

## **A new compact MDT wire tension meter**

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### **Abstract**

This note describes a low-cost, compact, reliable, homemade wire tension meter used to check the wire tension of the MDT tubes during assembly -before leaving the wiring line of the University of Athens.

## 1 Introduction

University of Athens is responsible for the wiring of about 30,000 MDT tubes, to be used for building the BIS chambers. These tubes are ATLAS muon drift tubes of finished length of 1671.5 mm. In separate notes (**ref 1,2**) we describe the University of Athens wiring line. Here we describe the device built for our purposes in order to measure the wire tension during tube production.

The wire tension under the nominal wiring temperature of  $20 \pm 1$  °C has to be within 5% of the nominal tensioning value of 350grs. Normally the tension is checked during the QA/QC check of the tubes in National Technical University of Athens. Since the rejected tubes - with a tension outside the above specifications- cannot be recovered afterwards, we decided to check the wire tension in the clean room, before the tube leaves the wiring bench. The reason is the following: if we observe that the tubes fabricated deviate systematically from the mean value of the desired tension then, using our DAQ program, we can readjust the tensioning value of the linear actuator which performs the tensioning procedure. This way we can achieve better results: better centered tension value and smaller percentage of rejected tubes.

## 2 The wire tension meter

The wire tension is derived by measuring the frequency of the wire oscillations excited by a current pulse in presence of a magnetic field. The frequency ( $f$ ) is then converted into wire tension ( $T$ ) using the formula:

$$T = \pi \rho d^2 L^2 f^2$$

where  $\rho$ ,  $d$ ,  $L$  are the density, diameter and length of the wire respectively.

The usual methods followed for the frequency measurement are: a) finding the resonant frequency by means of a sweep generator and a RMS-to-DC converter (**ref 3**) and b) performing a spectral analysis (**ref 4**). Both methods have some drawbacks. The first method is not always very accurate because of the low quality of the resonant contour and the large number of frequencies, which are necessary to be swept through in order to find the resonance. The second method requires expensive hardware (like ADC, DSP) plus complex mathematical computations.

We decided to use a third method, which would be deprived of the above drawbacks. We designed and built a low-cost, homemade tension meter, which acts as a self-sustained electromechanical generator using the MDT tube as a frequency-defining element. The measurement is performed as follows:

The tube is placed on two clamps on the wiring bench (**photo 1**). A permanent U-shaped magnet is placed below the middle of the tube. The tension meter (**photo 2**) is then connected to both ends of the tube and current pulses are sent to the tube.

The general block diagram of the device is given in the **Figure 1**.

The device is simple enough; the MTD tube- together with the U-shaped magnet- is the frequency-defining element. The instrumentation amplifier and the analog comparator, which senses the zero crossing, provide receptions of the signal from the resonant contour. The hi-speed RISC CPU and the current pulser provide a positive feedback. The function of the positive feedback is the submission of a series of pulses, which increase the amplitude of the wire oscillations- “accelerating” current pulses- in phase with the mechanical movement of a wire. The phase ratios of these signals are shown on the **Figure 2**.

As follows from this figure, the positive semi-wave of the sensor response corresponds of the time interval when the wire is moving "downwards" from the upper peak point to a lower peak point. During this time interval the processor activates the current generator in order to provide an acceleration of the wire movement and thus increases the mechanical energy of the wire. We found out that a few tenths of full periods (about 1sec) are enough for the wire to reach its maximum amplitude.

In spite of the fact that the amplitude of the oscillations after this phase of "acceleration" is already sufficient and the oscillations are stable, it is not safe to carry out a measurement of the frequency because the accelerating pulses bring in some noise and subsequent distortion of the frequency of the oscillations. It is therefore, necessary to reduce the influence of the current pulses on the oscillations of the wire. For this purpose the duration of pulses decreases but their center stays tied to the zero-crossing point of mechanical oscillations. This phase takes about 1sec and at the end of it the wire is moving almost freely. The relative wave forms are shown on **Figure 3**.

Then, the submission of the current pulses stops and the form of oscillations becomes close to clean sine wave. At that point, the frequency of the oscillations is equal to the resonant frequency. The measurement of the frequency is performed during several periods and the tension of the wire is then calculated. The duration of a complete set of measurement does not take more than few seconds. The variations of the oscillations' amplitude during a complete measurement cycle is shown in **Figure 4**.

In order to cross calibrate our meter, prior to installation in our wiring line, we measured several tenths of tubes using both our device and an independent frequency measurement device (**ref 5**). After the initial adjustments, the two measurements agreed within 0.1 Hz.

In addition to the frequency measurement and tension calculation, the wire tension meter has a build-in sensor for the measurement of the room temperature. For this purpose we have used the Dallas Semiconductor temperature sensor DS1821, which has a built-in ADC and a digital output. The accuracy of this sensor is  $\pm 0.5$  degree of Celsius.

In order to integrate the present meter with our data acquisition system we made use of the device's microprocessor. All data taken (wire resonant frequency, tension, and temperature) are sent through the serial channel communication (RS232) directly to our PC. A simple protocol was developed which communicates with the DAQ software platform LabView and provides remote control functions. At the end, the measurements are logged in our data base.

### 3 Results

Since November 2000 we have been measuring all tubes assembled with the above tension meter. The results are shown in **Figure 6**. A few times we had to program-adjust the linear actuator final tensioning value (350grs), by a few grams, in order to achieve more uniform and better-centered measurements of the wire tension for the produced tubes.

Of all tubes measured so far we had to reject a **0.4%** due to too low wire tension (<335 grs) and **1.1%** due to too high wire tension (>365)

## **Acknowledgements**

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## **References**

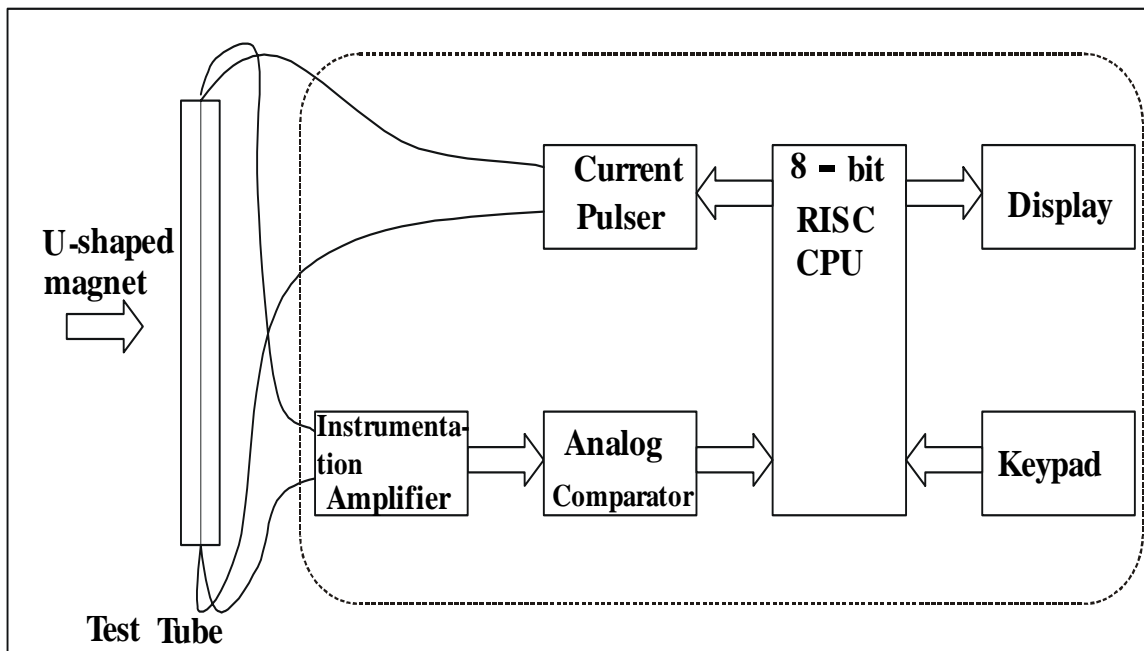
- (1) Atlas internal Note ATL-MUON-2000-014
- (2) Improvements/Experience derived from wiring 10% of BIS MDT's: Atlas Internal note (under submission)
- (3) CAEN module SY502
- (4) Dubna tension meter: <http://nuweb.jinr.ru/~dcbp/atlas/QAQC/tension/tension.htm>
- (5) The measurements were done using a module from the University of Rome 1 group (kindly provided by Prof. G.Ciapetti)



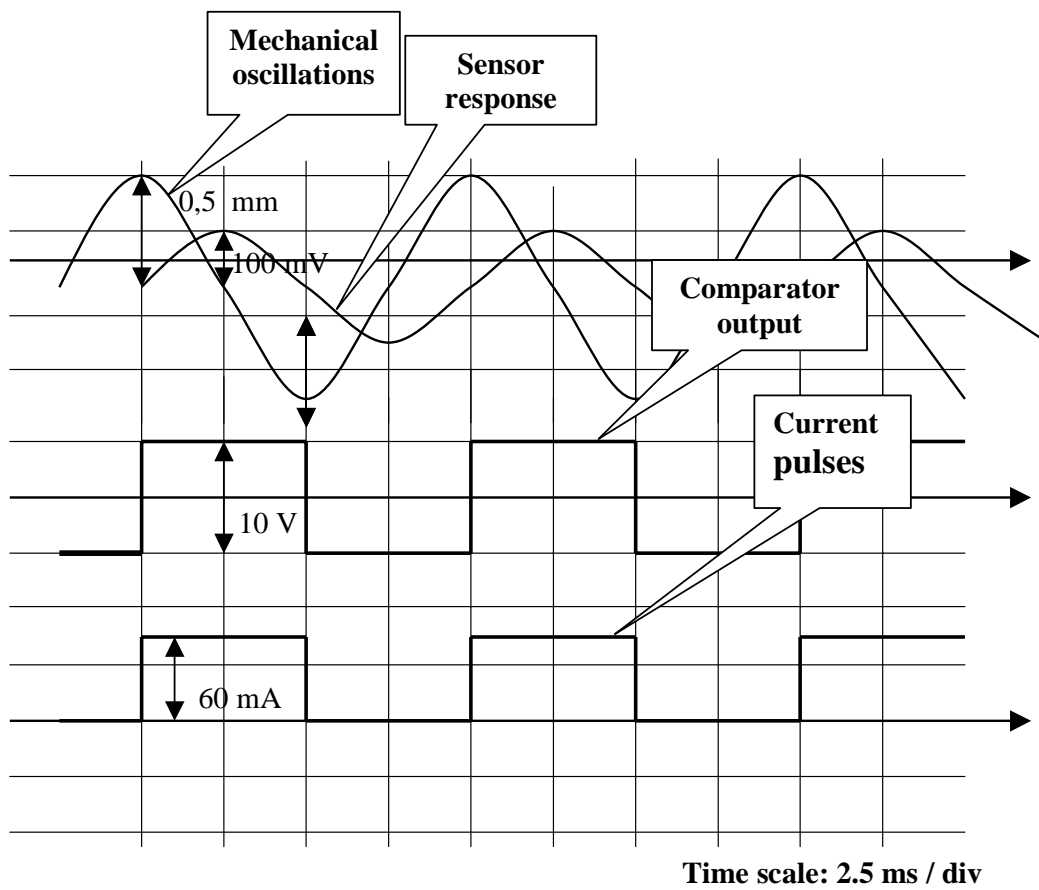
**Photo 1 :** The tension measurement set-up.



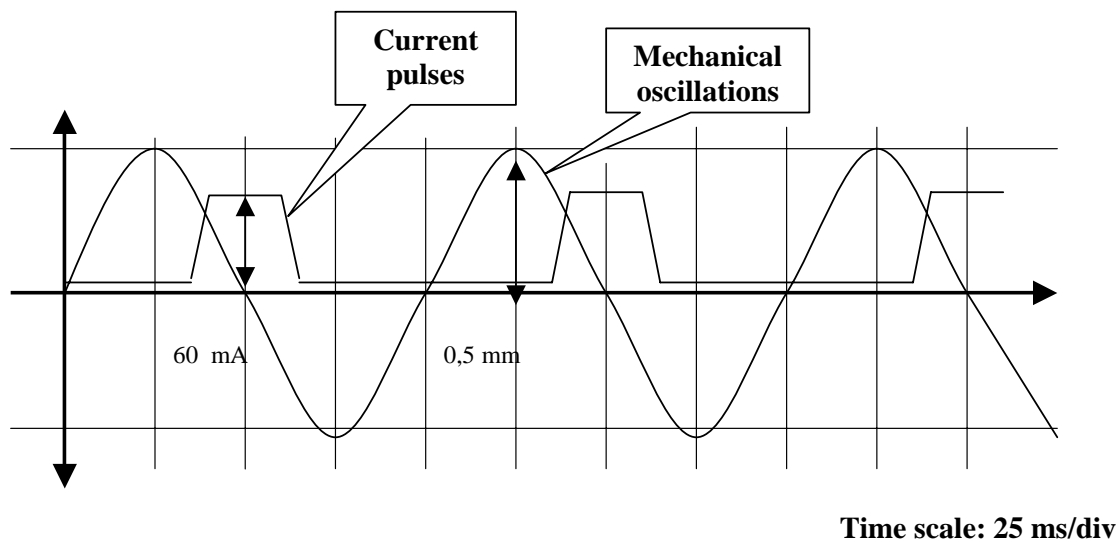
**Photo 2:** The tension meter



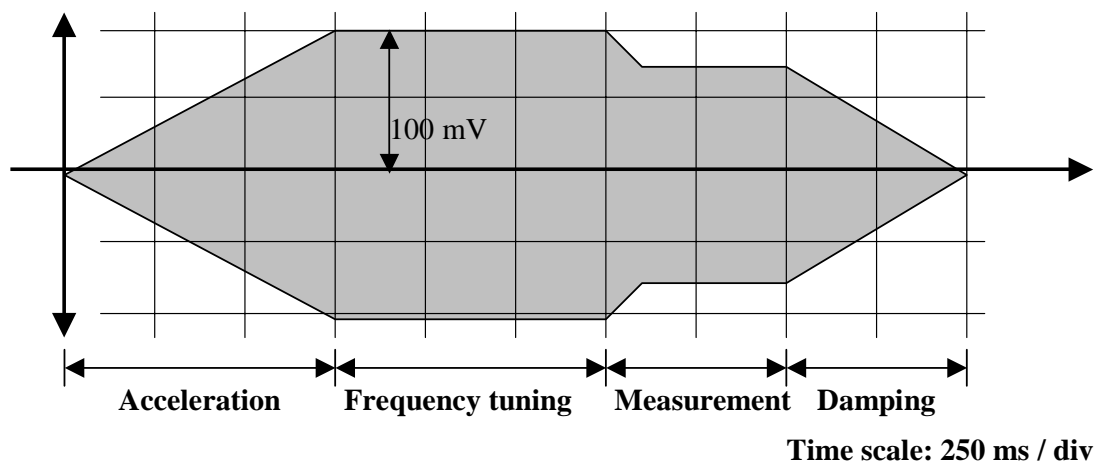
**Fig 1.** The block diagram of the Wire Tension Meter



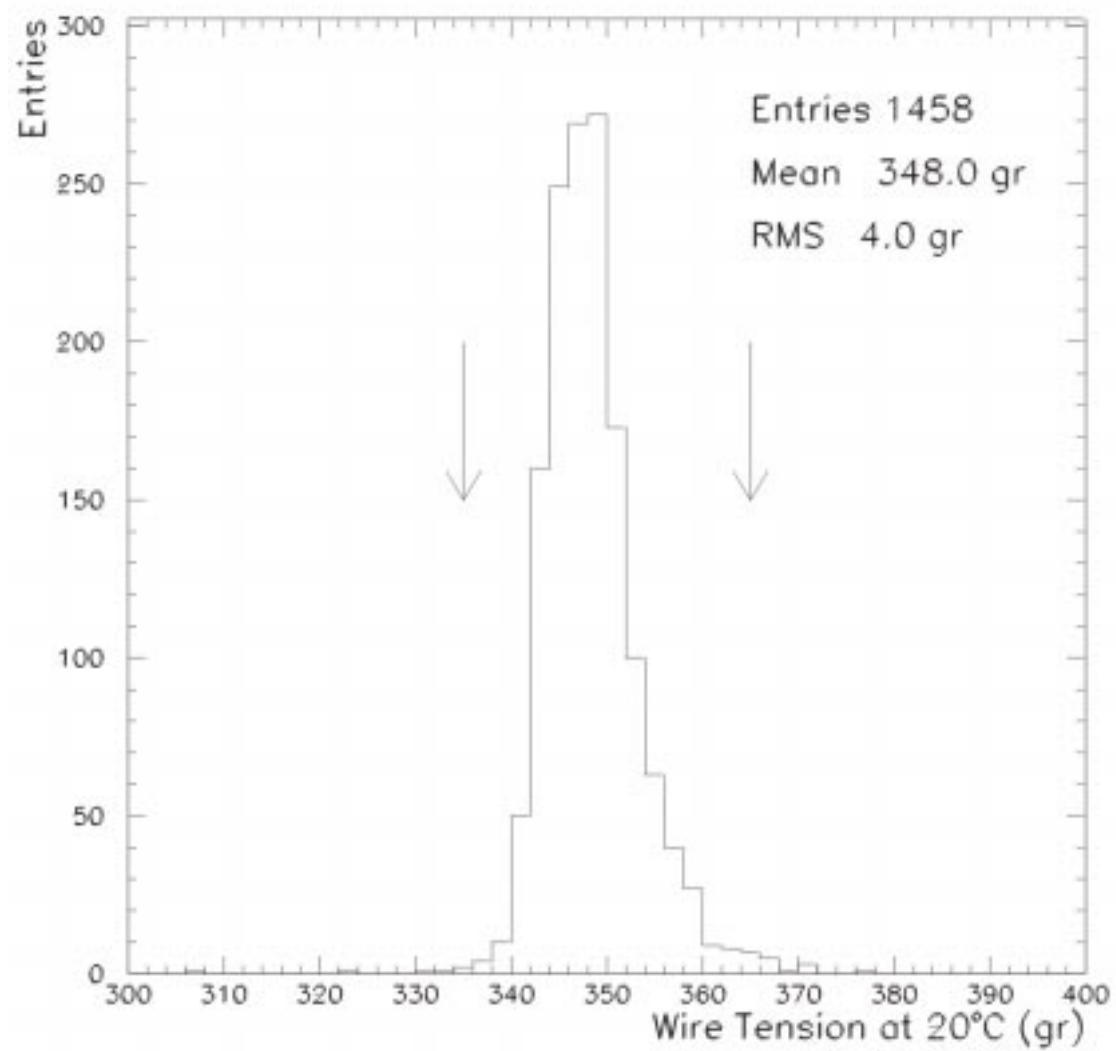
**Fig 2.** The form of all pulses sent to and received from the wire.



**Fig 3.** The form of the wire mechanical oscillations and the current pulses applied to the wire during the “frequency tuning” phase.



**Fig 4.** The mechanical oscillation profile during one complete measurement cycle.



**Fig 5.**The wire tension distribution measured with the present device