

## DATA ANALYSIS OF SLS HYDROSTATIC LEVELLING SYSTEM IN 2003

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The Hydrostatic Levelling System (HLS) of the SLS was modified and re-calibrated in 2002. Since January 2003 the system has collected approximately 2 million measurements. The analysis of the data shows that displacement of the SLS storage ring foundation and the girder support was in the range of 0.15 mm. The long term HLS stability was significantly improved. The short term precision of the HLS is in the micrometer range. This allows to observe level variations induced by tidal forces.

### HLS DATA ANALYSIS 2003

The HLS System of the SLS consists of 192 level sensors (see Fig. 1), four mounted on each of the 48 girders. Since January 2003 we have collected time series of approximately 2 million voltage data. The voltages of each sensor were collected by a central PC that converted them into vertical positions, called raw data.



Fig. 1: HLS-Level sensor mounted on a girder.

The raw data showed significant drifts before 2002 [1]. These drifts consist of the following contributions:

- \* Drift due to evaporation and re-filling
- \* Drift due to different heat expansion coefficients between the pipe and the working fluid during the temperature variation
- \* Real displacements of the basements of the HLS
- \* Stability of the sensors
- \* Errors of sensor calibration
- \* Other gross errors due to known and unknown effects

Analysis of these effects allowed the manufacturer Edi Meier + Partner AG to modify and recalibrate the system which led to significant improvement of the long term stability.

In order to exclude shifts due to evaporation, re-filling and different heat expansion coefficients between the pipe and working fluid, the mean of the 192 sensor values is subtracted from the raw data. Fig. 2 shows the mean deviations of all girders at the beginning, in the middle and at the end of year 2003. The contribution of Sensor 3 on Girder 12 is excluded because of 1 mm unknown gross error.

The RMS value of the deviations was 0.047 mm at

11<sup>th</sup> January, 0.039 mm at 3<sup>rd</sup> July and 0.049 mm at 3<sup>rd</sup> December. These deviations reflect essentially the real vertical position displacements of the girders. The errors due to HLS sensor stability and sensor calibration are difficult to separate. Experience with other HLS systems shows that the evaluation of HLS stability is a time consuming task [2] that will be further pursued in the future.

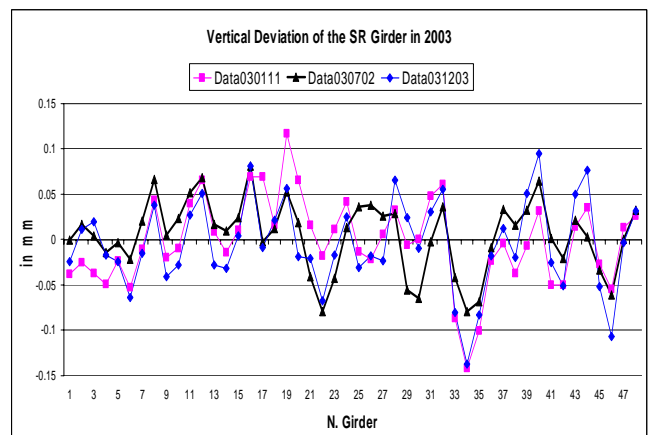


Fig. 2: Deviations of the SR girders in 2003.

The vertical displacements of the SR girders in 2003 are shown in Fig. 3. The displacements from winter to summer and the displacements from summer to winter are nearly symmetrical. The maximum displacement is less than 0.15 mm. Compared with other SR foundations that show a range of displacement by one to two millimeters per year [3] [4], the stability of SLS storage ring foundation and the supports can be considered as excellent.

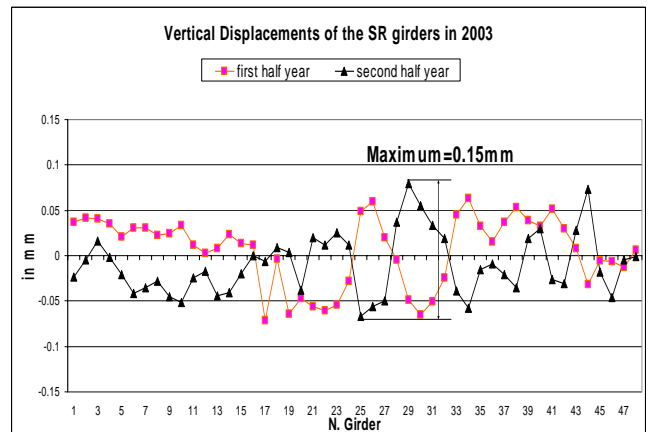
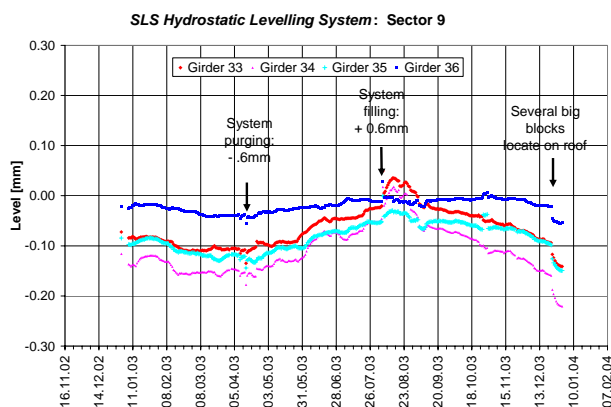


Fig. 3: Vertical Displacement of the SR Girders in 2003

## HLS LONG TERM PRECISION

Fig. 4 shows the level of the four girders N.33, N.34, N35 and N36 in sector nine during the year 2003. Because of the exceptionally hot weather in August 2003, the air conditioning system in the SLS reached its limits and the temperature inside the tunnel of the storage ring increased by about 4 degrees. Girders N.33, N.34 and N.35 are located on top of the media channel with water pipes and cable trays. Consequently the sharpest curves of displacement appear for these elements during the hot period.



**Fig. 4:** Levels of the four girders N.33, N.34, N35 and N36 in sector nine in 2003

A few data, which are different to the main data, were measured during purging and refilling processes of the HLS System in April and July. The refilling is necessary to replace the evaporated working fluid and is performed every half year. The disturbance caused by this process is damped out after about a day. At the end of December 2003 the roof of the SLS storage ring tunnel in sectors 4 and 5 was opened. Several concrete blocks, weighing about 10 tons each, were temporarily stored on the nearby parts of the tunnel roof. This major operation in 2003 is documented by Fig. 4 that clearly shows that the levels of the HLS experienced significant changes.

Figs. 2, 3 and 4 show that the SLS HLS precision over one year is of the order of a few micrometers.

## HLS SHORT TERM PRECISION

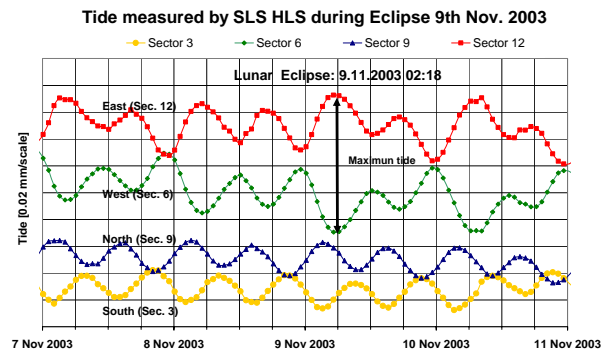
Oscillations of the SLS HLS with small amplitudes between 0.001 mm and 0.005 mm have been observed in 2003. The temporal wavelength of the oscillations was found to be on the order of 12 hours.

Further investigations showed that the oscillations can be correlated to tidal forces. In case of an eclipse the influence of sun and moon is known to be particularly high because sun, earth and moon are aligned and the superimposed gravity forces lead to stronger motion than usual.

Fig. 5 shows the mean level of 4 sectors during the period of the lunar eclipse on November 9, 2003. It can be clearly seen that the level difference in the SLS HLS becomes a maximum at the time of the lunar eclipse. It can be also clearly observed that the

level differences between east (Sector 12) and west (Sector 6) are larger than the level differences between north (Sector 9) and south (Sector 3) of the storage ring.

The level variations measured by the HLS are combinations of real ground motion and fluid movements inside the HLS channel. The precision of SLS HLS is, however, on the order of a micrometer over the period of a few days.



**Fig. 5** Tide measured by SLS HLS in East-West and North-South direction during eclipse 9<sup>th</sup> Nov. 2003

## CONCLUSIONS

Since January 2003, the vertical displacements of the girders of the SLS storage ring have been continuously monitored by the HLS. The results reveal a very stable basement of the storage ring. The high HLS precision over short term periods allows the observation of tides, induced by the gravity forces of sun and moon.

## REFERENCES

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