THE SPRING RESEARCH AND MANUFACTURERS' ASSOCIATION

# SRAMA PASS-THROUGH
# SPRING LOAD TESTER

Report No 372

by

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## 1. INTRODUCTION

With increasing emphasis being placed on quality throughout the spring industry the need for more accurate and faster methods of load testing springs is becoming vital. The use of electronics in recent years to measure the load-length characteristics has improved matters although the machine's operation is still identical to the old mechanical devices, in that so far as the spring to be measured is compressed to the test lengths and held whilst the load reading is manually noted. This is a time consuming and error prone operation which can be eliminated by using a 'pass-through' testing technique. With this technique the springs load-length characteristics are continuously monitored so that the measured load is logged automatically and displayed when the springs length passes through the test length. Although this method has been know for some time, only recently have the electronics been economically available which would allow the construction of a manually operated machine using this technique.

The potential for such a semi-automatic 'pass-through' type load tester was considerable and therefore SRAMA undertook the design, developement and construction of a prototype unit.

## 2. GENERAL REQUIREMENTS FOR SPRING LOAD TESTING MACHINES

The following is a list of desired facilities required to produce a machine of optimum use to the spring user.

1. High load accuracy (BS1610 1985 grade 1 or better)
2. High length accuracy (in order of 0.01mm)
3. Rapid set up
4. Facility for testing loads at length
5. Automatic measurement of spring rate
6. Automatic tolerance band indication to speed up batch testing
7. Selectable fine drive for precise length adjustment
8. Ability to test both compression and extension springs.

## 3. DESCRIPTION OF THE PASS THROUGH TESTING TECHNIQUE AND HARDWARE REQUIREMENTS

The pass through testing technique requires continuous monitoring of the springs length and load during the testing cycle so that the when the spring length equals the test lengths the instantaneous spring load is captured and logged for future analysis. It is at this stage of data capture that major problems can arise. The signal from both the length and load cells must be completely in phase so that there is zero time lag between each signal. Should this not be the case and for example the load signal lags behind the length measurement the captured load value will be lower than the true value. This cannot however, be simply overcome by using ultra high speed electronics since noise (both electrical and mechanical) and cost become very great obstacles.

A compromise must therefore be achieved in which the time lag generated is such that the overall system accuracy is not degraded beyond the specified accuracy limits. The choice of a high speed digital length measuring system eleminates the problems of both noise and speed in the length monitoring and maximises the time available for load sampling. The length measuring device used was a non-contact metal scale system with an accuracy of 5 m which was sufficiently rugged to withstand an industrial environment.

The capture of the spring load data requires three component parts:

The Load cell, the Conditioning equipment for the load cell and the Analogue to digital conversion of the conditioned load cell signal

The load cell must exhibit the standard and rarely achieved requirements of high rejection of non-axial forces, high stiffness, good thermal stability and low hystereses whilst having very good load accuracy. The high stiffness of the load cell is vital so that its frequency response is sufficiently high to allow accurate following of the springs load without a time lag. A high voltage output from the load cell is also advantageous for reducing electrical noise.

The conditioning amplifier which amplifies the small voltage output from the load cell up to a more usable voltage must be fast, have very low noise and be stable over a wide range of temperatures and time.

As previously stated speed and noise unfortunately tend to be linked and thus an acceptable compromise must be made between these two factors.

The analogue to digital convertor (A-D) converts the analogue (voltage) signals, from the amplifier into a digital signal for storing and processing by the computer. This item has to be sufficiently fast so that it is able to read the signal, convert it, and return back ready to read the next load value, in a time considerably less than the time taken for the load value to increase by its minimum resolution.

Failure of any of these three major component parts of the load measuring system (load cell, amplifier, A-D convertor) to operate at sufficient speed will cause an error in the measured load.

Once the load values are captured and logged in the computer memory, standard programming techniques can be used to process the load and length data to produce the required outputs, ie loads at lengths, spring rate, tolerance lights, etc.

## 4. GENERAL DESCRIPTION SPECIFICATION OF THE SRAMA PASS THROUGH ELECTRONICS

The overall block diagram of the system is shown in Figure 2.

### 4.1 Load Cell-Amplifier-A to D Converter

A high stiffness 2000 N low profile load cell was used for this machine. This load cell has a natural frequency of approximately 2800 Hz when fitted with a platten for spring testing. To maintain a phase error of better than 0.1% the fastest rise in load must be limited to approximately 28 Hz (ie approximately $^{1}/_{100}$ of the natural frequency). The signal from the load cell is then fed into the conditioning amplifier which has its own frequency response capabilities. The amplifier chosen was a hybrid device with a response of approximately 2800 Hz. The effect of this frequency response on the phase error is the same as that of the load cell response. This error effect is approximately additive to the load cell error and brings the total system response down to approximately 14 Hz (ie 500 N/mm spring being compressed a 50 mm/sec).

The A-D convertor chosen was a hybrid 12 bit device which allows 1 part in 4096 resolution. This device has a very fast conversion rate of 2 $\mu$sec which represents a sampling speed in the order of 500 kHz and adds no further significant lag to the load signal. This fast response is also required to allow sufficient time after the conversion for the reading of the converted data before the A-D starts to convert the next reading.

The layout and connection of these three major components was critical in order to minimise the noise due to interference effects. Considerable effort was required in order to optimise this feature and limit the signal noise to acceptable levels.

### 4.2 Length Measurement Device

The device used was an optical grating unit which, after conditioning, gave a resolution of 0.01 mm with an accuracy of 0.005 mm. This unit has a reading speed of 50 kHz, ie a traverse speed of 5000 mm/sec. The output from this device is fed directly to a display on the front panel and to the length comparator circuits, which detect when the spring length equals the preset length in the pass-through mode.

### 4.3 Input-Output

The load tester requires many input-output facilities. The inputs are needed for controlling the machine and include the test length digi-switches, the tolerance band digi-switches, tare, reset, range, manual and length zero switches. The outputs supply information to the user in the form of digital displays for length, load 1, load 2, spring rate and in the form of coloured lights as used for the tolerance bands indicators, error and ready signals. The reading of the input data and the feeding of the processed data to the various output displays are all controlled by an on-board Z80 based computer, via the data and peripheral control bus.

## 5. DESCRIPTION OF THE LOAD TESTING FRAME

The loading frame is of conventional 'H' frame type with the moving crosshead supported by two vertical guide pillars. This type of frame was used because it offered very high rigidity and mechanical accuracy which was vital for repeatable results.

The drive for the moving crosshead is by either the fast starwheel or the self locking worm drive. These engage via a gear box onto two parallel racks cut into the rear of the guide pillars. The gear box uses roller bearings throughout with phosphor bronze for the guide pillar bearings.

The testing of extension springs is accomplished by a steel frame work which passes through the main guide pillars from the top hook to the base of the load cell. This layout was selected so that whilst testing extension springs, the loading drives and the load cell all operate in the same manner and direction as for compression springs. The capacity of the loading frame allows the testing of springs 285 mm x 75 mm diameter with a maximum load of 2000 N. The electronic control box is mounted to the left of the loading frame on an extension of the base.

## 6. OPERATION OF THE SRAMA LOAD TESTER

The load tester has two modes of operation, 1) Manual mode, 2) Auto mode ('pass-through' mode).

### 1. Manual Mode

In this mode the machine operates exactly the same as a normal electronic load testing machine. Only the length and load 1 displays function. To carry out a spring load check in the manual mode, the following procedure is used.

1. Bring two plattens together, apply nominal spring load and press length zero.

2. Place the spring onto the centre of the platten.

3. Select 0-200 or 0-2000 N range, as required.

4. Press tare to zero load display.

5. Set upper and lower tolerance band on the digi-switches below load 1 display, if required.

6. Use starwheel or fine drive to compress the spring down to the desired length and note load reading or tolerance lights.

7. Place new spring on load platten and repeat step 6 if more than one spring is required.

2. <u>Auto Mode</u>

In this mode the pass-through system is engaged with load 2 and rate displays functional. To carry out a spring load check in the auto mode the following procedure is used.

1. Bring two plattens together, apply nominal spring load and press length zero.

2. Set the two test lengths on the digi-switches below the length display.

3. Place the spring on the centre of the platten.

4. Select 0-200 N or 0-2000 N range as required.

5. Set tolerance bands on digi-switches below load 1, load 2 and rate displays.

6. Disengage manual switch.

7. Press reset and then tare.

8. Compress the spring using starwheel past length 2 without stopping and release.

9. Note load and rate readings or tolerance lights.

10. Repeat steps 8 and 9 after ready light has illuminated (approximately 0.6 seconds after releasing spring) if further springs require testing.

In addition to measuring the spring, the computer also keeps a check on the operator inputs so that if incorrect procedures are used, the error signal will illuminate. These error checks include attempts to tare off excessive loads, length 1 and length 2 too close, over-range and several internal checks on the mathematical values being calculated.

## 7. TECHNICAL SPECIFICATION ON ACCURACY

The accuracy of load testing machines is the summed total of tranducer, mechanical and electrical errors.

The overall capacity and accuracy of the machine, as tested, is tabulated below.

| | |
|---|---|
| Maximum Testing Force (N) | 2000 |
| Measuring Ranges (N) | 200/2000 |
| Load Resolution (N) | 0.1/1.0 |
| Maximum test Length (mm) | 285 |
| Resolution (mm) | 0.01 |
| Maximum Rate (N/mm) | 999.9/99.99 |
| Resolution (N/mm) | 0.1/0.01 |
| Overall calibrated Accuracy of Load Cell (% Full Scale) | ± 0.3/± 0.1 |
| Accuracy on Length (mm) | ± 0.01 |

Accuracy of Rate (N/mm) =

$$\pm \frac{\text{Load 1} - \text{Load 2} + 2\ (\text{load error})}{\text{Length 2} - \text{Length 1} - 2\ (\text{length error})} - \frac{\text{Load 1} - \text{Load 2}}{\text{Length 2} - \text{Length 1}}$$

Overall calibration to BS 1610 A1 1964.

## 8. CONCLUSIONS

1. The machine has successfully implemented the "pass-through" technique with a manually operated drive.

2. Set up time from one spring design to another in the pass-through semi-automatic mode is very minimal (typically 30 seconds).

3. Batch testing of springs is very much faster with errors due to operator fatigue eliminated. Speeds of 600 springs/hour are typical for measurement and sorting on two load lengths and rate.

4. The successful development of this manually operated "pass-through" testing machine has paved the way for the construction of a fully automatic machine using the same technique.

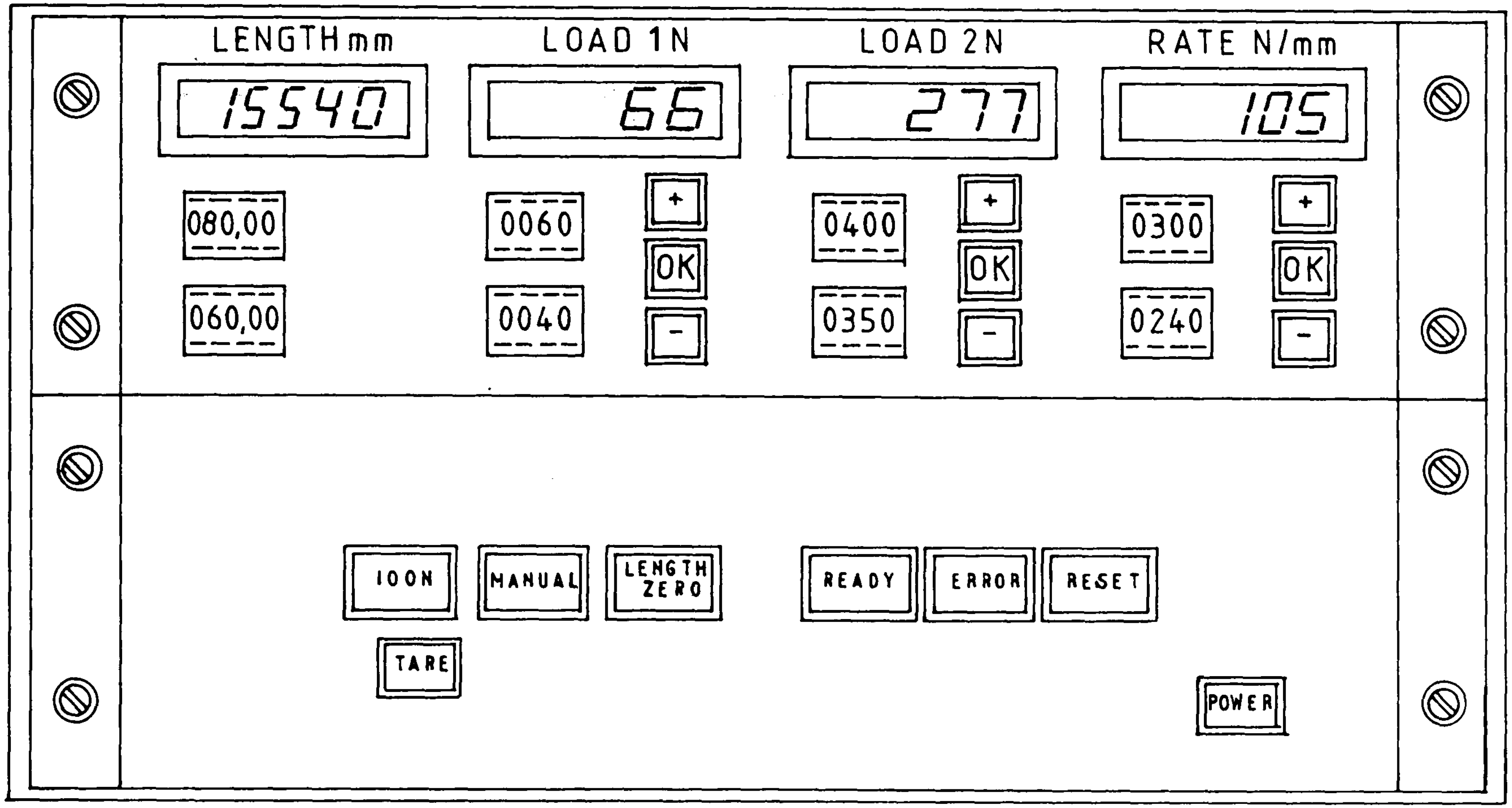


FIG 1 : FRONT PANEL LAYOUT

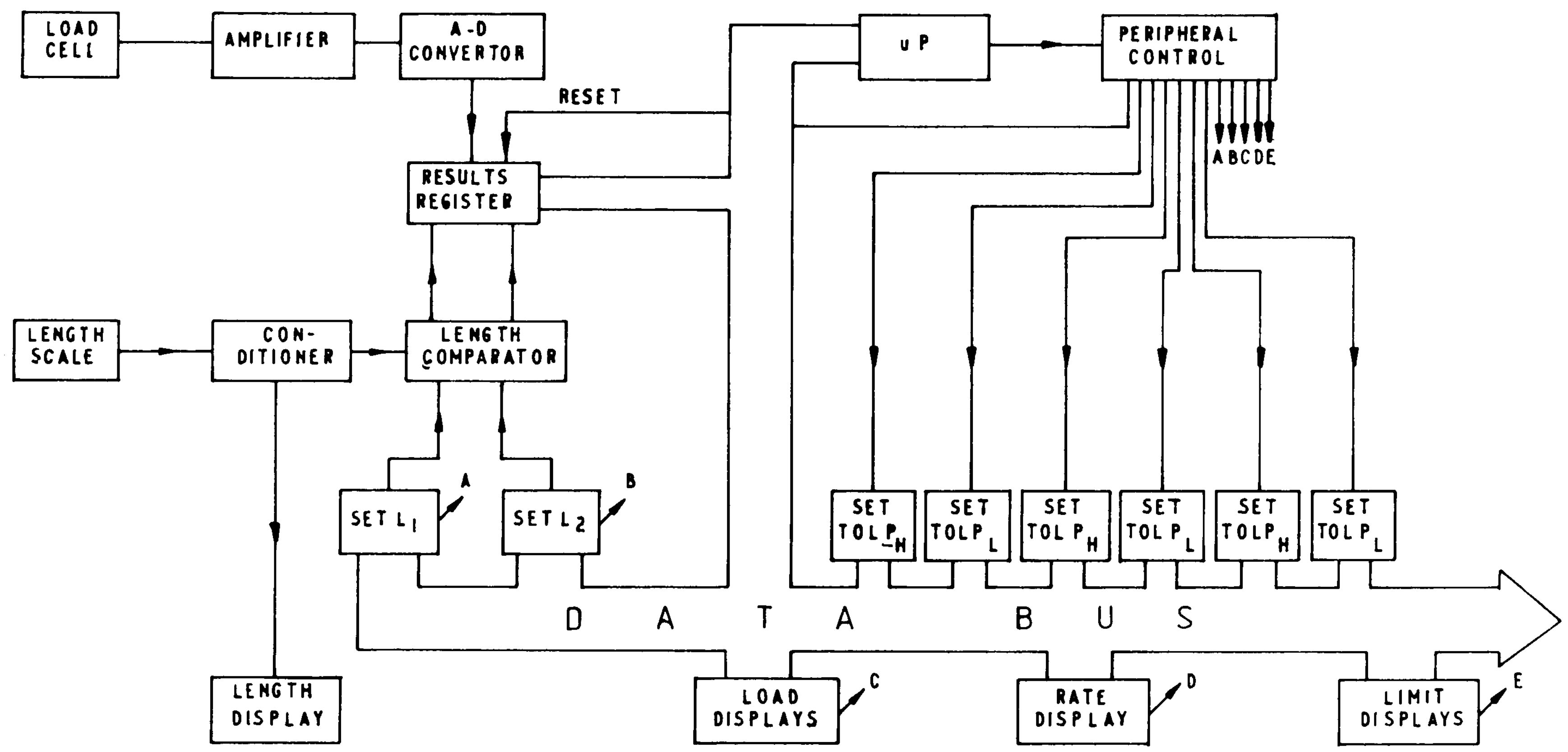


Fig 2 : BLOCK DIAGRAM OF ELECTRONICS

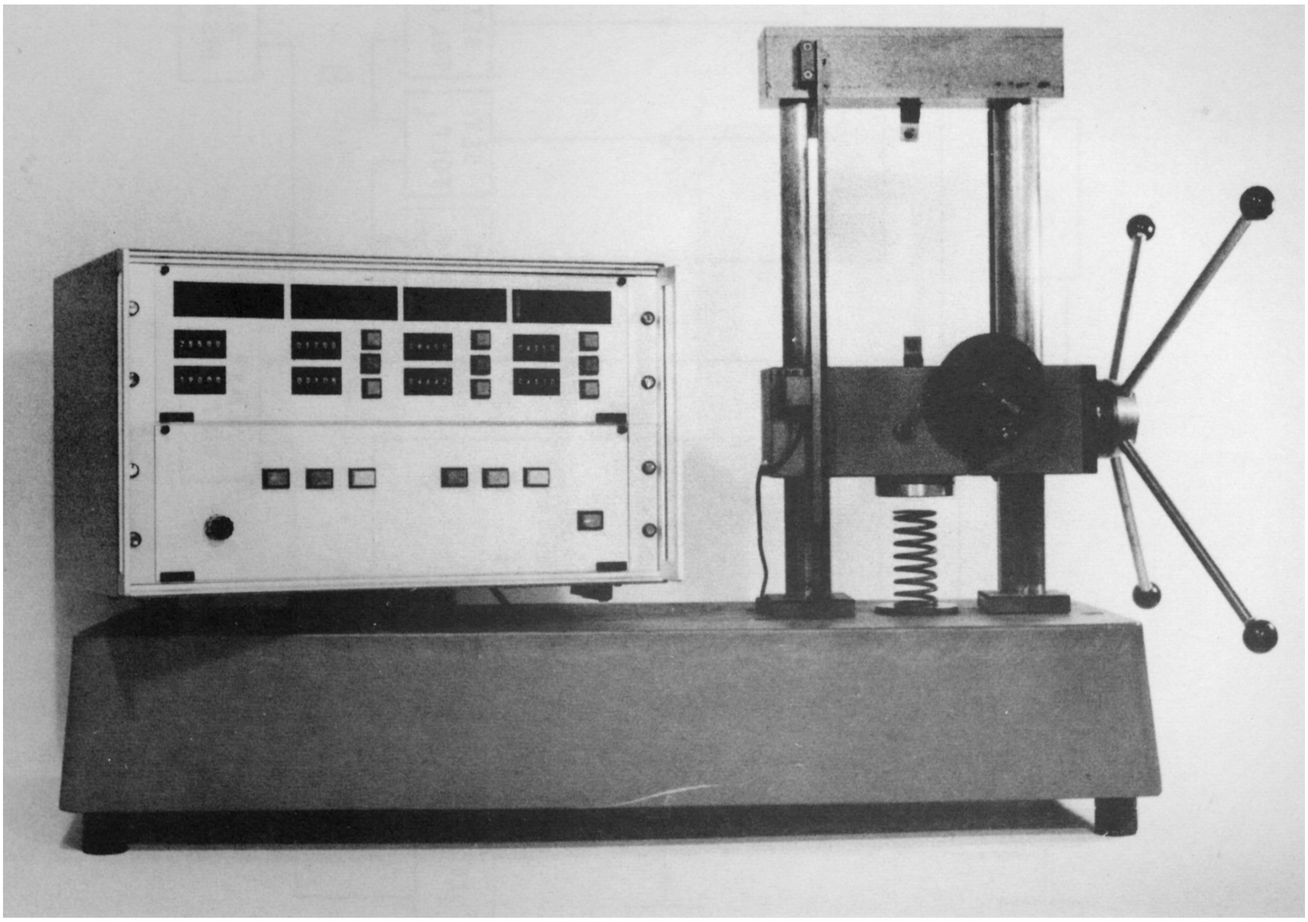

Fig 3  THE PROTOTYPE MACHINE