Wire Tension Tests During Assembly of the Prototype Region 1 Drift Chamber

Reinhard A. Schumacher and Stephan A. Roth
Department of Physics
Carnegie Mellon University
Pittsburgh, PA 15213

Abstract

The tension histories of 60 drift chamber wires were measured during important steps in the assembly of the CEBAF/CLAS Region 1 Drift Chamber Prototype. We attempted to keep the tensions on all wires within 20% of their nominal values (80-120g for the aluminum and 40-60g for the tungsten.) All of these tests were performed using the computer controlled tension measuring system developed at CMU.

Introduction

During the construction and testing of the Region 1 Drift Chamber at Carnegie Mellon University, the tension of 60 monitor wires was measured and recorded at all stages of the detector assembly process. This was done in order to understand how the mechanical manipulations to which the detector was subjected affected the delicate wires within the detector. The measurement technique was based on the idea of oscillating the wires in a weak magnetic field to measure their resonant frequencies, from which their mechanical tensions could be computed. This procedure was largely automated through the use of a computer controlled system which quickly tested each wire without operator intervention [1]. The goal of the exercise was to develop an assembly procedure which maintained the tensions on all wires within ±20% of their nominal values. We were successful in this undertaking, as will be shown below. It will be seen that the wire tensions often changed in ways that were not always predictable in magnitude and direction. However, the size of the changes were essentially always within the design limits.

Test Setup and Procedures

Figure 1 shows the locations of all the test wires on a single sector, and Table 1 shows to which wire each monitor channel is connected. Ten test wires per sector were selected. They were both aluminum and tungsten wires. All the monitor wires were "axial" wires; none of them were six degree stereo wires.

A total of 37 trials, numbered chronologically, were defined. Table 2 gives a description of the trials when the tension was recorded. For each trial we recorded the condition of the detector. The inner and outer posts refer to the structural members which held the single sectors together. The upper and lower weights referred to the lead bricks we used to simulate the weights of the circuit boards and readout cables. Each trial can be put into 1 of 7 steps in the construction and testing process. The first step in the construction was stringing the individual sectors (T 0). Next, all of the sectors had to be bolted onto the boss ring (T 1). All of the struts between the sectors had to be tightened to transfer the tension from the posts to the struts (T 2 - T 8), and shims were placed between the struts (T 9 - T 12).

The next steps involved subjecting the prototype to stresses similar to those the final chamber will undergo. During construction the chamber was standing upright (the beam path was perpendicular to the ground). We had to tip the chamber over to simulate the final position of the chamber (T 13 - T 17.) Figure 2 shows the orientation of the chamber when it was on its side. To simulate the stress on the chamber from the circuit boards and cables, we hung weights from the side struts (T 18 - T 24.) The weight distribution used in this step is shown in Table 3. The final chamber may have several carbon fiber posts attached to the outside struts. We replaced several outer posts to simulate their effect (T 21 - T 24.) Finally, in order to get the chamber into its final position at CEBAF it will have to be cantilevered at one end of a long steel rod, and rotated 30°. Figure 3 shows the chamber in its rotated position (T 25 - T 33.) Figure 4 shows how the chamber was cantilevered (T 35 - T 37.)

Results

Our goal during all of these tests was to see if the tension of the wires would stay within a range of ±20% of their nominal values. This meant that the tungsten wires should stay between 40 and 60 grams and the aluminum wires should stay between 80 and 120 grams. Most of the monitor wires stayed within these boundaries throughout the tests. Graphs "Wire A Data" and "Wire C Data" show the histories of the shortest tungsten wires. One sees that they were quite robust, with the show the histories of the shortest tungsten wires. One sees that they were quite robust, with the main systematic effect indicated when the detector was tipped onto its side. The next pages of graphs show a remarkable stability in the wire tensions throughout the assembly process. We believe this shows that our procedures were adequate to the task at hand. When looking into the details of how the wires behaved from one run to the next it was not always possible to explain the behavior of each and every wire. We remained assured since the tensions changes were almost always small.

The graphs mostly group wires from a given endplate location and then show corresponding wires from all sectors. The last figure however averages all wires in a given sector, regardless of length, and displays the average fractional change in tension as a function of run number. These average data tend to confirm one's simple ideas about what wire tensions in a given sector should do in response to a given change. For example when tipping the detector from its vertical to its horizontal configuration, one expects tensions in sectors 1 and 2 to go up, sectors 3 and 6 to stay about the same, and sectors 4 and 5 to have reduced tensions. This is indeed what is observed between T12 and T14.

Run T20 show the detector with the inner and outer posts removed, and with weights hung to simulate cables and circuit boards. In T19 the upper weights were not yet on. Indeed one sees that in this transition from T19 to T20 the tensions in the upper sectors rose as expected. The tensions in the other sectors felt, as one would expect. The last run, T37, shows the loaded, cantilevered detector. Again one sees how adding the weights between T36 and T37 one finds consistent changes in average fractional tension change.

Conclusions

It is clear that during the Region 1 detector assemby the wires will suffer tension changes which are easily measurable. We developed a procedure for the assembly process which keeps these changes within bounds. The results of the tests discussed here indicate that these changes stay mostly within the design bounds of ±20%, and in fact most wires are very stable. Isolated deviations that we saw were not particularly disturbing. We note that testing the robustness of the assembly procedure was a critical step in the construction of Region 1, and we feel that we have demonstrated this robustness. We plan to use the procedures developed in the course of these tests in the assembly and manipulation of the final detector.

References

[1] "A Computer-Controlled Tension Monitoring System for Drift Chamber Wires," Stephan Roth and Reinhard Schumacher, Nuclear Instruments and Methods A, accepted for publication, 1995.

Figure 1: The locations of all test wires (A-U) and posts (2-13) are illustrated here.

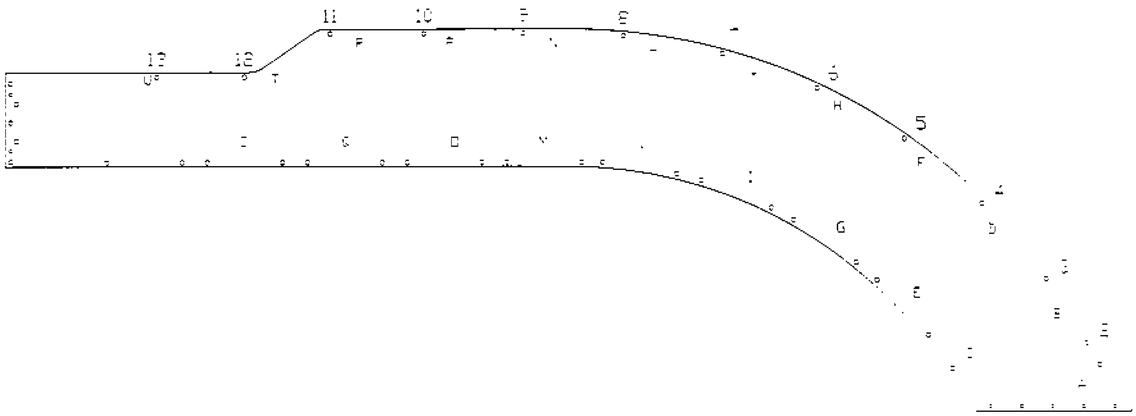


Table 1: Shows to which wire each channel was connected. The test wires all had a channel number assigned to them. The first digit in this number corresponded to the sector number. The second digit corresponded to the test wire in that sector. For example channel 46 was the 6th wire in sector 4.

Channel	Wire	Channel	Wire	Channel	Wire
10	A	30	A	50	A
11	D	31	D	51	D
12	H	32	H	52	H
13	L	33	L	53	L
14	P	34	P	54	P
15	T	35	T	55	T
16	C	36	C,E**	56	C
17	G	37	K	57	G
18	O	38	O	58	O
19	S	39	S	59	S
20	B	40	Between A and B	60	A
21	D	41	Between F and D	61	D
22	Between H and J	42	Between F and H, H**	62	H
23	N	43	Between J and L	63	L
24	R	44	Between R and P	64	P
25	C	45	T	65	T
26	G	46	I	66	C
27	K	47	K	67	G
28	O	48	O	68	K
29	S	49	S	69	S

**This wire was broken and moved. This is the latest wire for the channel.

Table 2: Catalog of the run parameters corresponding to the construction of the drift chamber.

Run Number	Time in Chamber Construction	Upper Weights	Lower Weights	Inner Posts	Outer Posts
T 0	The tension measured when the sector was first strung. Note that this measurement was made with the single wire monitor and not the computer controlled wire monitor.	off	off	on	on
T 1	The tension when all the sectors were bolted onto the base plate. This was before tightening the struts.	off	off	on	on
T 2	The tension after tightening the struts.	off	off	on	on
T 3	The tension after tightening the struts.	off	off	on	off
T 4	The tension after tightening the struts.	off	off	off	off
T 5	The tension after loosening the struts between sectors 4 and 5 to reduce the tensions on Channels 47 and 48 (K and O wires.)	off	off	off	off
T 6	The tension after the struts between sectors 4 and 5 were re tightened and the chamber was shaken.	off	off	off	off
T 7	The morning after the chamber was shaken	off	off	off	off
T 8	The tension after re loosening channels 47 and 48 (K and O wires.)	off	off	off	off
T 9	The tension after the outer shims were put in place.	off	off	off	on
T 10	The tension after the inner and outer shims were put in place.	off	off	off	on
T 11	The tension after all the shims were in.	off	off	off	off
T 12	The tension after all the shims were in (compare this data with T 10.)	off	off	off	on
T 13	With the setup from T 12 we lifted the chamber off the ground.	off	off	off	on
T 14	The tension after the chamber was tipped over. When we were tipping the chamber someone broke channel 42's wire. Channel 42 is now an H wire. See Figure 2 for the orientation of the sectors.	off	off	off	on
T 15	The morning after the chamber was tipped.	off	off	off	on
T 16	The tension after the chamber was tipped	off	off	off	off
T 17	The tension measured the morning after T 16.	off	off	off	off
T 18	The tension with the chamber tipped	on	off	off	off
T 19	The tension with the chamber tipped	off	on	off	off
T 20	The tension with the chamber tipped	on	on	off	off
T 21	The tension with the chamber tipped. Posts 2 and 5 were put on the top two sectors.	on	on	off	off
T 22	The tension with posts 5, 8, 11 attached to emulate the three 0.085" diameter carbon fiber posts used in the ANSYS calculations.	on	on	off	off

Run Number	Time in Chamber Construction	Upper Weights	Lower Weights	Inner Posts	Outer Posts
T 23	The tension with posts 3 and 6 put on the top two sectors.	on	on	off	off
T 24	The tension with posts 3 and 6 put on the top and side sectors.	on	on	off	off
T 25	The tension after the chamber was rotated. Now sector 2 is on the top (see Figure 3.)	off	off	off	off
T 26	The tension after the chamber was rotated. Now sector 2 is on the top (see Figure 3.)	off	on	off	off
T 27	The tension after the chamber was rotated. Now sector 2 is on the top (see Figure 3.)	on	off	off	off
T 28	The tension after the chamber was rotated. Now sector 2 is on the top (see Figure 3.)	on	on	off	off
T 29	Setup in T 20 again.	on	on	off	off
T 30	Chamber rotated with sector 1 on top (see Figure 3.)	off	off	off	off
T 31	Chamber rotated with sector 1 on top (see Figure 3.)	off	on	off	off
T 32	Chamber rotated with sector 1 on top (see Figure 3.)	on	off	off	off
T 33	Chamber rotated with sector 1 on top (see Figure 3.)	on	on	off	off
T 34	Chamber upright without posts on (compare with T 11.)	off	off	off	off
T 35	Chamber tipped over (see Figure 2 for the orientation of the sectors.) Before this measurement was taken, Channel 36's wire was broken. Channel 36 is now an E wire.	off	off	off	off
T 36	Chamber tipped over (see Figure 2 for the orientation of the sectors.) The chamber was cantilevered (see Figure 4.) While measuring the wire tensions, Channel 48's wire was broken. It was not possible to switch wires.	off	off	off	off
T 37	Setup in T 36.	on	on	off	off

Table 3: Shows the weight distribution used to simulate the circuit boards and cables that will hang on the final detector. This table shows the value of the weight hung on each strut.

Strut Number (at the same location as corresponding post number)	Weight Hung (pounds)
2	2
3	2.5
4	3
5	3.5
6	4
7	4.5
8	5
9	5.5
10	6
11	6.5
12	7
13	7.5

Figure 2: Shows the arrangement of the sectors when the chamber was in its operating position. The locations of the lead weights are also shown. During a given run the top, bottom, none or both sets of weights could be attached.

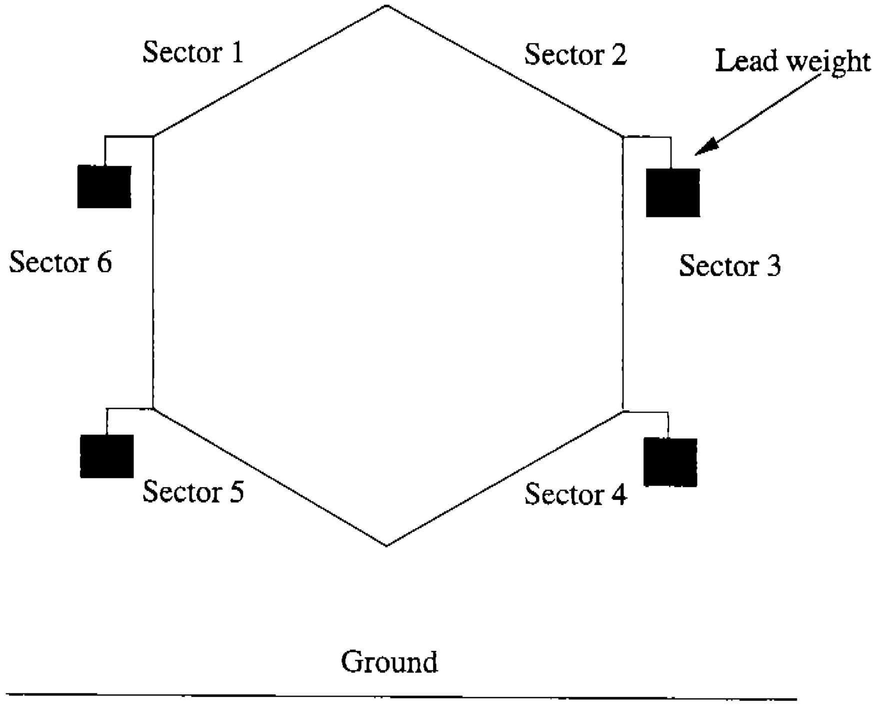


Figure 3: Shows the arrangement of the sectors after the chamber was rotated. The chamber was rotated so that alternately sectors 2 and 1 were at the top. The locations of the lead weights are also shown. During a given run the top, bottom, none or both sets of weights could be attached.

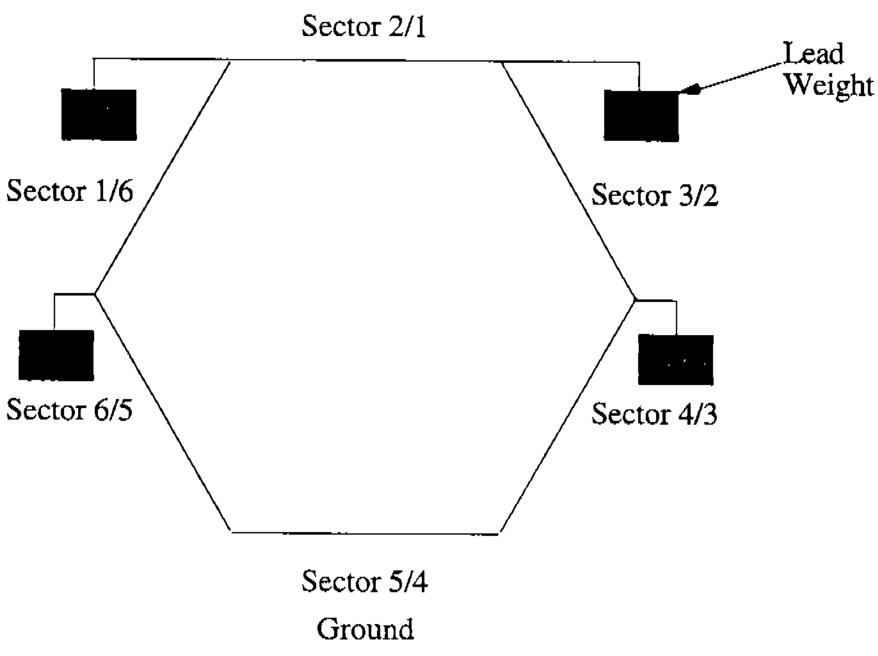
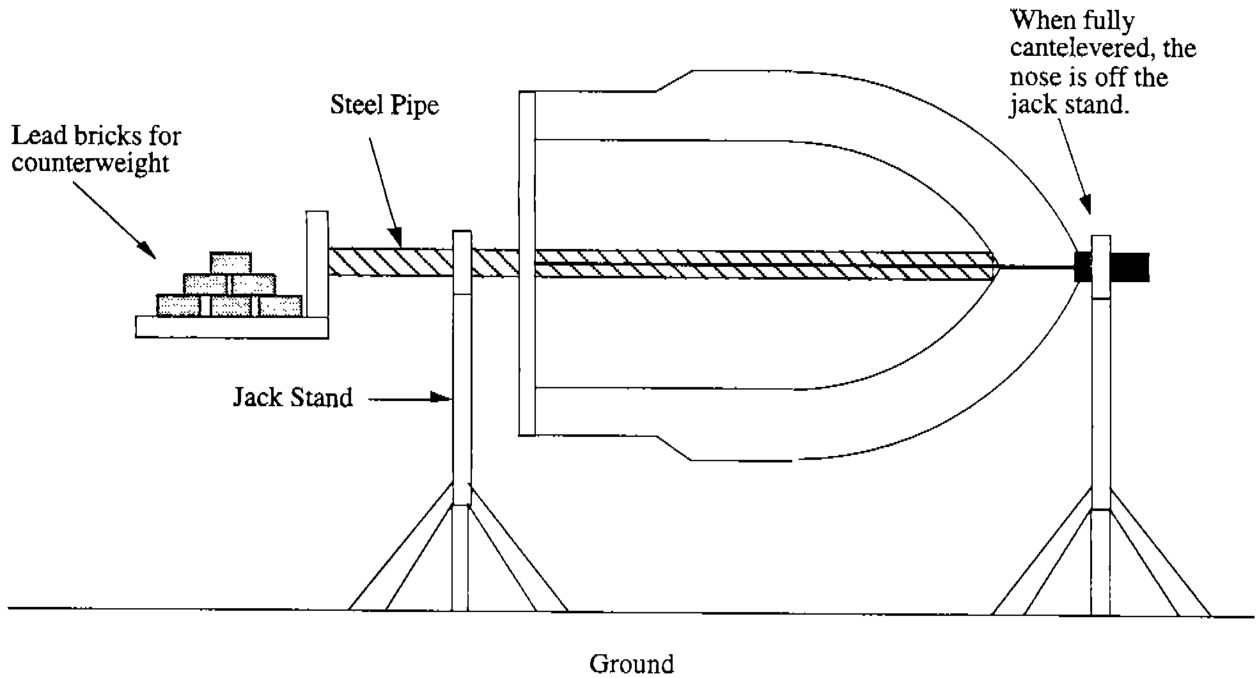
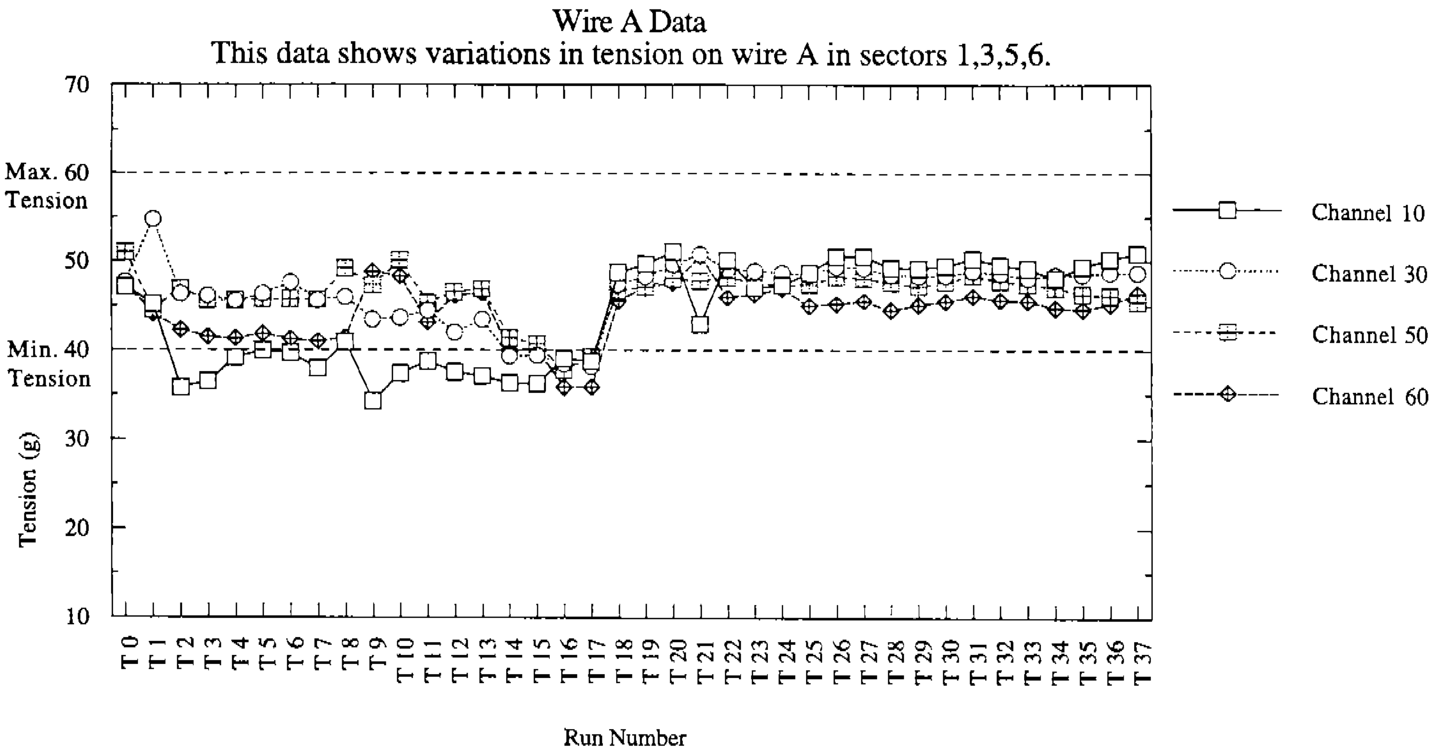
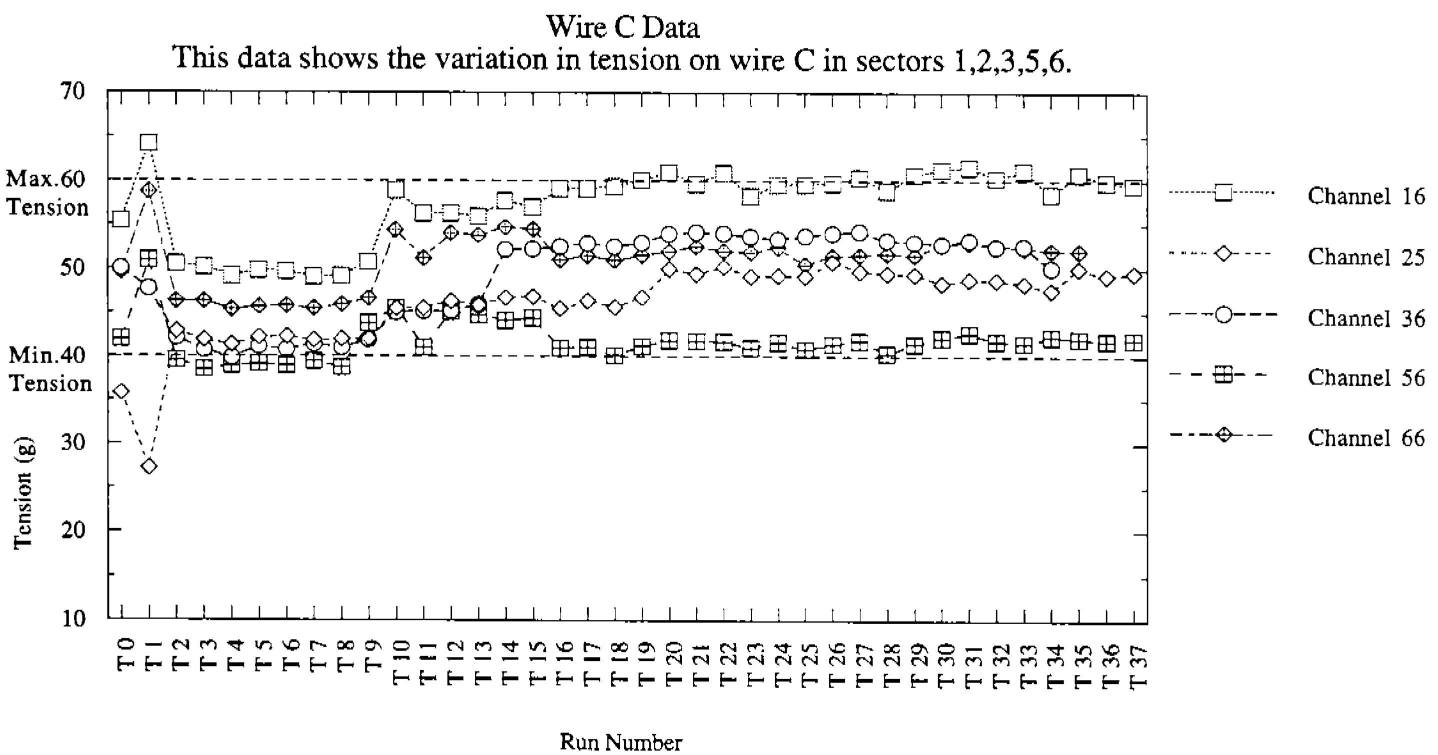


Figure 4: Shows the setup used to cantilever the chamber. In this configuration the detector was subjected to forces very close to those encountered during installation.





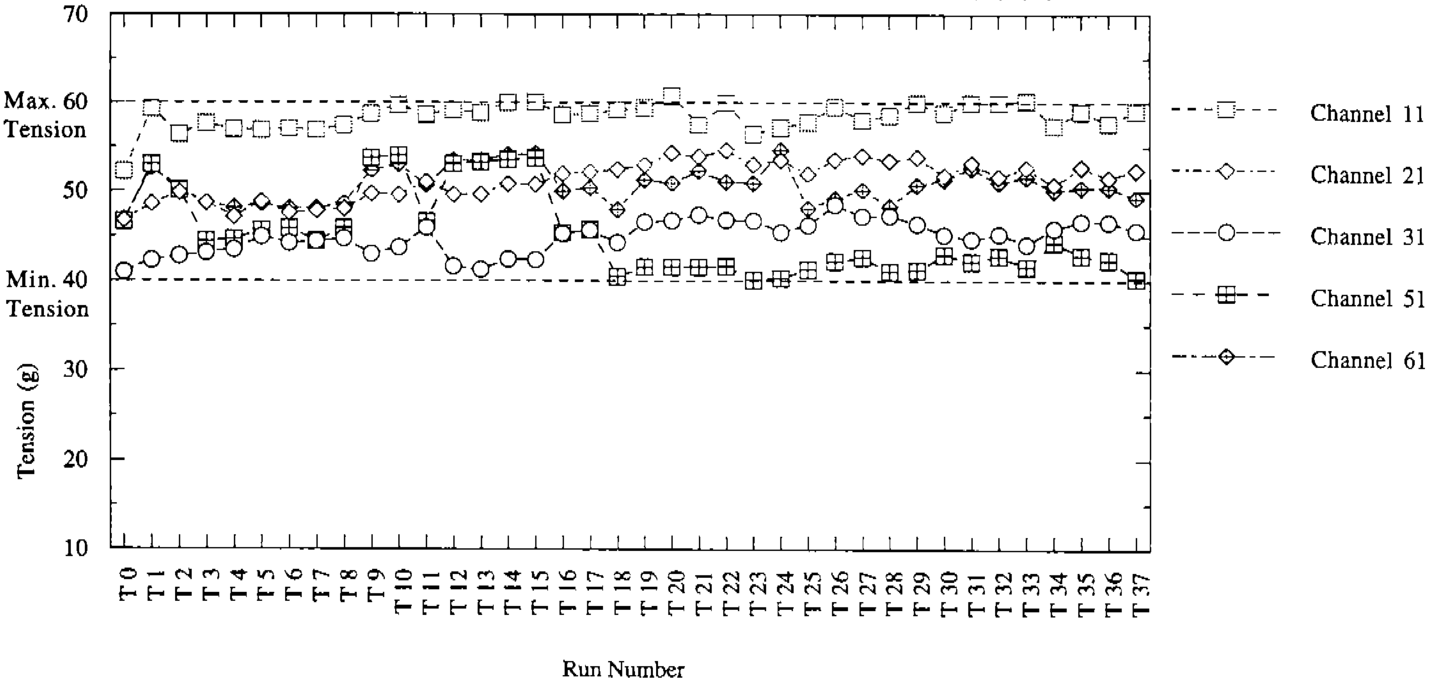
Wire A Data
This data shows variations in tension on wire A in sectors 1,3,5,6.
70
Max. 60 Tension
50
Min. 40 Tension
30
20
10
Tension (g)
T0 T1 T2 T3 T4 T5 T6 T7 T8 T9 T10 T11 T12 T13 T14 T15 T16 T17 T18 T19 T20 T21 T22 T23 T24 T25 T26 T27 T28 T29 T30 T31 T32 T33 T34 T35 T36 T37
Run Number
Channel 10
Channel 30
Channel 50
Channel 60



Wire C Data
This data shows the variation in tension on wire C in sectors 1,2,3,5,6.
70
Max.60 Tension
50
Min.40 Tension
30
20
10
Tension (g)
T0 T1 T2 T3 T4 T5 T6 T7 T8 T9 T10 T11 T12 T13 T14 T15 T16 T17 T18 T19 T20 T21 T22 T23 T24 T25 T26 T27 T28 T29 T30 T31 T32 T33 T34 T35 T36 T37
Run Number
Channel 16
Channel 25
Channel 36
Channel 56
Channel 66

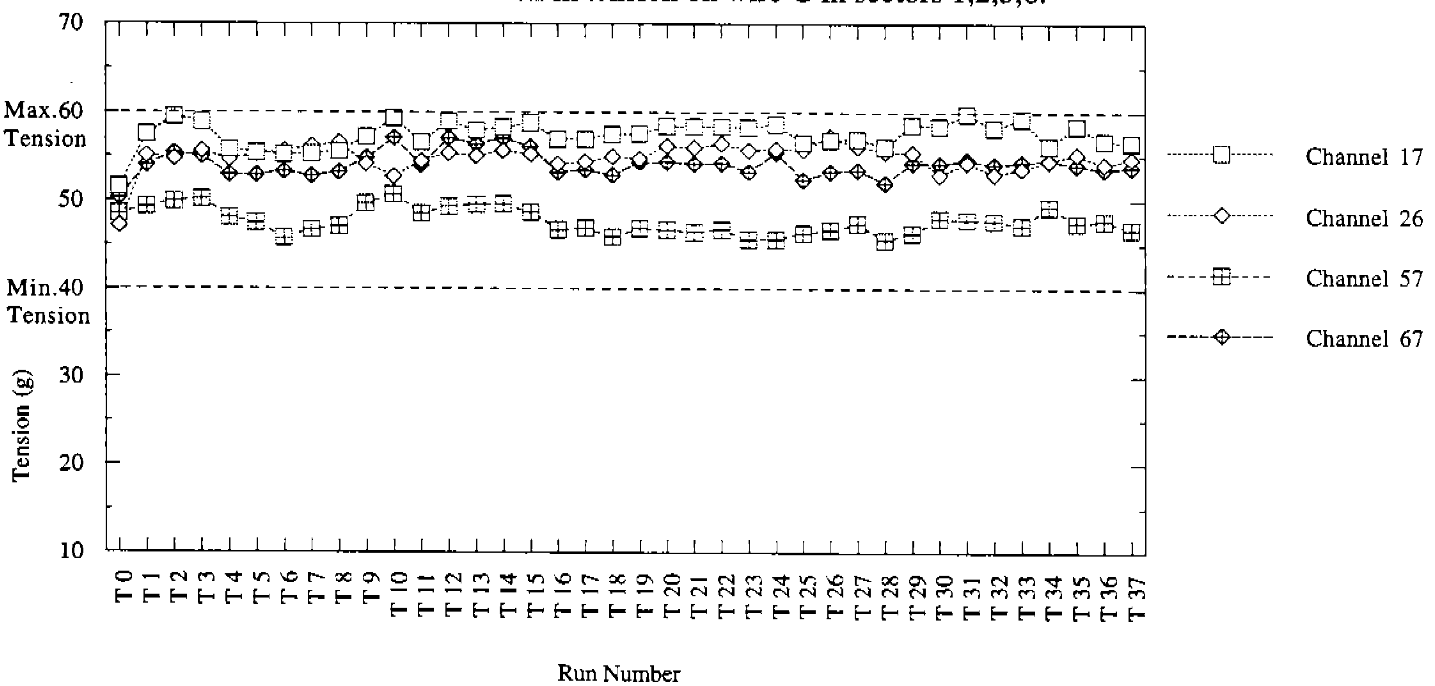
Wire D Data

This data shows variations in tension on wire D in sectors 1,2,3,5,6.



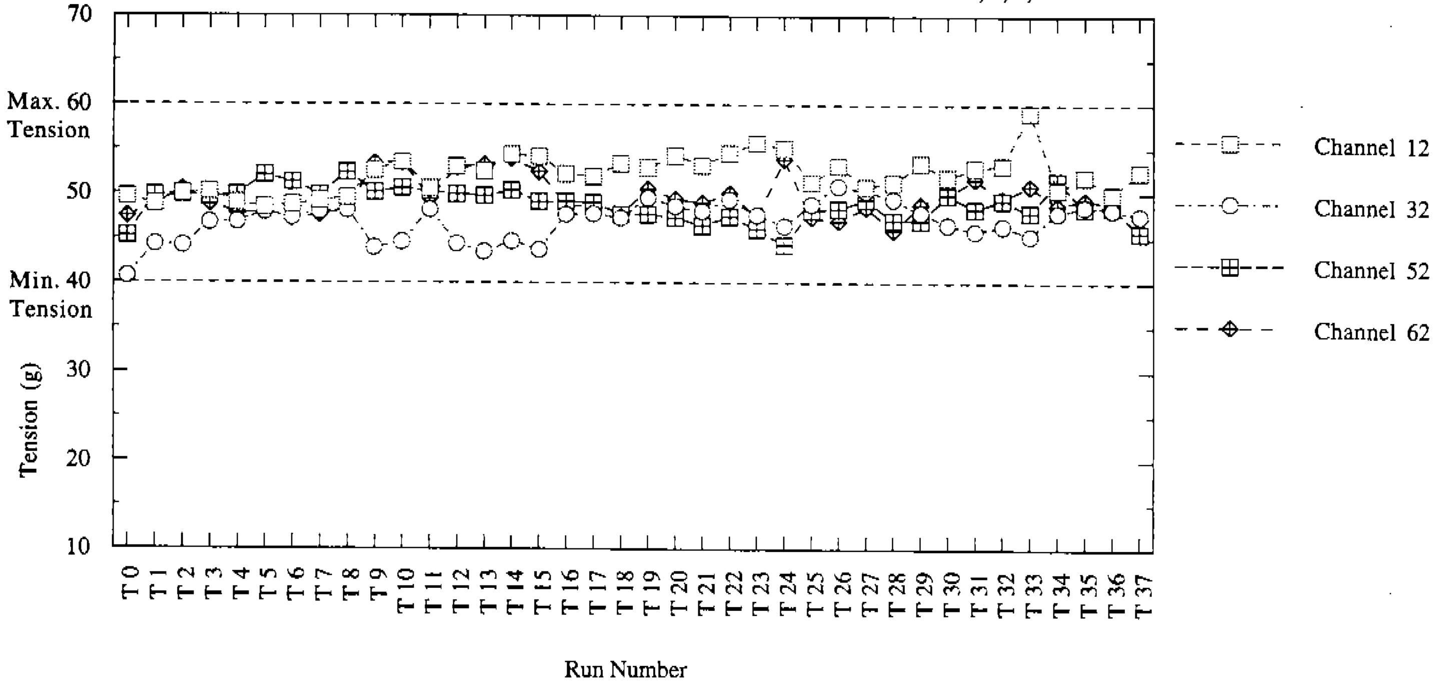
Wire G Data

This data shows the variation in tension on wire G in sectors 1,2,5,6.



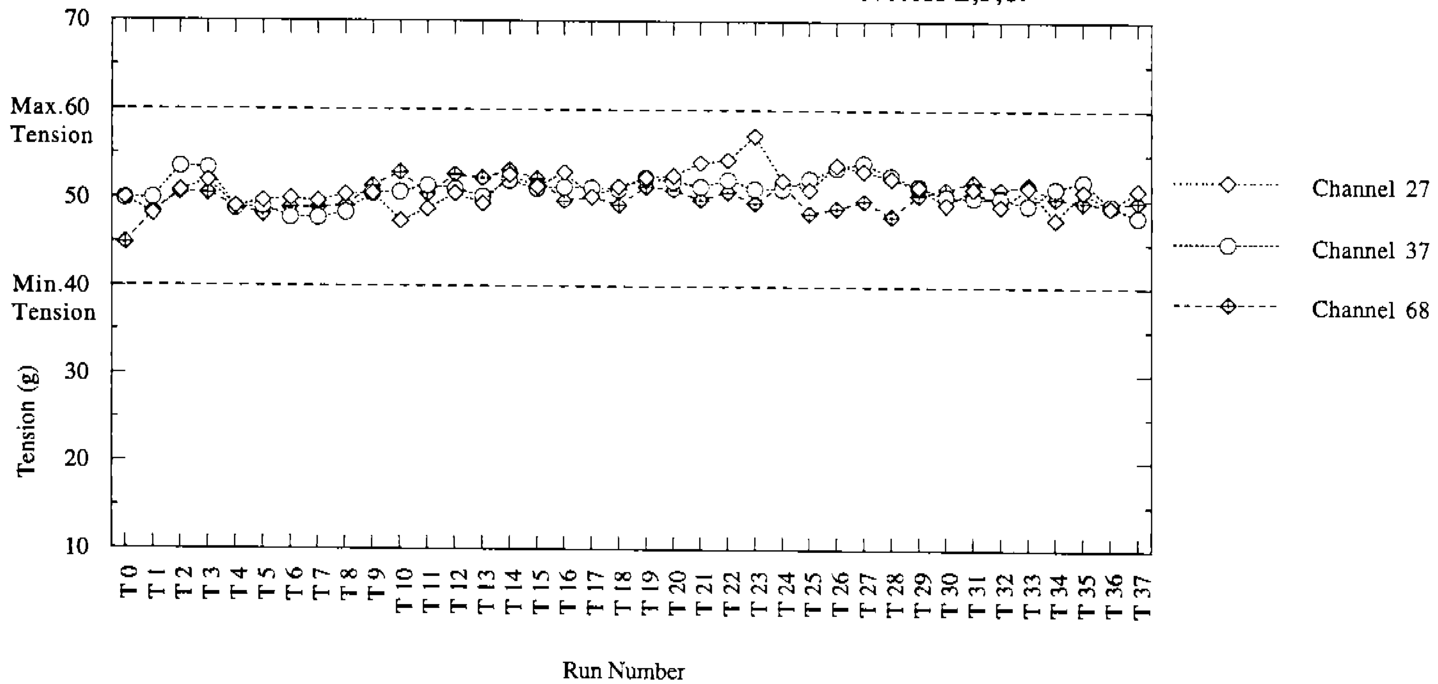
Wire H Data

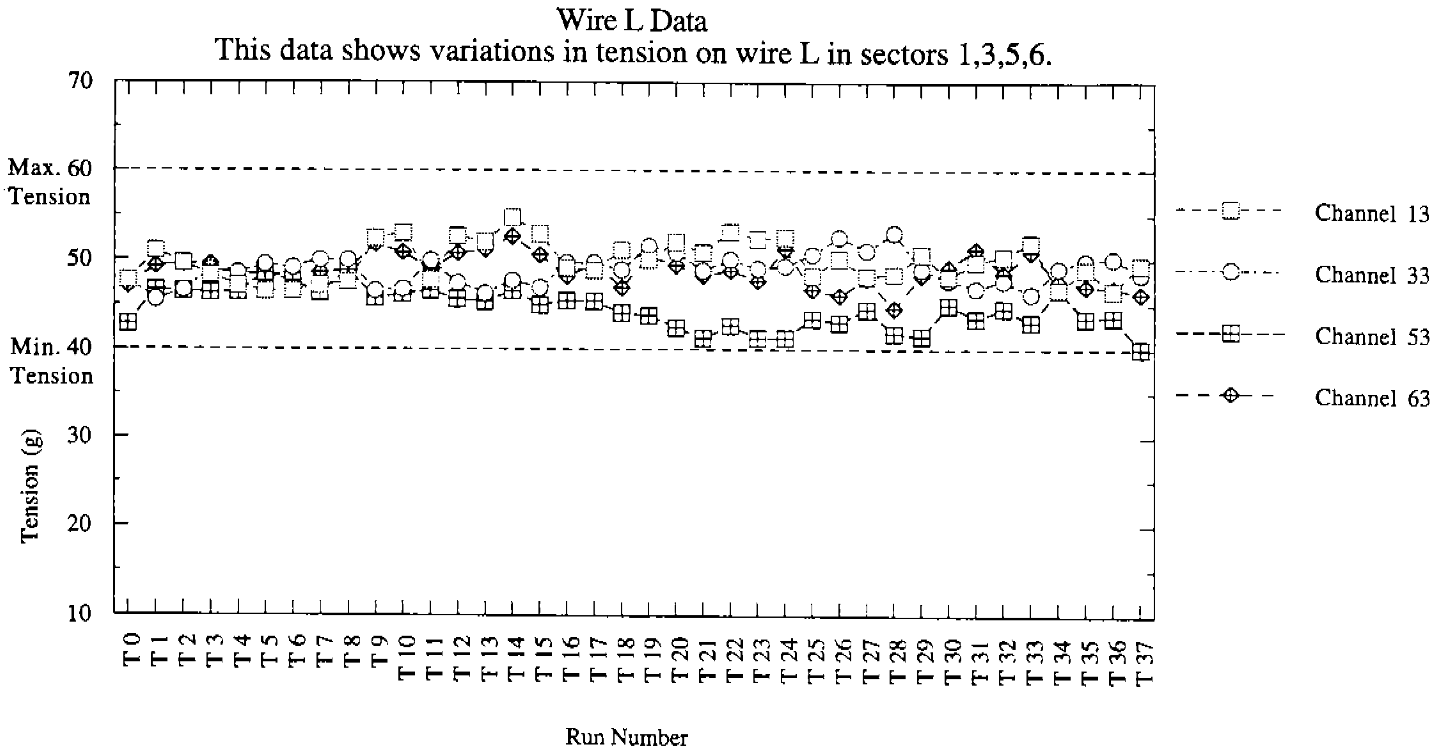
This data shows variations in tension on wire H in sectors 1,3,5,6.



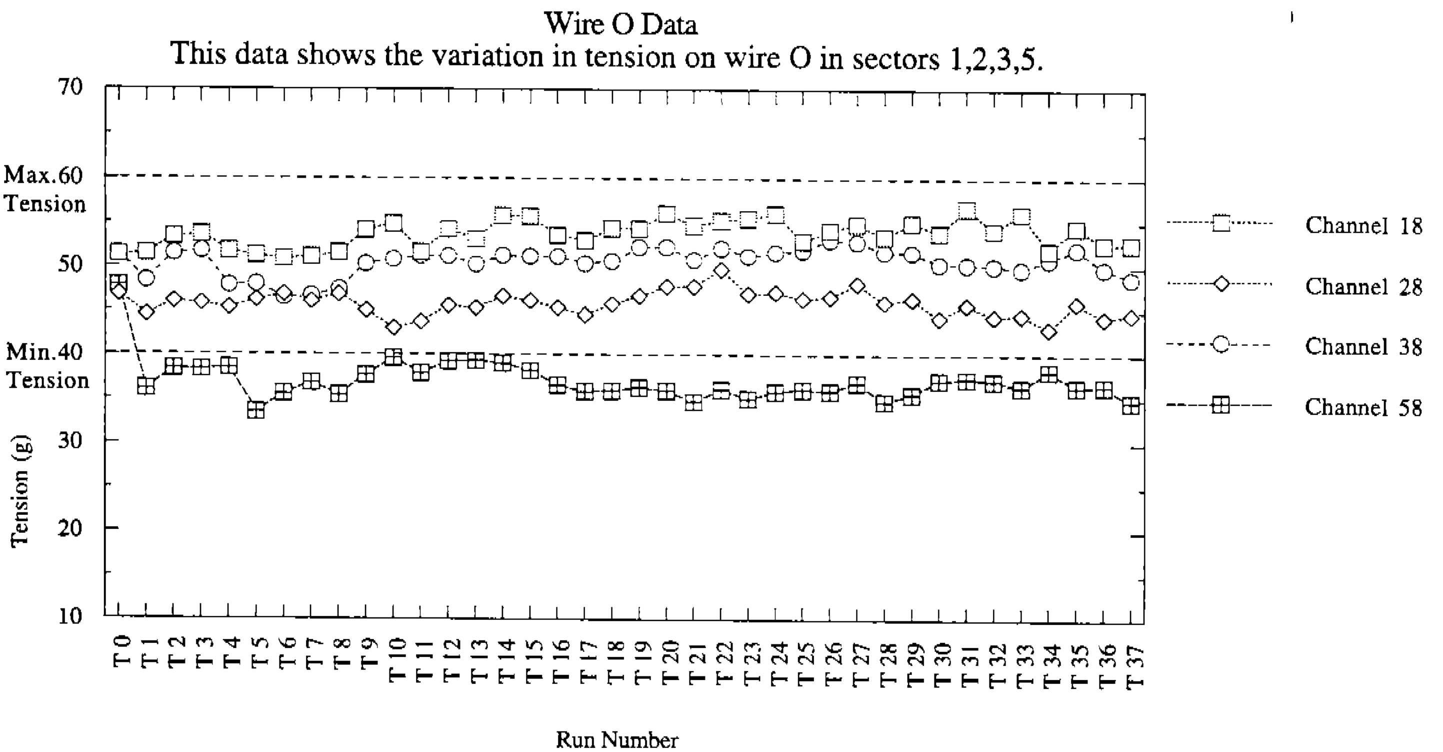
Wire K Data

This data shows the variation in tension on wire K in sectors 2,3,6.





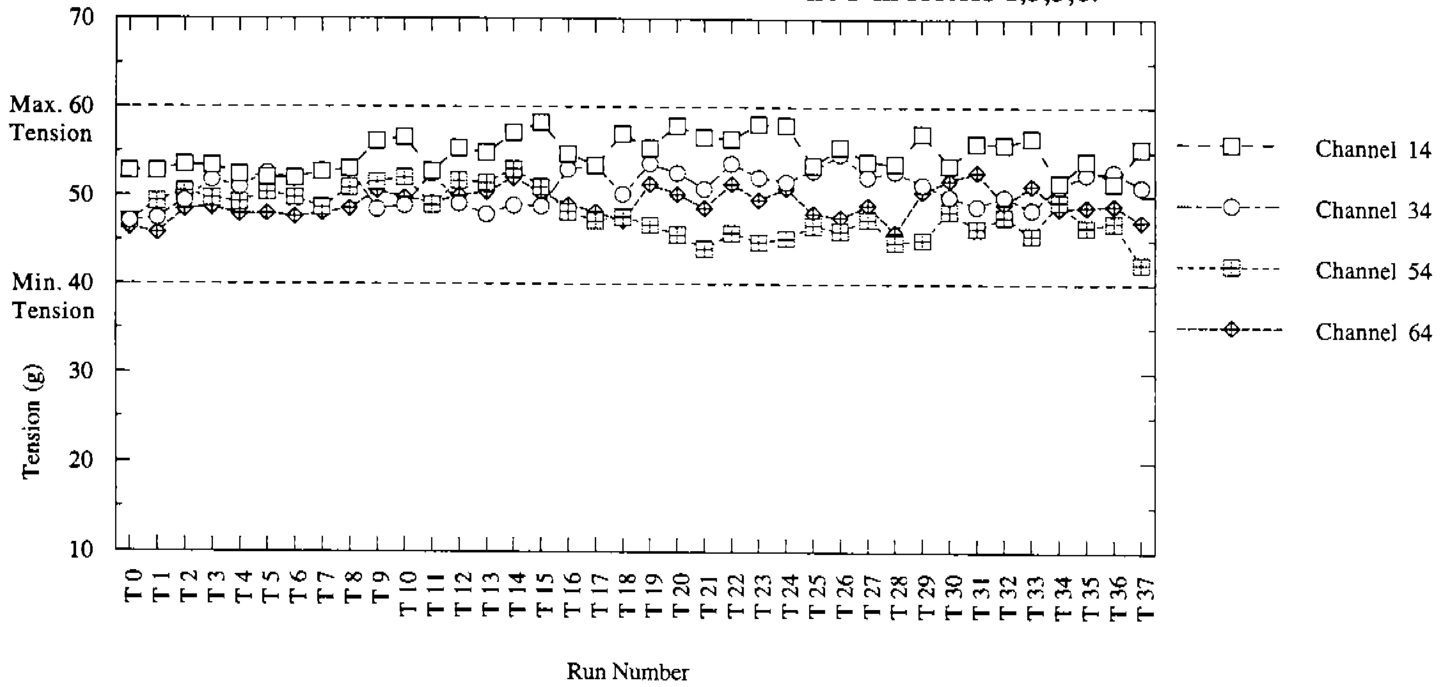
Wire L Data
This data shows variations in tension on wire L in sectors 1,3,5,6.
70
Max. 60
Tension
50
Min. 40
Tension
30
20
10
Tension (g)
T 0
T 1
T 2
T 3
T 4
T 5
T 6
T 7
T 8
T 9
T 10
T 11
T 12
T 13
T 14
T 15
T 16
T 17
T 18
T 19
T 20
T 21
T 22
T 23
T 24
T 25
T 26
T 27
T 28
T 29
T 30
T 31
T 32
T 33
T 34
T 35
T 36
T 37
Run Number
Channel 13
Channel 33
Channel 53
Channel 63



Wire O Data
This data shows the variation in tension on wire O in sectors 1,2,3,5.
70
Max.60
Tension
50
Min.40
Tension
30
20
10
Tension (g)
T 0
T 1
T 2
T 3
T 4
T 5
T 6
T 7
T 8
T 9
T 10
T 11
T 12
T 13
T 14
T 15
T 16
T 17
T 18
T 19
T 20
T 21
T 22
T 23
T 24
T 25
T 26
T 27
T 28
T 29
T 30
T 31
T 32
T 33
T 34
T 35
T 36
T 37
Run Number
Channel 18
Channel 28
Channel 38
Channel 58

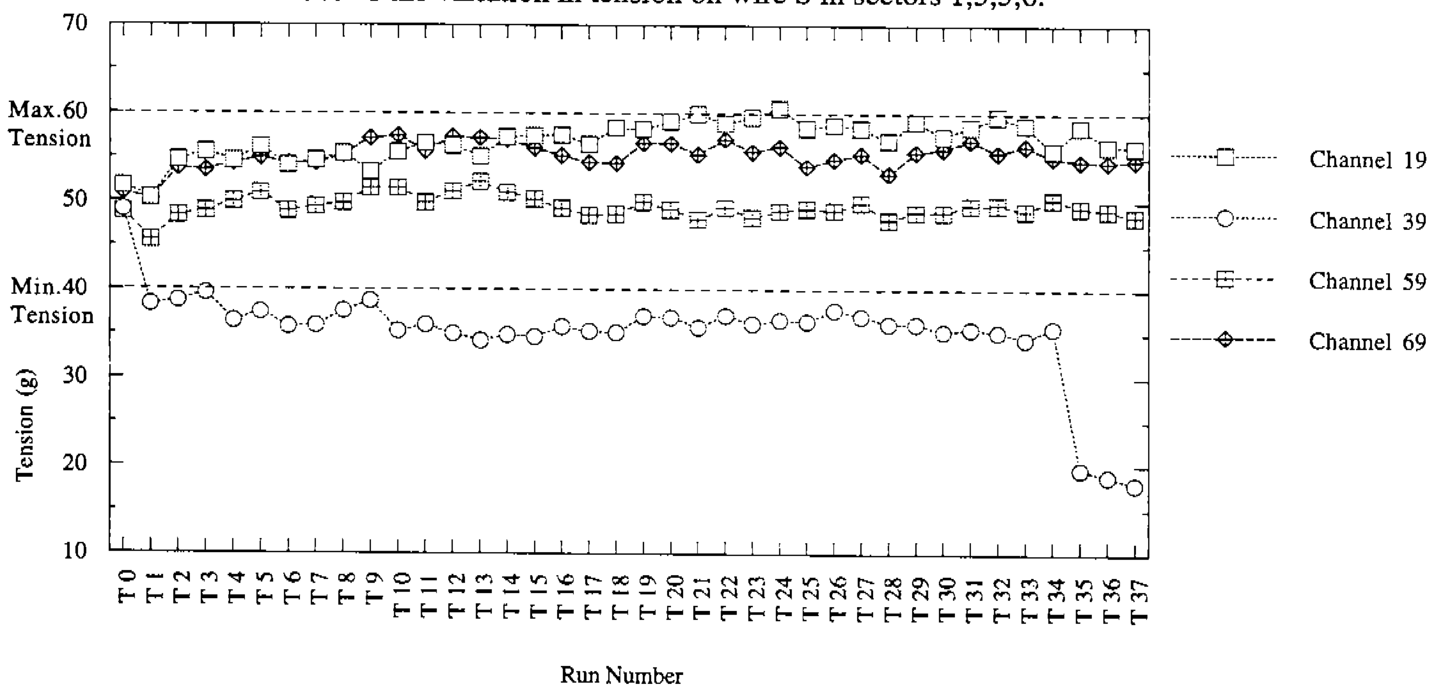
Wire P Data

This data shows the variations in tension on wire P in sectors 1,3,5,6.



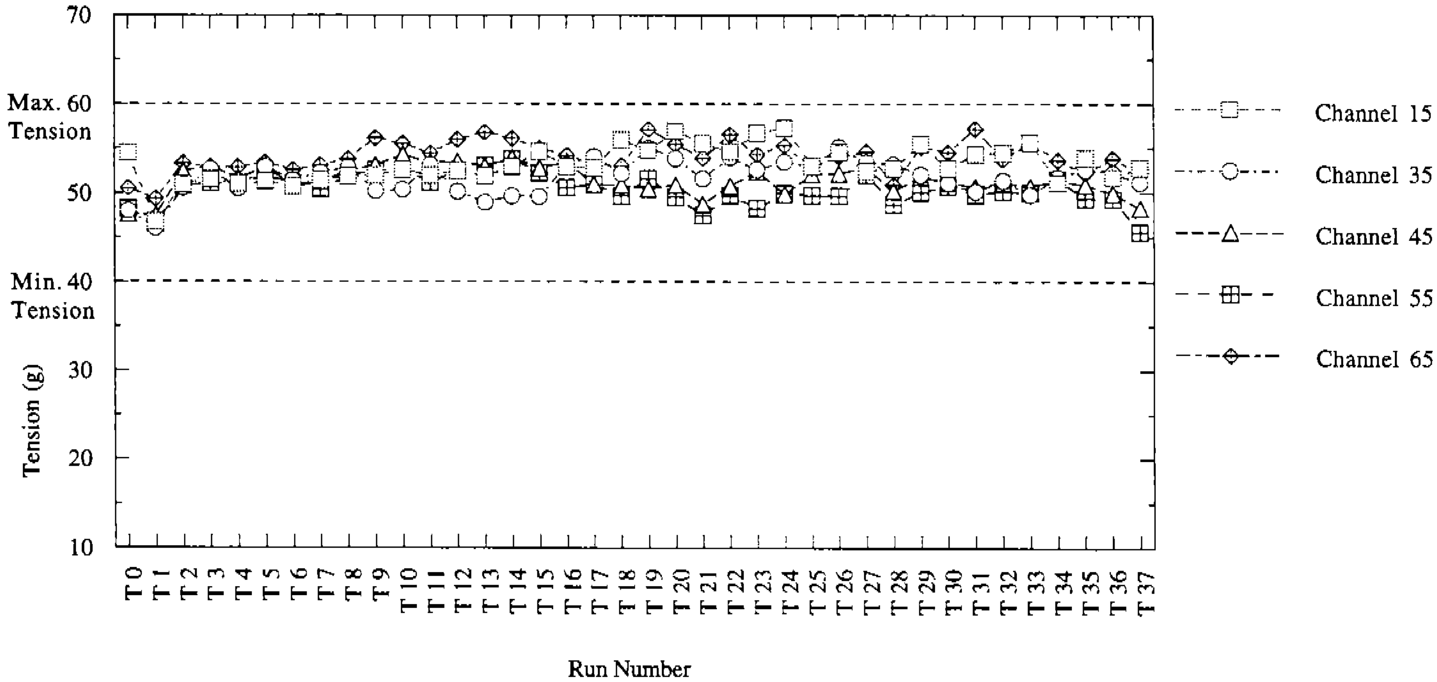
Wire S Data

This data shows the variation in tension on wire S in sectors 1,3,5,6.



Wire T Data

This data shows tariations in tension on wire T in sectors 1,3,4,5,6.



Average dT/T on Sectors

This graph shows the average percent difference between the nominal and actual tensions on each sector.