# HYDROSTATIC LEVELLING SYSTEM WITH LASER SENSORS.

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*Abstract*

A hydrostatic levelling system that uses laser triangulation sensors for sensing the water level in the levelling vessels has been developed. The laser triangulation sensors makes the design rather rugged. It is easy to move the sensor vessel from measuring point to measuring point without splashing water on the sensor surfaces since the distance from the sensor to the water level is several centimetres. The resolution of these sensors are in the µm range. The sensors have been used to align and check the MAX II machine components.

## 1. INTRODUCTION

The principle of the hydrostatic level has been known for a very very long time. We have used the technology of to-day to improve this ancient method. The basic hydrostatic level is based on the natural law of gravity and can not be refined. However it is the method of measuring the water level in the levelling vessels that we have approached. We use a laser sensor that is based on the principle of triangulation, which also is a rather ancient method of measuring distances.

We developed these instruments to align our new third generation synchrotron light source, MAX-II [1] where it is necessary to align the magnets with a precision in the order of 30 µm with respect to each other on one jumbo girder that holds all the magnets of one cell. The alignment tolerances for the girder alignment are more relaxed and in the order of 100 µm.

## 2. PRINCIPLE

The laser triangulation measurement head, seen in fig. 1. and which is commercially available measures the distance from the measurement head to a diffuse surface. If this distance is vertical and kept constant and a part of the distance is in water the level of the water surface in the vessel can be measured. How this is done can be seen in Fig. 2 and 3.

In the triangulation sensors mid range the target distance b = 40mm [2] and the angle β = 28°. We can now calculate the fixed distance *a* using the well known formula:

$$a = b \ \text{tg}\,\beta \tag{1}$$

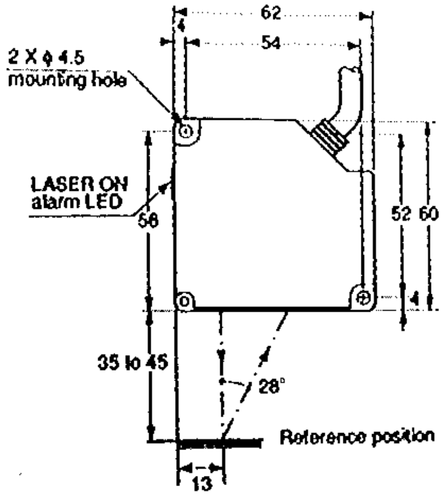


Fig. 1. The measures of the laser sensor in mm.

## 3. TRIANGULATING THE LEVEL OF A WATER SURFACE

When the water surface is between the sensor and the diffuse object the water surface will diffract the laser ray and the distance measured by the sensor is affected by the refractive index of the water. The part of the distance that is in water will be longer than what is measured. When the water surfaces level changes the sensor will indicate different distances although the distance from the sensor to the diffuse surface at the bottom of the vessel is constant.

The distance we want to measure is the distance d shown in fig. 3. The laser uses a wavelength of 670 nm. At this wavelength the refractive index of water n = 1.33. We can now from

$$\sin\beta = n \sin\alpha \tag{2}$$

find that the angle α = 20.67°. From the geometrics of fig. 2. we can derive the following equations needed.

$$f\,\text{tg}\,\beta = d\,\text{tg}\,\alpha \tag{3}$$

$$f = b - T + d = d\,\frac{\text{tg}\,\alpha}{\text{tg}\,\beta} \tag{4}$$

$$T = d\left(\frac{\text{tg}\,\beta - \text{tg}\,\alpha}{\text{tg}\,\beta}\right) + b \tag{5}$$

$$T = d \ 0.29 + 40 \text{ mm} \tag{6}$$

We choose d = 15 mm and then Eq. (6) gives T = 44.4 mm.
Of course the distances T and d could be varied a certain amount without degrading the performance too much, but the given distances is what we have chosen. The detector gives in air a signal of 1V per mm. In our case we get 0.3V per mm change in the water level.

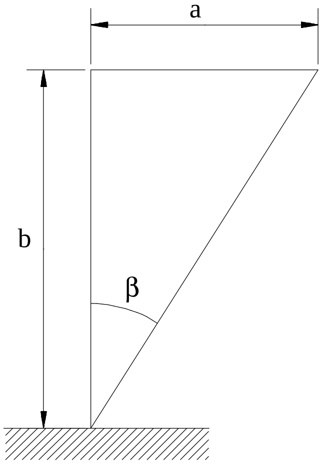


Fig. 2. The basic triangulation of the detector.

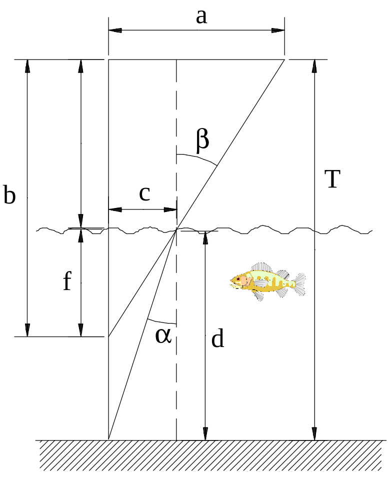


Fig. 3. The triangulation through a water surface.

## 4. USE AND PERFORMANCE

The sensor gives out a voltage proportional to the water depth. We use only two sensors since they are relatively easy to move without recalibration. The signal from each sensor is displayed on a chart recorder. In this way we can clearly see when the water level has stabilised and we can also record long term drifts. In fact we have seen the evaporation of water from the levelling vessels. When the hydrostatic level is to be used, it has to be calibrated first. This we do by putting both vessels on the same reference table. Since the differences in read-out is small we simply zero the pen positions on the chart recorder used as read-

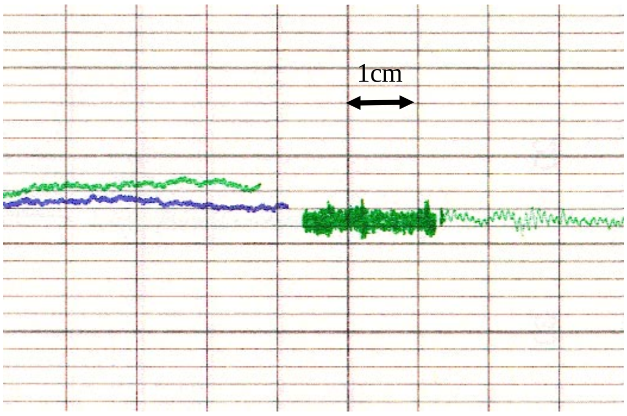


Fig. 4. The signal output from the laser sensor is rather noisy. We added a lowpass filter with a $f_0$ = 0.3 Hz. The right part shows the signal without filter at 1cm/s, the middle part at 1cm/min and the left part with filter and 1cm/min.

out. Then one detector is moved to the object to be adjusted. Fig. 5. shows a typical adjustment run. The upper trace is the signal from vessel 1 and the lower one is from vessel 2. One division is 2.7µm, so we start with 78µm and after some iterations the adjustment is done.

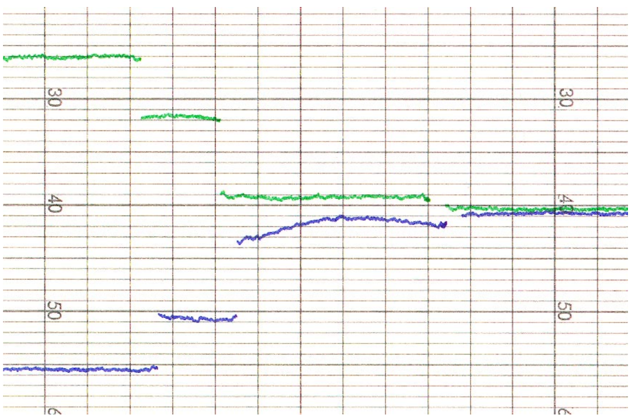


Fig. 5. Chart recorder read-out of an adjustment run. The upper line is the signal from vessel 1 and the bottom line is from vessel 2. Time is from left to right at 1 cm/min.

## 5. CONSIDERATIONS FOR USE AND WATER QUALITY

We have also noted that draught causes waves in the water and gives erroneous readings. This has been cured by using various kinds of shields as can be seen in fig. 7. The big handle is there to prevent heat from being transferred from the hands to the vessel when moving the device.
The water used in the system must be very clean. The wiggle to the left in the upper curve in fig.6. is a typical disturbance from a small particle floating on the surface and swimming into the laser beam disturbing the measurements, but since we measure over several minutes this has no effect on the obtained precision. We have also experi-

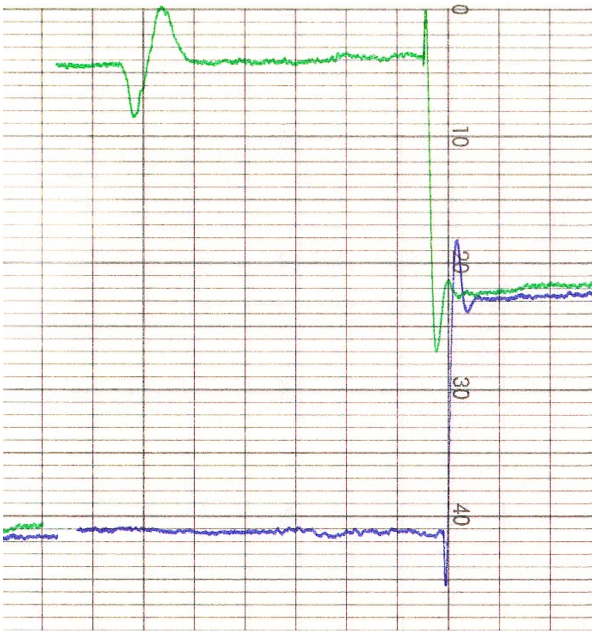


Fig. 6. Calibration of scale. The connection between the vessels is closed and $1 cm^3$ of water is added to one vessel. Then the connection is opened and the levels equalised. $1 cm^3$ equals 0.1mm.

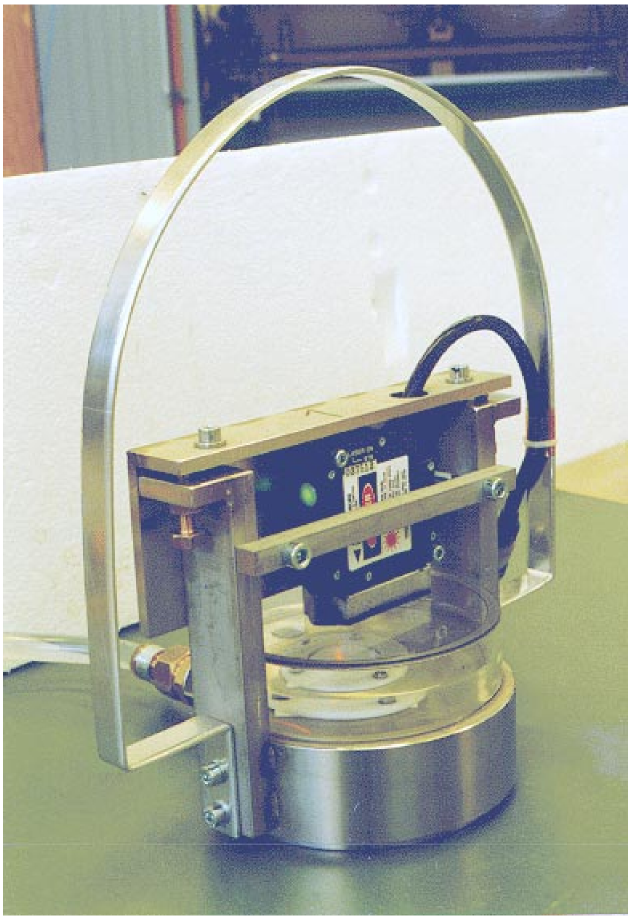

Fig. 7. The prototype. Note the dust cover over the water and the draught protector just below the sensor.

enced algae in the water if the system has been standing with the same water in it for some time.

Each of these problems got a solution. The particle problem was solved by using absolutely pure water and having a dust cover on the levelling vessel. The algae problem was solved by adding a very small amount of chlorine to the water. Anything that prevents the growth of algae is useful.

## 6. REFERENCES

[1] M. Eriksson et. al., Design report for the MAX II Ring, MAX publications
ISRN LUNTDX/NTMX--7019--SE (1992).

[2] Keyence manual for Triangulation sensor LB-041.