A High Precision Double Tubed Hydrostatic Leveling System for Accelerator Alignment Applications

Fermilab

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Content

- The general dependence of a water level.
- How to model HLS?
- A variant of thermostabilized of HLS
- Summary

pipe flow basics between two pool

- In HLS present laminar flowing of a Newtonian incompressible viscous liquid
- For steady flow we have Poiseuille's relation for mass flow rate :

$$\Phi = \frac{dy}{dt} \cdot S_p = \frac{S_p}{8 \cdot \eta} \cdot \frac{P_1 - P_2}{\ell}$$

- equations of level ***y*** at the opened both ends of pipe of none steady flow in gravity filed:

$$\frac{d^2}{dt^2} y + 2\omega \frac{dy}{dt} + \omega_0^2 y = 0, \qquad \omega_0 = \sqrt{g/l}, \omega = \frac{8v}{D_p^2}$$

pipe flow basics continue

- Resolving equation give:

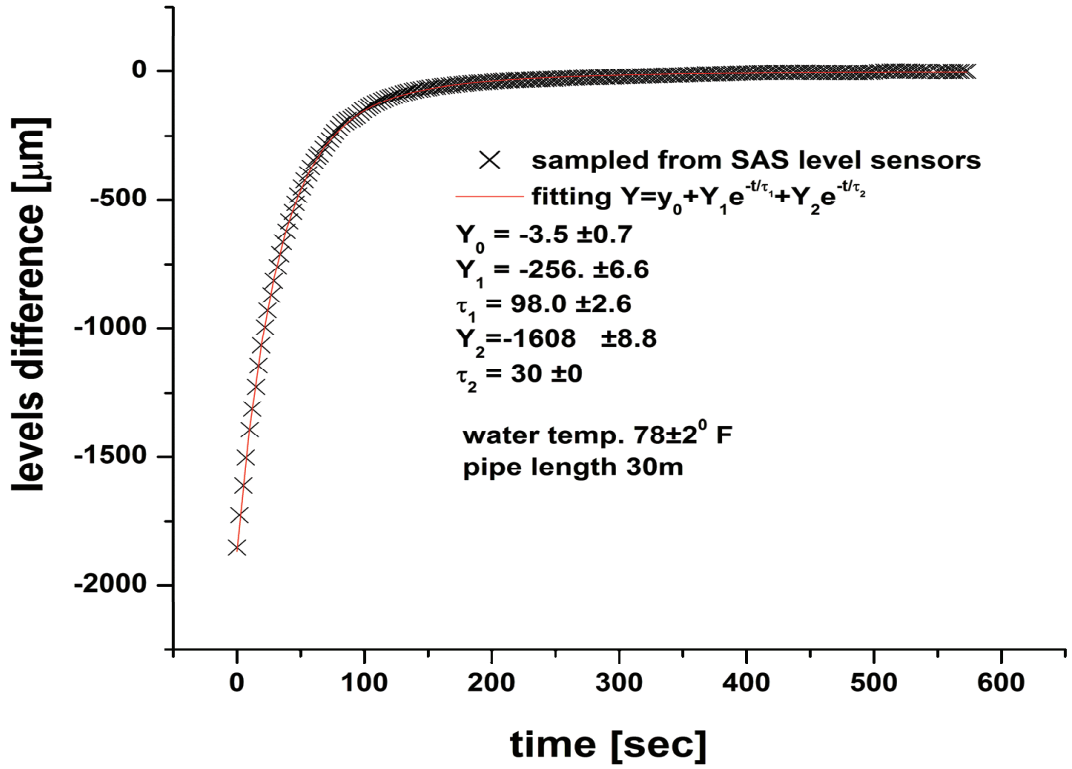
$$y(t) = C_1 e^{-t(\omega+\sqrt{(\omega^2-\omega_0^2)})} + C_2 e^{-t(\omega-\sqrt{(\omega^2-\omega_0^2)})} + C_3$$

- Since we have at the end of pipe vessels with other diameter , we have to make additional substitution

$$\omega_0 = \sqrt{\frac{g}{l}\frac{D_p^2}{D_V^2}}$$

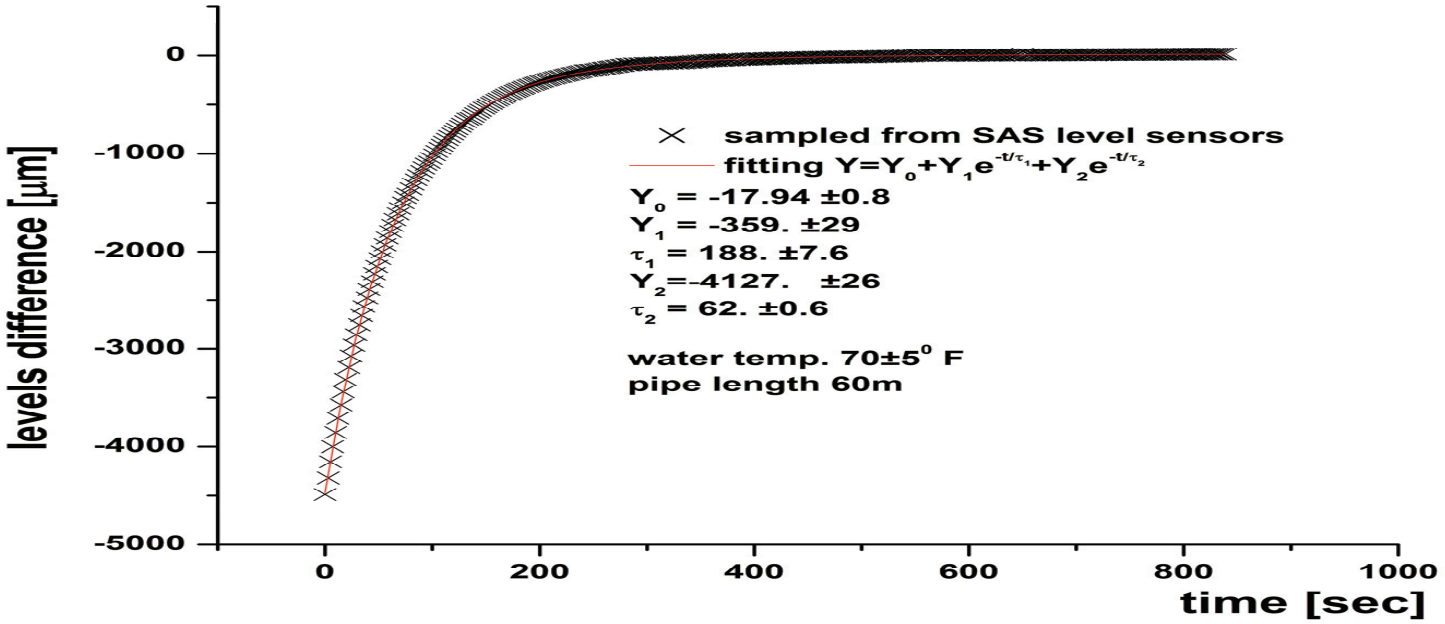
- Estimations with a pipe m(100 foot's) with diameter 9.5[mm] and vessel diam. = 77[mm] self-resonance freq $\omega_0 = 0.07$ and $\omega = 0.088$ [1/sec].

Dynamic of full filled tube L=30m



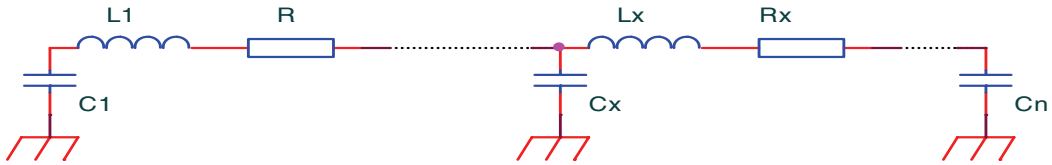
- two different decay values with different amplitude for tube Length=30m, I.D.=3/8” characterized with good prediction

Dynamic of full filled tube L=60m



- decay values twiced with twiced pipes length from 30 meters to 60, I.D.=3/8”

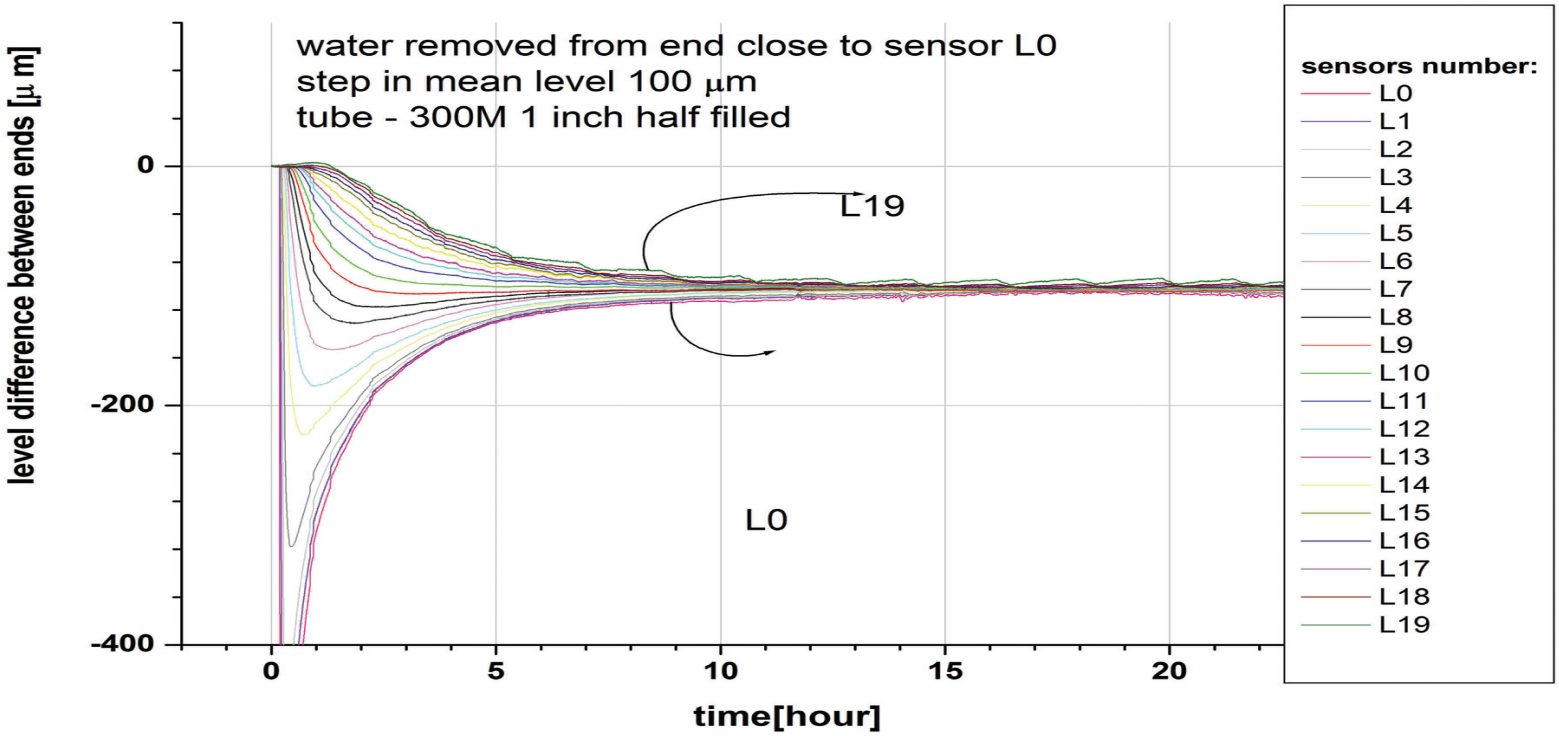
Model of full filled HLS as electrical circuit with lumped elements



$$L = \frac{\rho \ell}{S_P} \qquad C = \frac{S_V}{\rho g} \qquad R = \frac{2\pi \nu \rho \ell}{S_P^2}$$

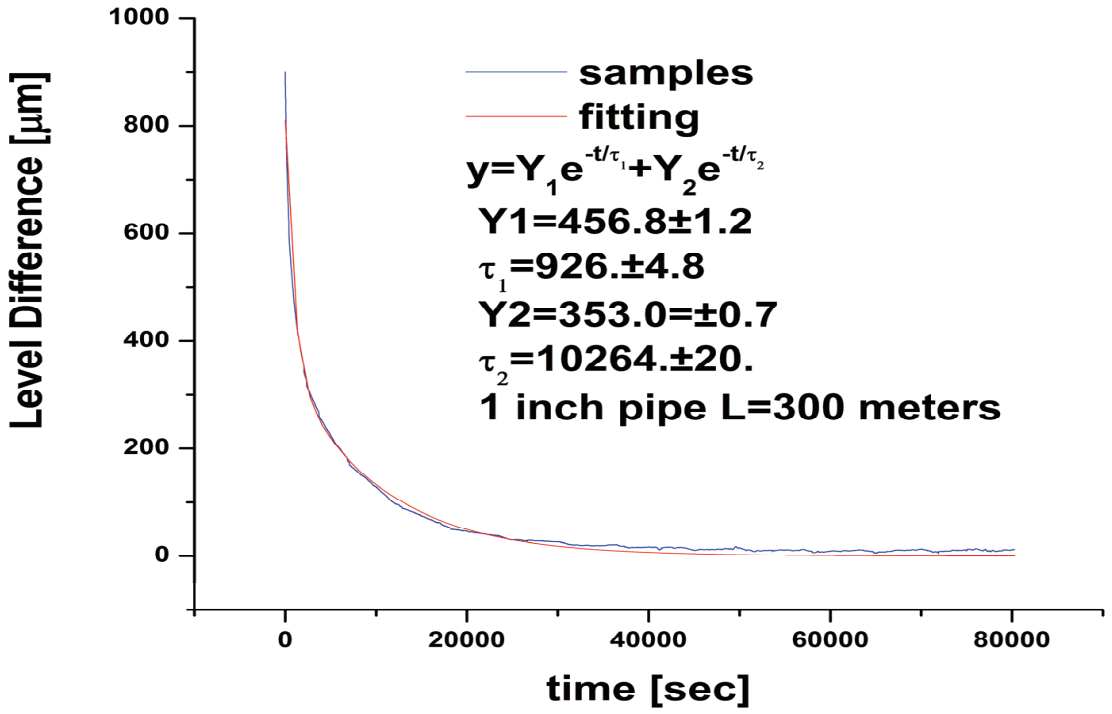
- Each pipe between sensors similar serial connected of Resistance and Inductance
- Vessel as capacitors of gravity energy
- ***S***- cross section area of pipe and vessel, ***l****-pipe length* , ***g*** - gravity, **ρ** – water density, **v** – cinematic viscosity.

Step reaction half filled HLS



HLS system had stabilized in band +/- 10 micrometers just after 15 hours with shifting of mean level 0.1 mm.

Dynamic of half filled 1” tube L=300m



- **Fitting reactions on steps HLS in Main Injector 8GevLine**
- **fitting equation gives decay times: 5 min. and ~3 hour.**
- **pipe system has be to supported very well to exclude sag.**

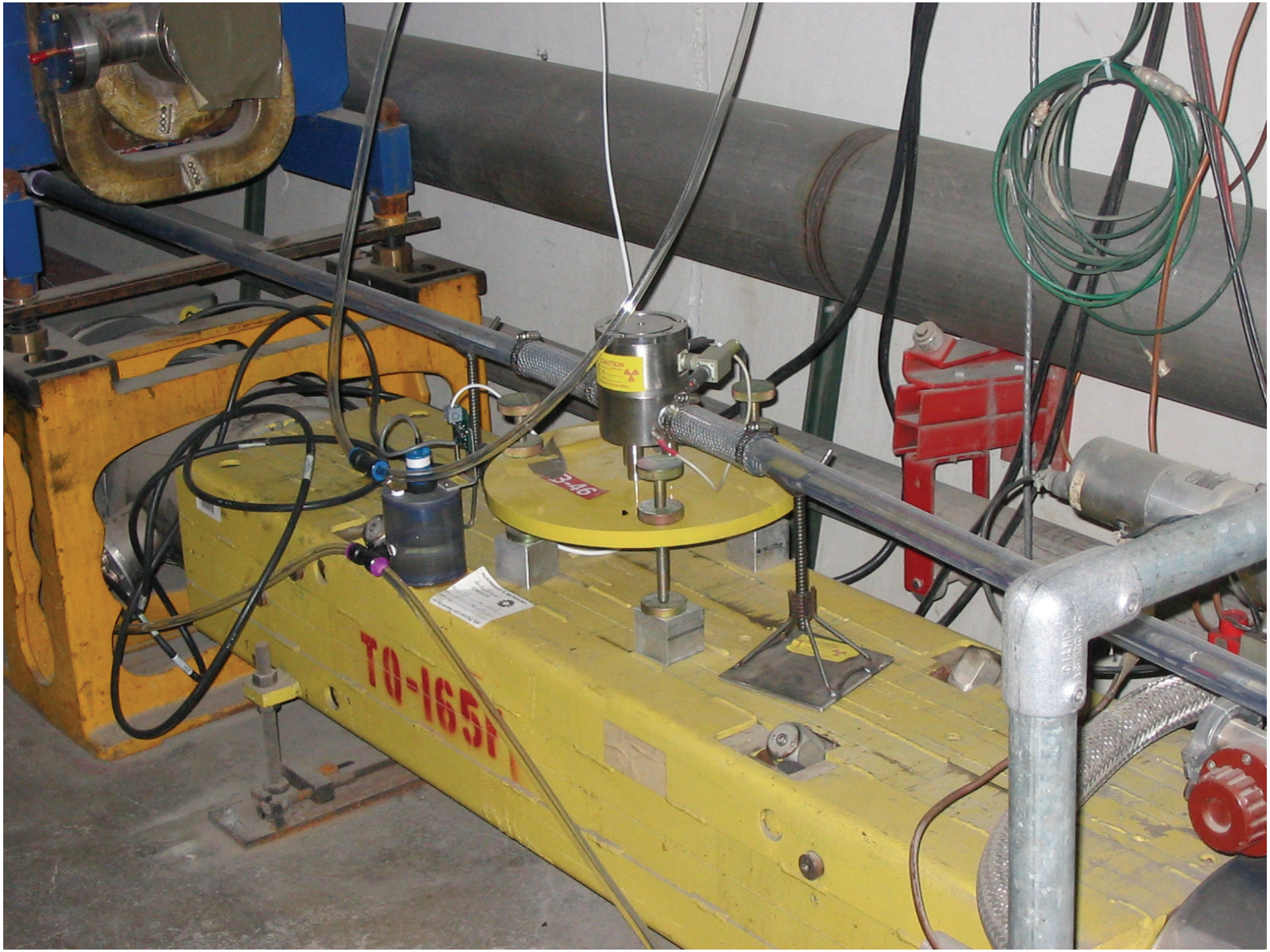
Satellite view to Fermilab HLS

MI8
Half Filled
HLS 2001

Full Filled
TeV
3 HLS

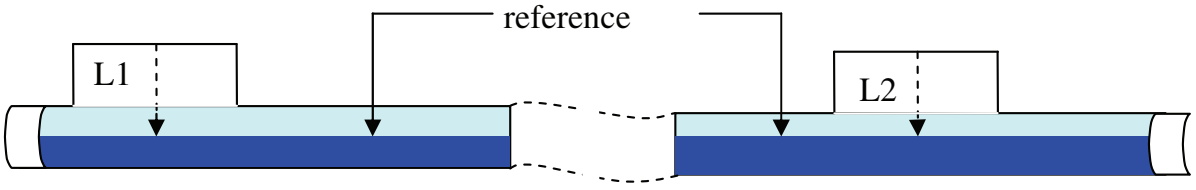
- All HLS system full filled now

B-sector Tevatron Half Filled HLS

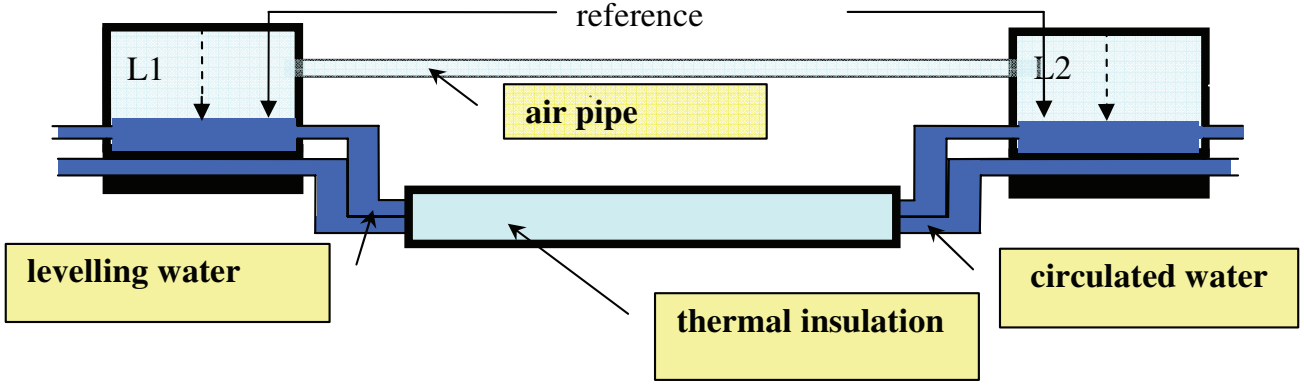


SAS level sensor on CDF detector example of full filled HLS

HF and DTFF HLS



Double Tubed Full Filled



Comparison table of alternative tubing

Properties	Full Filled	Half Filled	Double Tubed Full Filled
Temperature stability	Depend from temperature	Excellent	Excellent
Material of tube	Cheaper, transparent Plastic	High cost Stainless tubes	Cheaper, transparent Plastic Common shield for water tubes
Length	2xL	L	4xL or 3xL
Supports	No	Strong support	No
Tube Mounting	Simple	In some location – It is impossible! Labour-consuming, Supports Realignment	Simple
Additions	Nothing	Cleaning of tubes, Alignment tools	Need water recirculation system in one of tubes
Total:	Good accuracy Low Cost	Excellent accuracy High cost	Excellent accuracy Acceptable in cost

Summary

- *1 inch Half filled HLS has 10 time higher setup time than 1/2 inch full filled*
- *We suggests to use "Double tubed" full filled system for vertical alignments, as cost effective solution for high precision hydrostatic levelling system instead of half filled. Accuracy results by the help stabilizing temperature in all system.*
- *The parametrical model, acceptable for HLS is reminded.*

THANKSGIVING

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- SLAC - Collaborators from Metrology departments as a source of new ideas for level sensors and future projects.

- Thank You for attention

5.Reference

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Test device