THE SPRING RESEARCH ASSOCIATION

AN EVALUATION OF THE LION SPRING GAUGE WHEN USED IN CONJUNCTION WITH A BENNETT S.C.O. AUTOCOILING MACHINE

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SUMMARY

A Lion spring gauge has been evaluated when used in conjunction with a Bennett S.C.O. coiling machine.

The gauge, which used a proximity capacitance probe to detect spring free lengths, was attached to the coiling machine and was controlled such that the free lengths were gauged during the pause before cut off. The springs were sorted by means of solenoid controlled deflectors into three batches according to whether or not they were short, within tolerance, or long. A feedback system made slight corrections to the pitching tool each time a spring was rejected.

Two spring designs were produced from 0.012 in and 0.028 in diameter music wire to B.S. 1408 M Range 1. The machine's sorting ability was tested at different production rates and with and without feedback control.

Good sorting ability was apparent under all conditions, in that the vast majority of springs were sorted correctly, but sorting errors did occur when free lengths were close to either of the limits of the set tolerance band. It would be necessary, therefore, to set a closer tolerance than that required if 100% of accepted springs were to be within tolerance.

The feed back control was effective in maintaining mean free lengths and did not significantly affect the sorting accuracy.

Some mechanical problems associated with the design of chute and deflectors were encountered which impaired their efficiency. The durability of this part of the device was questionnable. These problems would probably not apply if the air blast deflecting system, available as an alternative, had been used.

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1. INTRODUCTION

The advantages of automatic spring gauging over manual methods are numerous: higher output, consistency and accuracy of results and adaptability to automatic processes. A further advantage of automatic gauging lies in the possibility of controlling the spring making process using feedback information from the gauging.

Such a system has been employed by the Lion Research Corporation whose spring gauge attachment has been evaluated by the SRA.

This report describes the gauge and assesses its sorting ability and the way in which it can improve the accuracy of spring manufacture.

2. SPRING DESIGNS

Two spring designs were used in the assessment of the Lion gauge and these were produced from music wire to B.S. 1408 - M, Range 1.

DESIGN NO.	WIRE DIA.	LENGTH	O/D	TOTAL COILS	ACTIVE COILS	SPRING INDEX
1	0.012 in (30 gauge)	.625 in	.15 in	12½	10	11½
2	0.028 in (22 gauge)	1.450 in	.35 in	12½	10	11½

3. EQUIPMENT

3.1 Bennett Coiler

The Bennett S.C.O. coiler fitted with the Lion gauge is shown in Fig. 1. The coiler was supplied with standard tungsten carbide tooling and was equipped with a free running swift.

3.2 Lion Gauge

The Lion gauge was supplied already fitted to the coiling machine. The gauging mechanism is shown in Figs. 1 and 4, and consisted of a micrometer adjusted capacitance probe together with two solenoid controlled deflectors. This assembly was mounted on an adjustable vertical column which was fitted on to the coiling machine. A selection of probes was available to suit varying diameters of springs. Both the column and the clamping bracket were partially adjustable to allow alignment of the probe with the spring end.

To complement the gauging mechanism there was an electronic control box which could be placed in a position adjacent to the coiling machine to suit the convenience of the operator. The control box (shown in Fig. 2) facilitated the calibration of the probe and the settings of the micrometer adjustment. A meter and the controls on the front panel provided for the setting of various sensitivities to suit different spring designs.

The principle of operation of the unit was that different spring free lengths produced on the coiling machine produce correspondingly different capacitances between the tip of the probe and the spring end coil. The capacitances produced by each of the springs are in turn compared with reference levels in the control box. Such comparisons then determine whether an electrical impulse is sent to one of the solenoids which control the deflectors.

The Lion gauge incorporated a unique pitch feedback control which worked from the gauge decisions. The feedback arrangement, which was optional, moved the pitching tool an increment in the appropriate direction whenever a spring was gauged as 'rejected'. This was not a proportional feedback, however, and feedback control was affected by a similar amount on every spring rejection.

4. EXPERIMENTAL PROCEDURE

4.1 Experiment Design

The performance of the Lion gauge (and the Bennett S.C.O. autocoiler to which it was attached) was assessed by comparison of spring free lengths and their tolerances. Diameters were not compared because only the pitch control and the free length gauging apparatus were being assessed.

The performance of the gauge was also assessed by plotting frequency distribution curves of the rejected and accepted springs. From these, the wastage in manufacture, extra wastage in sorting and error in accepted springs (see Fig. 3) were calculated.

For each run 250 springs were produced according to the conditions on the following page:-

RUN NO.	SPRING DESIGN NO.	PRODUCTION RATE	SET TOLERANCE	PITCH CONTROL
1	1	40/min	±.0095	YES
2	1	40/min	±.0095	NO
3	1	80/min	±.0095	YES
4	1	80/min	±.0095	NO
5	2	20/min	±.017	YES
6	2	20/min	±.017	NO
7	2	40/min	±.017	YES
8	2	40/min	±.017	NO

4.2 Coiling

The coiling machine was set to produce the first spring design. The required tolerance was set according to the calibration instructions issued by the Lion Research Corporation. Finally, the nominal free length was adjusted to meet the design specification using the micrometer probe.

The coiling machine was fitted with a variable speed drive and this was adjusted until the appropriate production rate was achieved.

Three boxes were strategically placed under the gauge so as to catch the three resultant batches of springs to be produced: rejected (short), accepted (mean) and rejected (long).

The first run utilised the pitch control device controlled by feedback from the gauge. The second run was similar to the first except that the pitch control was not used. For those runs which did not utilise pitch control 2500 springs were made prior to the commencement of any gauging, so that free length drift effects due, for example, to the variance of wire properties, might become apparant.

4.3 Measurements and Analysis

The free lengths were measured on a Nikon profile projector. The means, variances and standard deviations of free lengths were calculated for both the accepted (medium) batch and the total batch of springs for each run.

5. RESULTS

The statistical results in terms of twice the standard deviation (which constitute a tolerance) are given in Tables I and II.

Percentage wastage in manufacture and the percentage gauging errors are given in Tables III and IV respectively.

Calibration curves of the gauge for each run are plotted in Figs. 6 to 9. From these curves the wastage in manufacture, extra wastage in sorting and error in accepted springs were derived.

6. DISCUSSION OF RESULTS

Tables I and II each show two production rates for the spring designs produced. The higher of the production rates for each design was that which was considered to be the fastest speed possible for gauging the spring design.

Establishing a mean free length that conformed to the design specification proved to be a difficult and time consuming activity. Only by the analysis of spring free length data such as in this experiment could any accurate corrective adjustment be made to the micrometer probe. Therefore some of the tabulated mean free lengths do not strictly conform to the spring design specifications. One of the advantages of the gauge was, however, that any manual adjustments made to the micrometer probe did not in any way affect the set tolerance of the gauge, and that such adjustments did have an exact effect on the subsequent free lengths (when using feedback control).

The British Standard Specification 1726 free length tolerances for spring designs 1 and 2 were ± 0.019 and $\pm .034$ in respectively. In testing the sorting ability of the gauge it was decided to use a smaller tolerance (50% of the British Standard) and thus provide for a more stringent sorting test for the gauge.

The effects of feedback control on spring manufacture were beneficial in that the effects of free length drift during continuous spring manufacture were largely eliminated. For the run involving the second spring design and the higher production rate, vibration of the spring, a shorter gauging time and occasional contact with the probe all contributed to poor feedback control. Under these conditions, therefore, feedback control was not an advantage.

Springs which become incorrectly orientated (see Fig. 5) immediately prior to gauging were nearly always rejected because they were either too far from the probe or were in contact with it, thereby causing an undersize or oversize gauging. This was a failsafe factor in the design of the gauge.

During the continued use of the gauge it was noted that the micrometer thimble gradually rotated due to vibration caused by the deflectors. This caused the nominal free lengths of the springs to change. Although attempts to stop this were partially successful (by adjusting the Micrometer nut), the provision of a micrometer barrel lock would have eliminated the problem altogether.

A further problem concerned the solenoid operation. During fast and continued use (gauging at 80/min) there was some hesitancy for the deflectors to return to their rest position which was apparently due to a solenoid fault. No extraneous electrical impulses could be detected in the solenoid windings. The problem was largely overcome by placing a mica disc on top of the end of the armature inside the solenoid. The effect of this was to increase the reluctance of the magnetic gap and hence eliminate the sticking of the solenoid.

When the second spring design was being gauged the probe tip used for this design constricted the occasional passage of springs between the probe tip and the chute sides (see Fig. 5b). Therefore some advantage would be gained if the chute sides were adaptable to different spring designs and to different autocoiling machines. The suitability of the chute for accurate and reliable spring selection (for those spring designs used) was sometimes doubtful when springs became trapped on the leading edge of the chute or lost between the leading edge and the front face of the coiler (Fig. 5c). Part of this problem is due to the uncertainty of the spring shearing action (sometimes the springs were seen to 'jump' immediately after being sheared off) but these problems could relatively easily be overcome. If an air blast spring collection system was used (as an alternative to the chute and mechanical deflectors) then presumably none of these problems would exist.

It is considered that the spring clearance problems with the second design (the larger spring) at the higher production rate were responsible for the relatively poor gauging and incorrect feedback control. Large springs gauged with close tolerances need low production rates. Smaller springs gauged with close tolerances may still be produced and gauged at higher rates (80/min when using 50% B.S. tolerance).

The assessment was designed to put the gauge through a stringent test. If British Standard tolerances were used then it is envisaged that fewer springs would be rejected and hence fewer problems would occur.

7. CONCLUSIONS

1. The Lion gauge successfully sorted the vast majority of springs into their correct batches of 'short', 'within tolerance', and 'long'.

2. The feedback control improved the manufacturing tolerance and reduced drift effects by automatically maintaining the mean free length.

3. If it is necessary for 100% of accepted springs to be within the required tolerance, it is advisable to set the gauge to accept a closer tolerance than required.

4. The British Standard tolerance for the first spring design was maintained with the aid of the feedback control from the gauge.

5. Although the British Standard tolerance was not maintained for the second spring design the actual sorting tolerance (i.e. $\pm$.018 in for both production rates using feedback) compared well with the set tolerance ($\pm$.017 in).

6. Micrometer faults experienced during the tests, together with the spring collection difficulties (mainly on the second design when using feedback), caused erroneous feedback information.

7. The air blast type of sorting may be advantageous for some spring designs. This was not tested but it is thought that some of the spring clearing problems associated with the chute might be eliminated using this method.

The Lion Research Corporation have now produced a modified gauging machine by which it is possible to set the gauging and feedback tolerances independently. This would allow greater control of the feedback system.

8. ACKNOWLEDGEMENTS

The Association wishes to thank Bennett Tools Ltd. and Lion Research Corporation for their co-operation in supplying the Bennett S.C.O. coiling machine and Lion gauging machine for evaluation.

TABLE I — 1ST SPRING DESIGN GAUGING RESULTS

TOLERANCE ON GAUGE SET TO ±0.0095 (INCH UNITS)					
BATCH	PRODUCTION RATE	WITH FEEDBACK		WITHOUT FEEDBACK	
		MEAN	TOLERANCE OBTAINED	MEAN	TOLERANCE OBTAINED
Gauged as being within tolerance	40/min	.625	±.012	.628	±.015
	80/min	.633	±.014	.632	±.014
Overall spring distribution	40/min	.625	±.019	.621	±.026
	80/min	.633	±.020	.631	±.020

TABLE II — 2ND SPRING DESIGN GAUGING RESULTS

TOLERANCE ON GAUGE SET TO ±0.017 (INCH UNITS)					
BATCH	PRODUCTION RATE	WITH FEEDBACK		WITHOUT FEEDBACK	
		MEAN	TOLERANCE OBTAINED	MEAN	TOLERANCE OBTAINED
Gauged as being within tolerance	20/min	1.440	±.018	1.411	±.023
	40/min	1.412	±.018	1.402	±.017
Overall spring distribution	20/min	1.440	±.041	1.409	±.051
	40/min	1.422	±.065	1.408	±.050

TABLE III

PERCENTAGE WASTAGE IN MANUFACTURE

RUN NO.	DESIGN	PRODUCTION RATE	FEEDBACK	PERCENTAGE WASTAGE ACCORDING TO 50% OF B.S.TOL. (GAUGE TOL.)*	PERCENTAGE WASTAGE ACCORDING TO B.S. TOLERANCE
1	1	40/min	Yes	33	4
2	1	40/min	No	41	21
3	1	80/min	Yes	36	7
4	1	80/min	No	32	8
5	2	20/min	Yes	42	7
6	2	20/min	No	47	14
7	2	40/min	Yes	54	28
8	2	40/min	No	41	12

* See Fig. 3.

TABLE IV

PERCENTAGE GAUGING ERRORS

RUN NO.	DESIGN NO.	PRODUCTION RATE	FEEDBACK	EXTRA WASTAGE IN SORTING (%) *	ERROR IN ACCEPTED SPRINGS (%) *	ERROR IN REJECTED SPRINGS (%) *
1	1	40/min	Yes	4	12	13
2	1	40/min	No	3	18	10
3	1	80/min	Yes	6	15	19
4	1	80/min	No	6	13	22
5	2	20/min	Yes	15	3	27
6	2	20/min	No	11	6	20
7	2	40/min	Yes	15	6	23
8	2	40/min	No	11	2	22

* See Fig. 3.

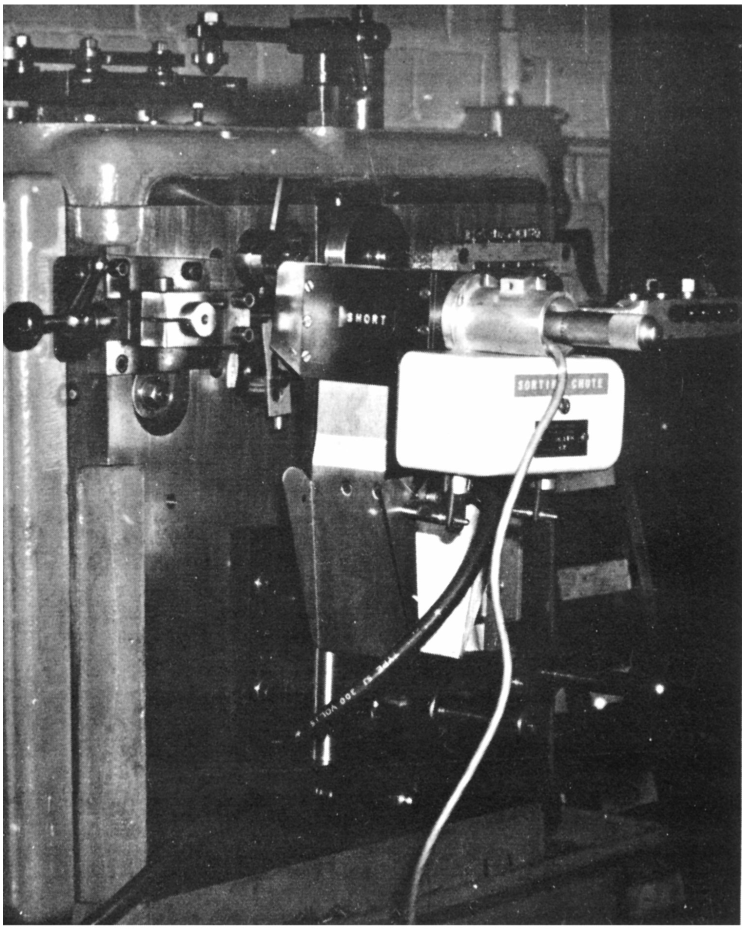


FIG. 1. LION GAUGE

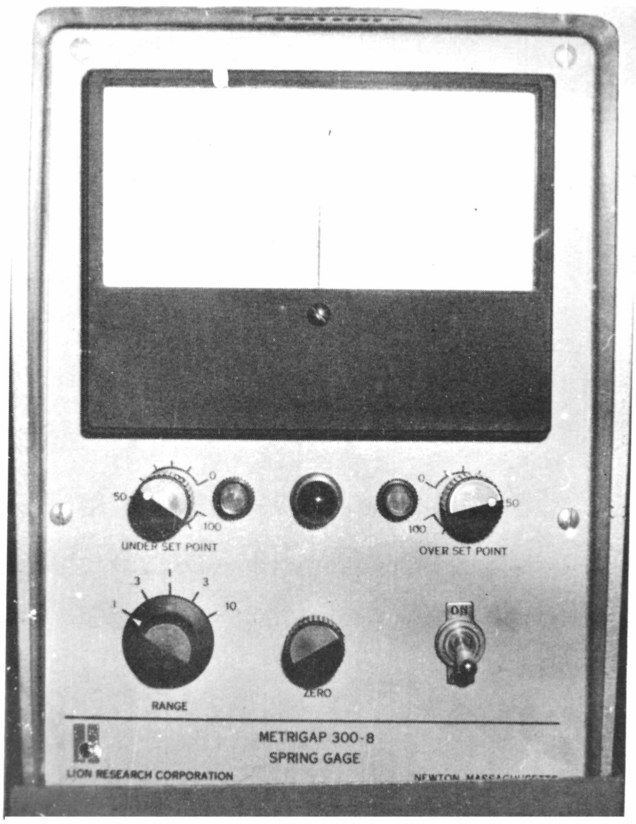
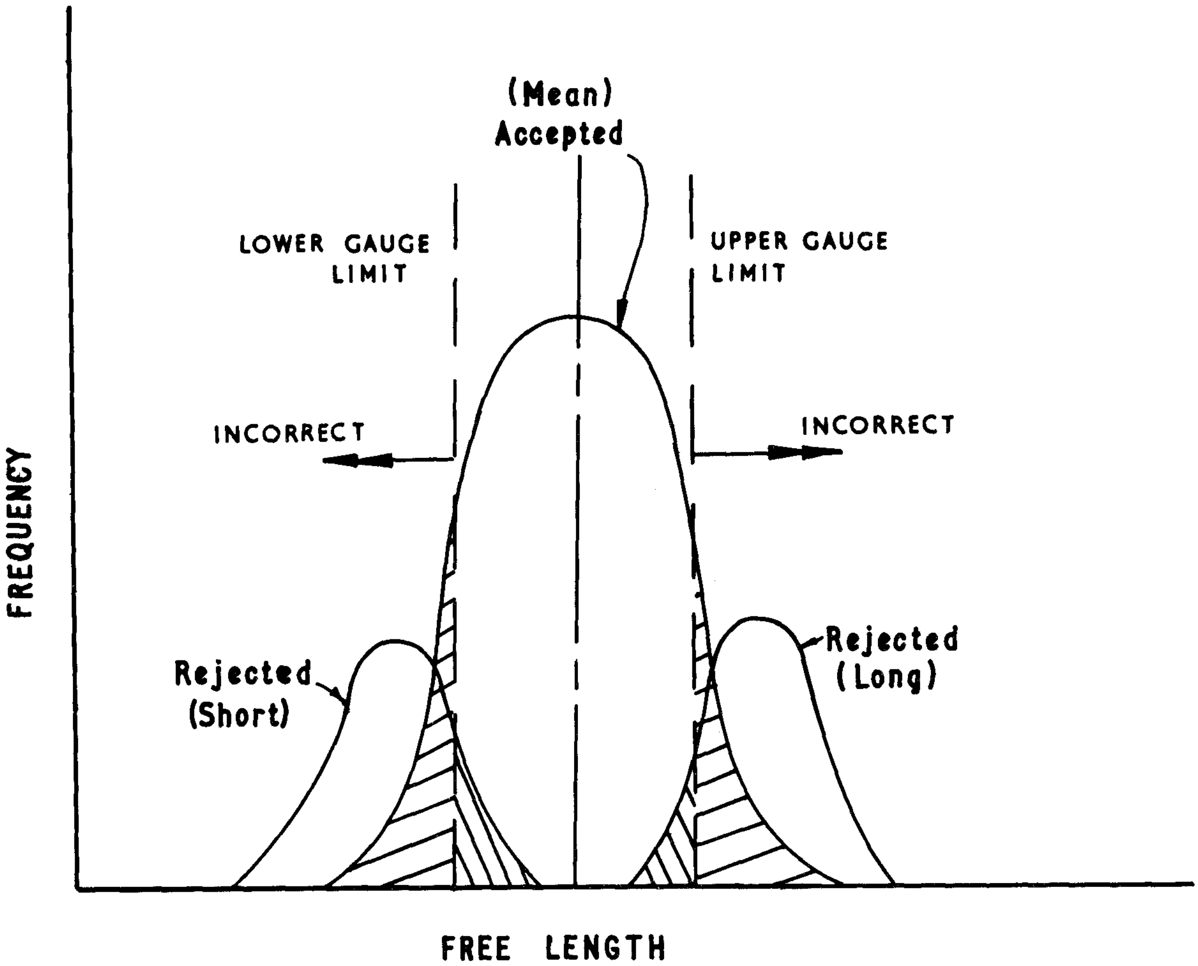


FIG. 2. CONTROL BOX



Wrongly Accepted

Wrongly Rejected

$$\text{WASTAGE IN MANUFACTURE} = \frac{\text{NO. OF INCORRECT SPRINGS}}{\text{TOTAL NO. OF SPRINGS}}$$

$$\text{EXTRA WASTAGE IN SORTING} = \frac{\text{CORRECT SPRINGS REJECTED}}{\text{TOTAL NO. OF SPRINGS}}$$

$$\text{ERROR IN ACCEPTED SPRINGS} = \frac{\text{INCORRECT SPRINGS ACCEPTE}}{\text{TOTAL ACCEPTED}}$$

$$\text{ERROR IN REJECTED SPRINGS} = \frac{\text{CORRECT SPRINGS REJECTED}}{\text{TOTAL REJECTED}}$$

FIG. 3. KEY TO DISTRIBUTION CURVES FOR GAUGED SPRINGS

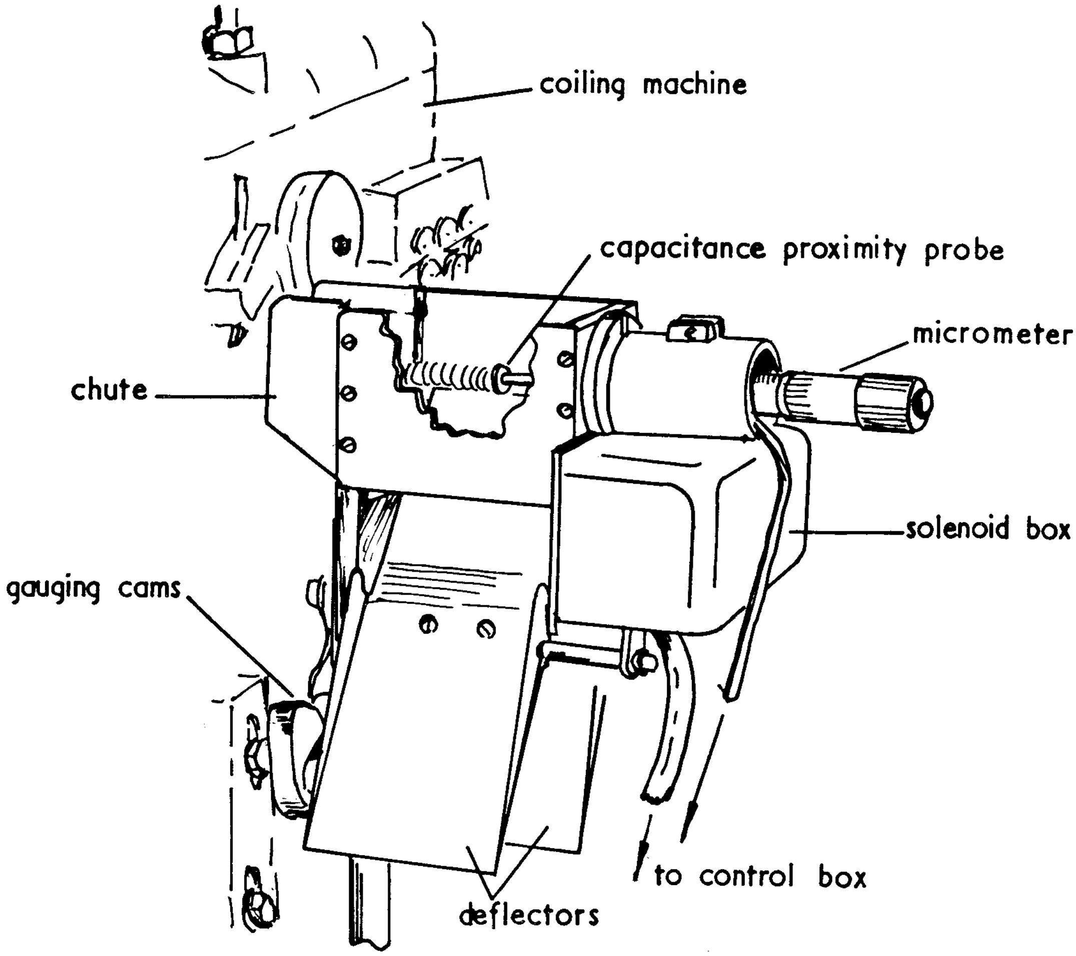


FIG. 4. LION GAUGE

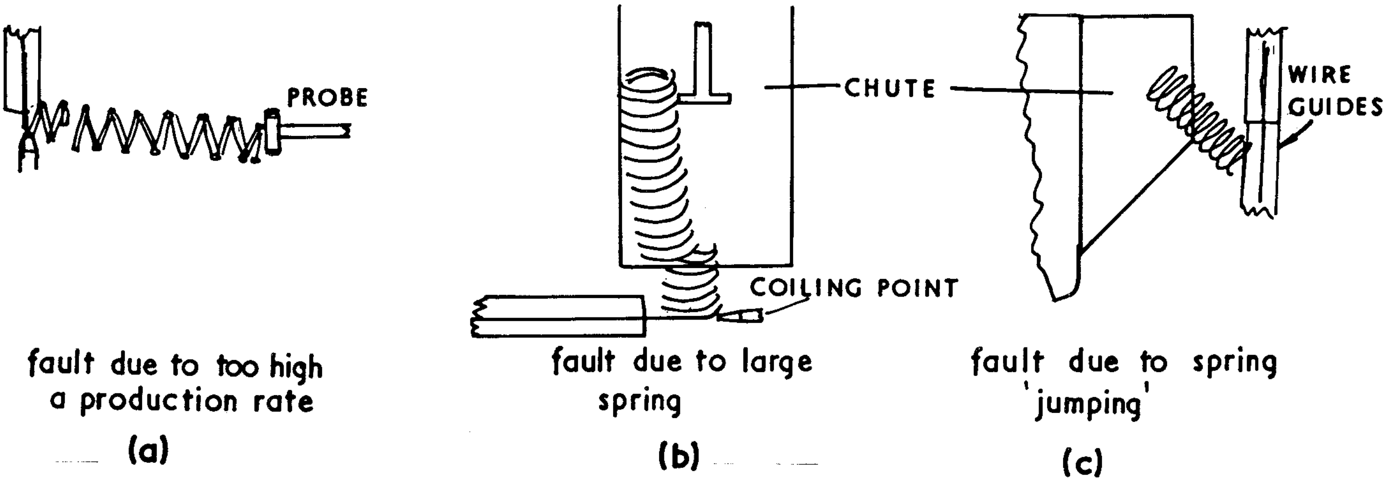


FIG. 5. SPRING DELIVERY ERRORS

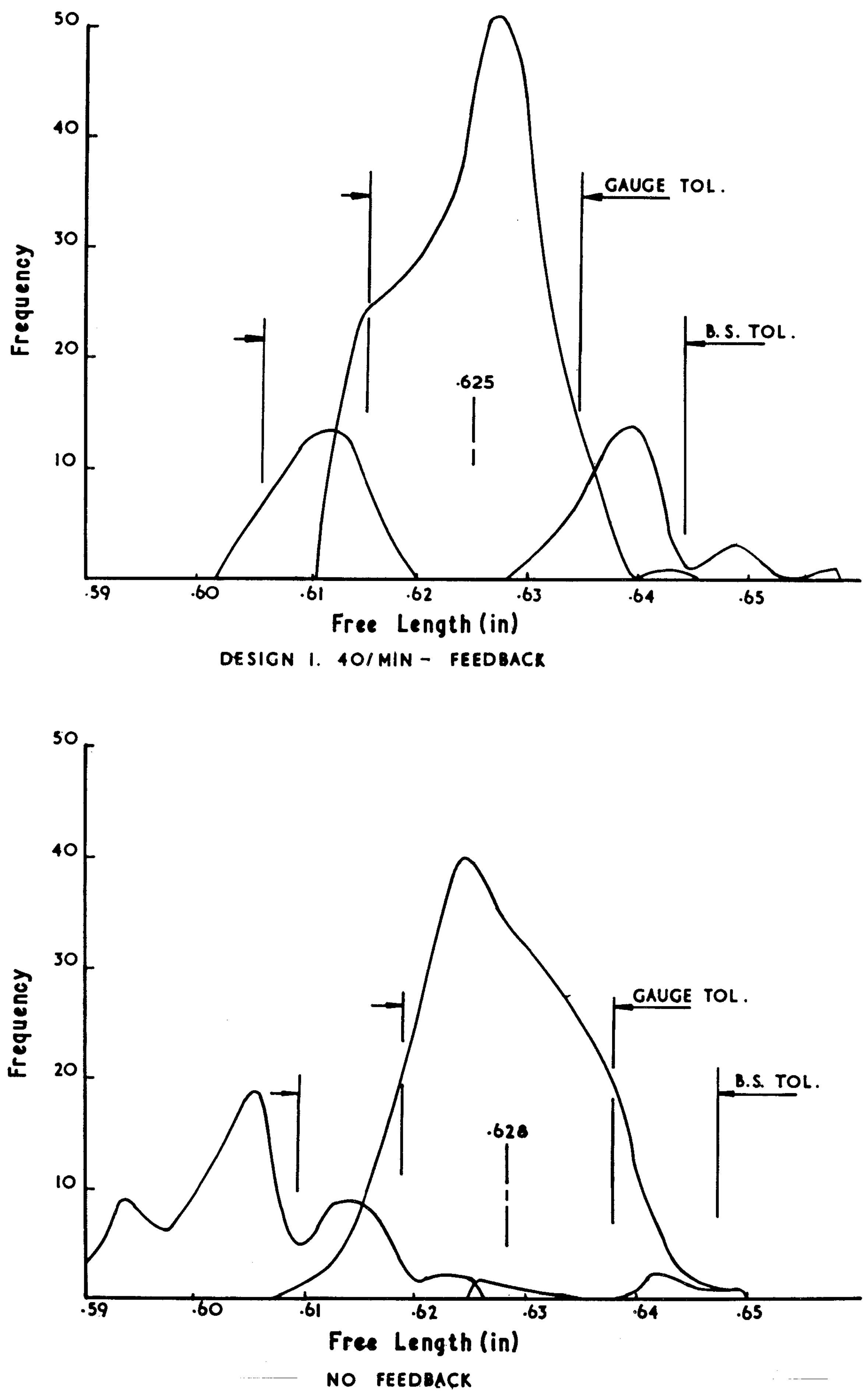
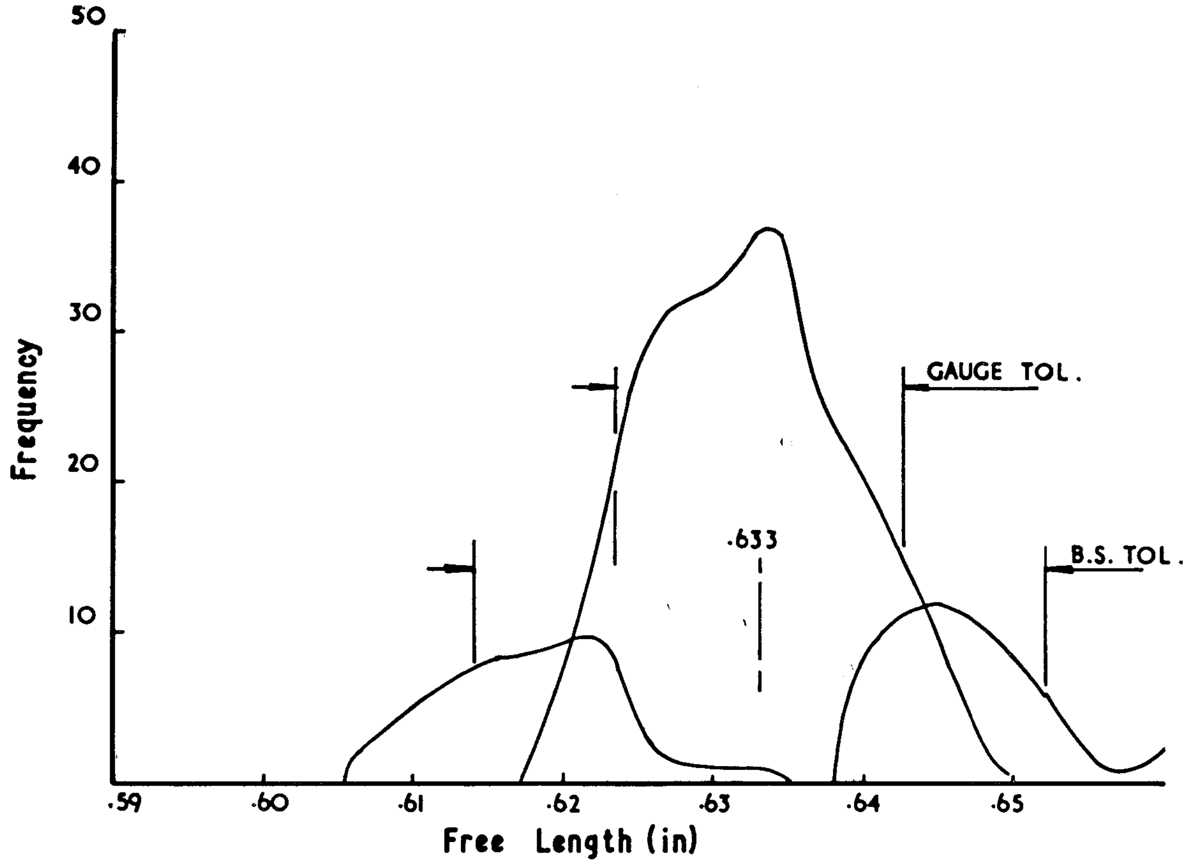
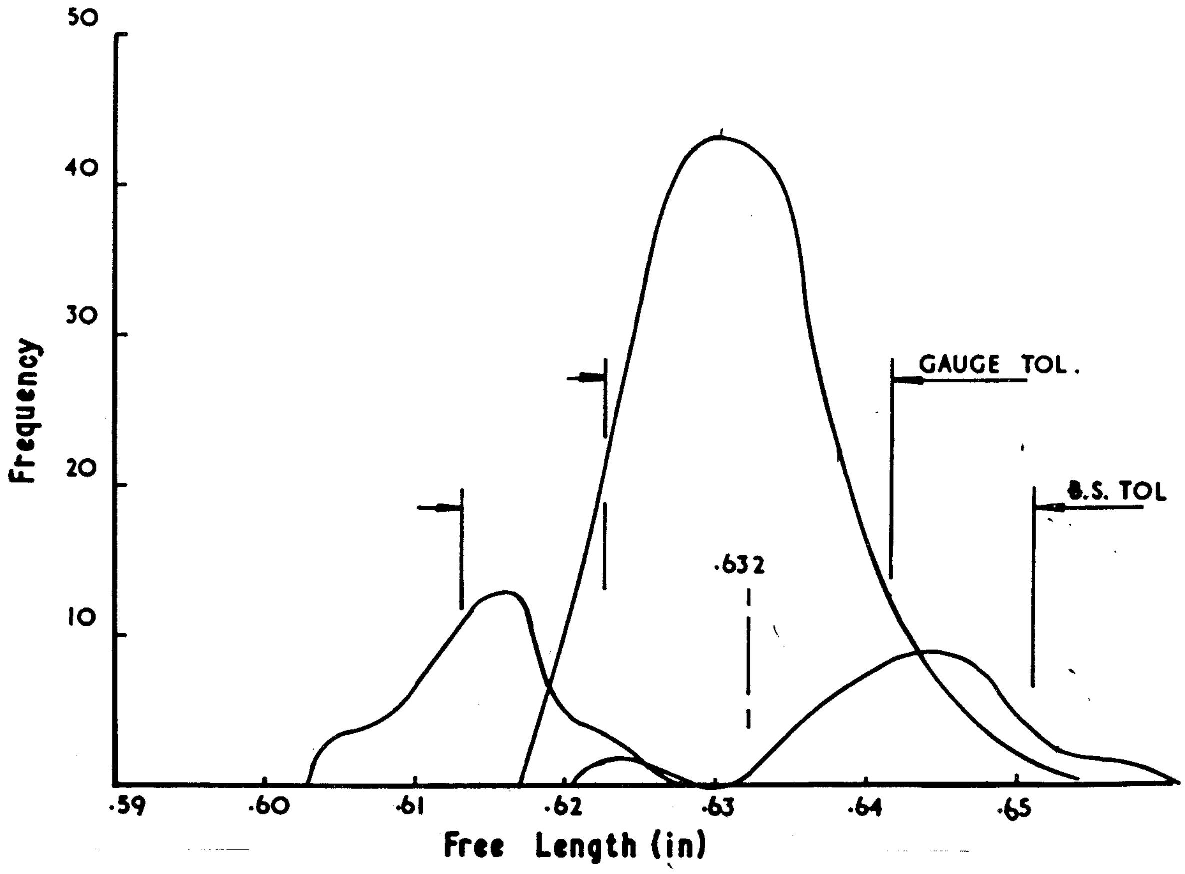


FIG. 6. CALIBRATION CURVES — RUNS I AND 2

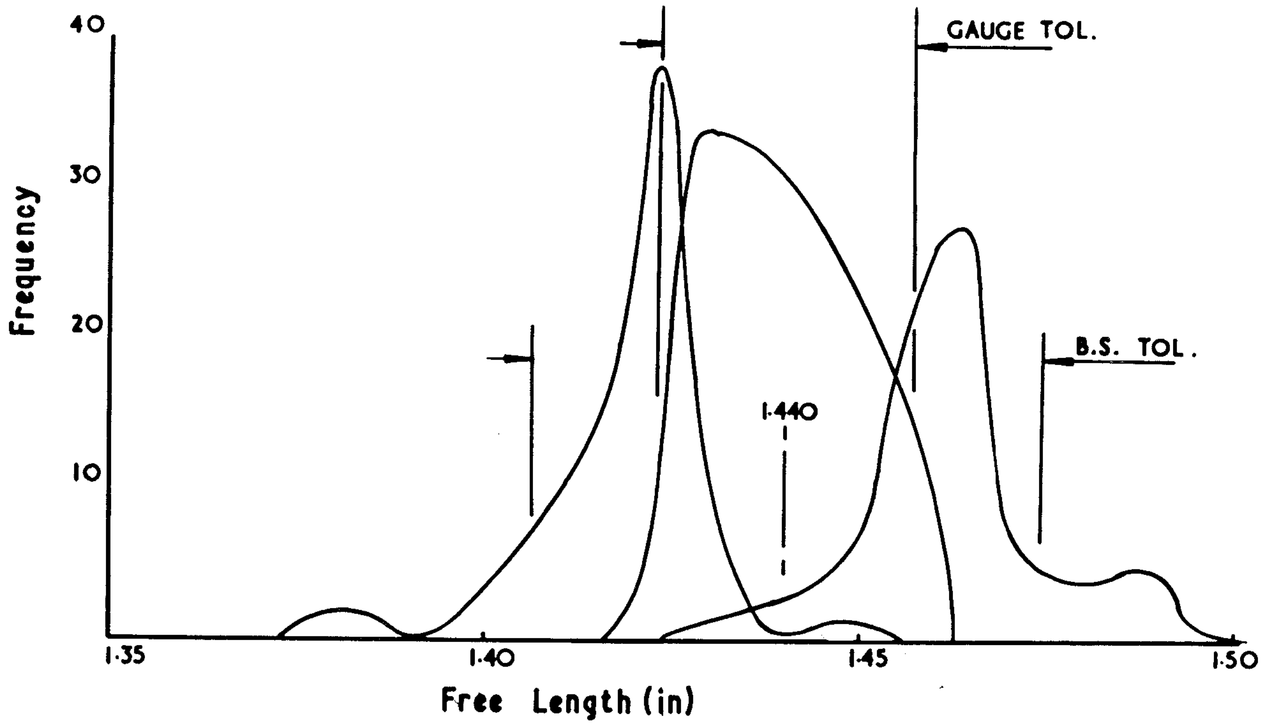


DESIGN I. 80/MIN – FEEDBACK

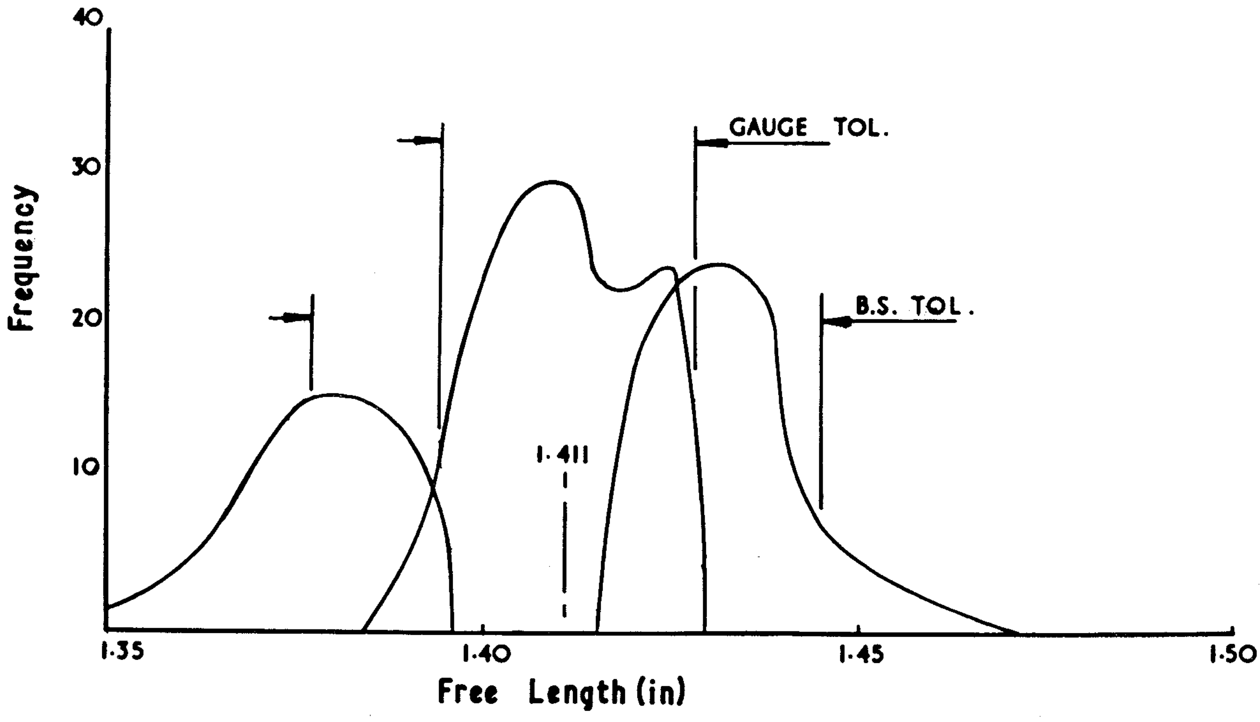


NO FEEDBACK

FIG. 7. CALIBRATION CURVES — RUNS 3 AND 4

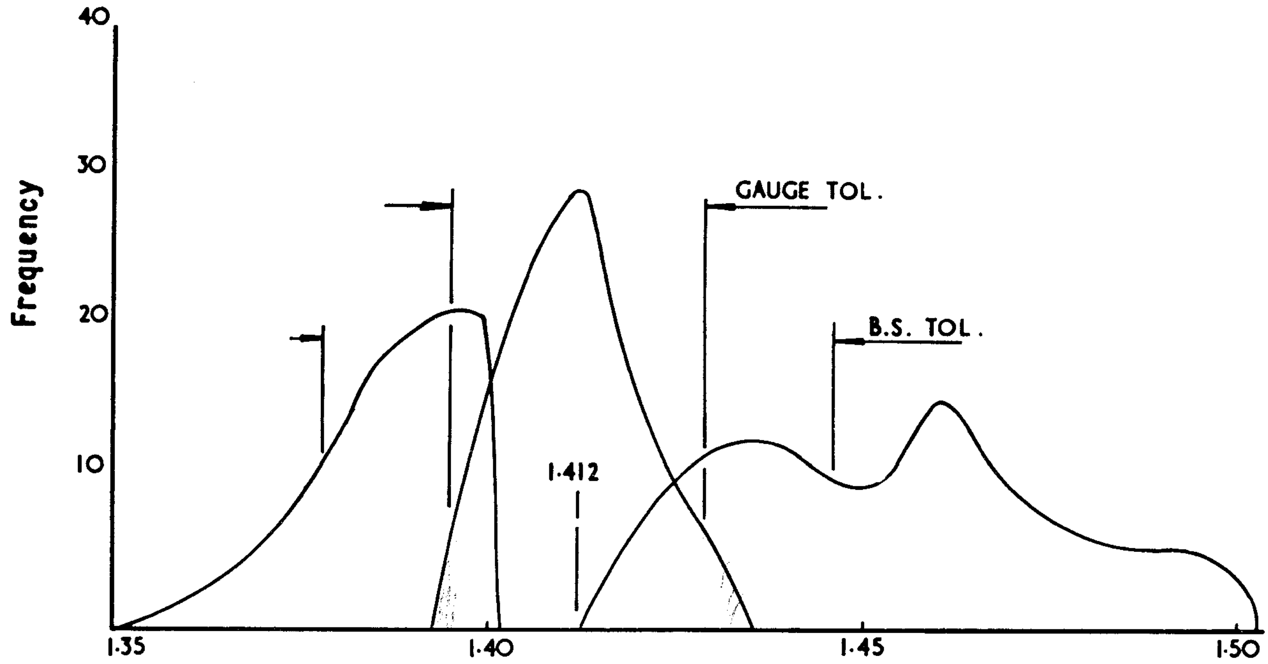


DESIGN 2. 20/MIN – FEEDBACK

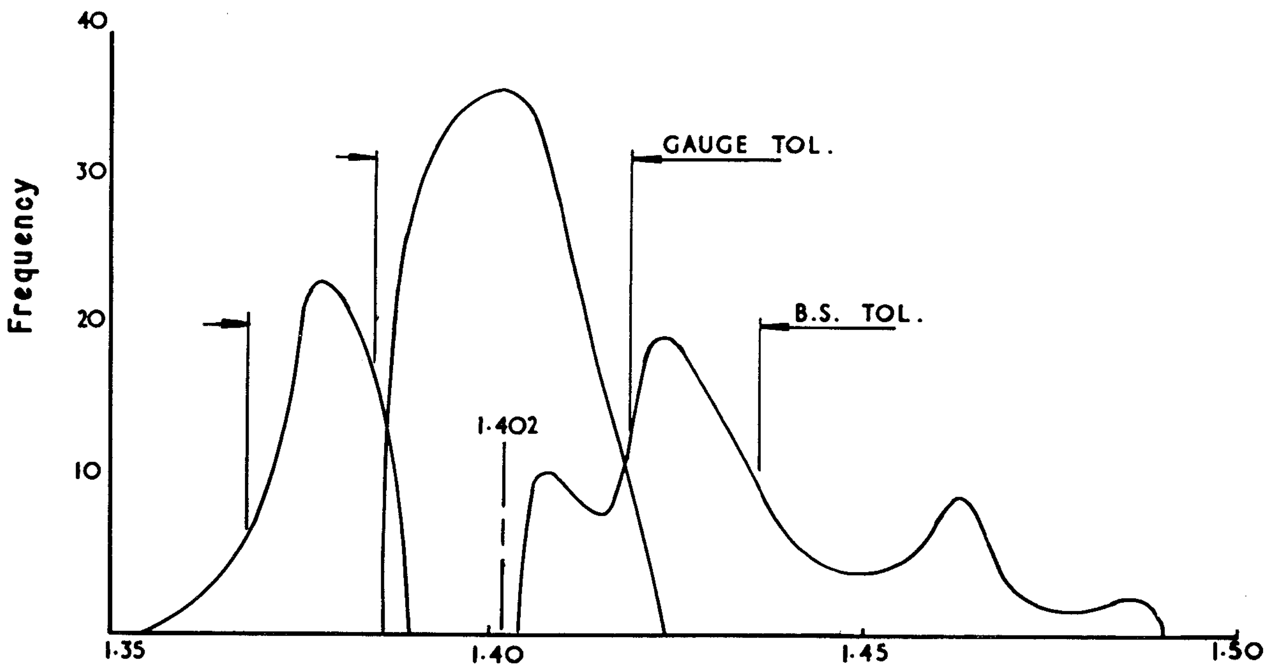


NO FEEDBACK

FIG. 8. CALIBRATION CURVES – RUNS 5 AND 6



DESIGN 2. 40/MIN – FEEDBACK



NO FEEDBACK

FIG. 9. CALIBRATION CURVES — RUNS 7 AND 8.