LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

- LIGO –

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The GAS blade creep measurements, problems and some solutions.

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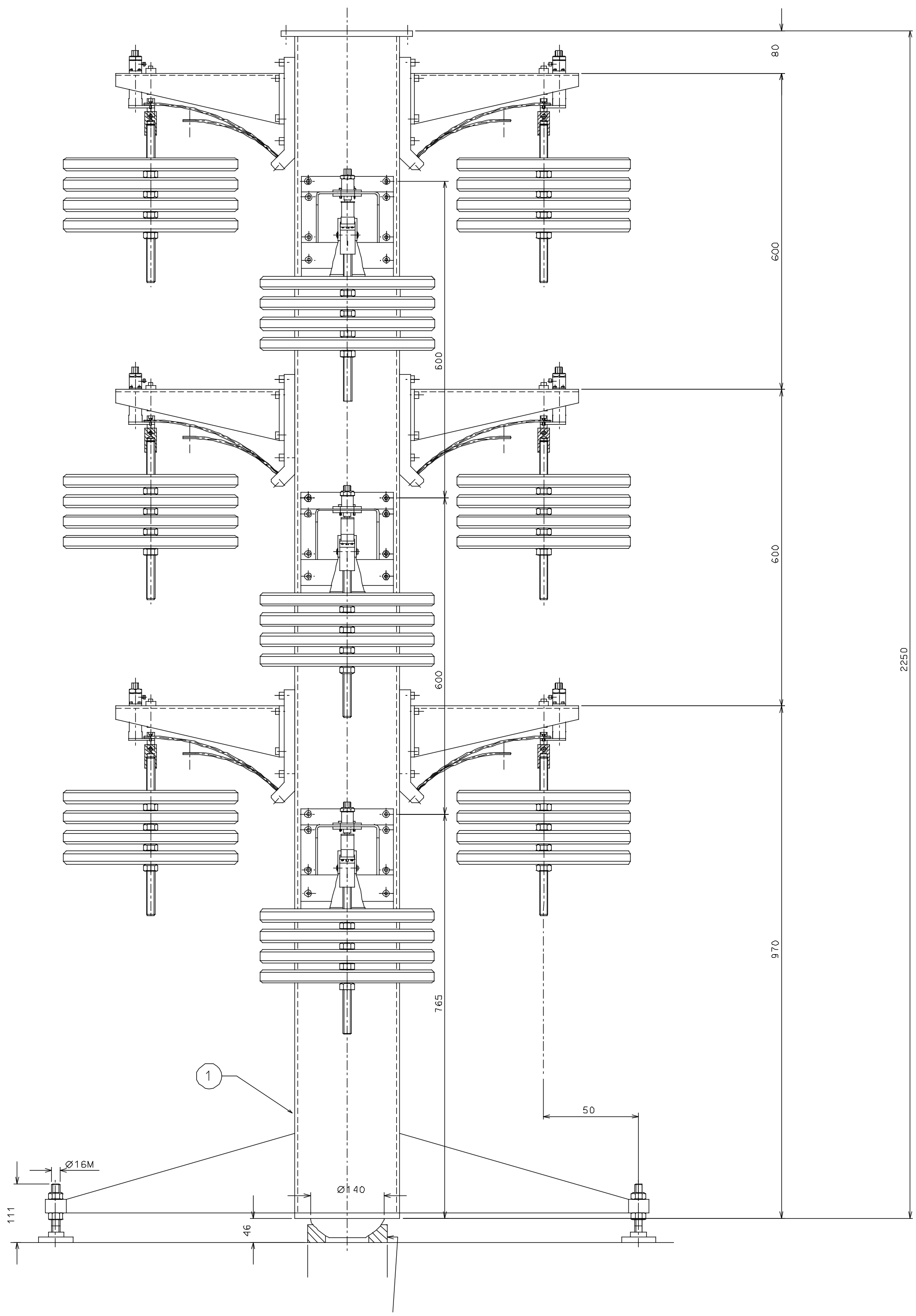
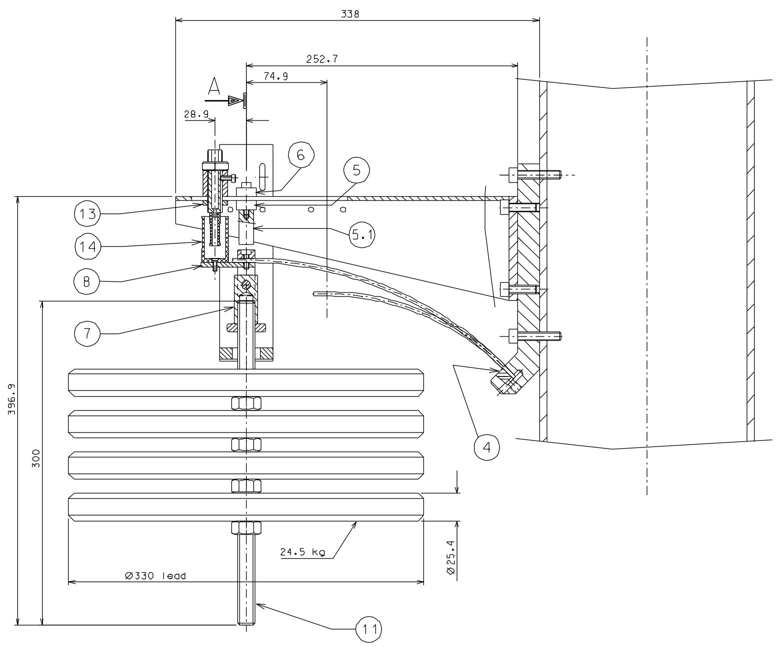
A measurement of creep of the blades used in GAS filters have been started. The mechanical setup is shown below



Blades have been fastened to a central pole (totem) and loaded with weights.

The drooping produced by creep is readout by LVDT position sensors (13 and 14 in the figure below).

The experiment is made in a thermally stabilized room with less than +/- 50 m°K temperature fluctuations.



The measurement proved very difficult.

We have been baffled by several funny behaviors of the creep measurements.

What was most unbelievable of the observed behaviors was to see steps, both upward and downward, of the creep measurements.

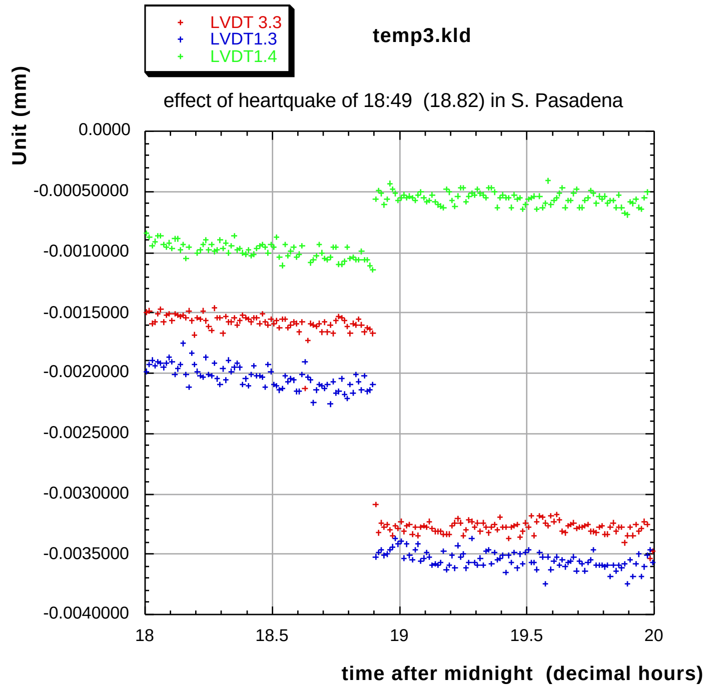
Steps were often happening in groups and during human activity, but in a seemingly random combination, some up, some down and some no visible effect. Some steps happened even in the quietest situations. It was very confusing

For long time we suspected data acquisition problems with the assumption that no mechanical event can raise the position of the masses attached to the blades. If a catastrophic creep or slipping event must happen it will be downward.

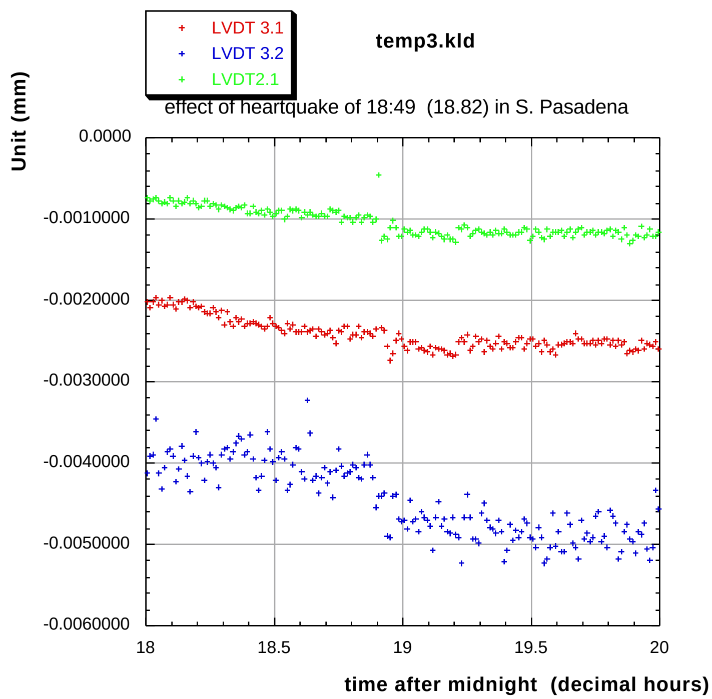
Finally on Sept. 26th at 18:49 we had a small earthquake that clarified the picture.

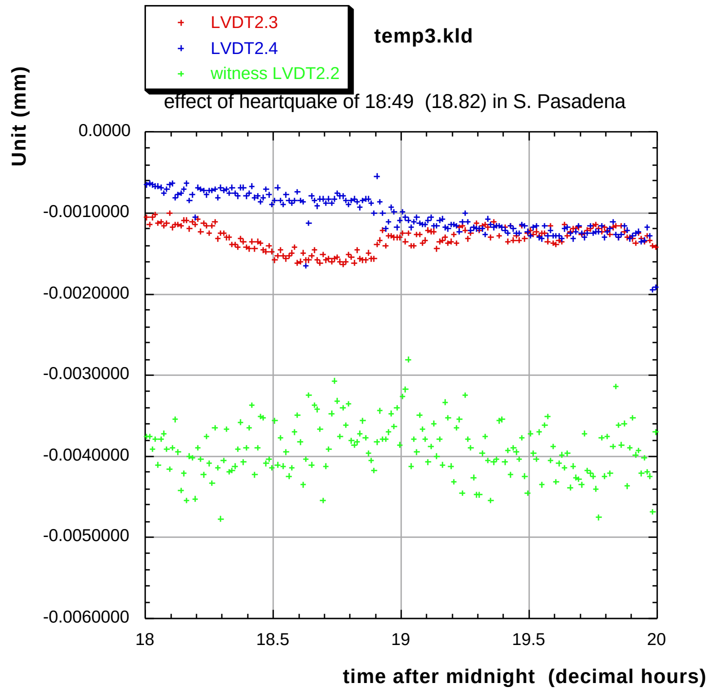
We eventually realized that there was not a single cause of steps in the measurements, but at least two.

The earthquake produced large LVDT reading changes, on some blades



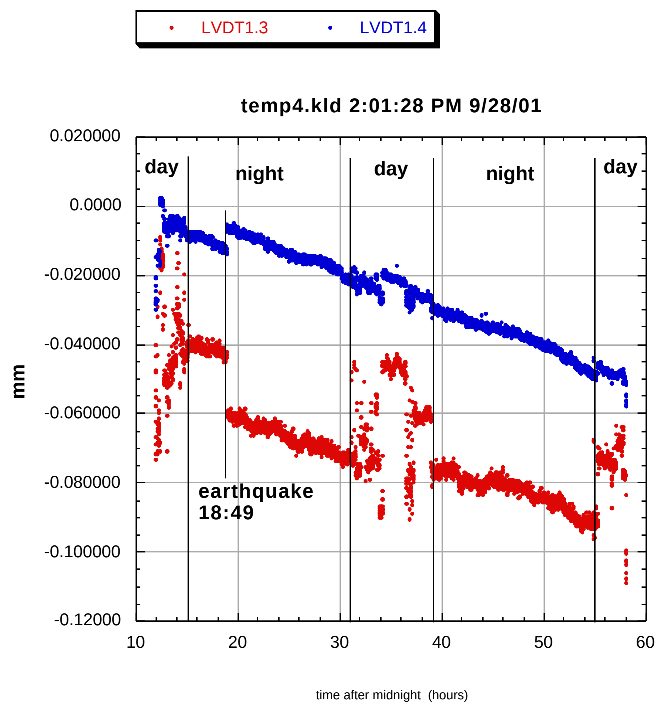
Small or no steps on other blades:





The only possible explanation being that the verticality of the center column of the totem was tilted on one side by about 150 μradians. If this tilt happens the blades on one side will raise while the blades on the other side will lower and the blades in front and back will not be (or be little) affected by the tilt. Each blade will respond with a step proportional to the amplitude of the tilt in its longitudinal direction, times its integrated elongation from its at rest position to its loaded position. Of course no earthquake effect is visible on a witness LVDT.

This large event finally seemed to explain the multiple small event visible during the Minos working time. The observed small steps can be easily explained with small (of the order of 10 μradian) shift of verticality of the totem, which in their turn can be explained with the overhead crane movements.



One could think of just gating out the daytime data and measure the creep with the remaining night time data. Occasional earthquake events could be reconnected by hand. The problem with the Minos activity is that at the end of the day it does not necessarily leave the totem in the original verticality and it is difficult to determine the integrated tilt to be substracted and the creep measurement is strongly polluted.

One only solution we could figure out, apart to relocate the experiment, is to simply suspend the totem pole from its top with the aid of a wire.

Then the totem will hang down and supposedly find its verticality. Of course it will be useful to mount identical blades in opposite positions to both balance the totem pole and allow filtering of the differential mode of the residual variations of verticality.

Also we will have to replace all cabling with cabling running along the suspension wire.

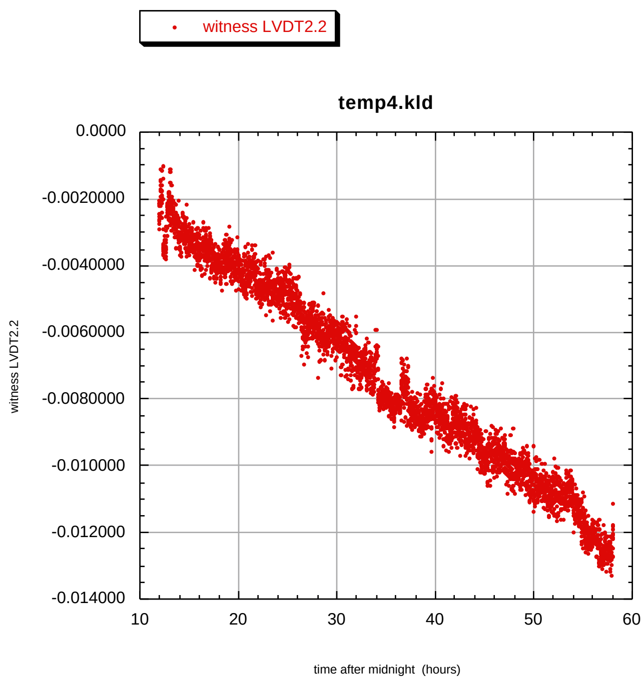
This is the first fix that we will apply to the totem system.

There are two additional problems identified.

Several days after the startup we inserted two witness LVDTs to check out their stability.

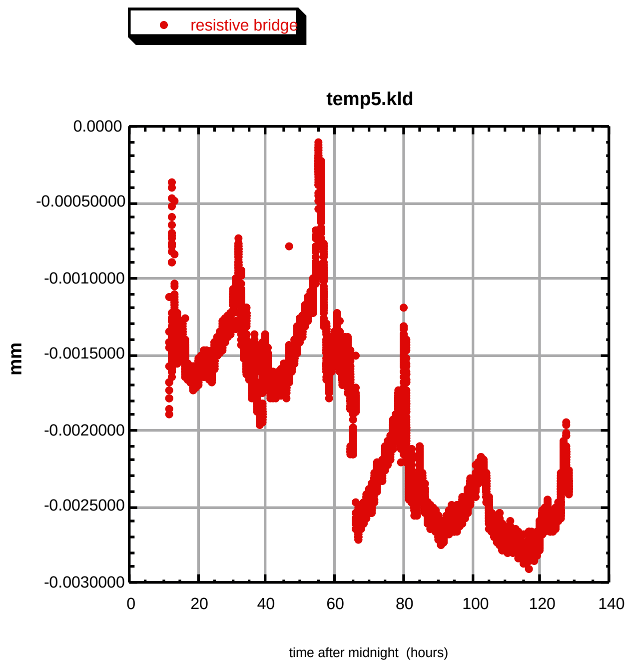
They also show some “creep”-like signal, i.e. the readout position did progressively move to lower values with decreasing rate despite the fact that the two parts of the LVDT were rigidly mounted together.

The most likely explanation for this effect is the following. Since the system was not intended for “in vacuum” applications, we decided to make the LVDTs of nylon, and some of PVC. It turns out that nylon absorbs up to 4% in weight of water and can expand more than 1% in length, which, over the 50 or 60 mm of LVDT, makes for up to a few hundred microns. We suspect that the plastics, in the dry oven atmosphere, will lose humidity and shrink. As they shrink the emitter and the receiver are effectively separated, just as it would happen in creep.



One could think that this drift is generated in the electronics.

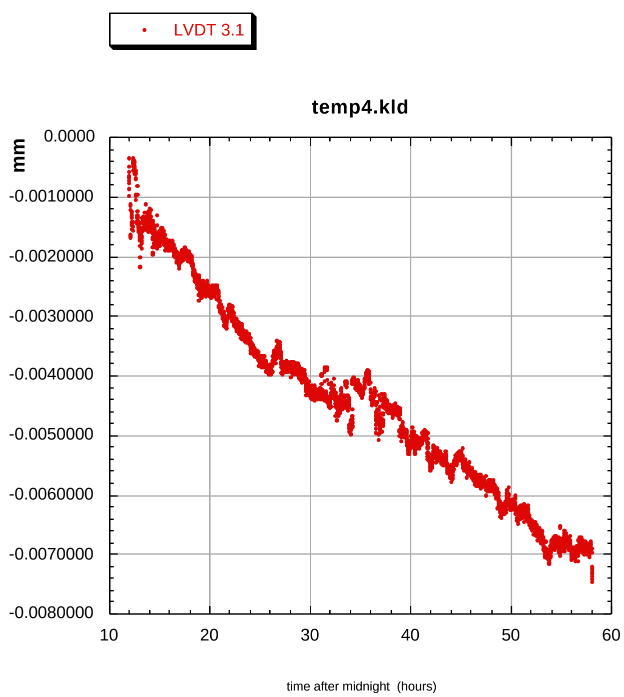
The observed “creep” is not in the electronics, as can be seen by examining the signal of a resistive bridge “LVDT”. Also this effect was not visible in Virgo where ceramic LVDTs were used.



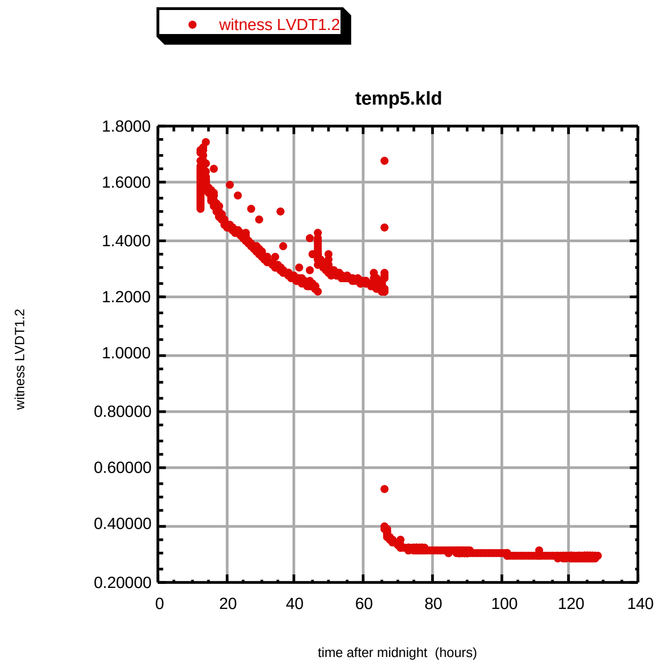
The LVDT shrinkage and the blade's creep are indistinguishable. The only solution is to **replace all the LVDTs with ceramic or Peek ones**.

This is the second fix to be applied to the totem system.

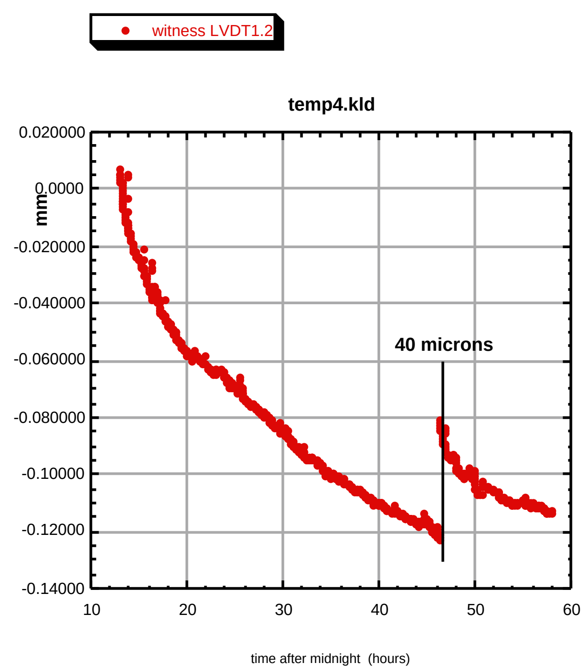
Of course the creep observed in certain channels is only the upper limit of the real creep, because creep and LVDT shrinkage add up with the same sign.

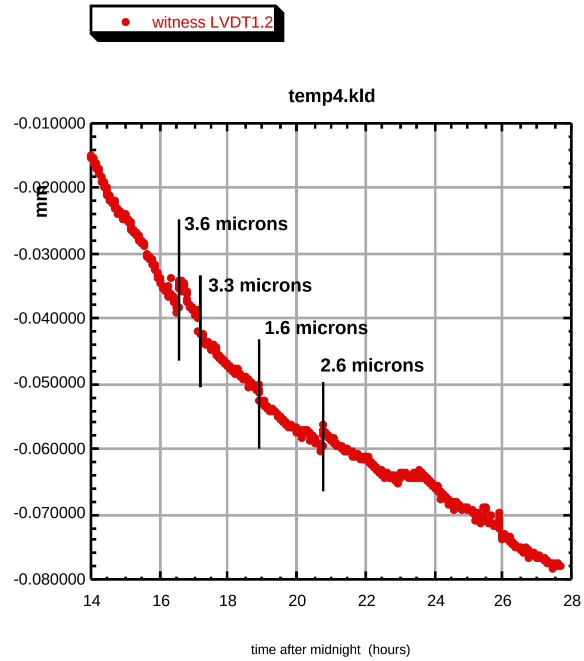


The last **major** problem recognized is a second kind of signal jump, that seems to be purely software in nature. The jumps can be large or small, and go both directions and appear in selected channels, see the resistive bridge above or the graphs of a witness LVDT below.

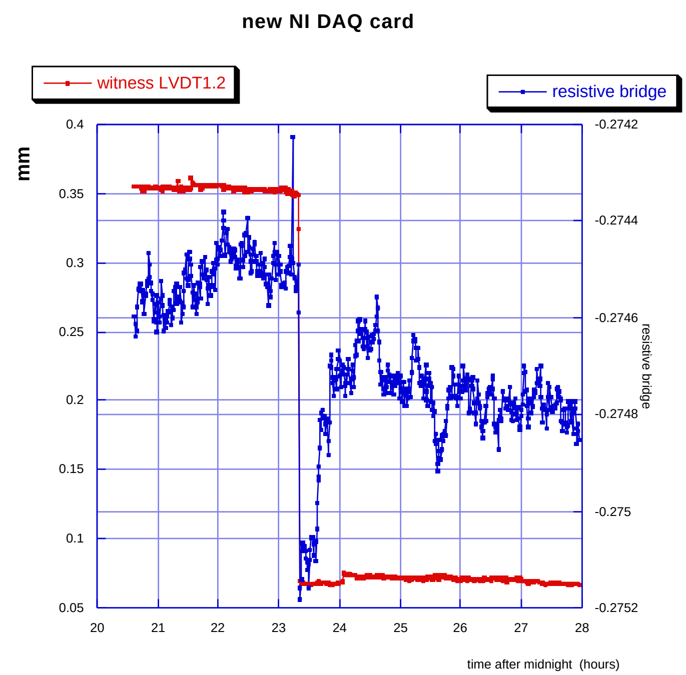


The jumps have both a macro, a meso and a micro structure





The first suspect was the acquisition card hardware, possibly some bit jumping. The jumps have been observed in two separate NI DAQ cards; it is unlikely to find two cards, bought at one year of distance from each other to fail in the same way.



The same jumps have been observed using two separate computers thus ruling out also a computer bus failure.

We concluded then that the jumps may have purely software origin. In fact we were lucky enough to observe two jumps in the online, non averaged data display showing a sharp and clean cleavage and shift of an otherwise perfectly smooth sinusoid from an oscillating blade. The cleaved signal did not show any variation of amplitude or phase before and after the cleavage thus excluding a mechanical nature of the effect. At the same time the preceding and following channels showed no perturbation at all. As this behavior is rare, it was caught only two times on the online display. In one case only one signal shifted, in the second case two signals shifted at the same time. No correlation was ever found with anything physical.

This behavior was difficult to distinguish from the tilt induced shifts discussed at the beginning and difficult to explain after finding the tilt explanation for a large fraction of the events.

The theory to explain these unexplainable shifts is that some pedestal file in the DAQ driver may be corrupted and overwritten at random times and random amplitudes.

We will try first to use different DAQ software. If this fails and this behavior will continue to be observed, we will try to use DAQ cards from another company.

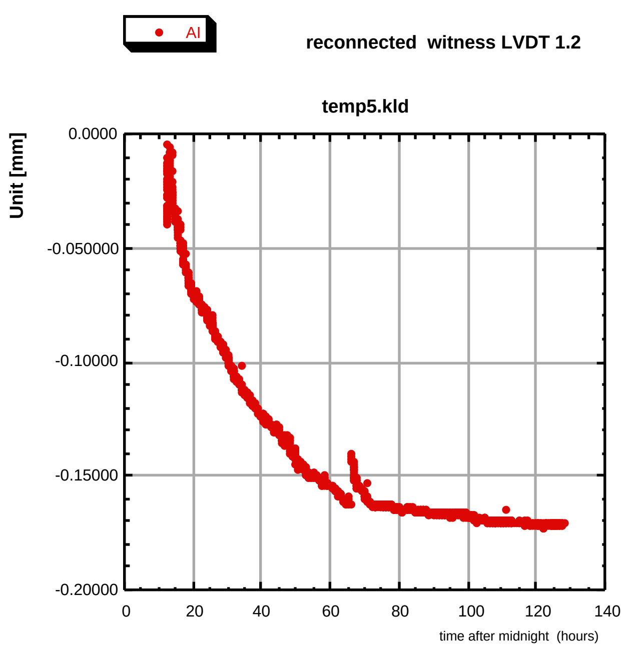
As we will suspend the totem we will have to replace all the wiring and we will take the occasion to **install anti-aliasing filters in front of all DAQ channels**.

The installation of the new computer required a degradation of the thermostabilized electronics box. As a result the electronics now sits in a thermal environment that is only marginally more stable than the ambient temperature. **The electronics box also will necessitate some refurbishing.**

Is there any good news in all of this?

Actually some small ones.

The signal of the first witness LVDT, after roughly recombining its cleavages, is behaving roughly logarithmic, as one would expect from drying, with a overall drop of 170 microns. The recombination of cleavages, though is far from satisfactory.



The other witness LVDT shows a drop of only 45 microns (no information about the materials used except that it could be either nylon or PVC, we need an inspection inside the oven). These LVDTs are expected to drift much more than the LVDts mounted on the blades in the oven several days before (they should be drier by now).

The "resistive" LVDT shows a stability well inside a micron, with the exception of a single 1 micron cleavage after 63 hours.

The differential readout of different voltages (-3+0, +3+0, -1.5-1.5, and 3-3 Volts) all staid stable within 1 mV (<0.3 μm over the all period). This means that the linear electronics is stable.

The temperature in the oven staid between a +/- 50 m°K interval.

If we observe the behavior of the blades, we can at least set upper limits of the creep added to the LVDT shrinkage.

The data can be resumed as follows:

Blade 1.3	1.7 μm/day
Blade 1.4	2.3 μm/day
Blade 2.3	2.0 μm/day
Blade 2.4	3.4 μm/day
Blade 3.1	2.5 μm/day
Blade 3.2	4.0 μm/day
Blade 3.3	1.7 μm/day

These upper limits of creep are all consistent with what observed in similar conditions in the measurements made in Virgo in 1998 (NIM A 404 (1998) 455-469).