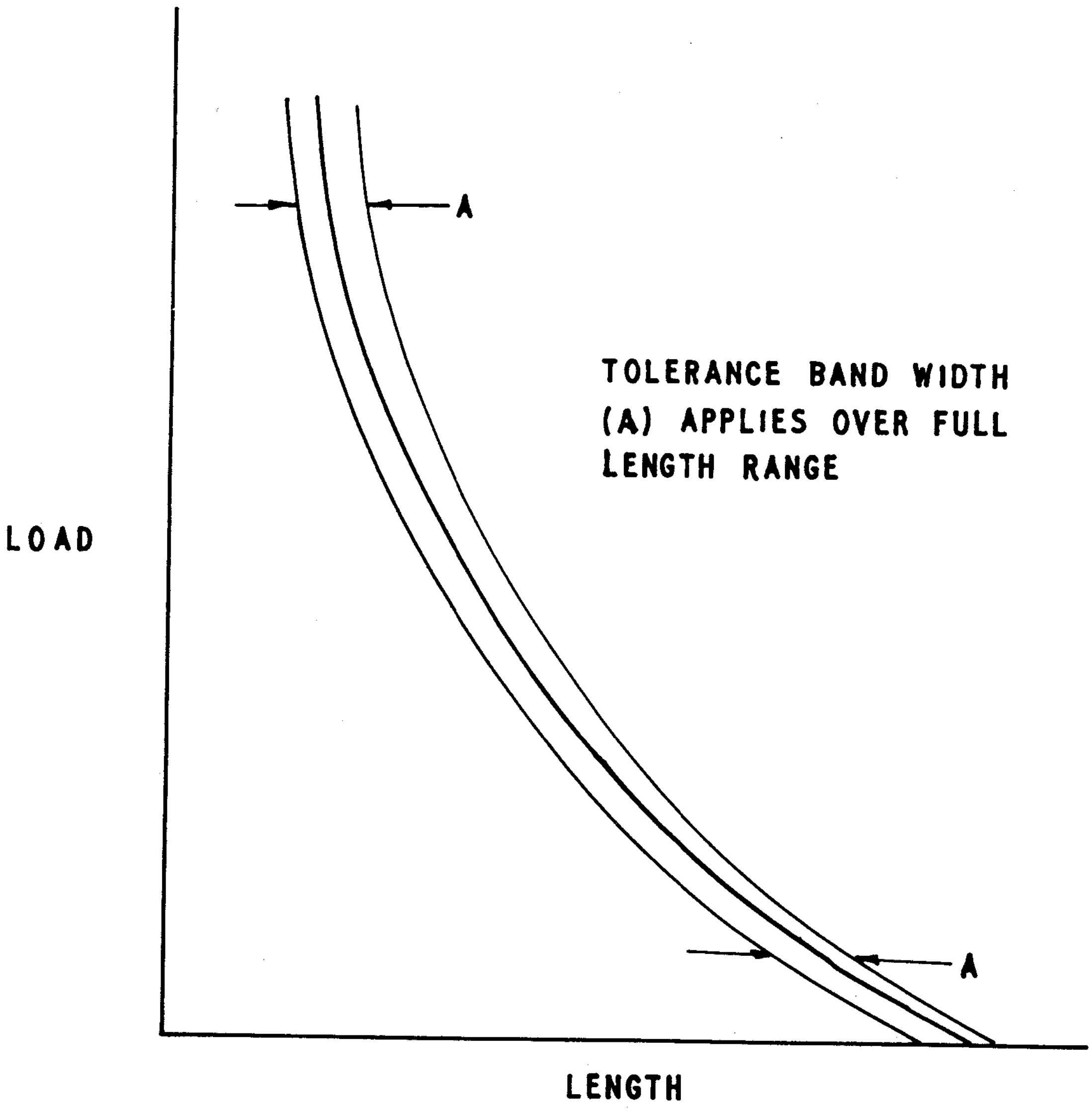


FIG. 3 NON LINEAR LOAD LENGTH DIAGRAM

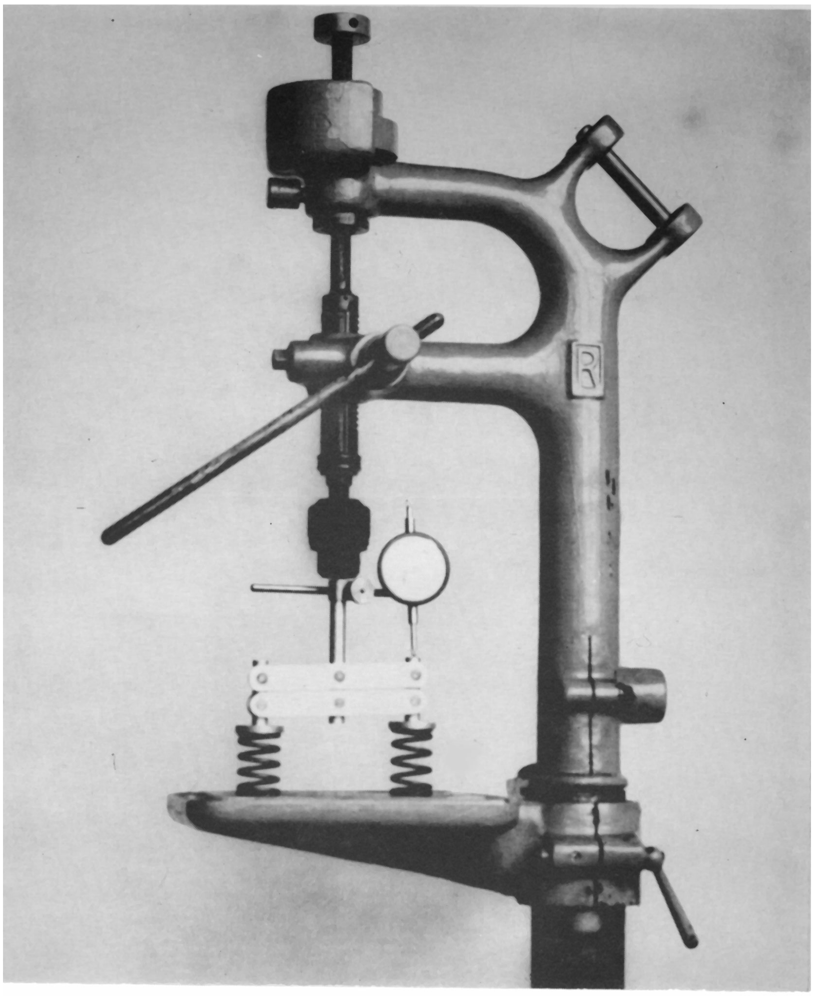


FIG. 4 TEST MODEL