

Development of a Set-Up for the Detection of Failed Fuels in TAPS BWR Spent Fuels Storage Bay

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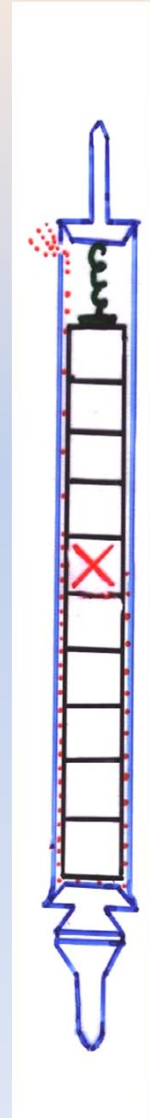
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When One Fuel Pin Fails

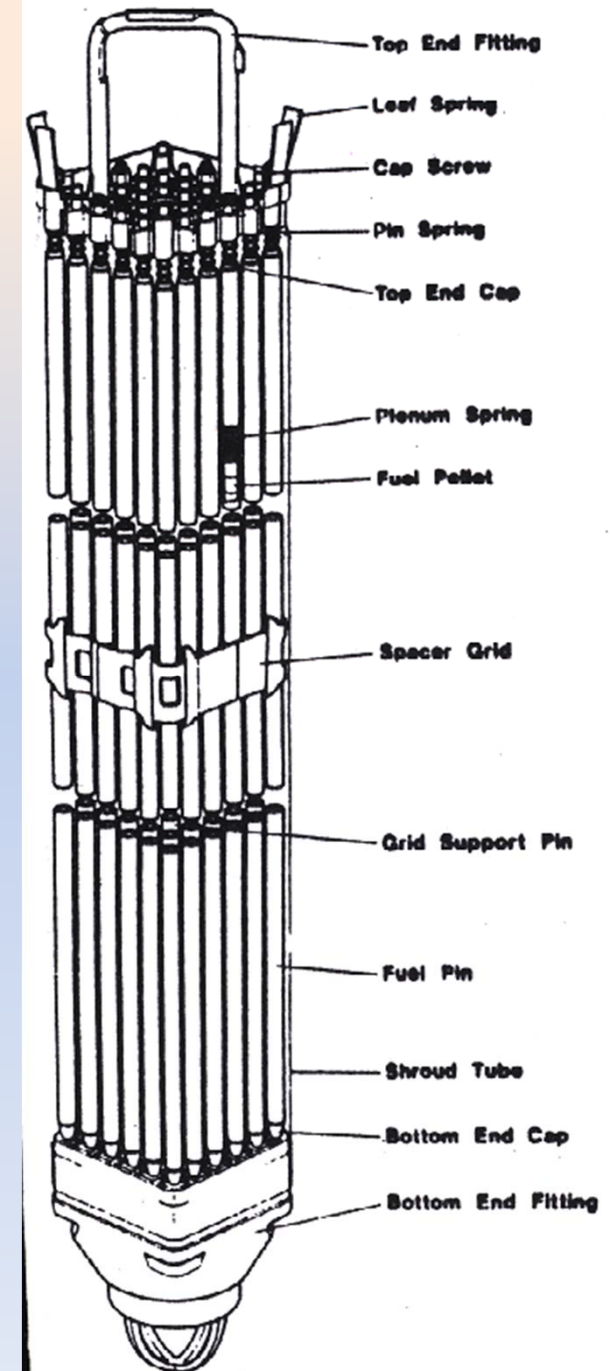
- Entire fuel assembly of 36 pins is discarded because of one leaky pin
- Material un-utilized
- 140 Kg of UO_2
- Enriched Uranium U^{235}
- Shortage of Uranium in India
- Zirconium used for fuel pins
- Steel top and bottom tie plate
- Failed fuel assembly contaminates pool water

Identify the leaker, segregate, replace



BWR Fuel Assembly

- India has two units of BWR, each 200 MW(e), currently operating at 160MW(e)
- Reactor core has 284 fuel assemblies
- Control rods 69, cruciform type
- Fuel assembly consists of 36 fuel pins
- Arranged in a 6 x 6 square array
- Fuel assembly length 4.24 meters
- Fuel elements spaced by 7 spacer grid
- Distance between two grids 48.8 cms

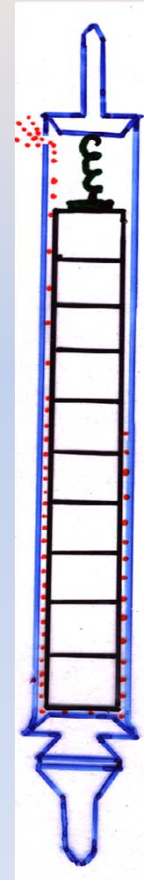


BWR Fuel Elements

Fuel material	Enriched UO_2
Average fuel enrichment U^{235}	2.24 W %
Fuel pellet diameter	12.24 ± 0.025 mm
Fuel pellet density	93% (T.D.)
Fuel column length	3658 mm
Fission gas plenum length	221 mm
Pellet to clad diameter gap	0.254 mm
Cladding material	Zircaloy-2
Clad ID	12.51 ± 0.039 mm
Clad wall thickness	0.89 mm
Clad OD	14.29 mm
Element Length	3892.6 mm

Water Log Detection

- Based on detection of water inside fuel pin entered through the leak site
- Leak at any place along the length
- Water in pellet clad gap in a failed pin known as **water logging**
- Un-failed pin pellet clad gap contains gases
- Water settles down near bottom plug
- UT-Wafer probes above bottom plug weld



Development of UT Technique

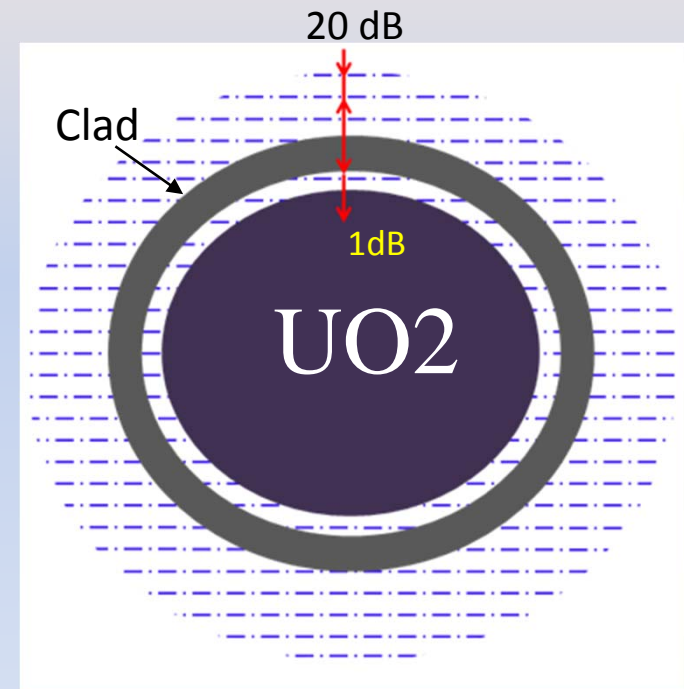
Problem with Pulse/Echo Technique

Reflection dominant ~ 88% energy back

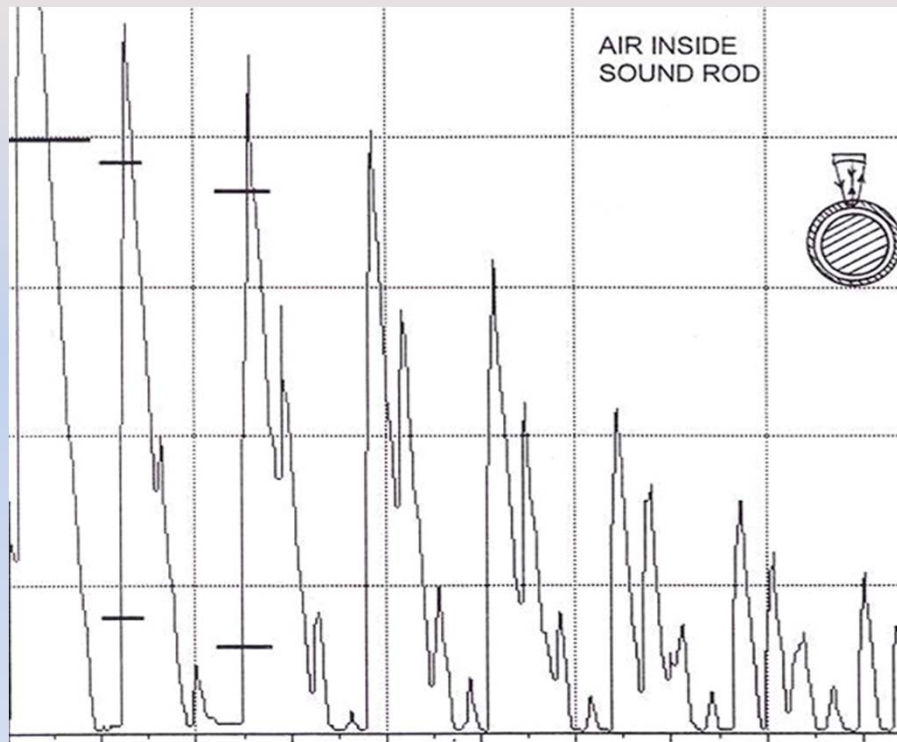
Transmission is only ~12%

Transmitted energy lost in the coupling inside is ~1dB attenuation in the failed fuel pin

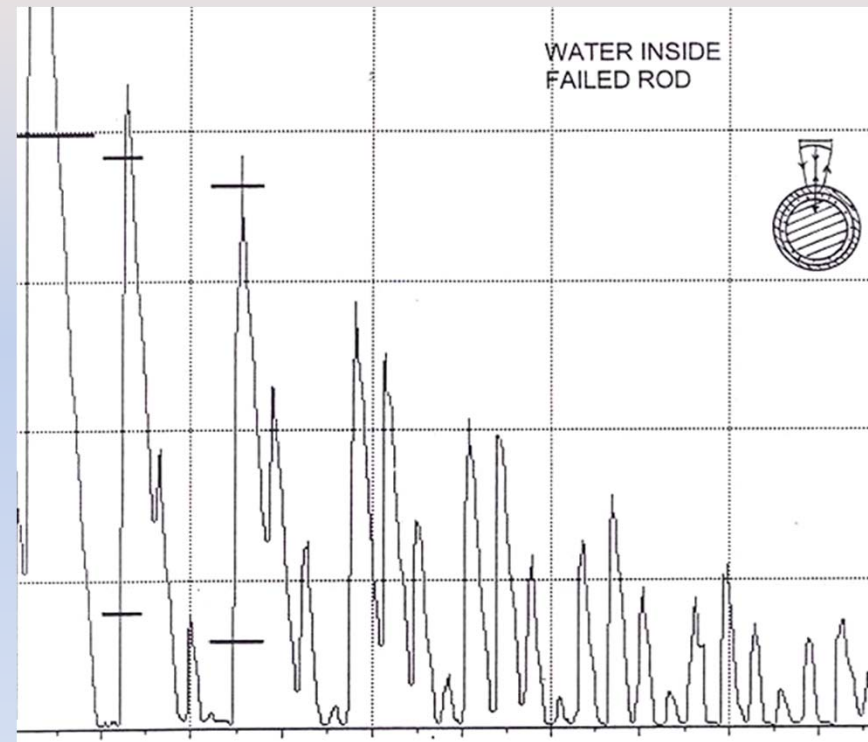
Misalignment can give 8-10 dB attenuation hence, poor S/N ratio



Poor Signal to Noise Ratio in Pulse-Echo



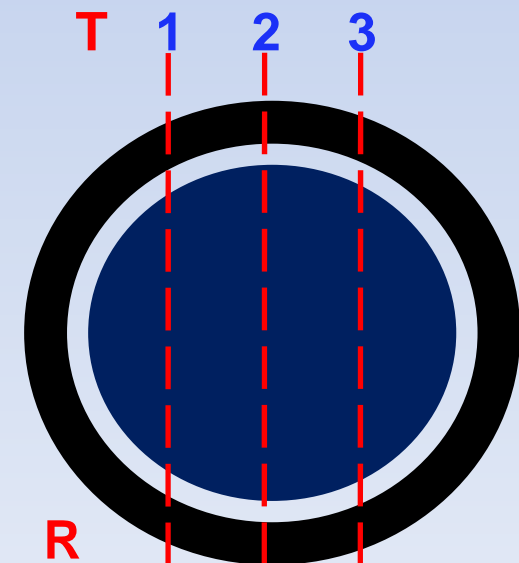
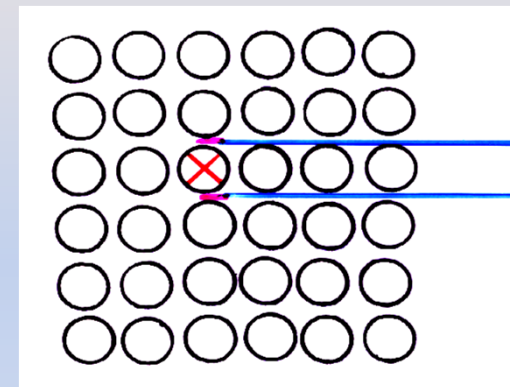
Multiple pulse echo back wall pattern



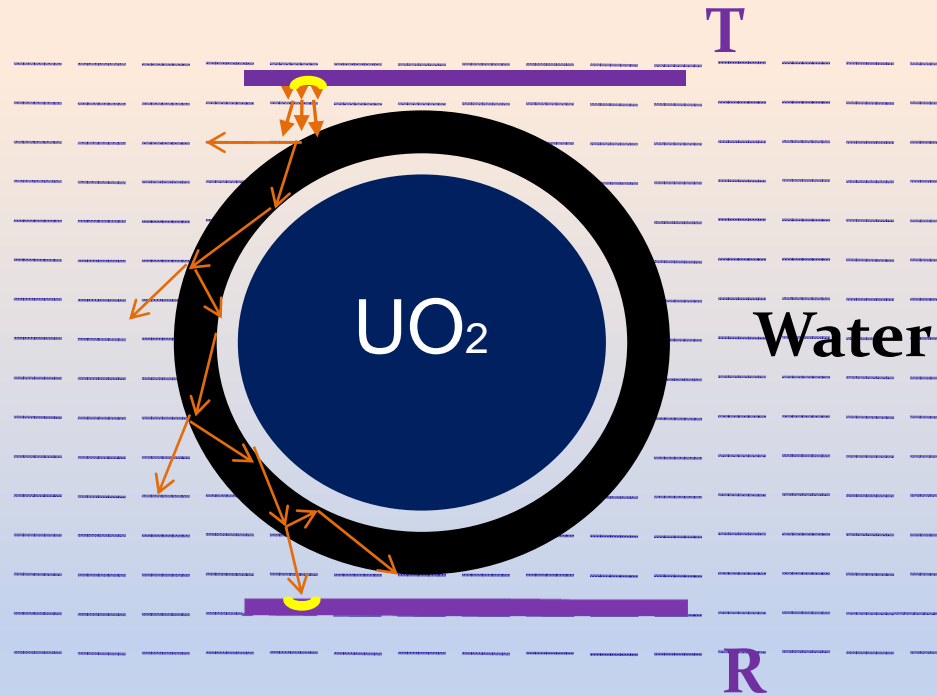
Attenuated back wall decay pattern

Transmit/Receive Technique

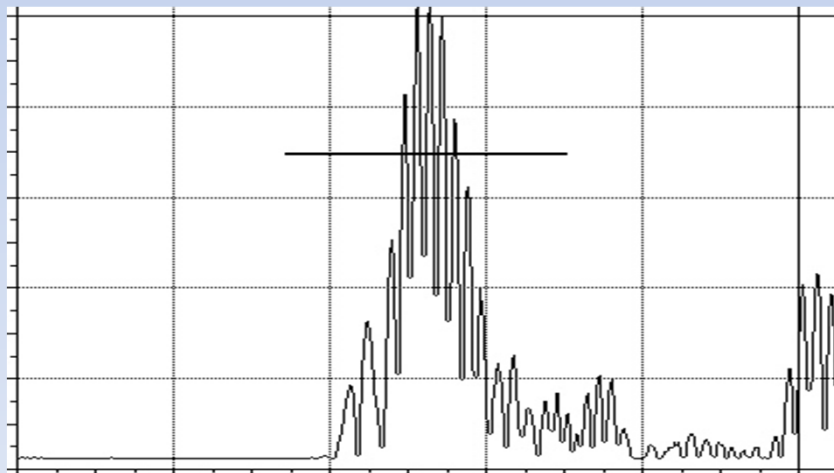
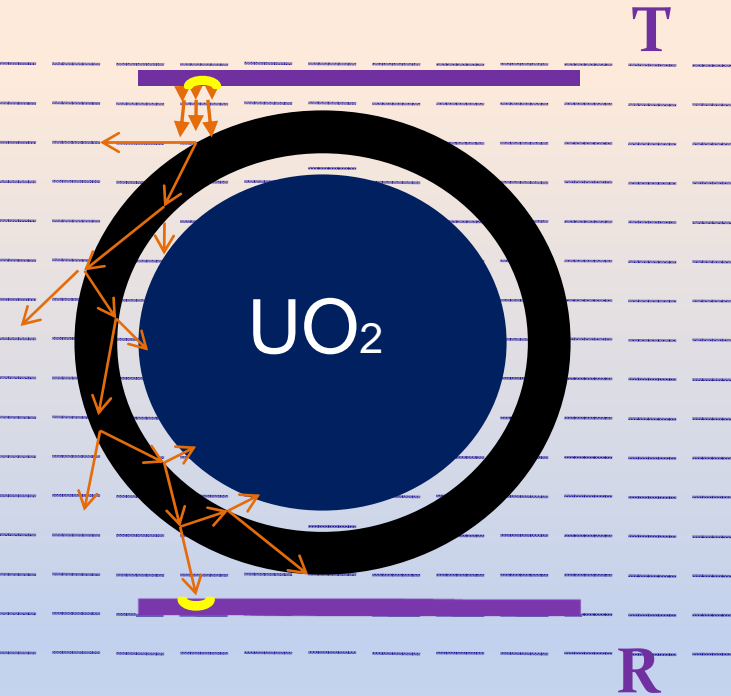
- Pair wafer probes inserted into the inter element spacing
- Transmitter probe sends ultrasound in the clad through coupling by pool water
- Receiver on the opposite side
- In failed pin beam travels further through the water coupling in pellet clad gap and lost in UO_2 pellet



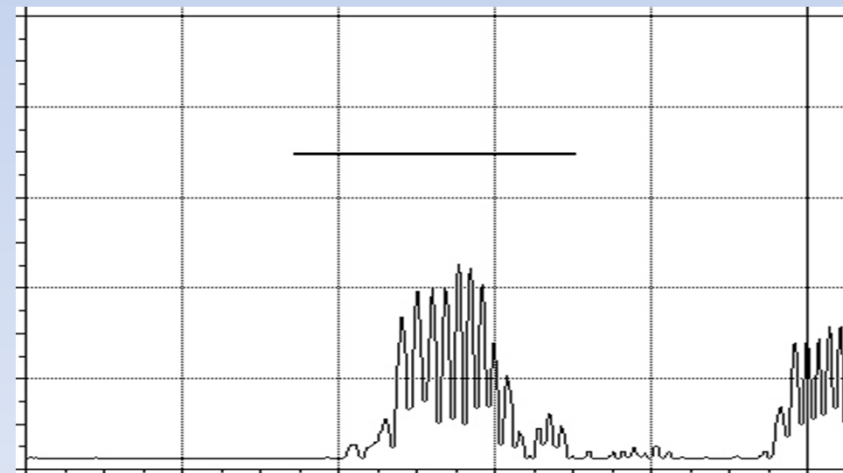
Unfailed Fuel Rod



Failed Fuel Rod

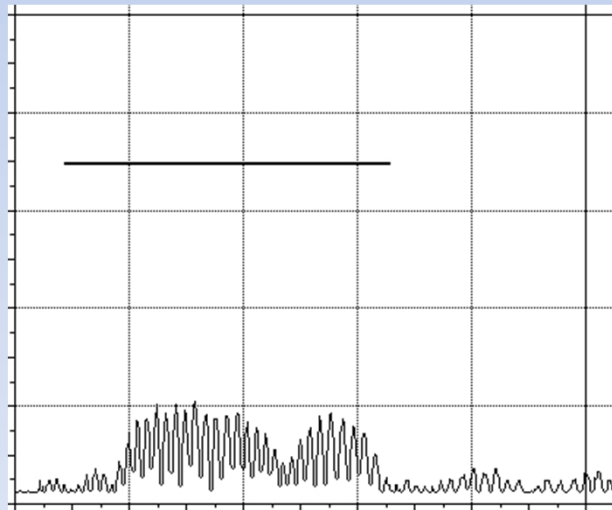
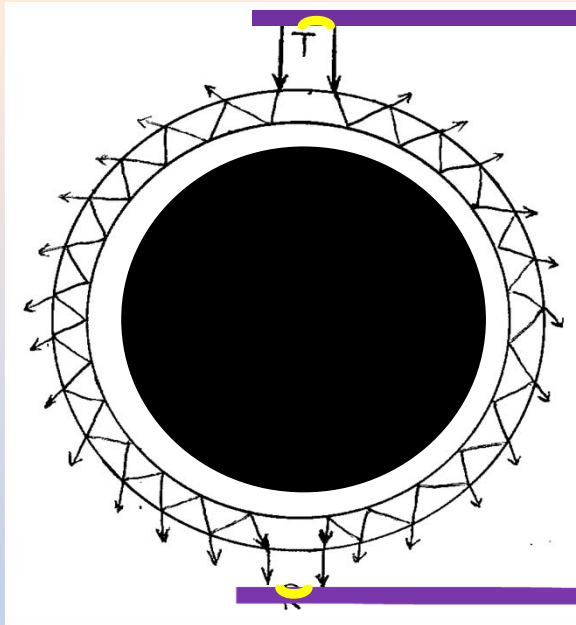


Signal at fixed off-set from sound fuel rod

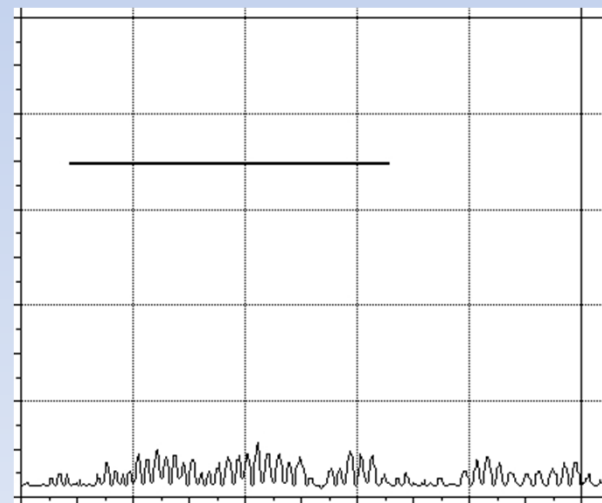
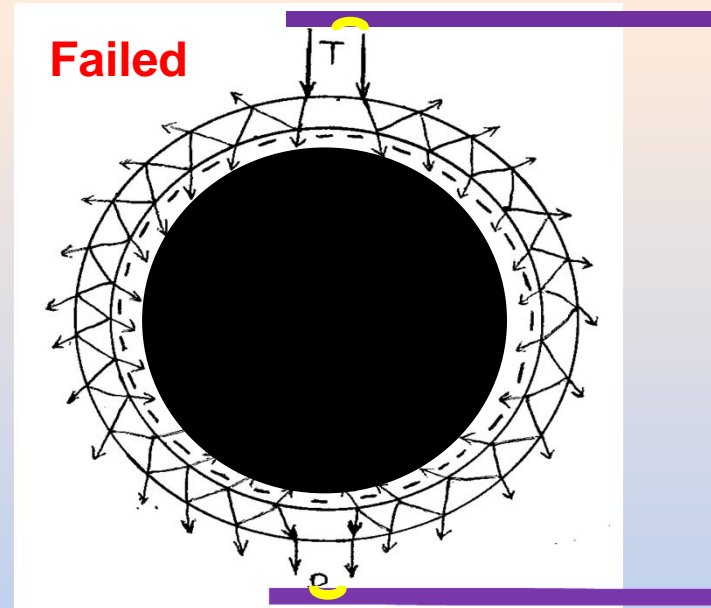


Signal at fixed off-set from failed rod

Probes at centre of fuel rod

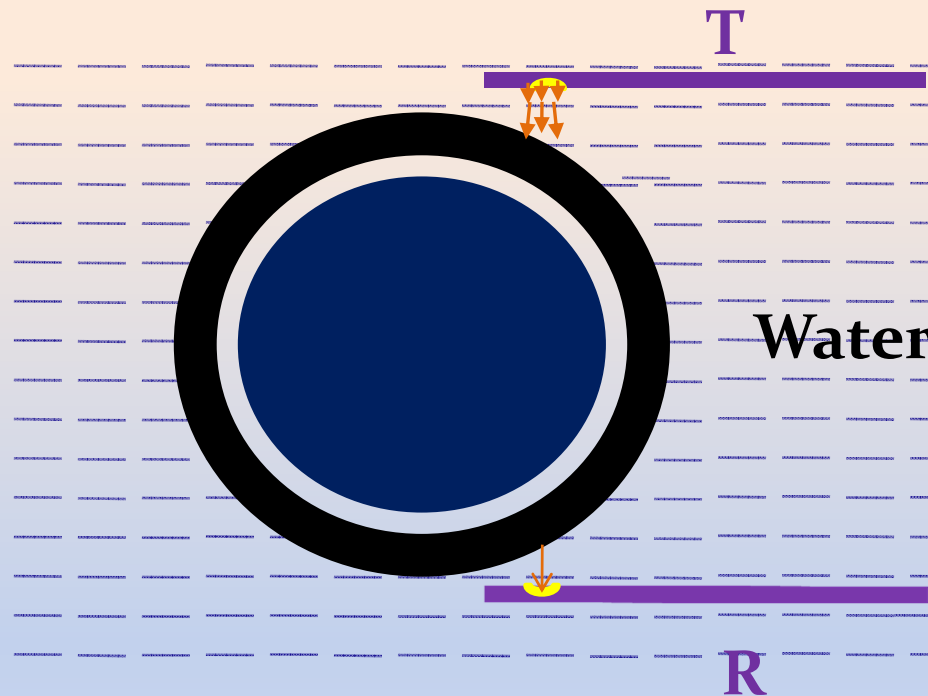


Signal at centre from sound fuel rod

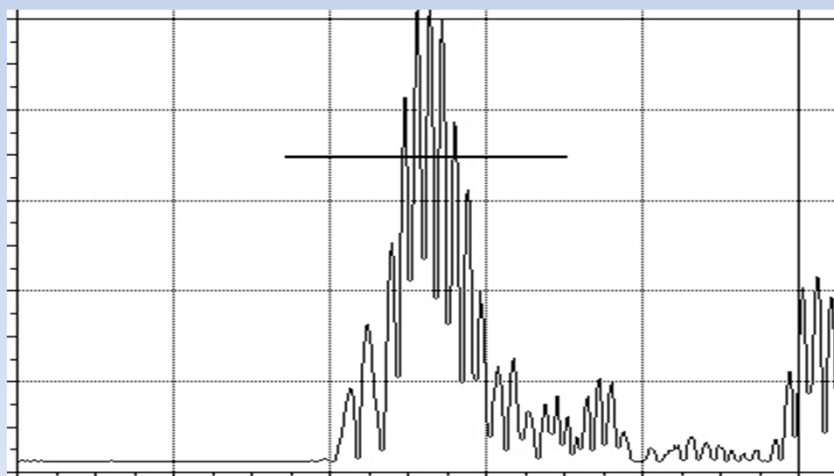
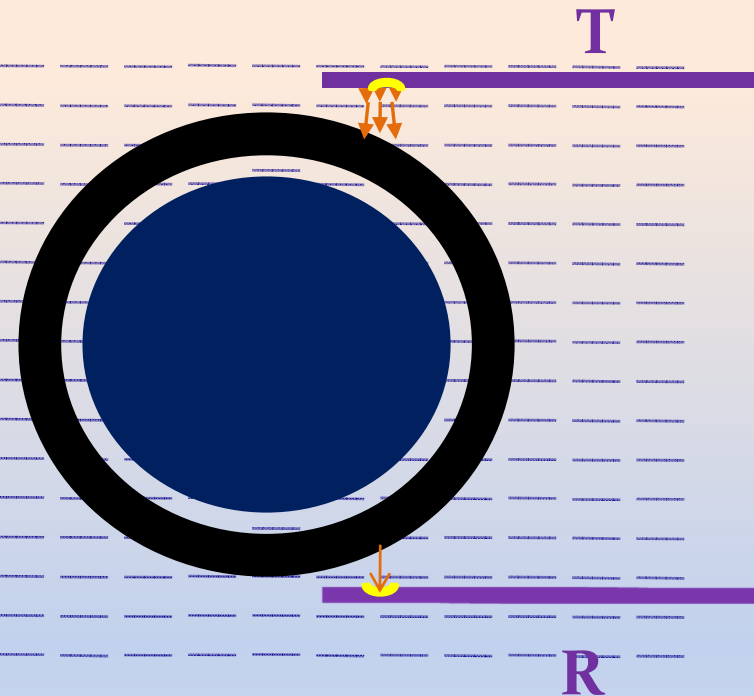


Signal at centre from failed rod

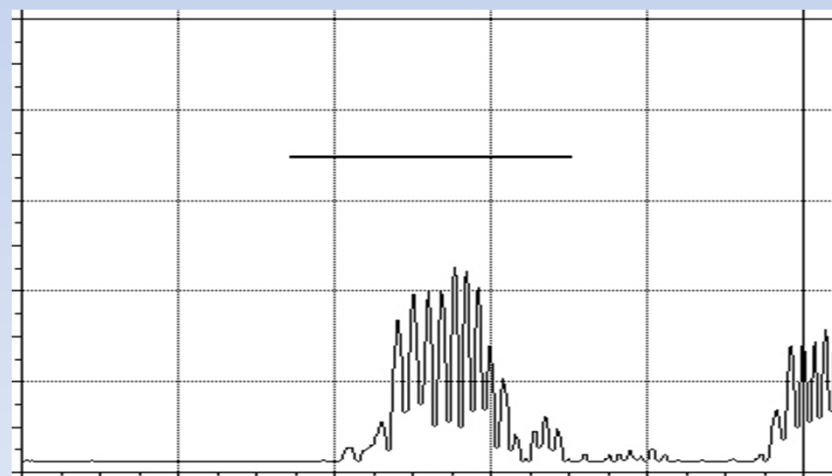
Unfailed Fuel Rod



Failed Fuel Rod

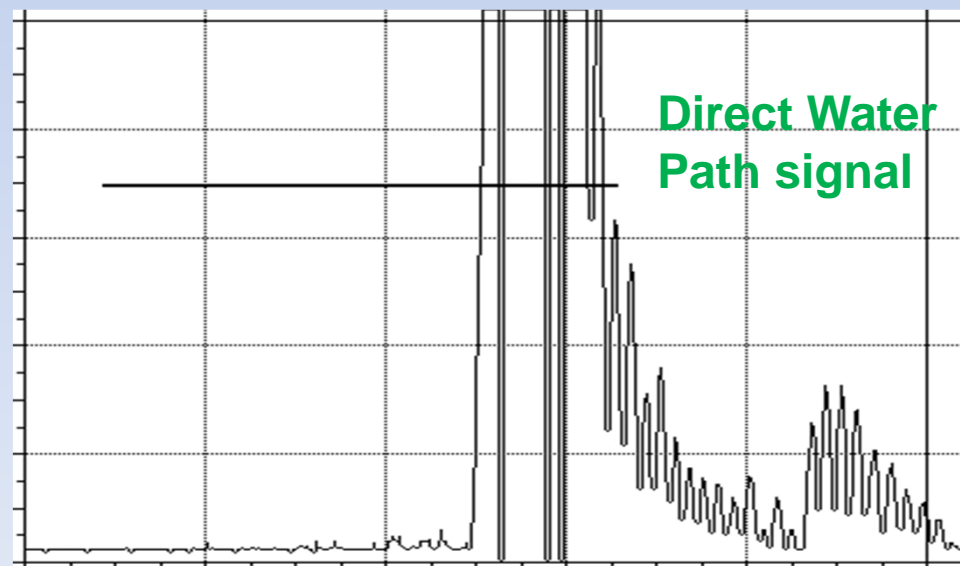
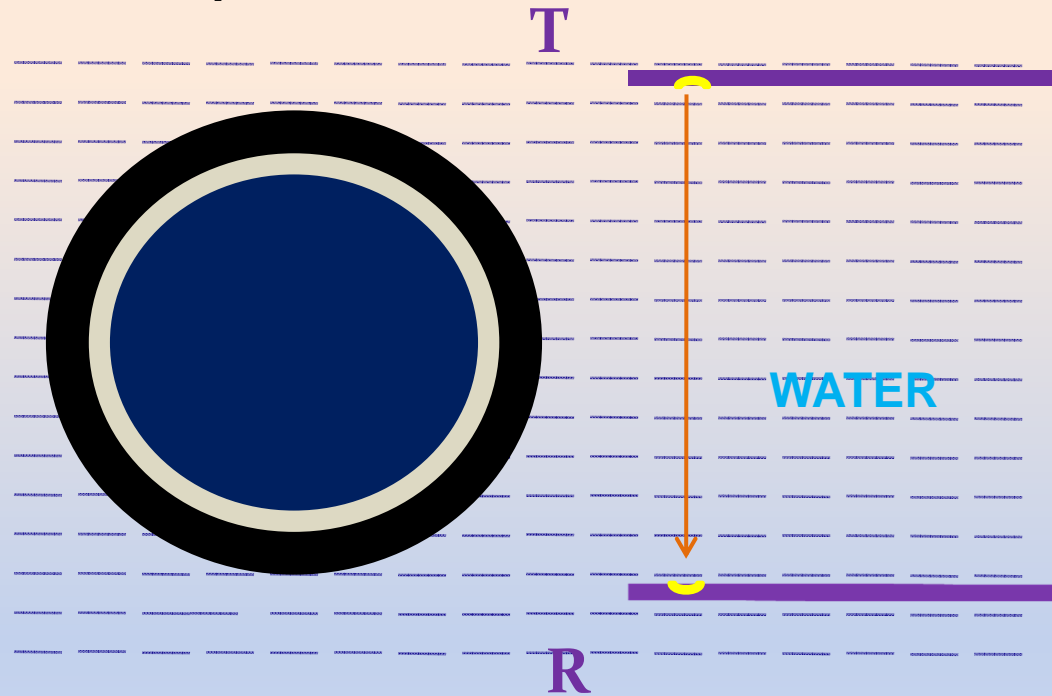


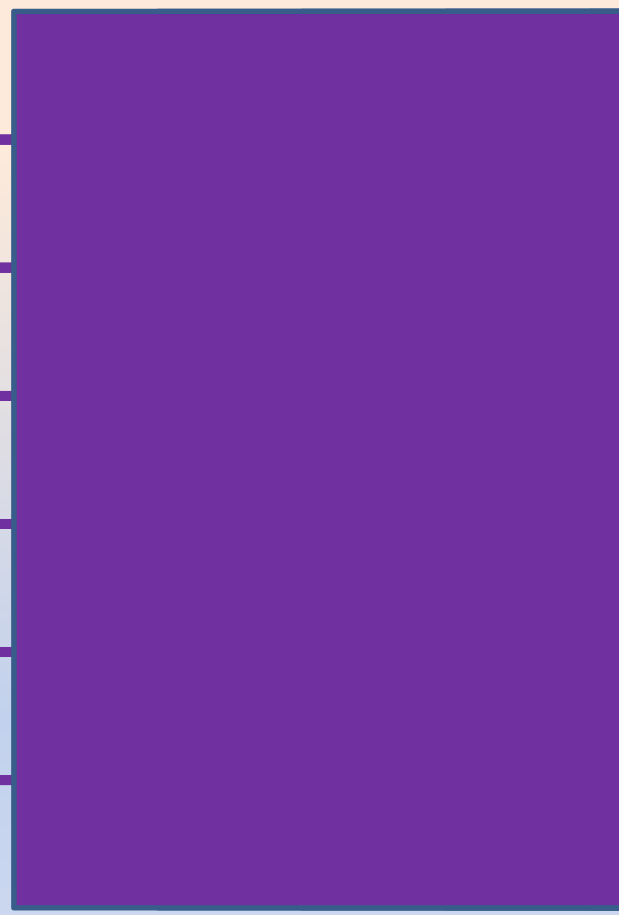
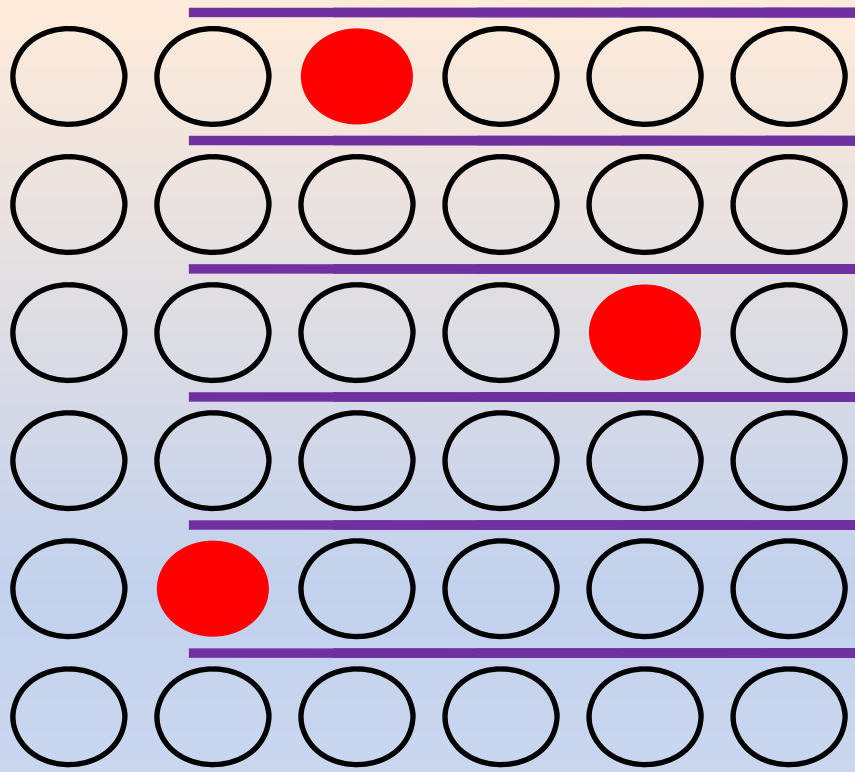
Signal at fixed off-set from sound fuel rod

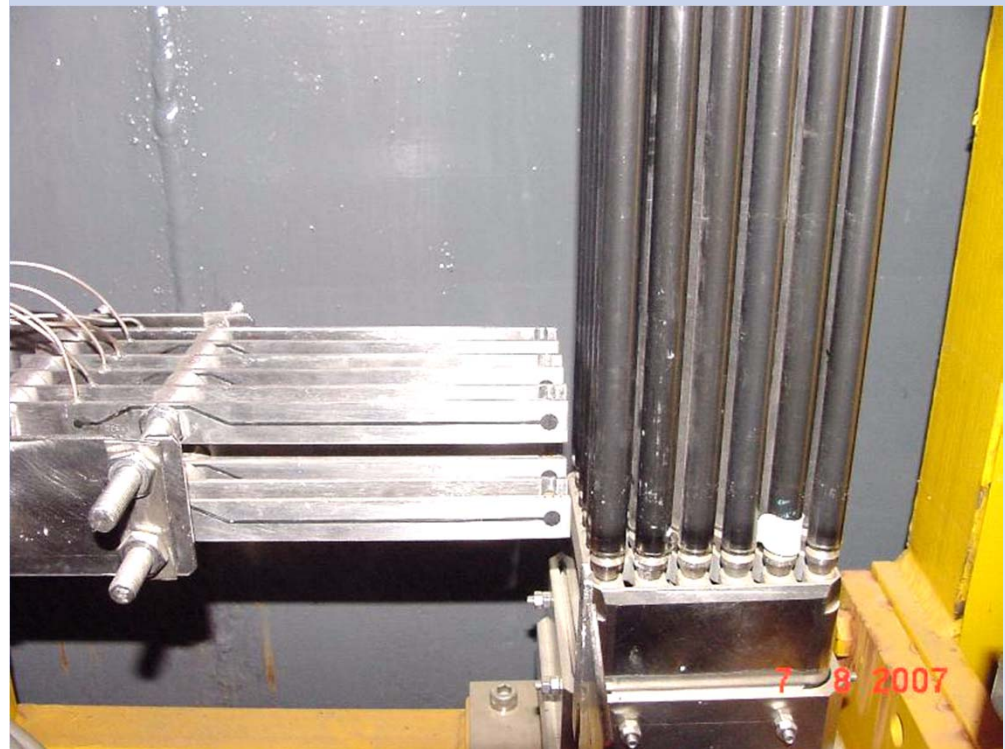
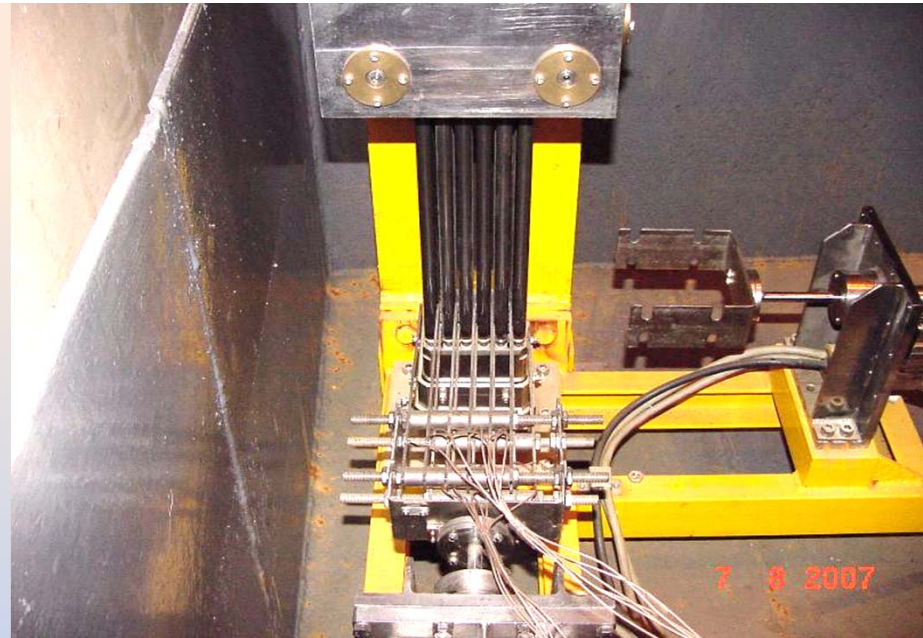


Signal at fixed off-set from failed rod

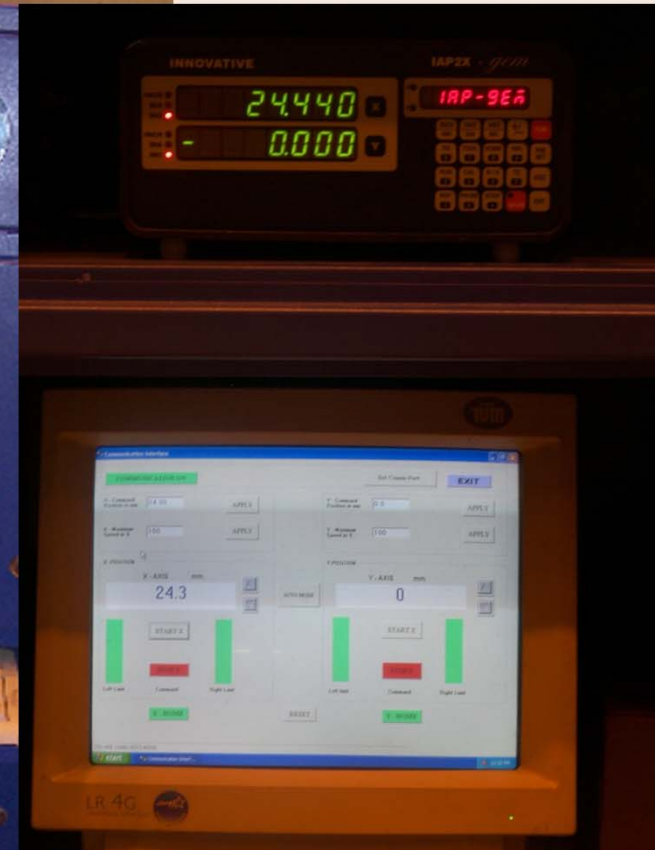
Home position of Probes out of fuel assembly







MOTION CONTROL PANEL



Controller Monitor

COMMUNICATION ON

Set Comm Port

EXIT

X - Command Position in mm. 24.30 APPLY

X - Maximum Speed in % 100 APPLY

Y - Command Position in mm. 0.0 APPLY

Y - Maximum Speed in % 100 APPLY

X POSITION

X - AXIS mm.

24.3

AUTO MODE

START X

STOP X

Left Limit Command Right Limit

X - HOME

RESET

Y POSITION

Y - AXIS mm.

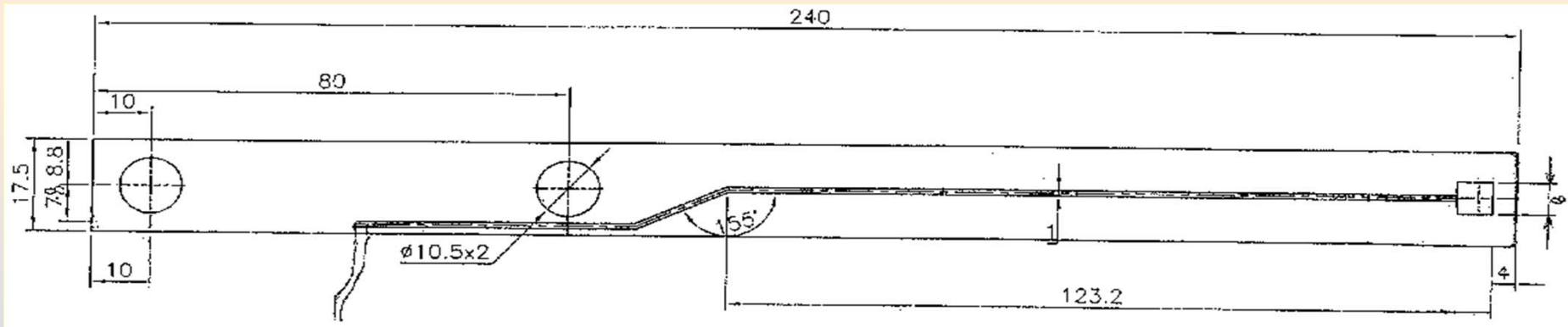
0

START Y

STOP Y

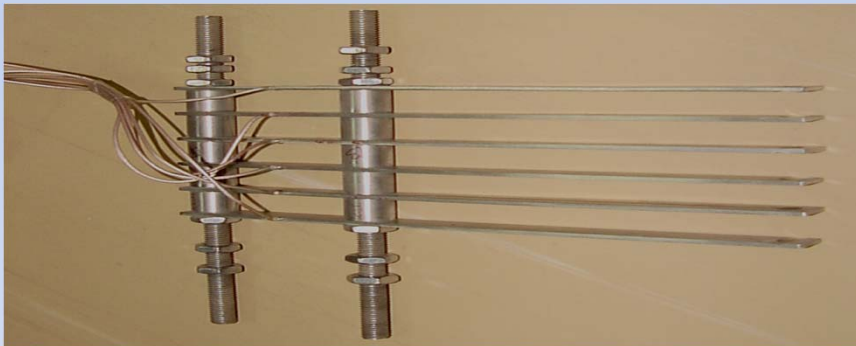
Left Limit Command Right Limit

Y - HOME



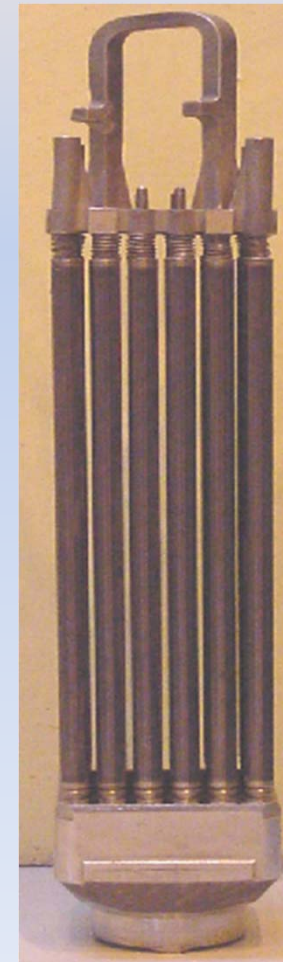
**25 m long
cable**

**Single ultrasonic wafer
probe**

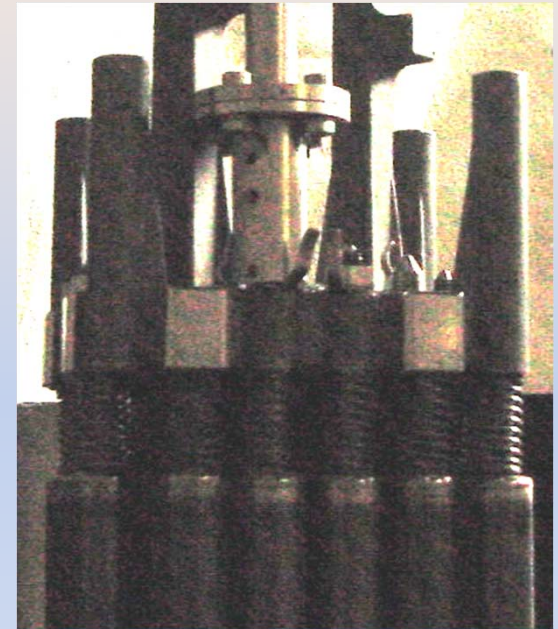
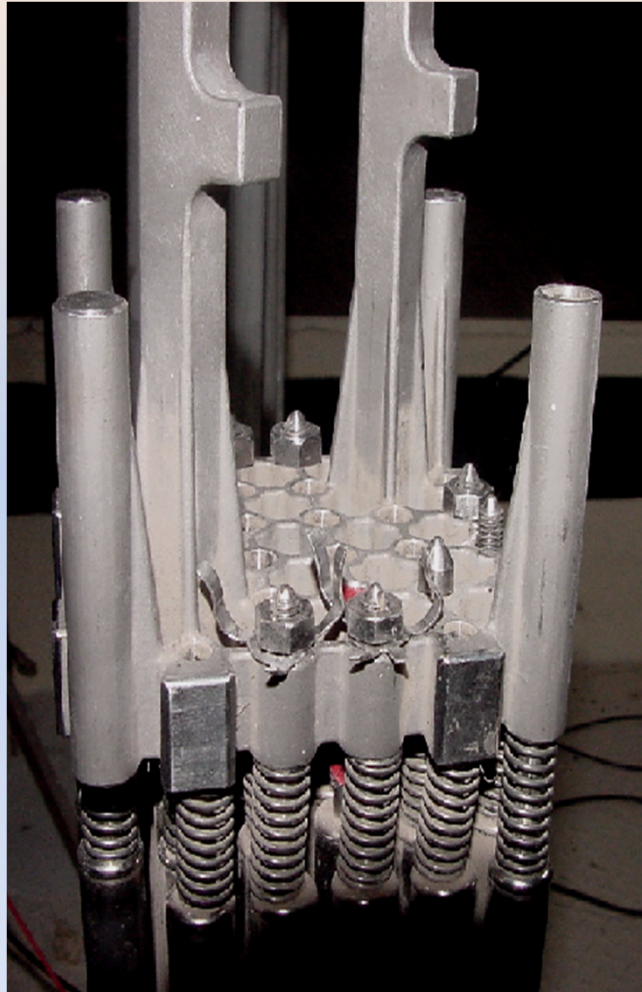


**Three pairs of probes in fixture sub-
assembly**

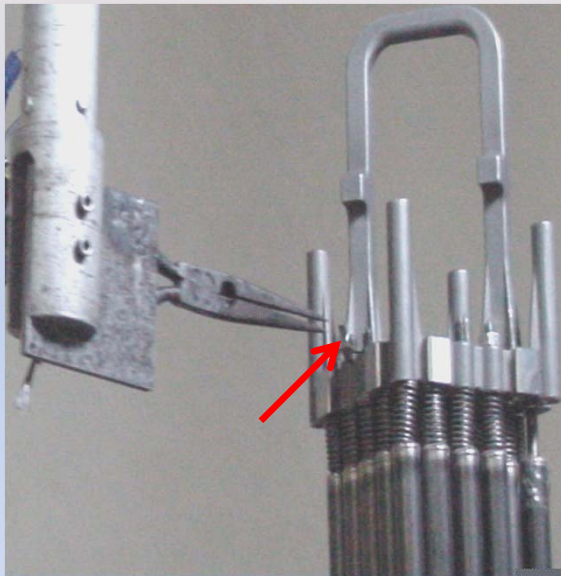
Calibration sub-assembly



Top Tie Plate Dismantling



Removal of Lock Tab Washer, Top Tie Plate, spring and fuel rod



Requirement during Testing

- 1. Motor of the probe movement system should be water tight**
- 2. Alignment of the probes**
- 3. Centre and offset positions of each pin should be known**
- 4. Probe arm thickness should be less than the gap between two pins**
- 5. Fuel assembly should be stable**
- 6. One probe assembly and one probe movement controller should be kept as standby**

Conclusion

1. The developed failed fuel detection system is highly reliable. Currently to segregate failed fuel assembly
2. It has good signal to noise ratio
3. Signals are recorded at three points of a fuel rod
4. Leaky fuel pin is rechecked during reversal of probe
5. Linear motion control is accurate up to 5 μm with feed back control
6. Failed fuel identification, removal and substitution has been demonstrated

Thanks for your patience

