JUNE 2005 GAS BUBBLE/MERCURY IN-BEAM TESTS AT WNR

Presented by

Mark Wendel

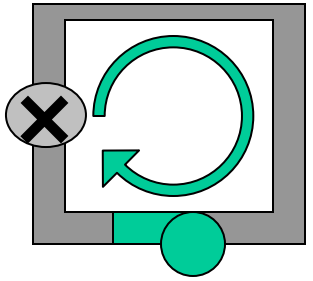
October 13, 2005

June 2005 Team at WNR (LANSCE)

- Team members are:
  - Hiroyuki Kogawa (JAERI)
  - Shoichi Hasegawa (JAERI)
  - Gunter Bauer (FZJ/ILL)
  - Duncan Earl (ORNL)
  - John Haines (ORNL)
  - Bernie Riemer (ORNL)
  - Phil Ferguson (ORNL)
  - Bobby Cross (ORNL)
  - Bob Sangrey (ORNL)
  - Jim Tsai (ORNL)
  - Mark Wendel (ORNL)
- LANL collaborators made it all possible

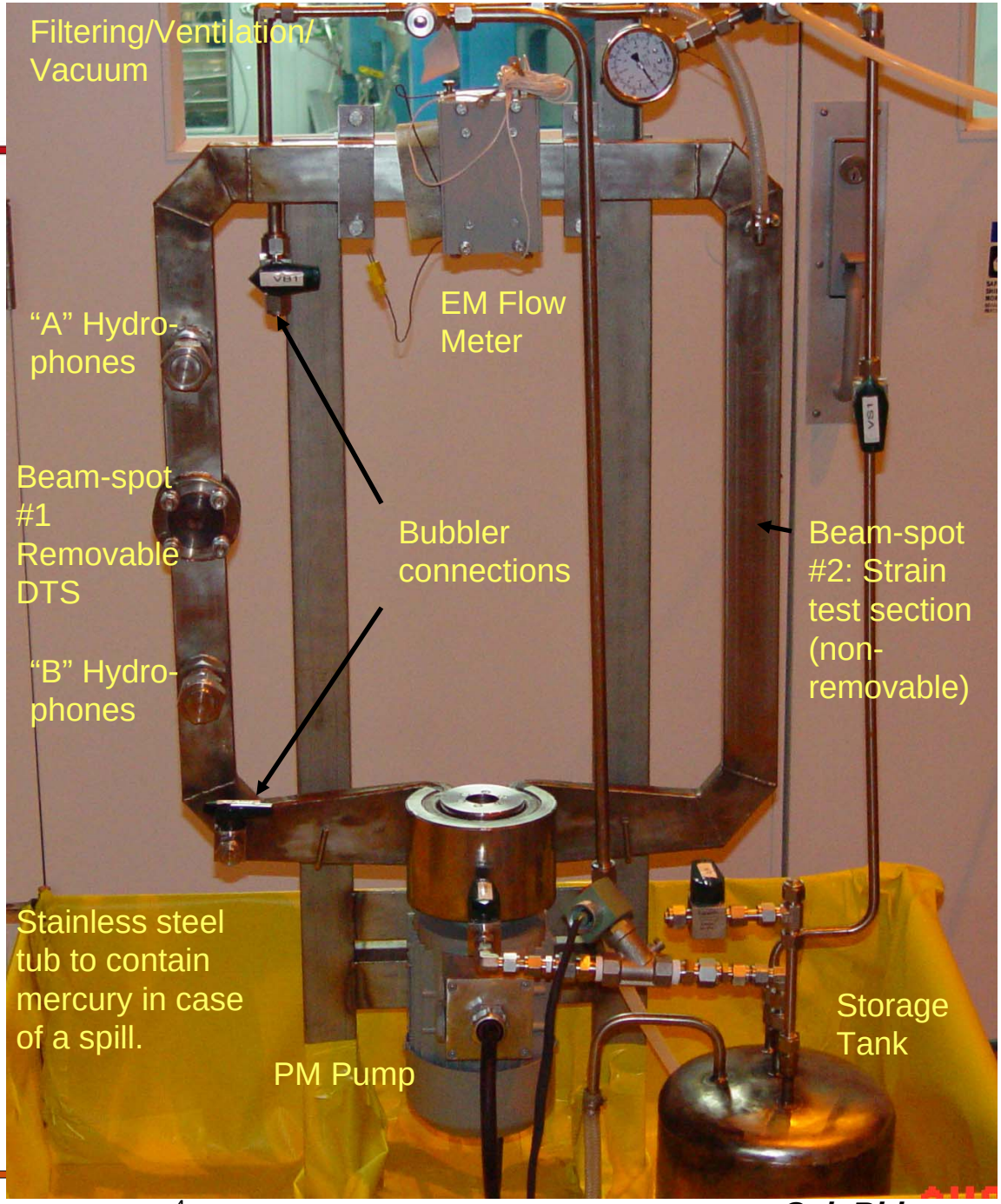
IBBTL Purpose

- The In-beam Bubble Test Loop is a mercury loop designed to:
  - Determine the degree to which beam-induced cavitation damage and strain are affected by:
    - Flowing mercury (as opposed to stagnant)
    - Helium bubbles dispersed within flowing mercury.
  - Utilize the laser vibrometer (supplied by J-PARC) to obtain in-beam cavitation-damage test data for correlation with mechanical (off-line) test data.
  - Visualize the mercury surface during a beam shot.

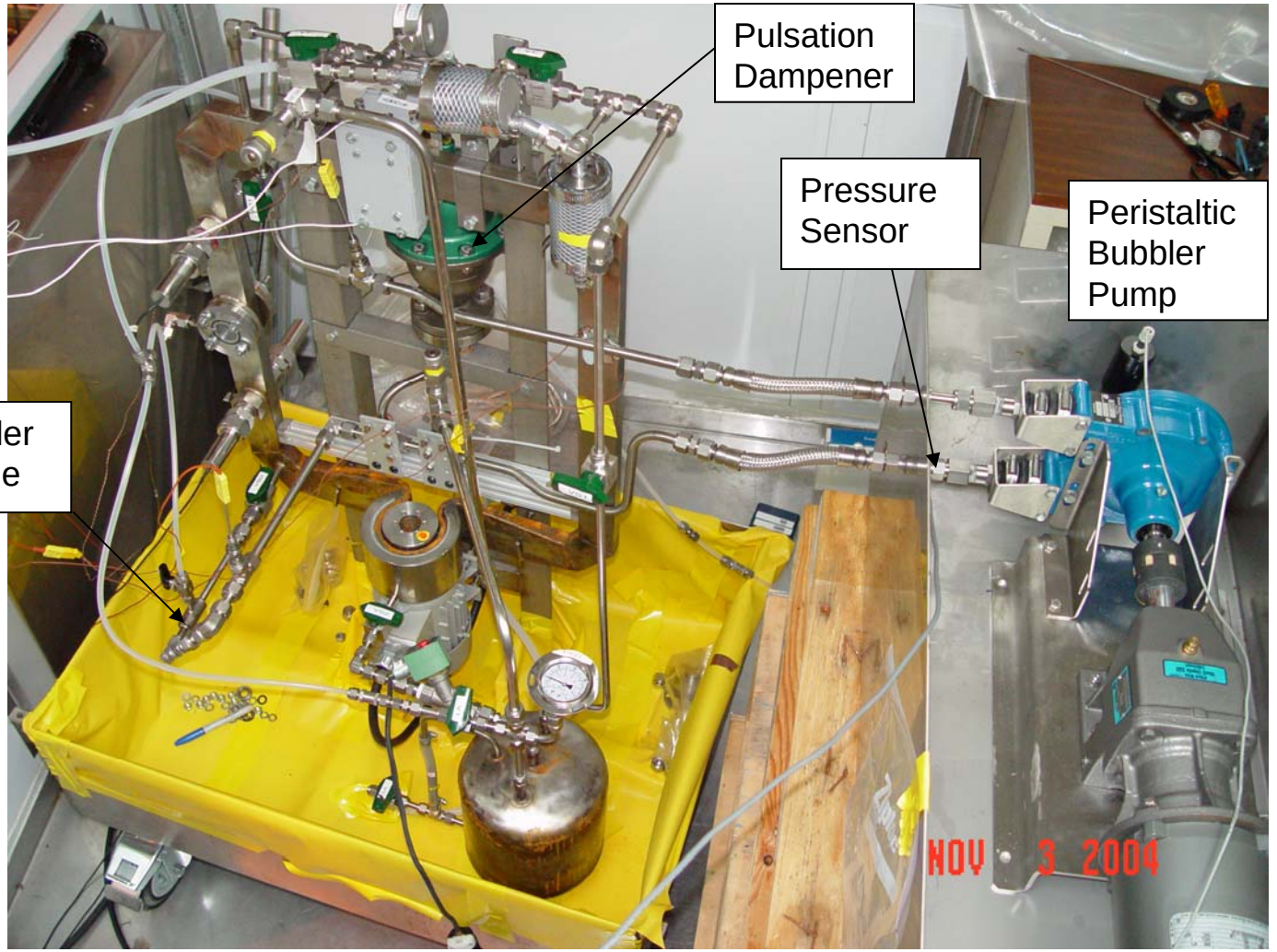


The Basic Loop was built in Latvia and shipped to Oak Ridge in July 2004.

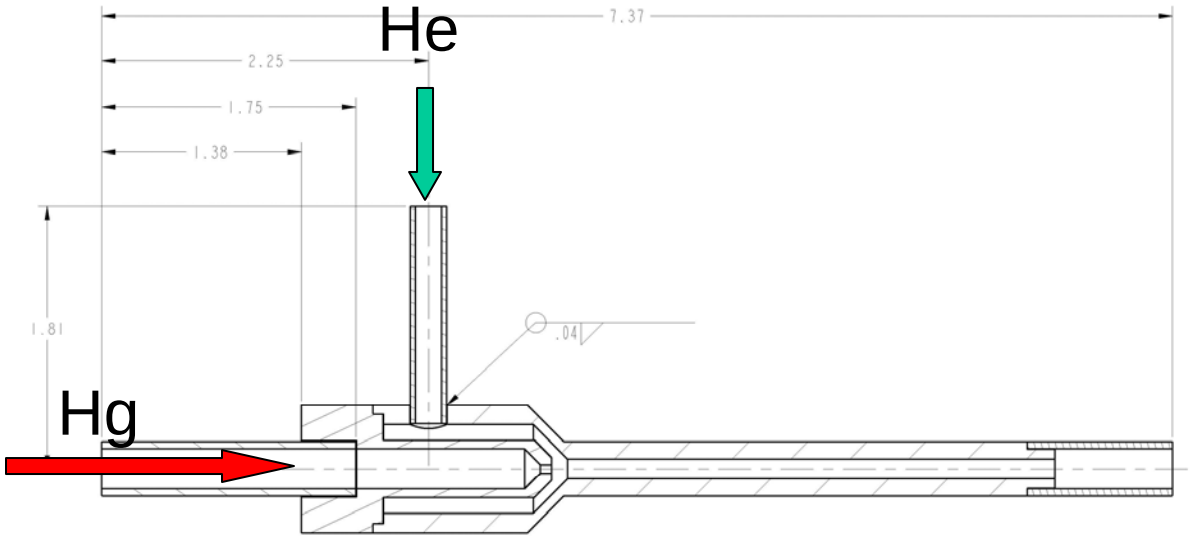
Dr. Imants Bucenieks from IPUL works on replacing the flow meter electrodes.

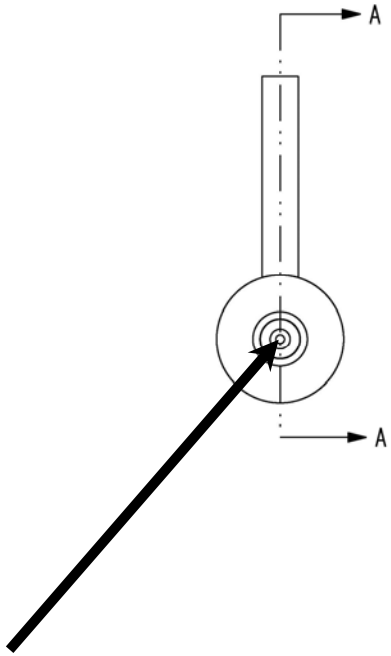


The loop was modified at ORNL including the addition of a helium bubble injection system.



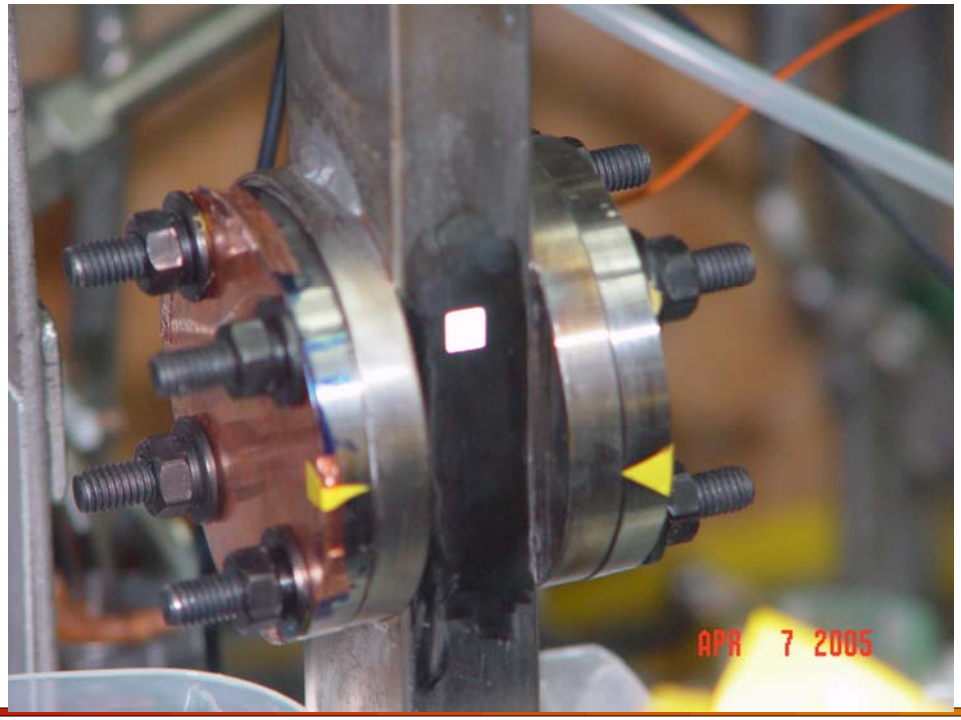
Bubbler jet design used by Helmut Soltner.



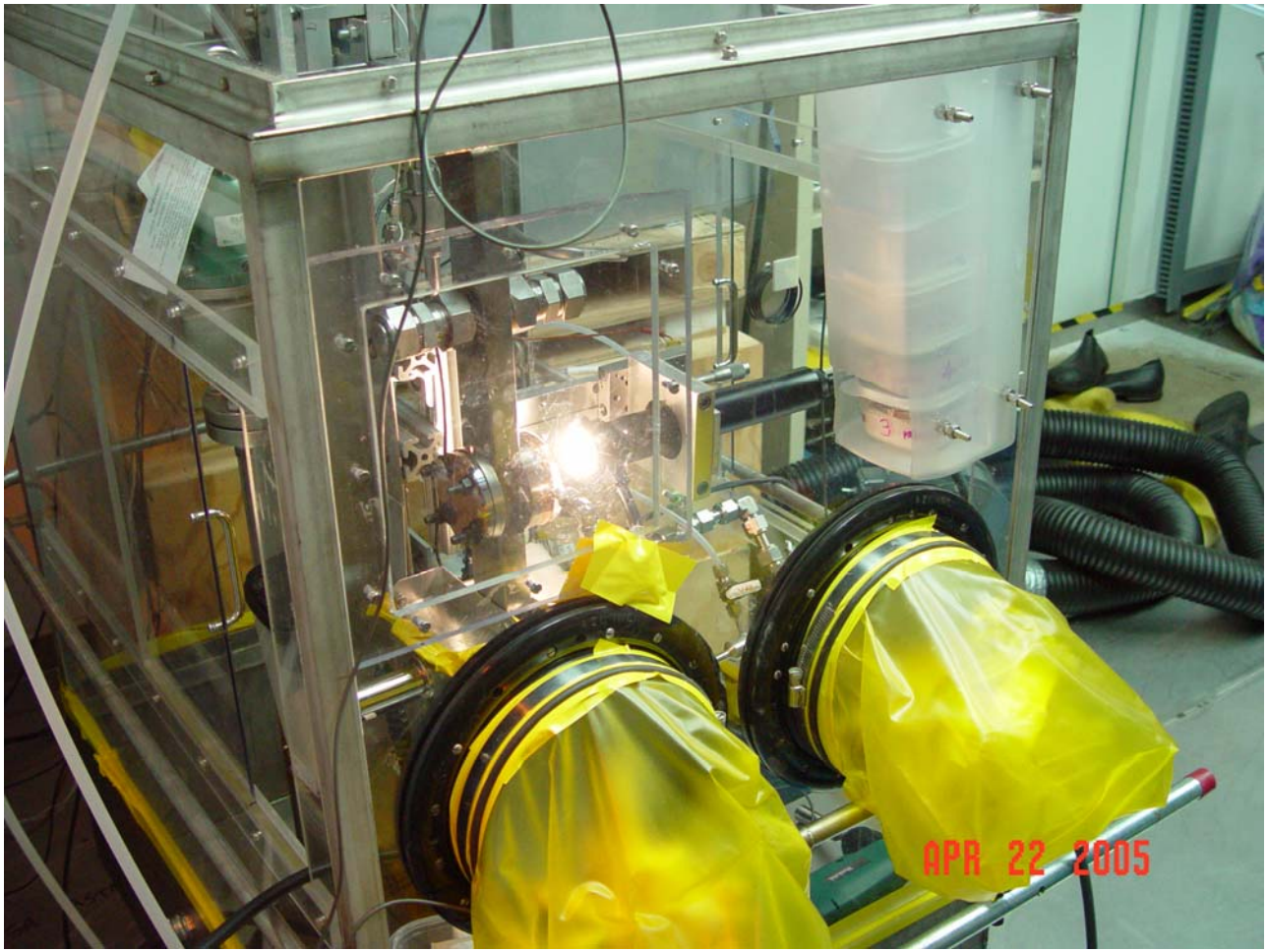


1.5 mm orifice corresponds to 8.5 m/s at nominal flow leading to cavitation

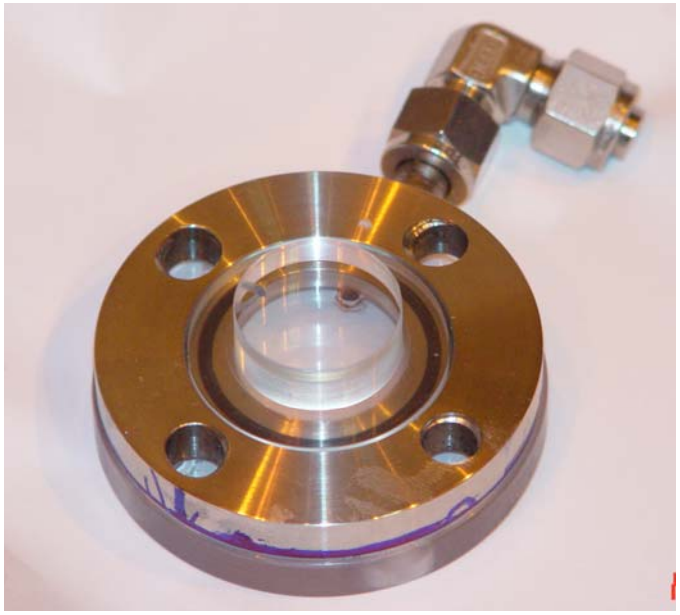
Nine damage test specimens have been pre-inspected and tested. They now await post-test inspection for pitting damage.



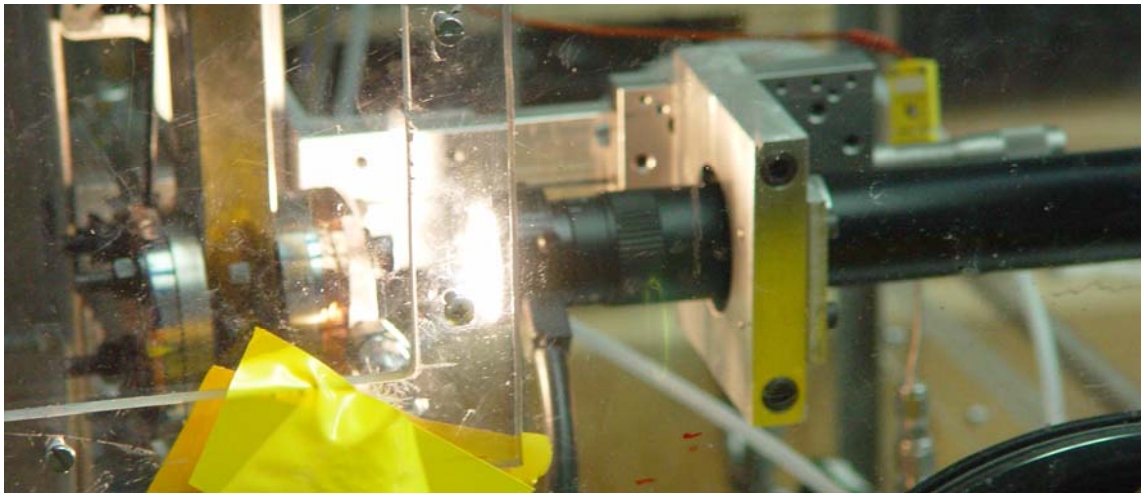
Secondary container was modified for handling DTSs.



A transparent test section was used to record visual images of the proton beam impact with the mercury target.



Unfortunately, the fiber completely darkened after only three pulses.

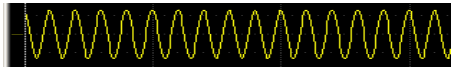


Operating conditions in the IBBTL

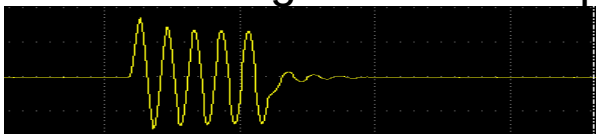
Loop Pressure	0–2.4 bar absolute (excludes bubbler)
Steady-state Operating Temperature	<40ºC
Nominal Hg Flow Velocity in Channel	0.4 m/s
Nominal Flow Rate	0.44 L/s (7 gpm)
Nominal Hg Pressure Rise at Circulating Pump	1000 Pa
Hg Inventory for IBBTL	4.5 L or 62 kg (1.2 gallons or 136 lbs)
Nominal Bubbler Hg Flow Rate	0.086 gpm (0.02 L/s)
Nominal Pressure at Bubbler Discharge	7–8 bar (provides 5 bar across bubbler jet)

Diagnostics for Bubbles Used in the IBBTL

- A pair of hydrophones were mounted into the channel to send and receive ultrasonic signals.
- Three instrument configurations are used:
  - Lock-in Amplifier sends a continuous sine wave and reports the received amplitude (0-100 kHz).



  - Function Generator sends bursts of 5 sine waves and received signals are viewed and measured on the digital oscilloscope (0-1 MHz).



  - Acoustic Bubble Spectrometer sends an array of sine bursts, then correlates the received signals with attenuation to deduce the bubble size distribution and total void fraction. The signal is fully saturated at 10^{-5}, and the instruments use is questionable for our configuration.

Hydrophone surface effects complicated the bubble diagnostics.

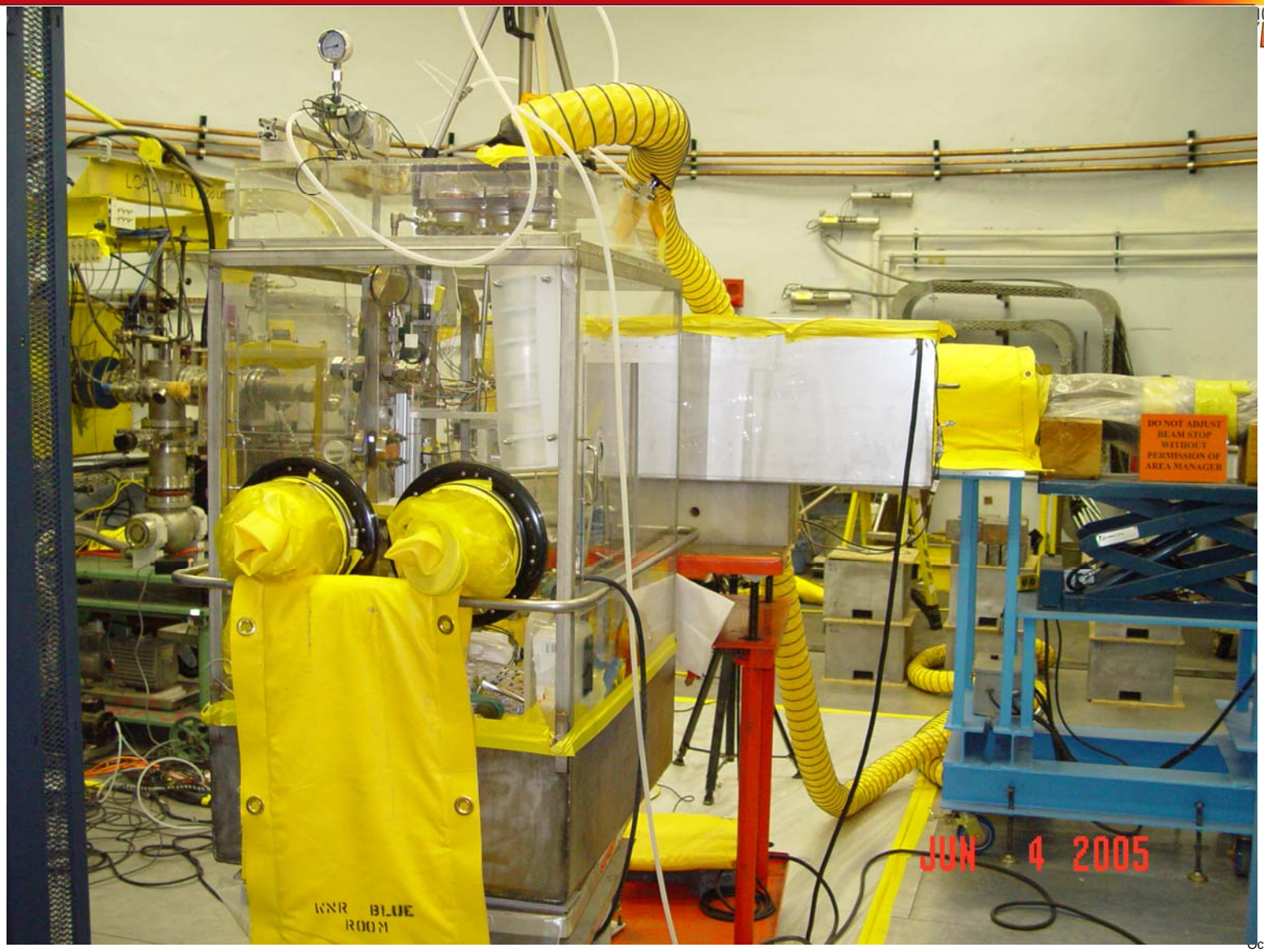
- The received transmission becomes less and less with each subsequent drain and fill operation.
- Full transmitted amplitude is re-established by cleaning the H-phone surface.
- An US gel film seems to stay around a while, and was be used in experiments for maximizing sensitivity.

The test schedule included six days of beam time at LANSCE/WNR June 2–7, 2005.

Objective	Hydrodynamic Condition
Rectangular Targets 1 and 2	NA
Rectangular Test Target 3	NA
Damage	Stagnant Hg
Damage	Flowing Hg
Strain	Stagnant Hg
Strain	Flowing Hg
Strain	Flowing Hg with He Bubbles
Damage	Flowing Hg with He Bubbles
Visualization	Stagnant Hg
Visualization	Flowing, no bubbles
Visualization	Flowing, with bubbles

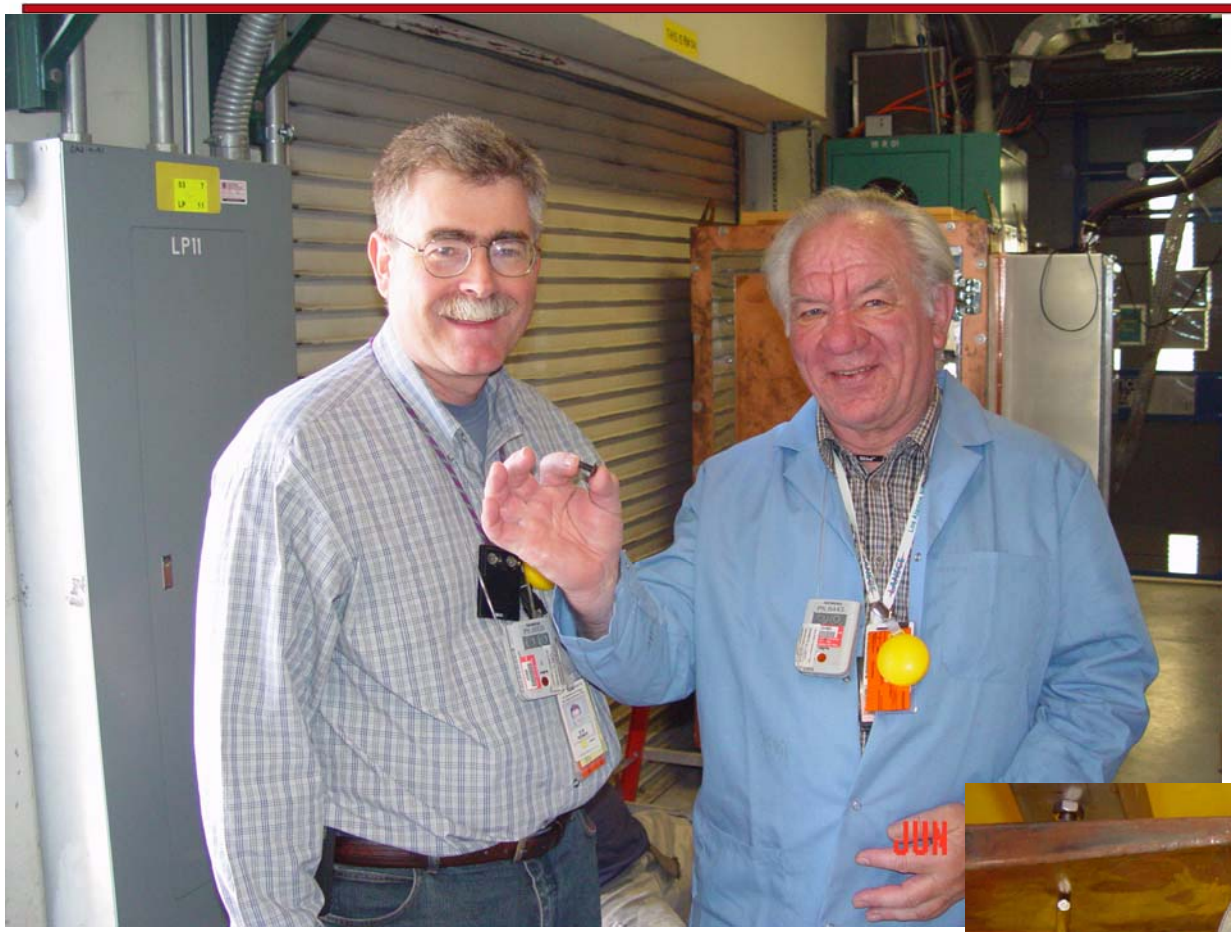
IBBTL prepared for action.

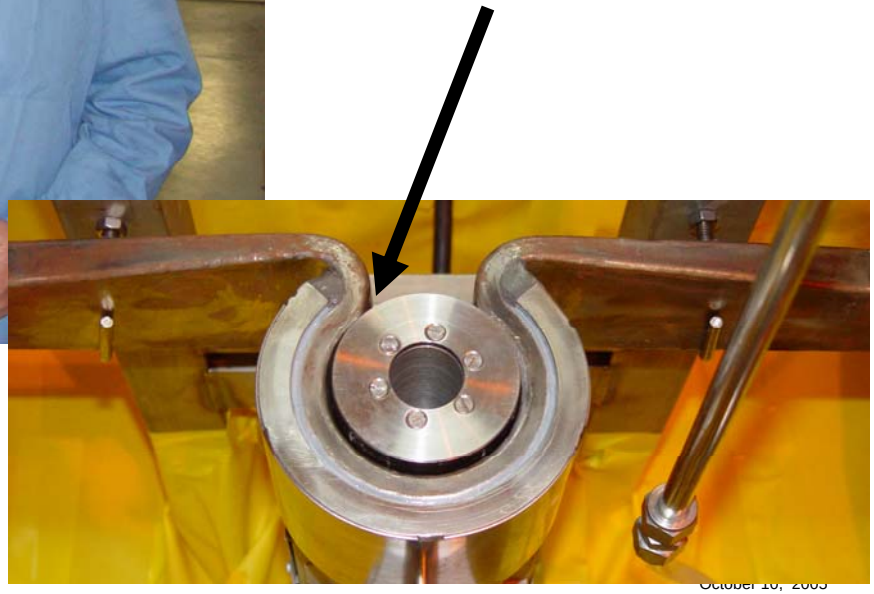
IBBTL in the beam room



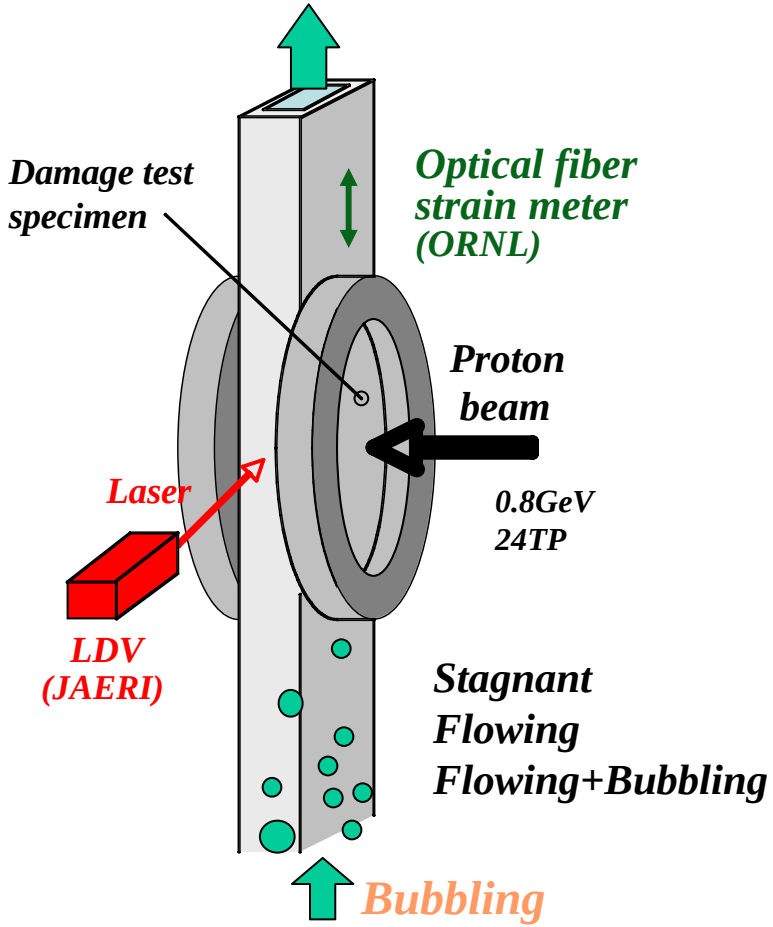
Lot’s of waiting and little sleep.

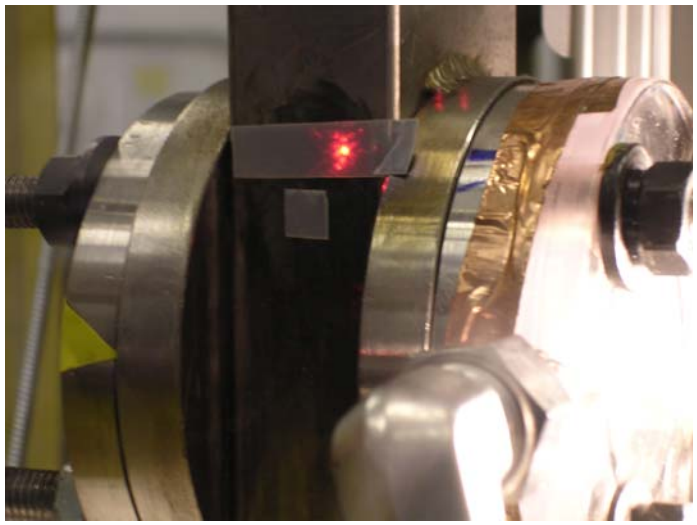
Despite problems and delays, all of the tests were complete in the six days allotted for beam.





Laser Doppler Vibrometer (LDV) was used to detect acoustic vibration.





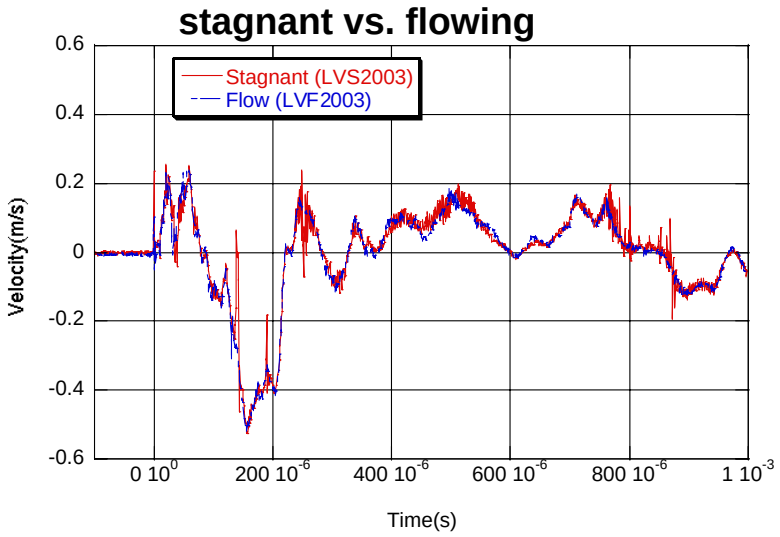
Bubbling effect on pressure wave and pitting damage.

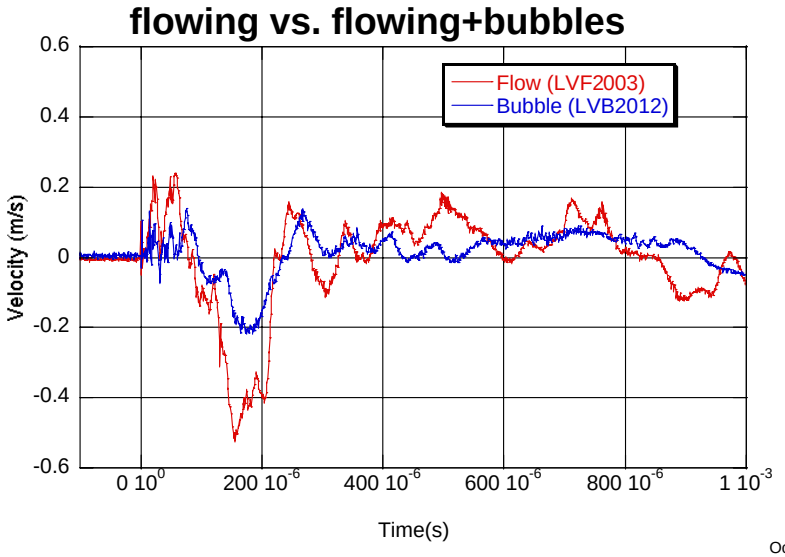
Optical fiber strain meter is to detect dynamic response of mercury flowing pipe.

Laser-Doppler Vibrometer

- Results are reported from Futakawa et al. that:
  - Less damage is expected with gas injection
  - Behavior was not repeatable with gas injection

⇨ possibly explained by periodic behavior of bubbler pump



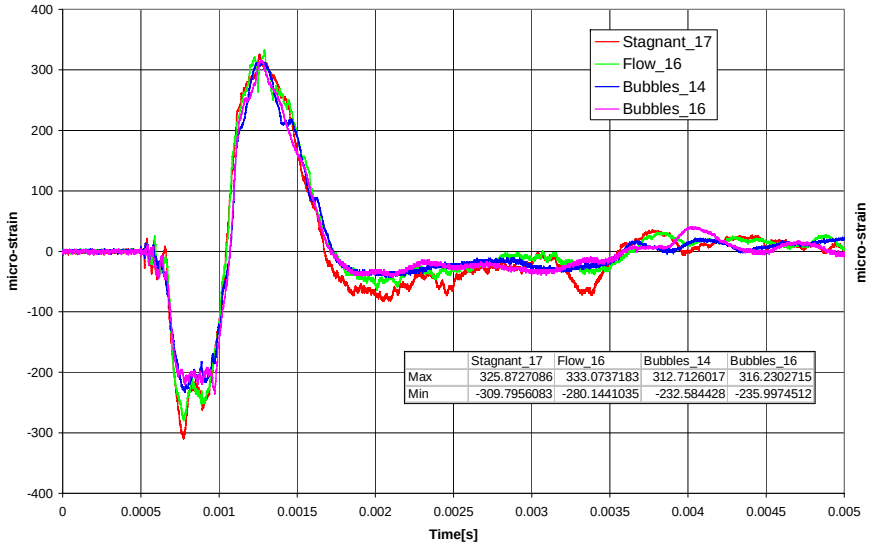


Strain data findings are somewhat different.

Strain magnitude near the beam spot is unchanged by the addition of bubbles.

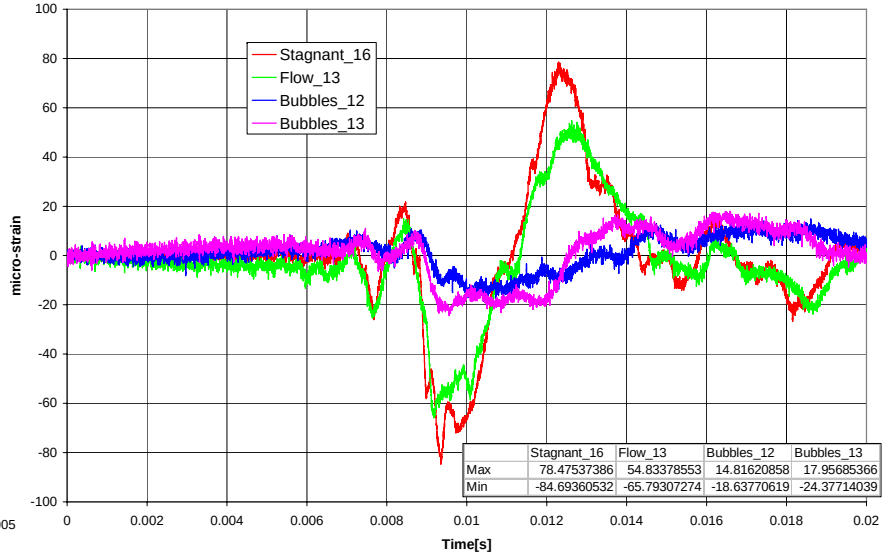
Strain magnitude is reduced at locations remote from the beam spot.

very near the beam impact



	Stagnant_17	Flow_16	Bubbles_14	Bubbles_16
Max	325.8727086	333.0737183	312.7126017	316.2302715
Min	-309.7956083	-280.1441035	-232.584428	-235.9974512

further away from beam impact



	Stagnant_16	Flow_13	Bubbles_12	Bubbles_13
Max	78.47537386	54.83378553	14.81620858	17.95685366
Min	-84.69360532	-65.79307274	-18.63770619	-24.37714039

The proof is in the pitting (or lack thereof).

Specimens should arrive to ORNL in the next two weeks.

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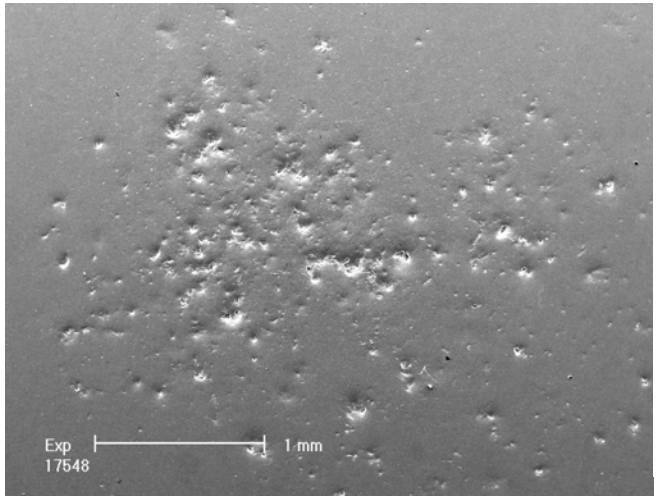
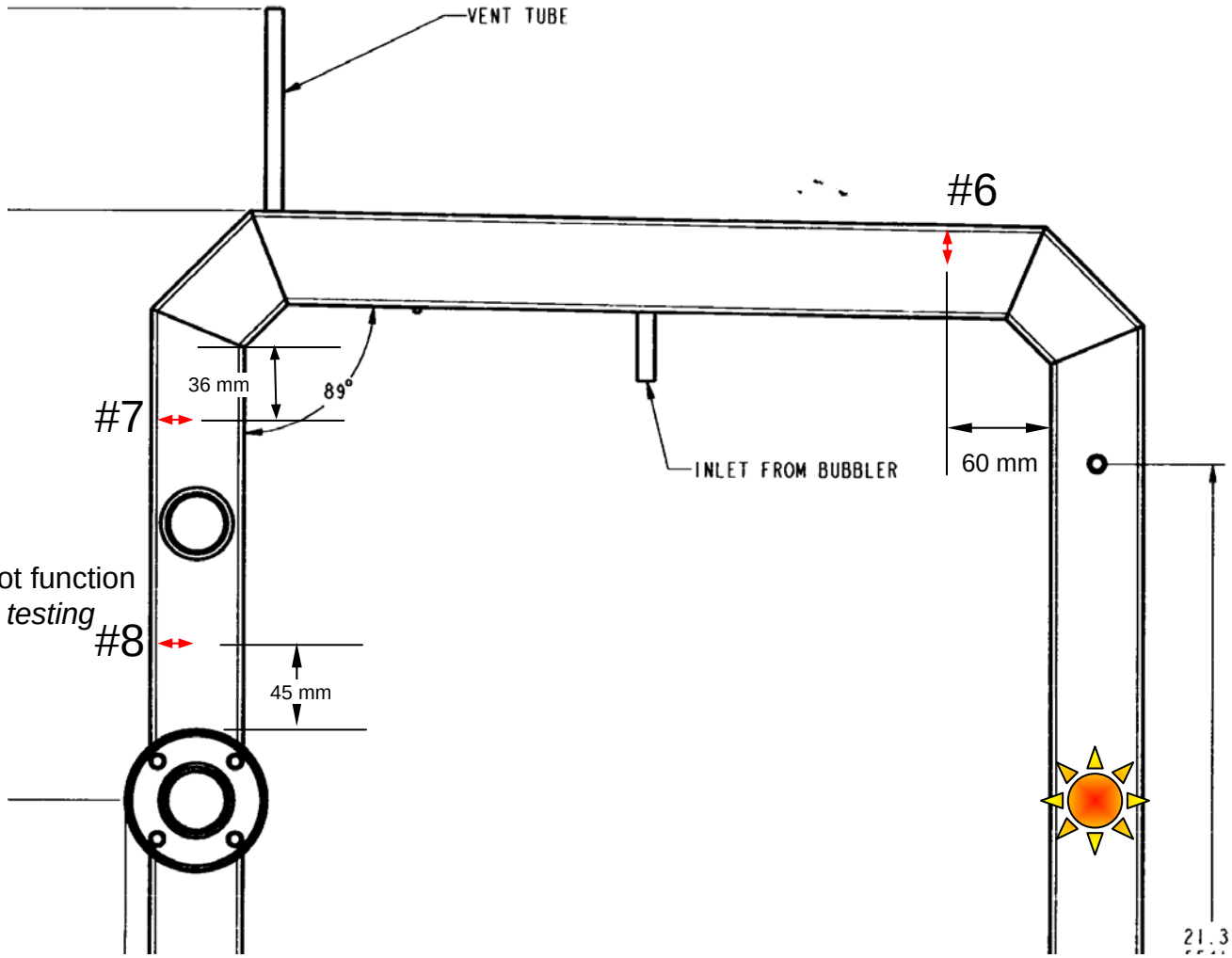


End

- show beam shot video

IBBTL Strain Sensor Locations



Sensor #8 did not function well *during DTS testing*