FIG Working Week 2004
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THE OPTOELECTRONIC SYSTEMS FOR VERTICAL DEFORMATIONS AND TILT MEASUREMENT OF OBJECTS AND TECHNOLOGICAL EQUIPMENT

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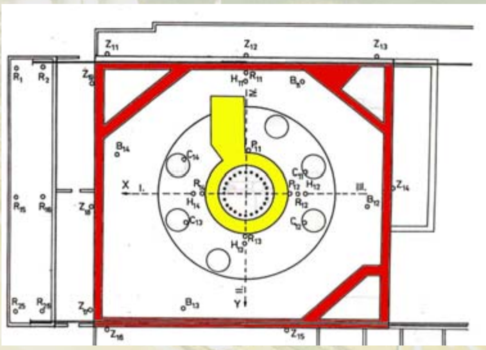
Nuclear Power Plants in Slovak Republic

J. Bohunice

Mochovce

Distribution of observed points in the reactor hall



Reactor tilt

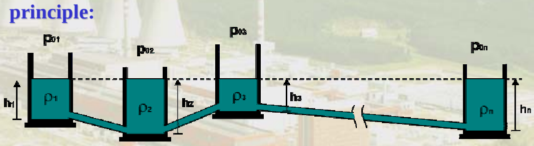
is determined on a base of two independent principles:

principle of connected pots
- ***hydrostatic method***

principle of physical pendulum
- ***pendametric method***

Subsystem of hydrostatic method

principle:



Equilibrium condition:

$$p_{01}+\rho_1 H_1 g = p_{02}+\rho_2 H_2 g = \cdots = p_{0n}+\rho_n H_n g$$

if $\rho_1 = \rho_2 = \cdots = \rho_n$
$p_{01} = p_{02} = \cdots = p_{0n}$

liquid levels lie in one horizontal plane

p_{0n} – atmospheric pressure
ρ_n - liquid density
g - acceleration of gravity
H_n - liquid column elevation

Methods of measurement of elevation level in sensors.

At Institute of Measurement of Slovak Academy of Sciences were examined:

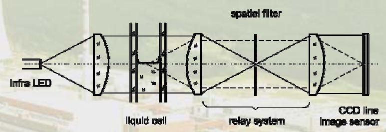
- **electro-mechanic method,**
- **measurement method of electric capacity,**
- **ultrasound method,**
- **gravimetric method,**
- **optoelectronic method.**

Into stadium of realisation were finalized:

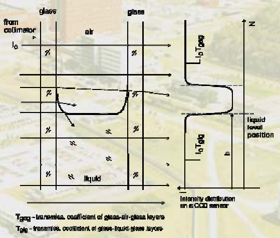
- **electro-mechanic method,**
- **optoelectronic method.**

Optoelectronic method

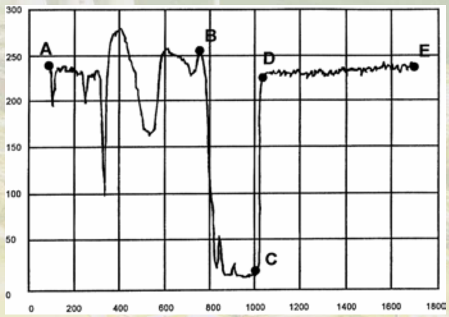
Scheme of optic system



Transition of luminous beam through sensor



Continuance of CCD chip illumination



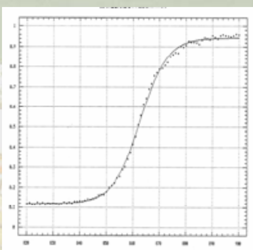
Interface liquid-air

$$I = b + \frac{a}{1+e^{(c-h)d}}$$

I - illumination intensity
h - vertical coordinate
a - difference between min. and max.
b - minimum of illumination intensity
c - inflexion point position-of level
d - curve slope of illumination

For non-linear regression was used

Marquard-Levenberg algorithm



….. measured data
—— regression curve

Correction of thermal dependency

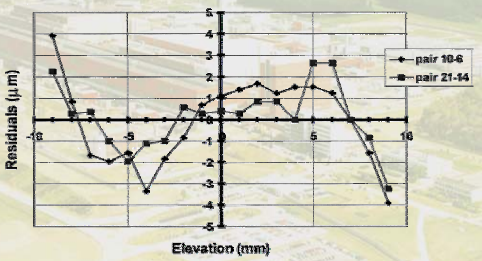
In systems there is used one liquid and a condition of the equal density of liquid is fulfilled if there is an equal temperature of sensors.

If this condition is not fulfilled, it is necessary to measure its temperature and to do corrections of elevations:

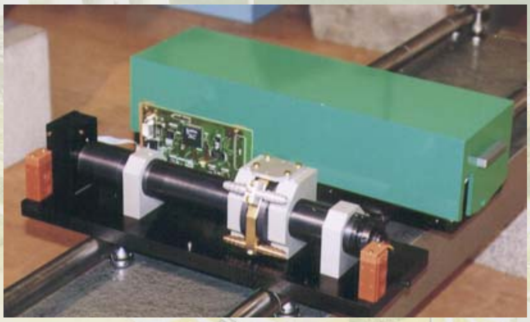
$$\Delta h = h_0 \gamma (t-t_0)$$

kde: h_0 **- elevation level by temperature** t_0,
γ **- coefficient of thermal expansion**
t **- liquid temperature**

Calibration curves of two pairs of hydro-levelling sensors



Sensor of subsystem of hydrostatic levelling



Basic parameters of subsystem of hydrostatic levelling:

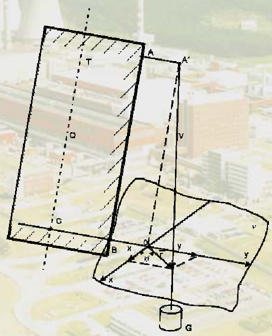
- Number of measured places: do 32
- Measurement range: ±10mm
- Measurement accuracy: 10µm
- Measurement resolution: 1µm

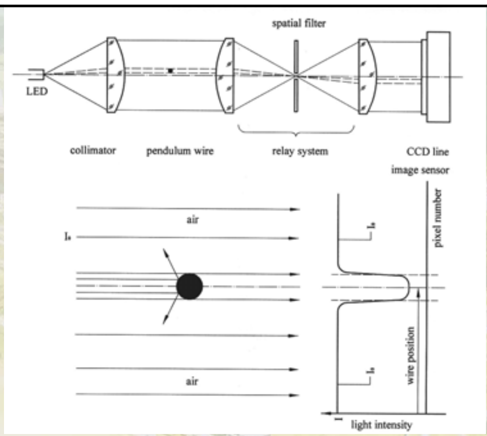
Note:

- with help of hydrostatic levelling it is possible to measure only relative high differences of points
- for tilt measurement of objects it is necessary to select min. 3 measurement points
- to render a plane through these points and to calculate its tilt

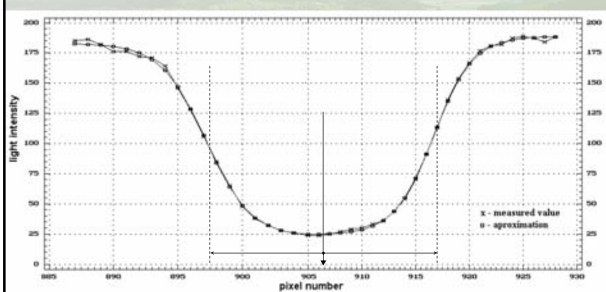
Pendametric subsystem

Principle:





Parallel light beam passing through the sensor measurement space with pendulum wire.

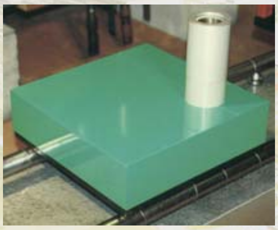


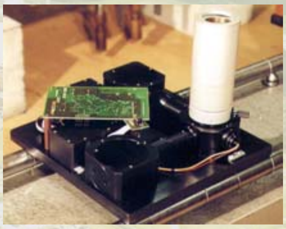
Estimation of pendulum wire position .

Continuance of CCD chip illumination

Joint hanger of pendameter

Sensor of pendametric subsystem



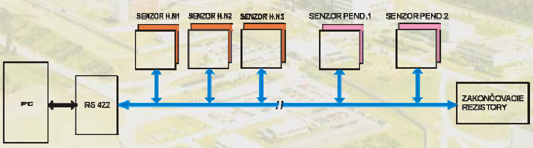


Basic parameters of pendametric subsystem:

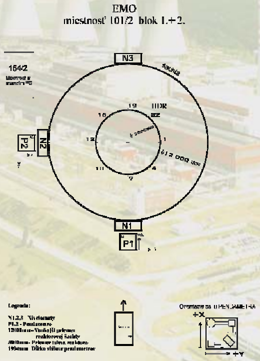
- Max. number of measured places: do 32
- Measurement range: ±2mm
- Measurement accuracy: 1µm
- Measurement resolution: 0.1µm
- Max. distance of measured places: 1200m
- Parameters of sensors w . d . h: 279 x 279 x 90 mm

System for tilt measurement of nuclear reactors

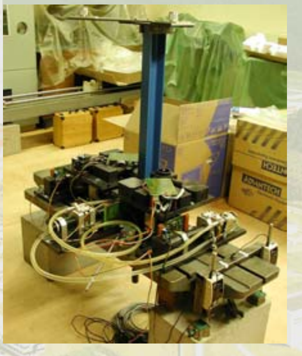
- 3 sensors for hydrostatic levelling
- 2 biaxial pendametric sensors



Sensor location on reactor

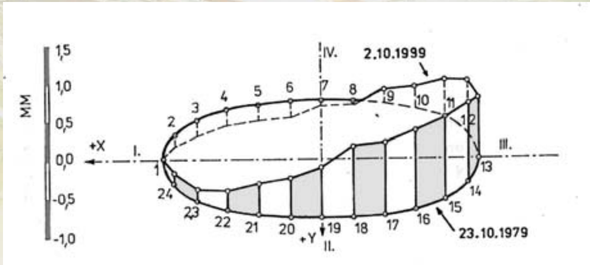


Laboratory simulation of measurement

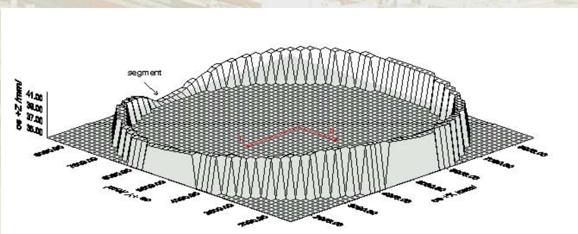


Operative computer

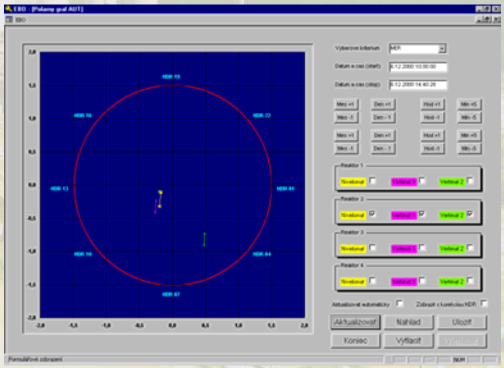
Presentation of vertical displacements of the reactor



Graphical presentation of flange deformation of the reactor protection cover in the orthographic projection



User interface of system for spatial stability measurement of nuclear reactor objects



Thank you for your attention !