PROBLEMS ENCOUNTERED IN WIND TUNNEL BALANCE DESIGN

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INTRODUCTION

This paper considers two problems which arose in the design of separate wind tunnel balances. They are presented here in the hope that someone in the audience will be able to shed some light on them, as perhaps these problems have occurred before at another laboratory. The first problem considered is the link design in a low frequency balance which is planned to replace the TEM balance beam balance in the high speed test section of the de Bray wind tunnel. The second problem considered is the lower than expected natural frequency of a high frequency base balance built for testing stiff building models.

SIX COMPONENT BALANCE FOR HIGH SPEED TEST SECTION

Balance Design

The de Bray wind tunnel is a closed circuit design, and the high speed test section which is 762 mm wide and 610 mm wide is often used for student projects such as testing model cars, power boats, and aircraft etc. The present balance is of the weigh beam design and weights have to be slid along manually until the beam is horizontal again after the wind is turned on. It is capable of measuring lift, drag and pitching moment, and it is fair to say that it has worked well over its say 50-year life. We would now like to record results directly by computer, and so a new six-component design was carried out based on using strain gauge load cells. The balance sits in the floor of the wind tunnel. It has a circular plate which can rotate to the desired direction. The live part of the balance consists of a Tee, with pads where models can be attached in various places. This can be seen in Fig. 1. The Tee can be seen in Figs. 2 and 3.

The load cells are connected to the balance through links. A typical link can be seen in Fig. 4. The link is there so that the location and direction of the load onto the load cell is known. The two necked-down regions are supposed to act as perfect hinges. The kind of deflection expected of the links is shown in Fig. 5.

Calibration Results

When it came time to calibrate the balance, it was loaded by means of weights on strings over pulleys in the normal way. However, it soon became apparent that there were significant interactions, and these were not expected. This is because when an earlier version of this balance had been built some years previously as a student project, the interactions had been rather small.

It is expected that the links are actually too stiff. Although they are supposed to isolate the load cell from unwanted loads, they seem unable to do this. In fact, when tested to destruction in a tensile testing machine, they failed at a considerably higher load than expected.

New Link Design

We now wish to redesign the links, and would appreciate any advice you might like to offer on how to go about it. We have tried gluing drill blanks into brass ends, and they have behaved quite well on some smaller balances, but they are rather slow to make. Some samples of the links can be seen in the overheads.

If you can see any other design errors in the balance, we would also like to hear about them so that we can attend to them at the same time.

HIGH FREQUENCY FORCE BALANCE

Design

We are very interested in measuring the dynamic forces on tall buildings, and built a balance especially to do that. Its design is based on an L-shaped girder, which is attached to ground through unbonded strain gauged units manufactured by Pioden. The balance was made to very high standards. The L was kept light to enable it to measure high frequencies, and the load cells were placed exactly where required.

Calibration Results

The balance has been calibrated by applying appropriate dead loads, and it is very linear with negligible interactions between components. The load cells have quite high electrical outputs so the signals are large and not very noisy. Recently the natural frequency was investigated, and that is when the unexpected results occurred.

Natural Frequency Calculation

It is useful to consider the balance a two dimensional as shown in Fig. 8. Here we have ignored the horizontal load cells, and only considered the vertical ones. This then becomes a two degree of freedom vibrations problem, as shown in Fig. 9. When the equation of motion is solved, the natural frequencies calculated are 80.5 and 246 Hz. We also replaced the load cell directly under the model with a rigid link. When this single degree of freedom system (Fig. 10) was analysed, the natural frequency obtained was 120 Hz. All these calculations are based on the manufacturers information that at full load of 1 kg, the extension of the load cell is 0.03 mm.

Natural Frequency Measurements

In order for the actual natural frequency to be determined, the load cells were connected up to amplifiers, etc., and the signals fed into a PC. The model was then given a little flick by hand and the signals recorded. A frequency spectrum was then plotted. The results of one such run is shown in Fig. 11. It can be seen that the lowest natural frequency is about 26 Hz. This is significantly lower than expected, and we have not yet been able to fathom why it is as low as this.

Possible Explanations for the Lower Than Expected Natural Frequency

One explanation is that the load cells are not as stiff as quoted. If the deflection is say 0.3 mm at full load of 1 kg instead of 0.03 mm, then the calculated natural frequency for the single degree of freedom model is 38 Hz, which is closer to the measured result, but still on the high side. We have not yet measured the stiffness of the load cells.

Another possibility is that the model itself is not stiff enough. The model was constructed out of Styrofoam glued to an aluminium base, and appeared to be very stiff. When such measurements were repeated with much shorter models, such as one diameter high, the natural frequency was still low, and this tends to rule out the effect of model stiffness.

CONCLUSIONS

Link design is difficult because they have to be strong yet flexible, and ideally should fail before the load cell to protect them from large loads applied by students.

Unbonded strain gauges like those from Pioden are wonderful devices, but care is needed when using them to construct balances which have high natural frequencies.

This is a Wind Engineering Workshop, and so the work presented herein is incomplete. I am hopeful that these kinds of problems have been solved elsewhere, and I therefore hope that you can help me.

Acknowledgements

I am most grateful to Hans Burggraaf and S. Sathianathan for carrying out these measurements as part of their Master of Engineering Projects.

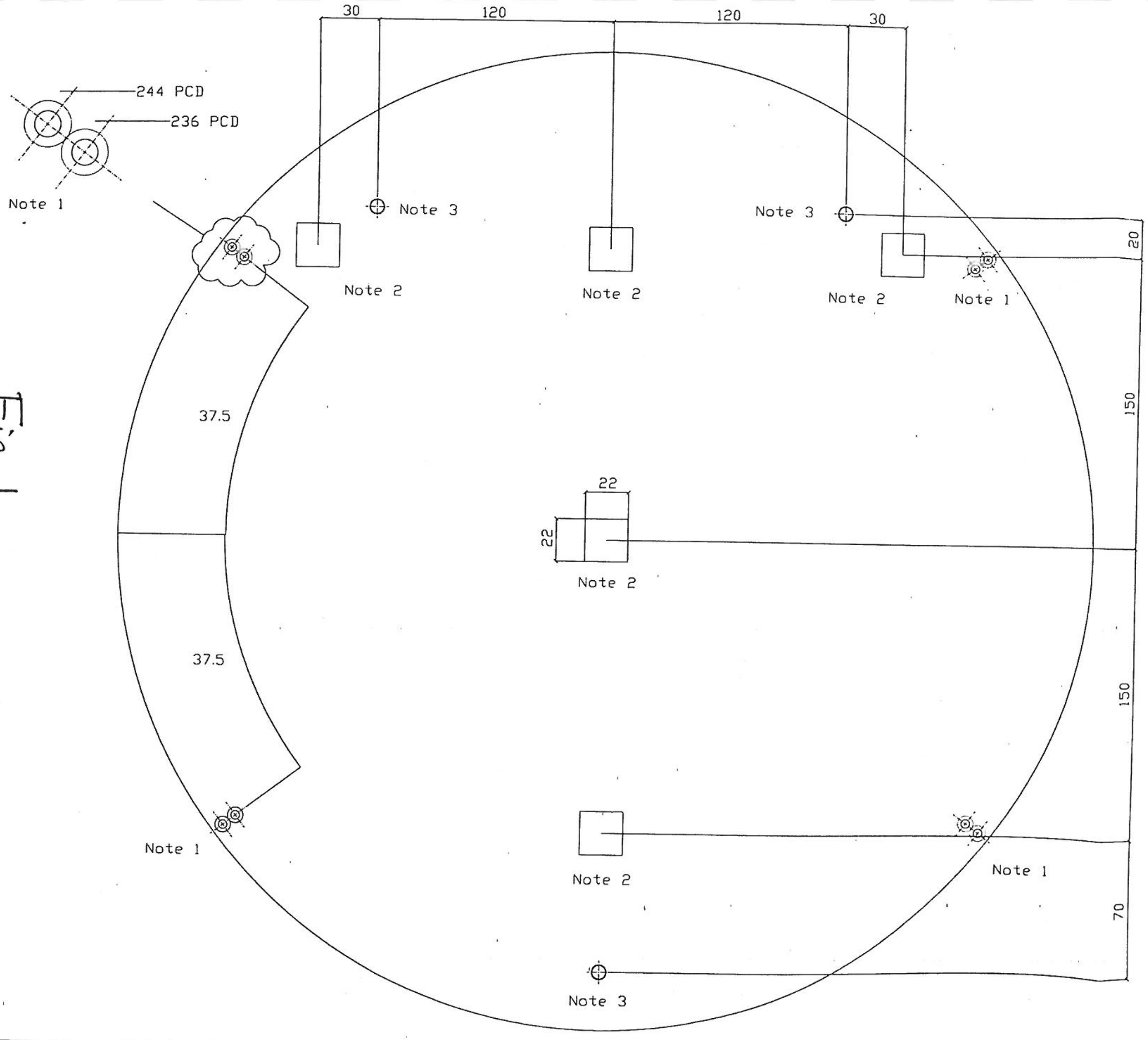


Fig 1

Notes

Note 1
4.5 mm holes countersunk to accept 4mm machine screw heads

Note 2
22x22 mm square cutouts with radiused corners

Note 3
Locking key holes tapped to M8

Materials
Existing aluminium top plate to be re-used

Title	
WIND TUNNEL BALANCE TOP PLATE DETAILS	
Drg No	Rev
001	DR
Scale	Date
1:2	2/5/96
Drawn	
H.Burggraaf	

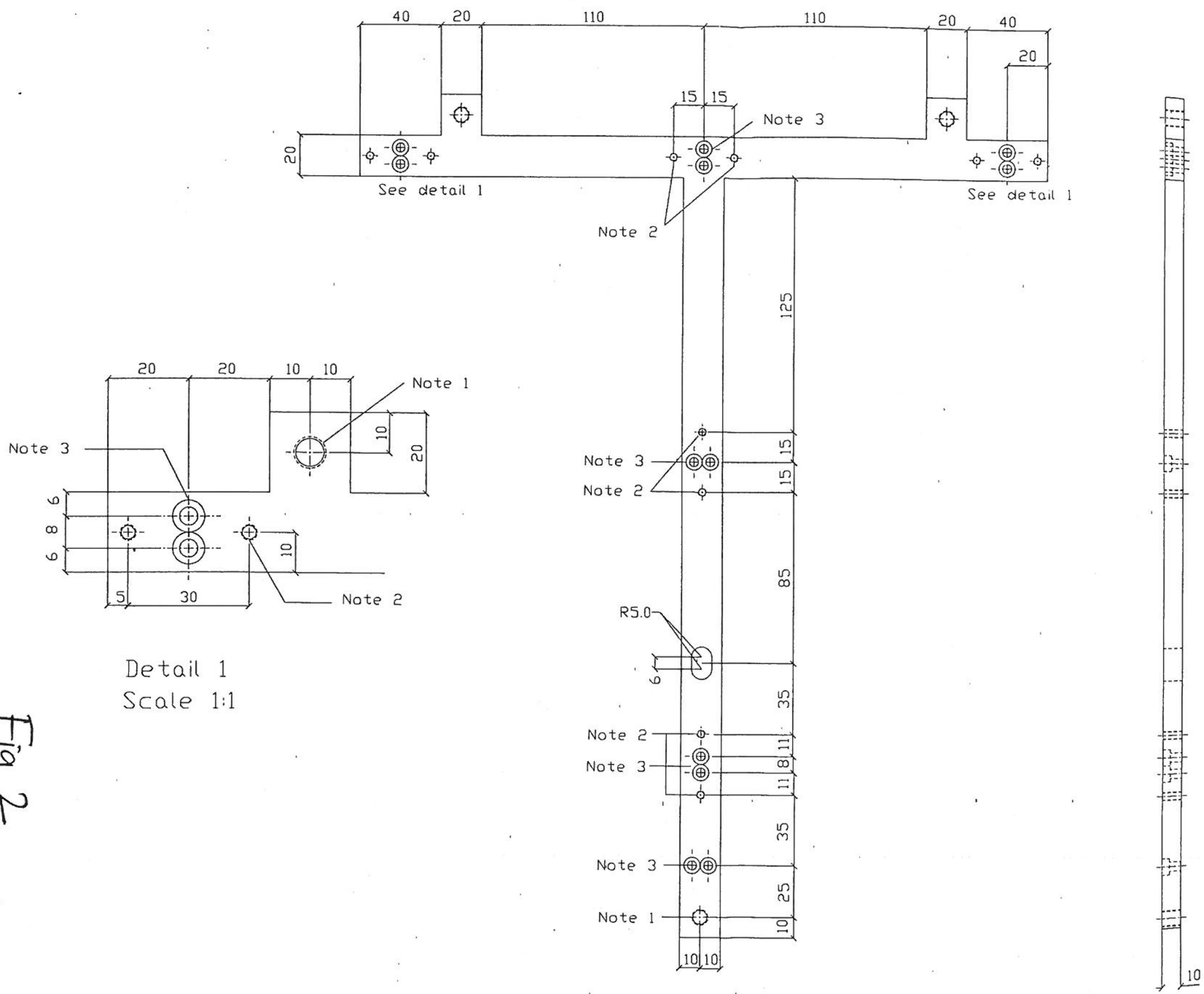


Fig 2

Notes:

Note 1
Locking key holes tapped to M8

Note 2
Holes tapped to M4

Note 3
4.5 mm holes countersunk from above to accept [illegible] screw heads.

Materials,
Balance Tee Aluminium alloy 6061 T6

Title	
WIND TUNNEL BALANCE	
TEE DETAILS	
Drg No	Rev /
002	0R
Scale	Date
1:2	2/5/96
Drawn	
H Burggraaf	

A4

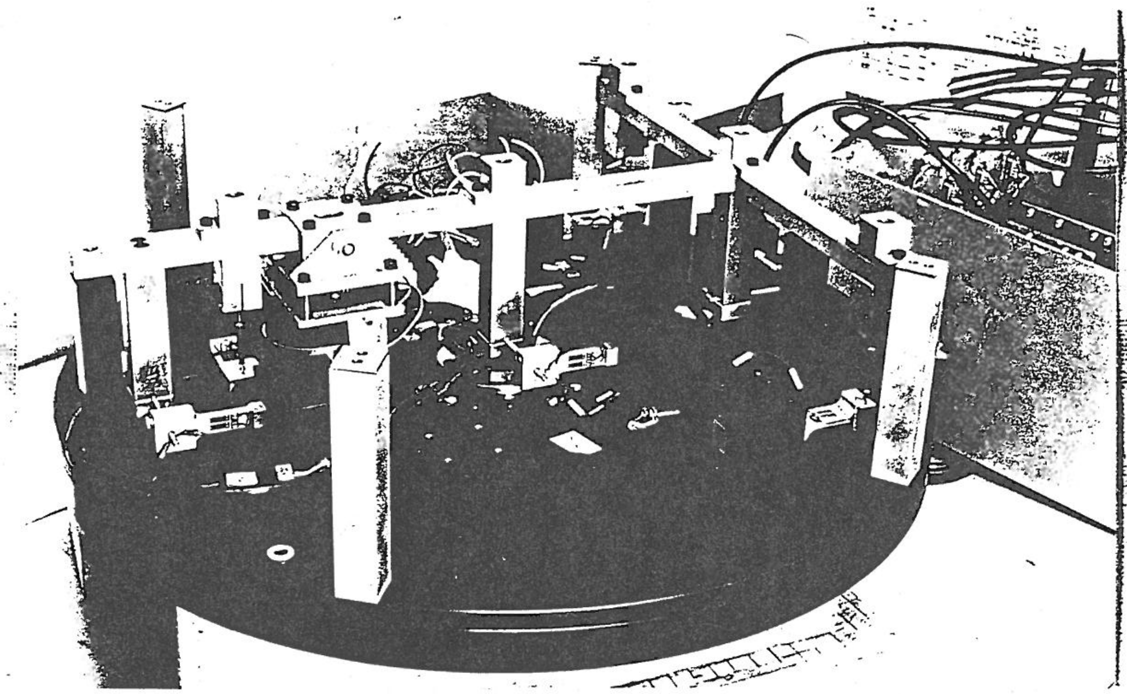


Fig 3

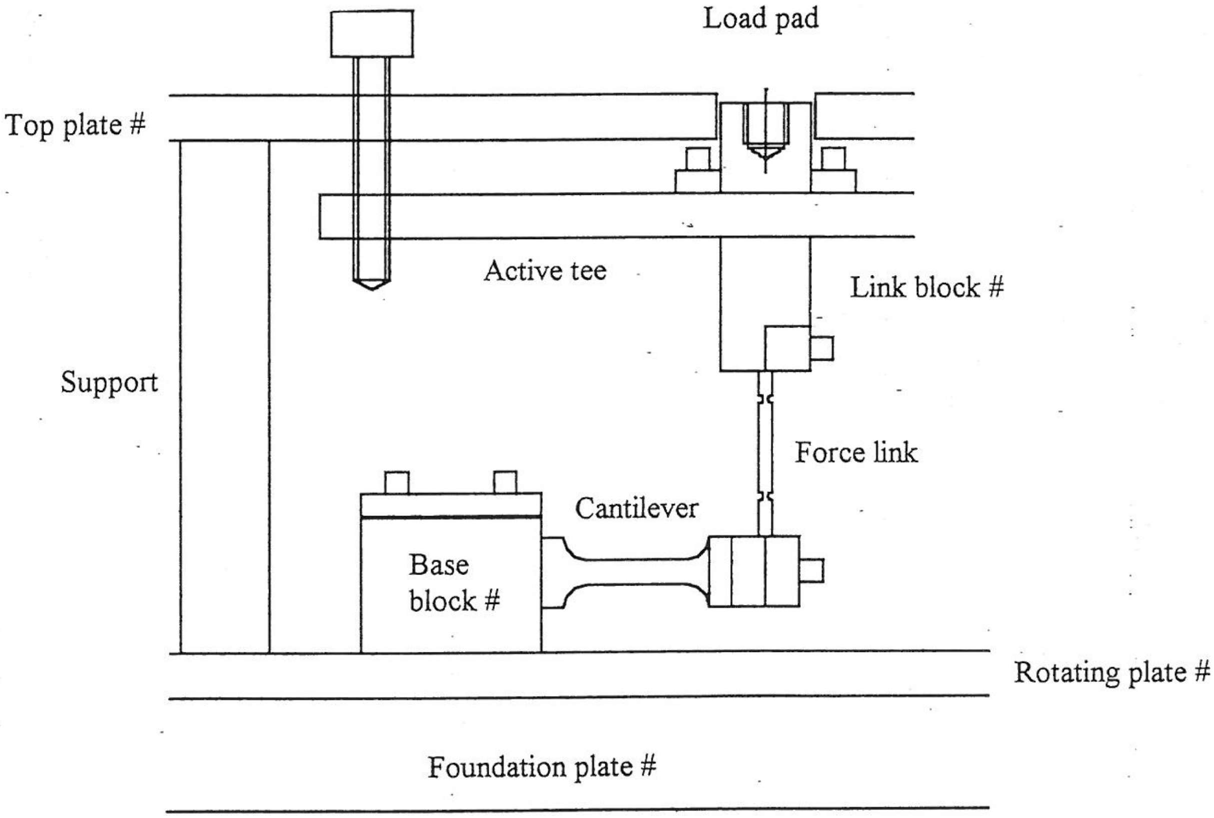
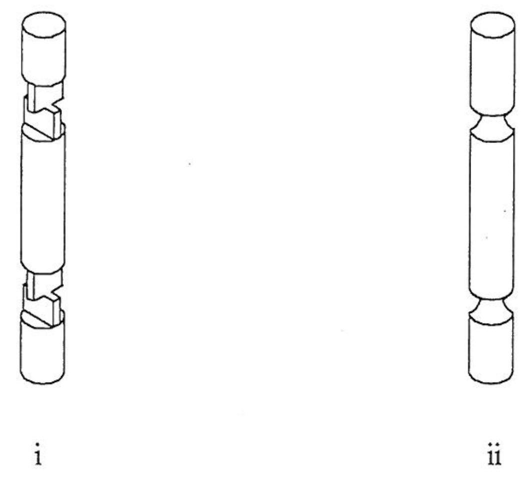
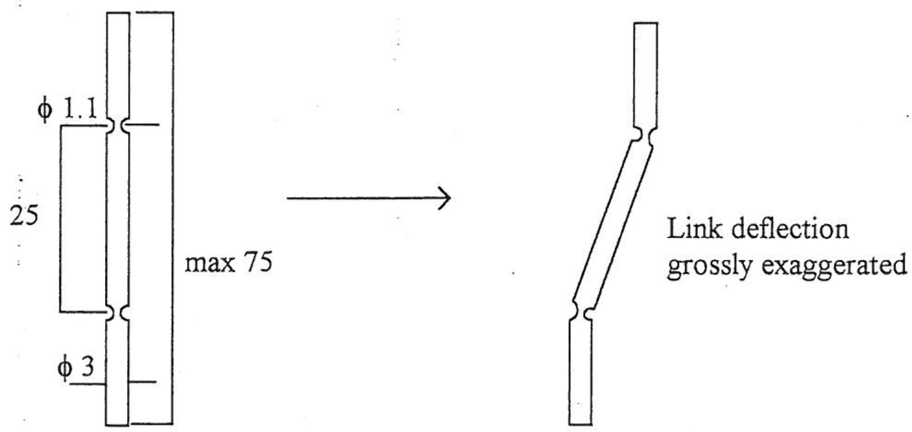


Figure 3.2 Typical cross-section of the balance. Items marked # are those which are reused from the previous design

Fig 4



Link types



Expected link deflection. Dimensions in mm.

Fig 5

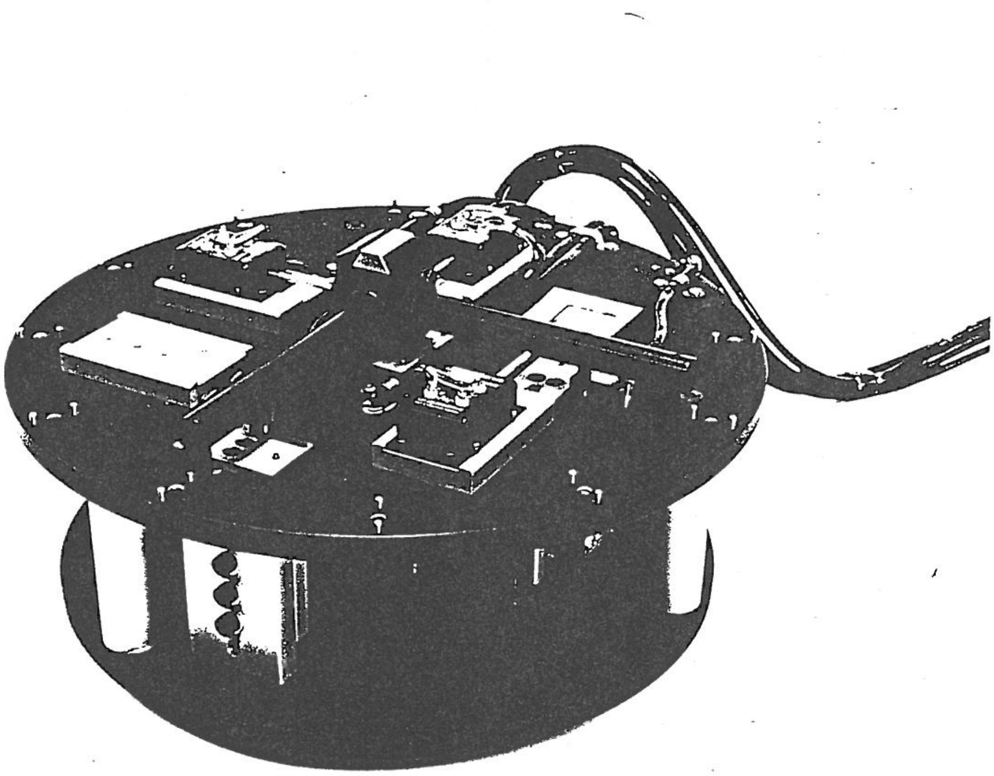


Fig 6

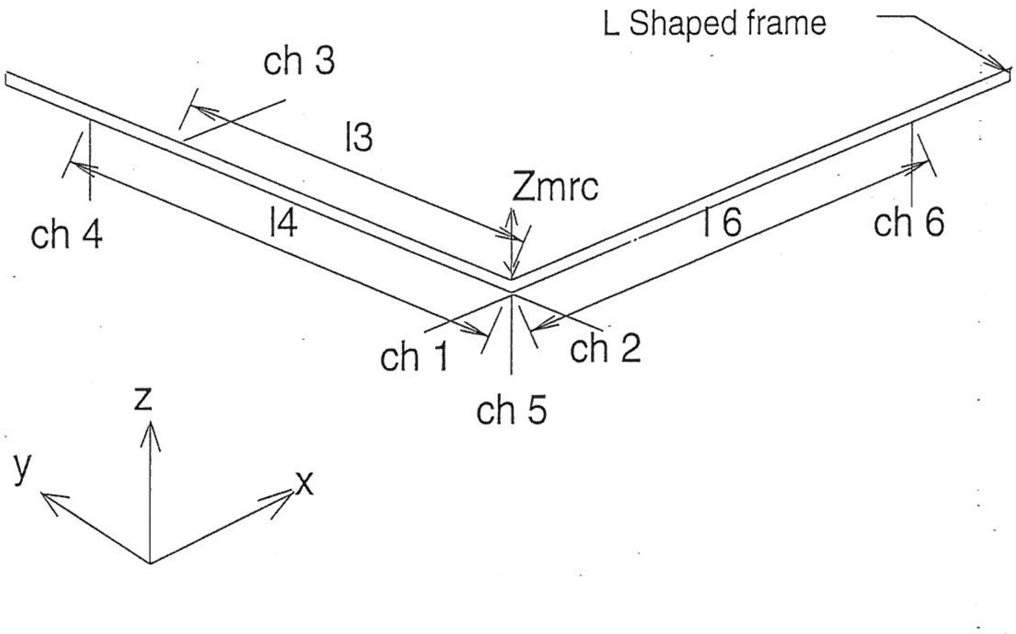


Figure 7

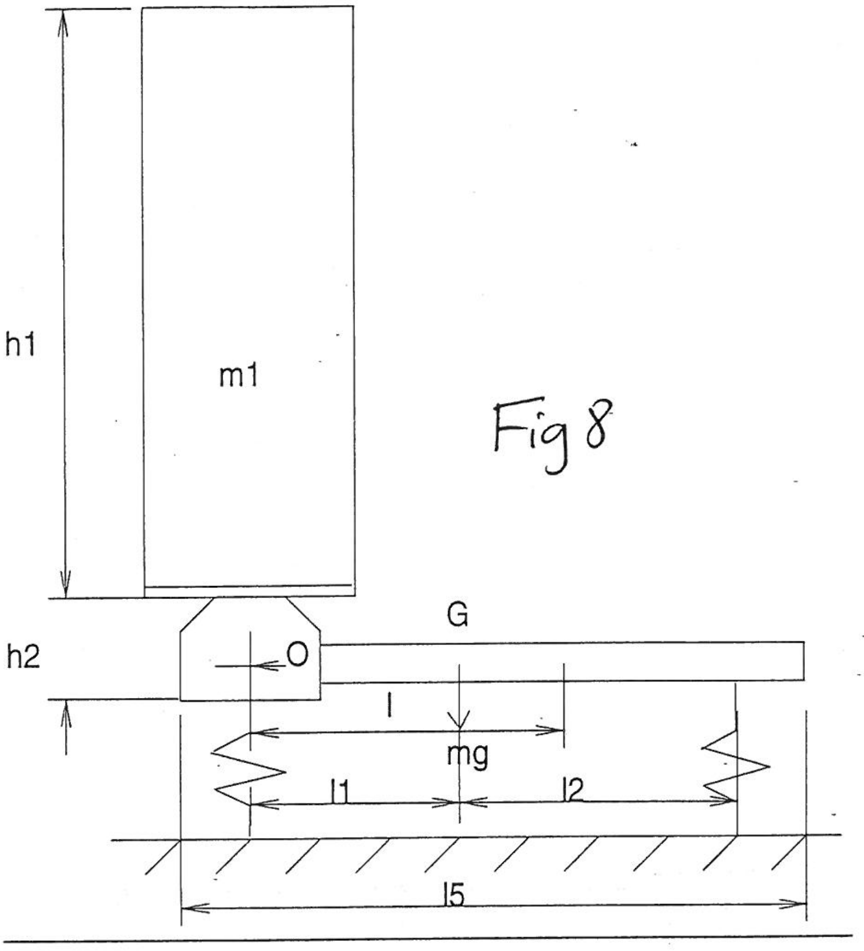


Fig 8

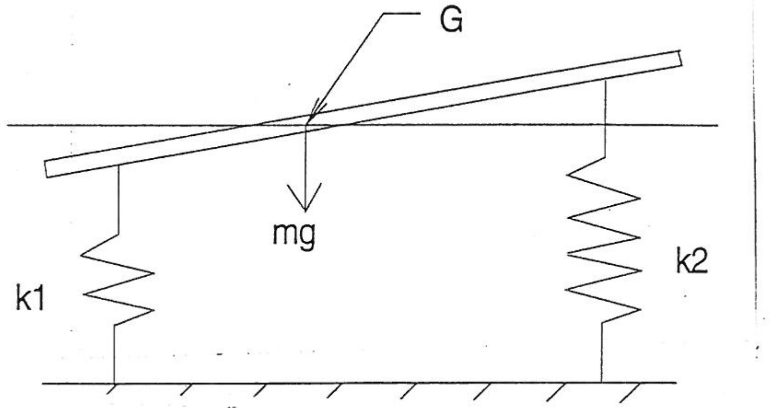


Fig 9

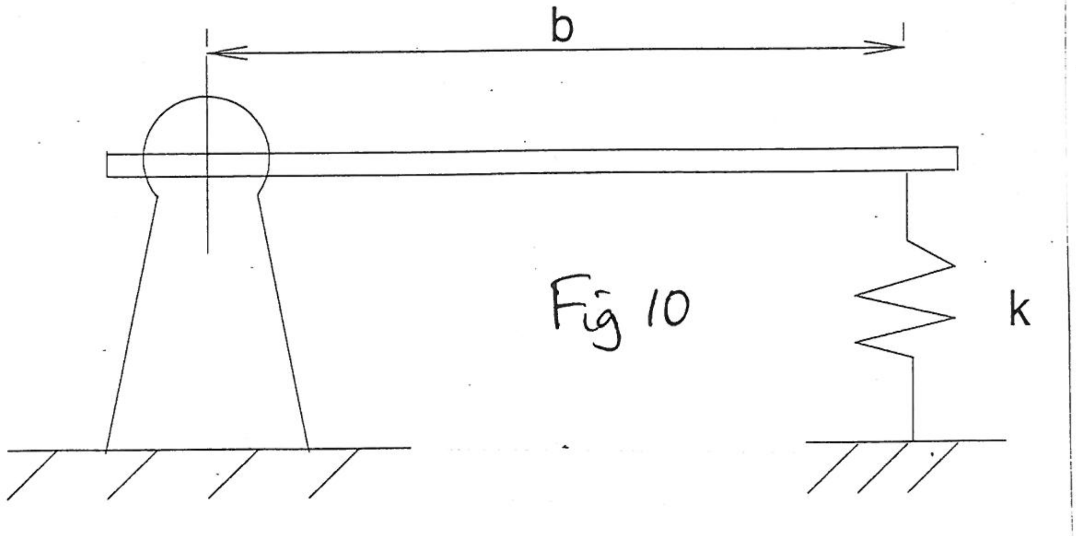


Fig 10

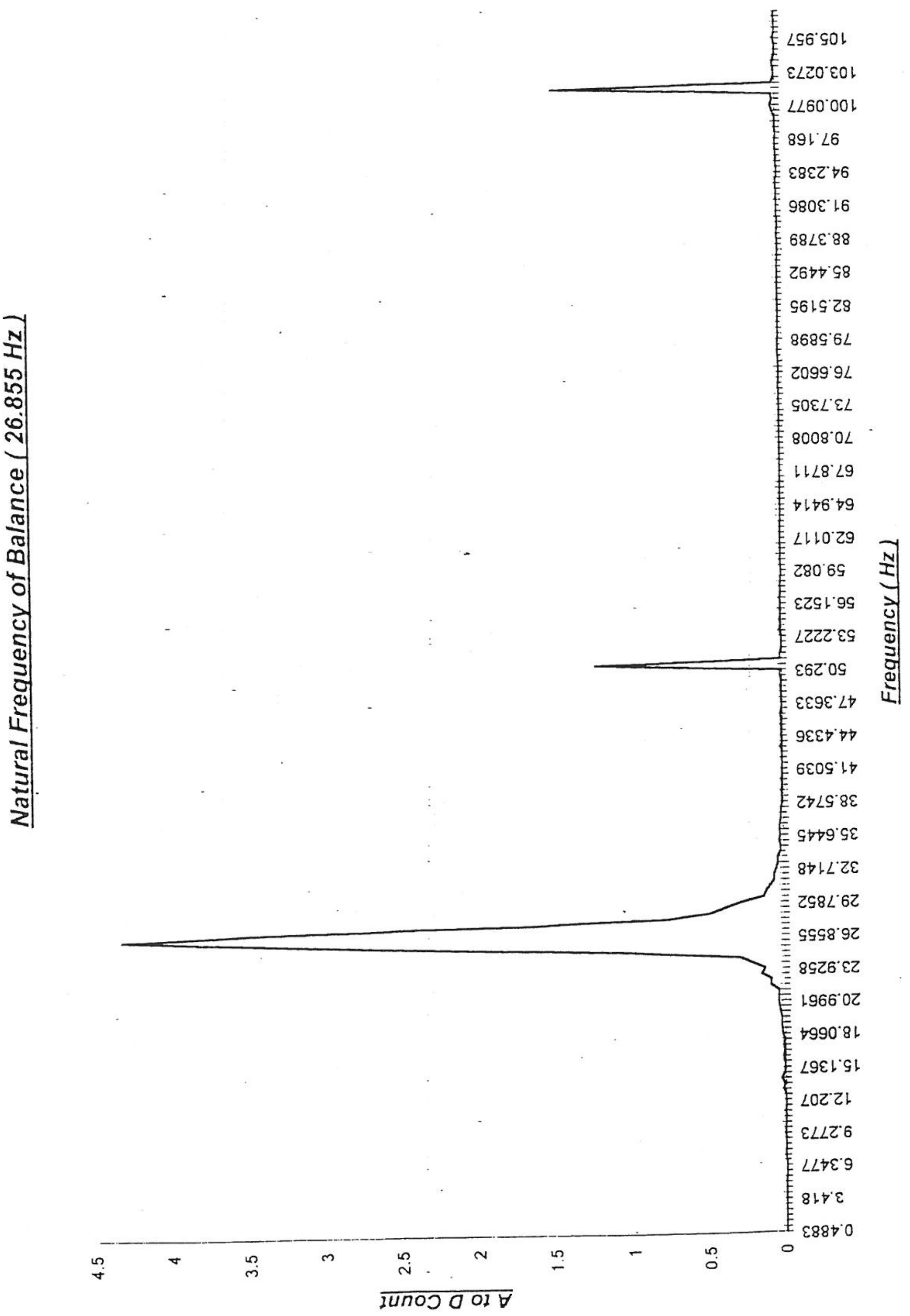

Natural Frequency of Balance (26.855 Hz)
A to D Count
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Frequency (Hz)
0.4883
3.418
6.3477
9.2773
12.207
15.1367
18.0664
20.9961
23.9258
26.8555
29.7852
32.7148
35.6445
38.5742
41.5039
44.4336
47.3633
50.293
53.2227
56.1523
59.082
62.0117
64.9414
67.8711
70.8008
73.7305
76.6602
79.5898
82.5195
85.4492
88.3789
91.3086
94.2383
97.168
100.0977
103.0273
105.957

Fig 11