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Nuclear expertise intelligently applied

Imaging and Tomography at Sellafield in the UK

Dominic Rhodes & Tim Tinsley
Nexia Solutions

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Nuclear expertise intelligently applied

Non-intrusive monitoring for nuclear applications

What can non-intrusive monitoring deliver?

- Process Monitoring
  - Control
  - Safety
- Process Diagnostics
  - Optimisation
- Better understanding of the process
  - Predictive power
  - Improved modelling

Imaging and Remote Sensing Capability

Which Techniques Should I use?

- What do you want to know?
  - Changes in density, radiation, conductivity, phase, chemical composition, etc…
- How much information do you need?
  - A point measurement, full 3D scanning, or something in between…
- Access to the process?
  - Does it need to be remote, completely intrusive, etc…
- Is the process/unit dynamic?

Imaging and Remote Sensing Capability

Which Techniques are Available

Modality	*Temporal Resolution*	*Spatial Resolution*	*Ease of deployability*
MRI	Excellent	Excellent	Poor
PET	Moderate	Good	Poor
PEPT	Excellent	Excellent	Poor
SPECT	Excellent	Good	Poor
Electrical	Good/Excellent	Moderate	Good
Acoustic	Good	Moderate	Excellent
X ray CT	Good	Good	Moderate
OCST	Excellent	Moderate	Moderate

Imaging and Remote Sensing Capability

Which Techniques are Available

Modality	*Delivered Information*	*Sensor/detector arrangement*
Radiation (transmission)	Attenuation coefficient (density)	Radiation source and detectors
Radiation (emission)	Location of radioactive material	Radiation detectors
Acoustic	Acoustic impedance (reflection, scattering)	Acoustic transducers
Electrical	Conductivity or permittivity distribution	Metallic sensor electrode arrays
MRI	Spectroscopic distribution of material	Induced current in antennae
Optical	Chemical species distribution	Diode Lasers, fibres and photodiodes (transmission)
Radiation (Naturally Occurring)	Location of high atomic number materials	High energy radiation detectors

Case Study 1

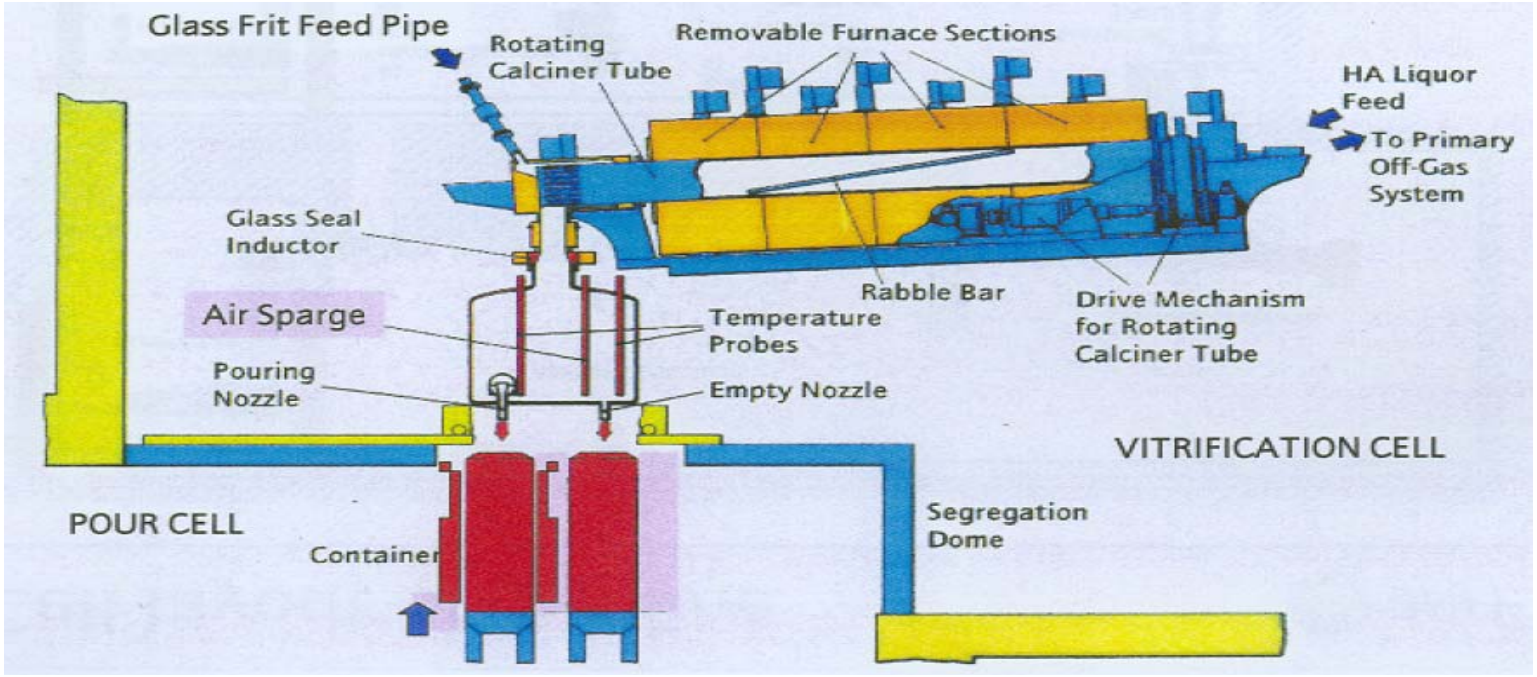
Gamma Applications on Vitrification Test Rig (VTR) and others.

Active and Passive applications.

Imaging and Remote Sensing Capability

Case Study: Vitrification Test Rig

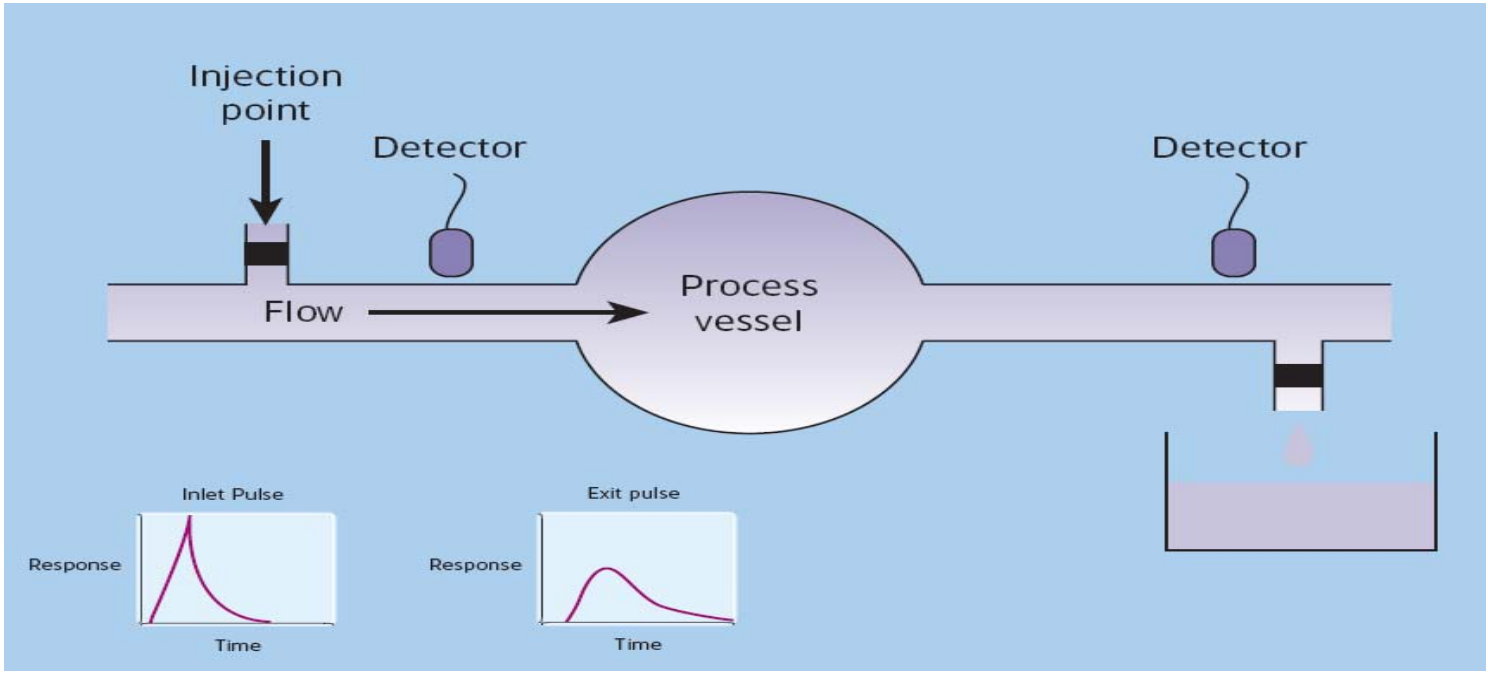
Residence Time of Calciner



Imaging and Remote Sensing Capability

Case Study: Vitrification Test Rig

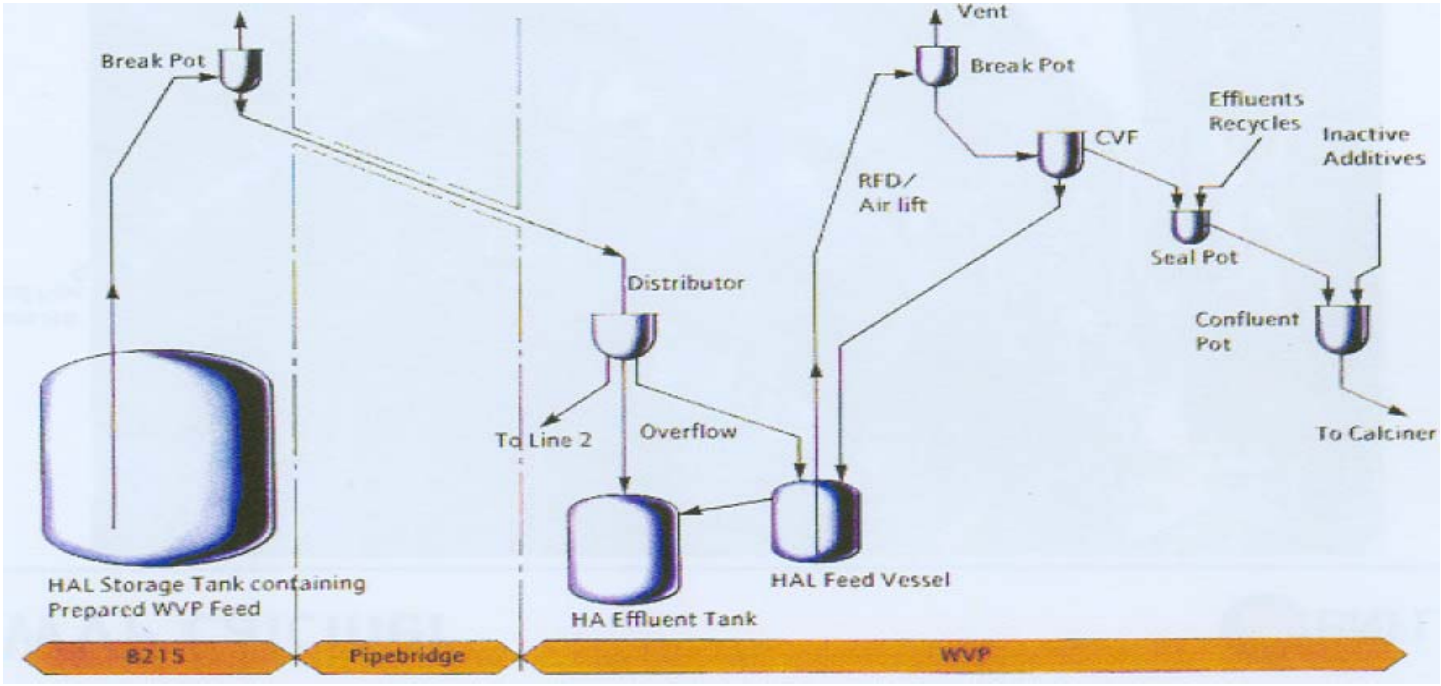
Residence Time of Calciner



Imaging and Remote Sensing Capability

Case Study: Vitrification Test Rig

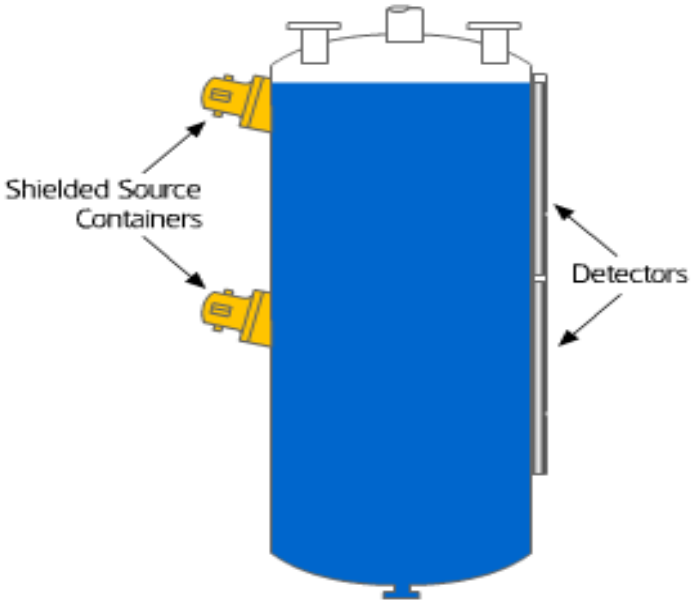
Non-invasive Level Detection

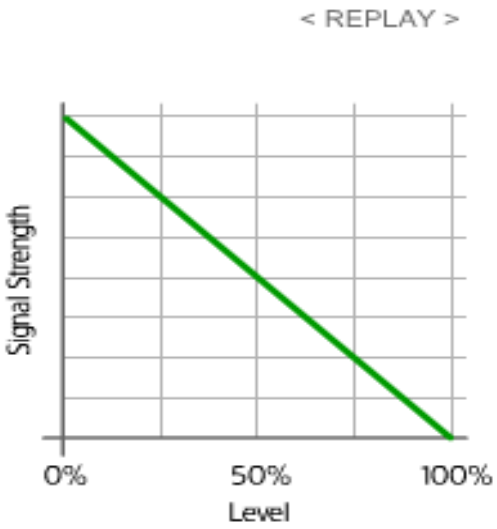


Imaging and Remote Sensing Capability

Case Study: Vitrification Test Rig

Non-invasive Level Detection

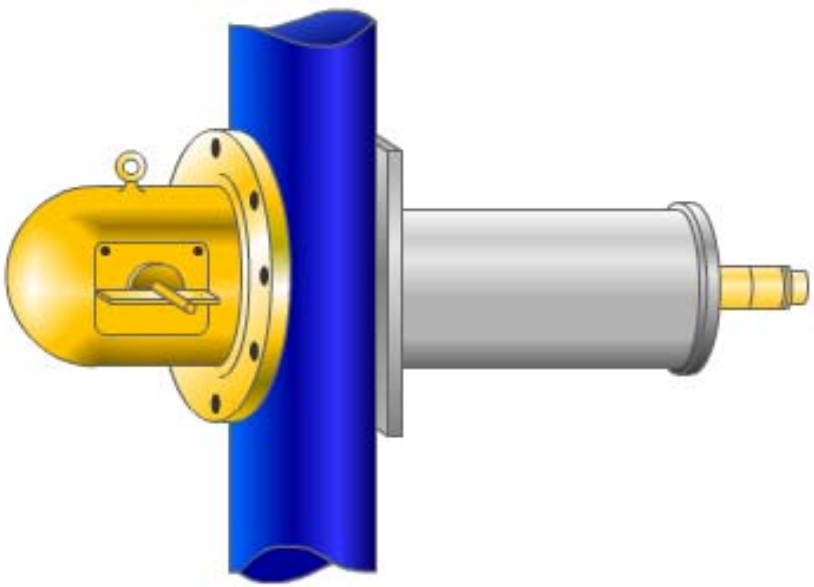




Imaging and Remote Sensing Capability

Case Study: Vitrification Test Rig

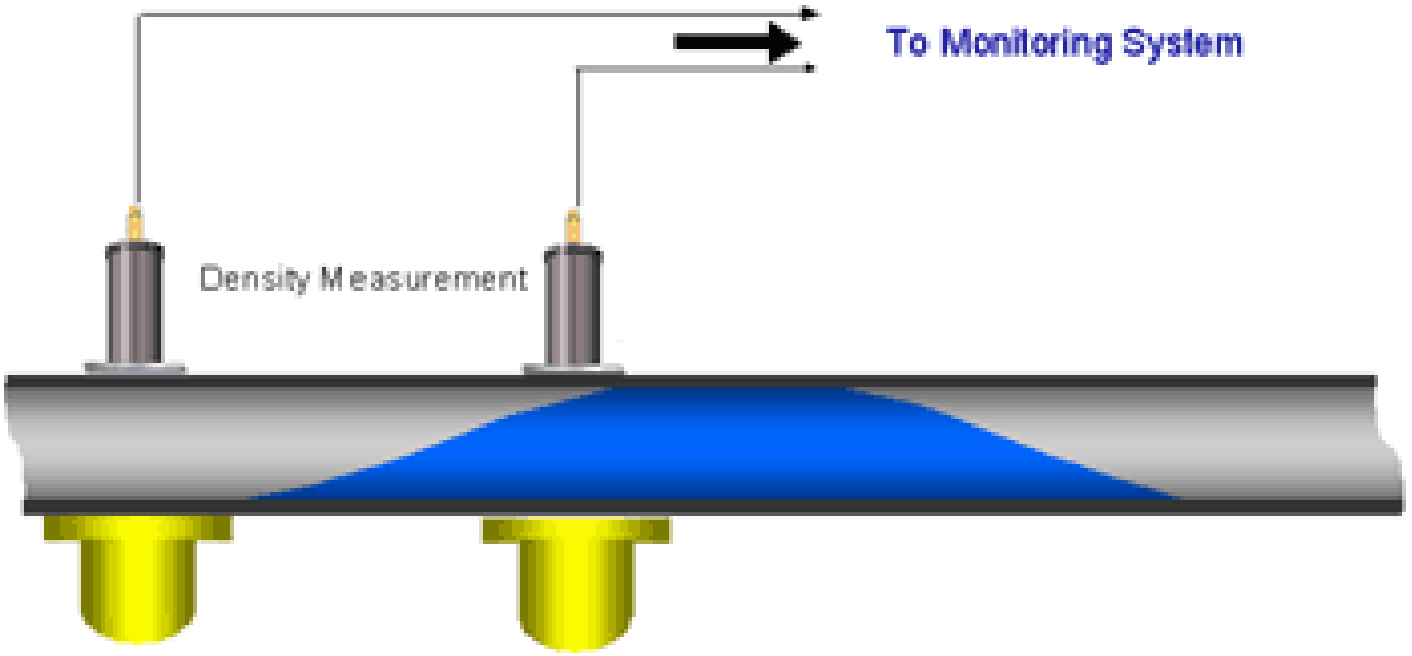
Density metering for the off-gas dust scrubber



Imaging and Remote Sensing Capability

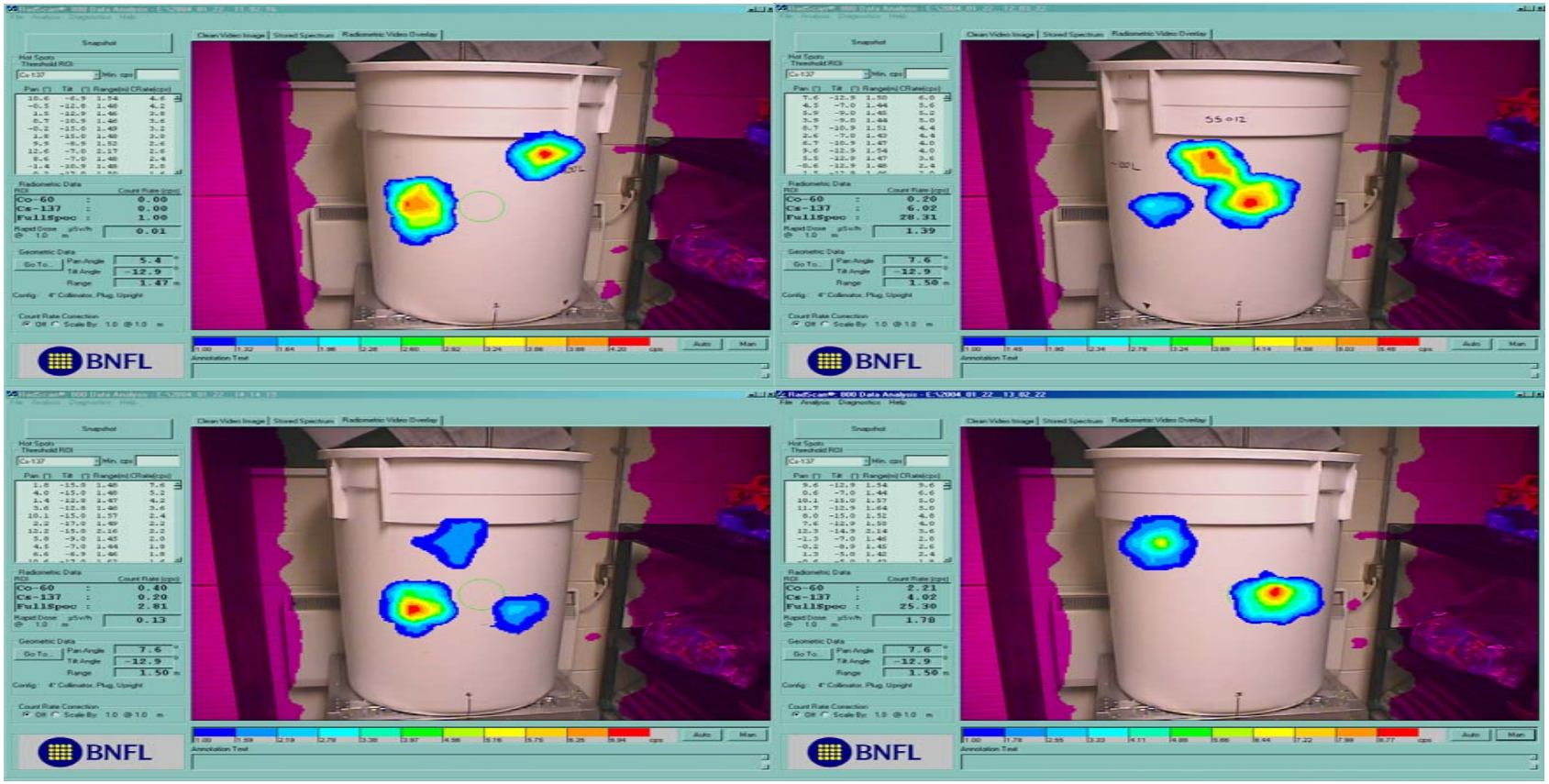
Case Study: Pipeline applications

Slug monitoring



Radiation Tomography Test

Radiation Survey



Tomographic Reconstruction

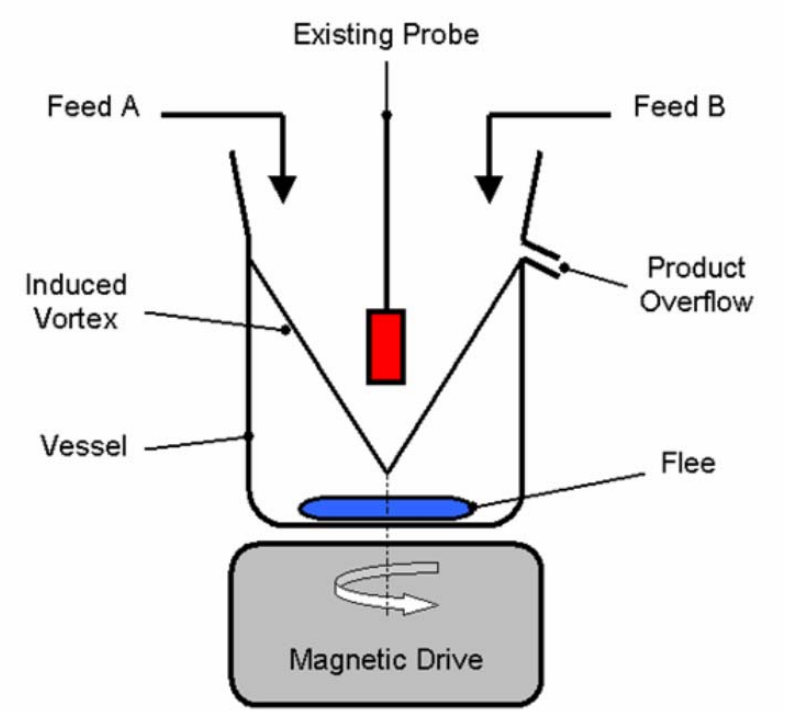
Case Study 2

Acoustic and Electrical detection of gas core inside a nuclear reprocessing precipitation reactor for heavy metals.

Acoustic Process Monitoring

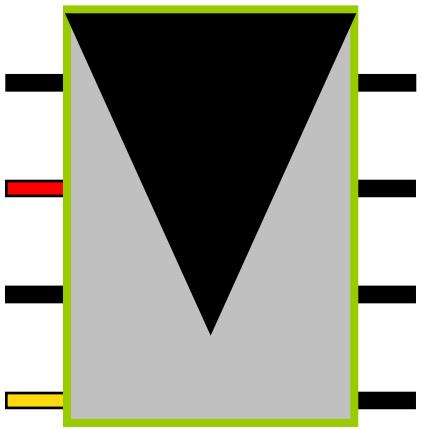
What do we want to know

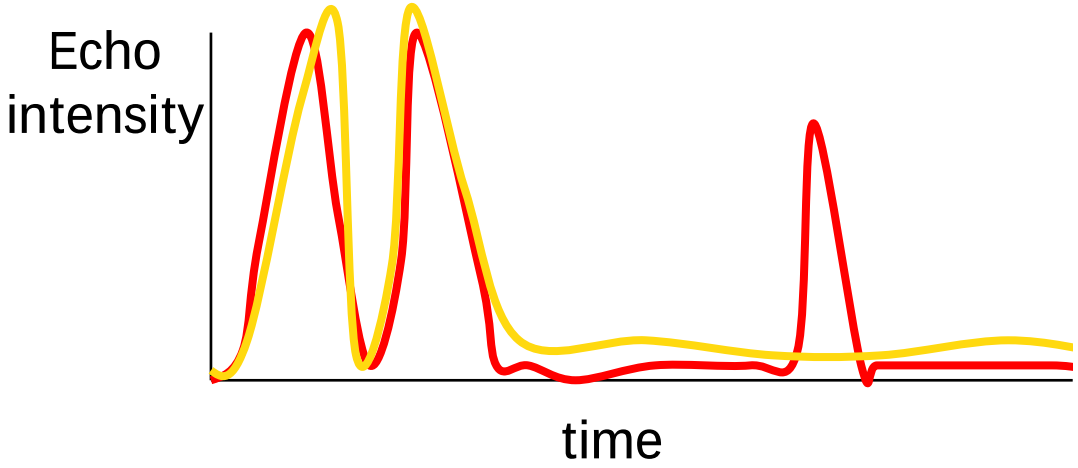
- Size of vortex indicates residence time for the reactor
- Can be used as a control point
- Monitoring of start up and shut down
- Approach to steady state



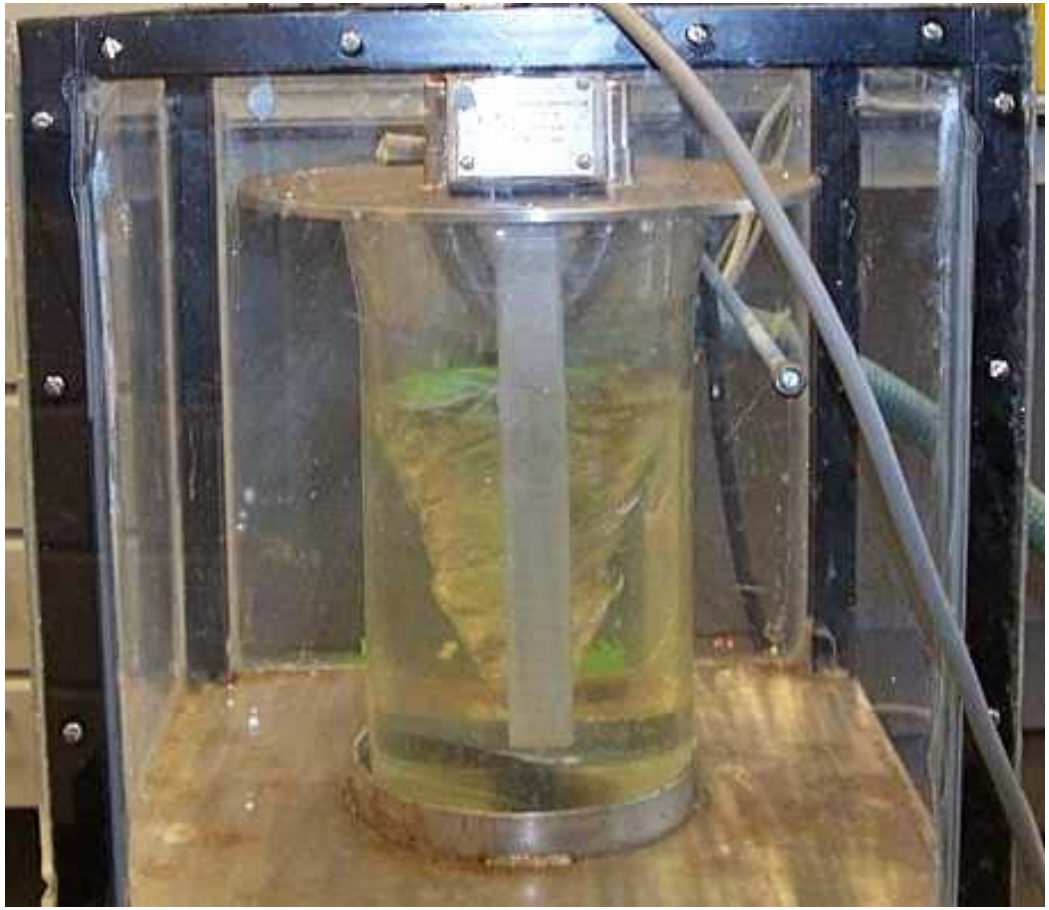
Acoustic Process Monitoring

Development of an acoustic monitoring system

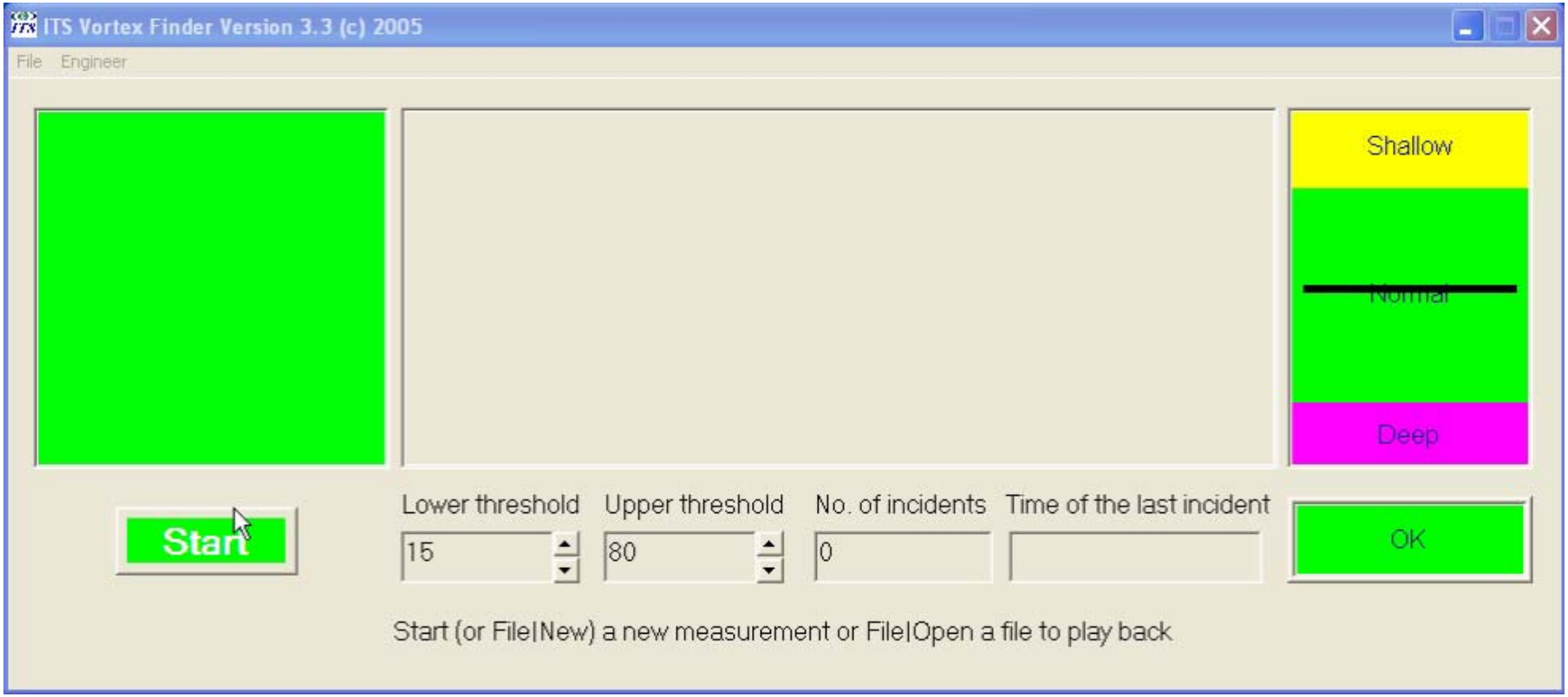




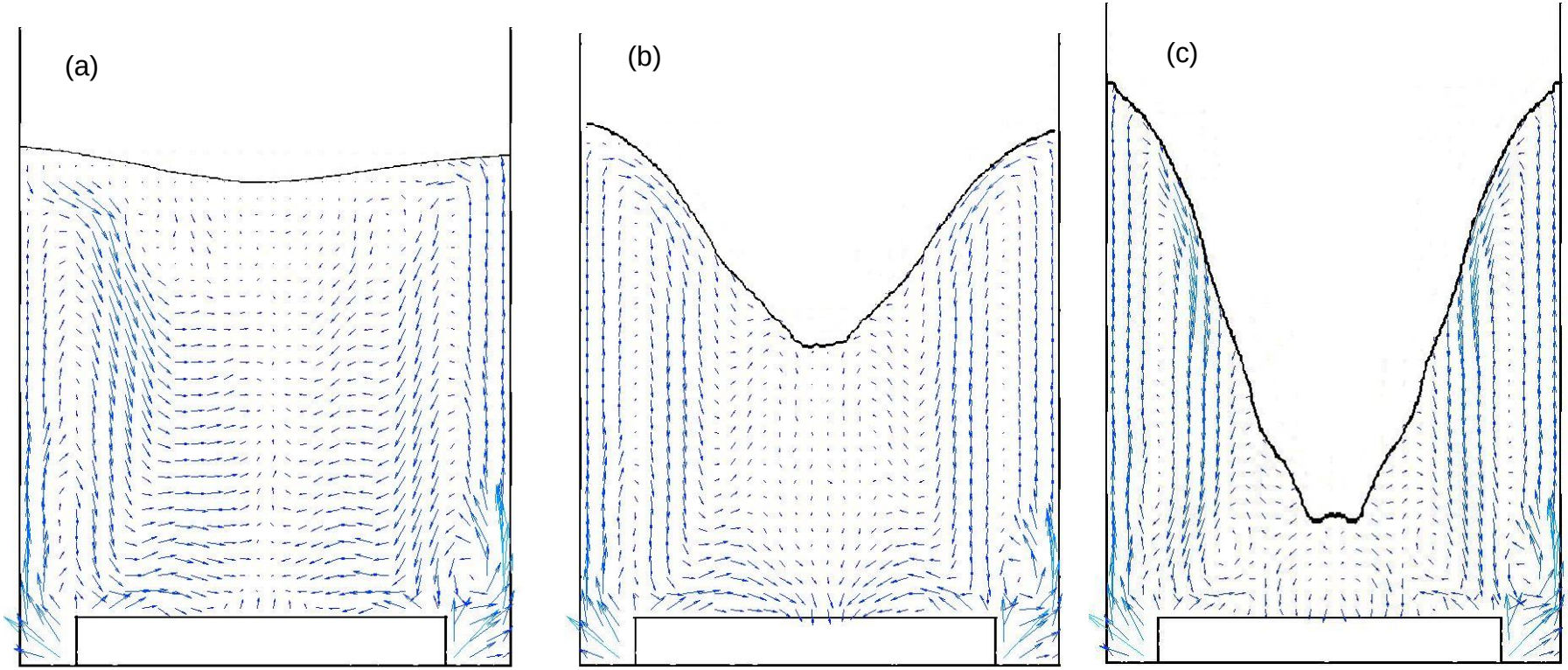
ERT Tomography: The Solution



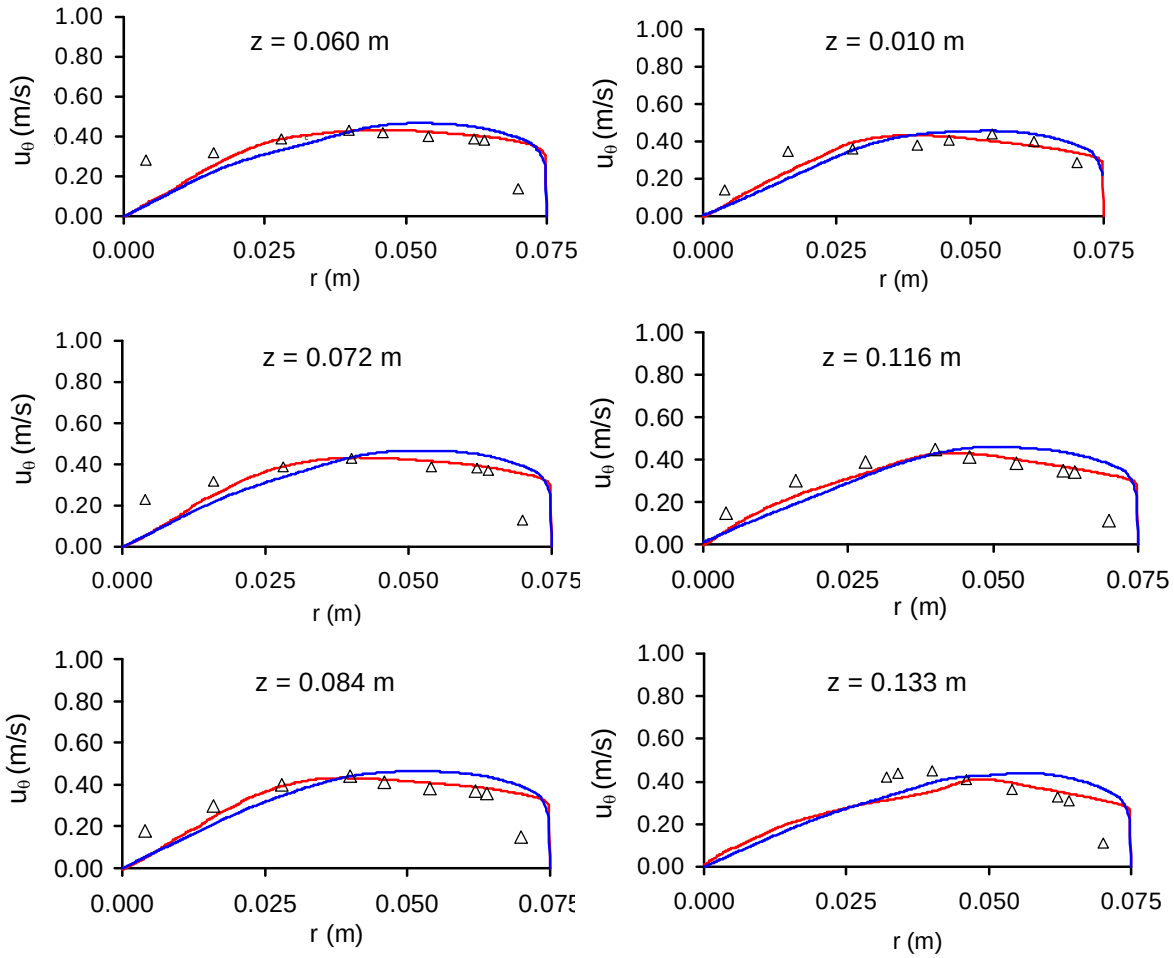
Vortex Video



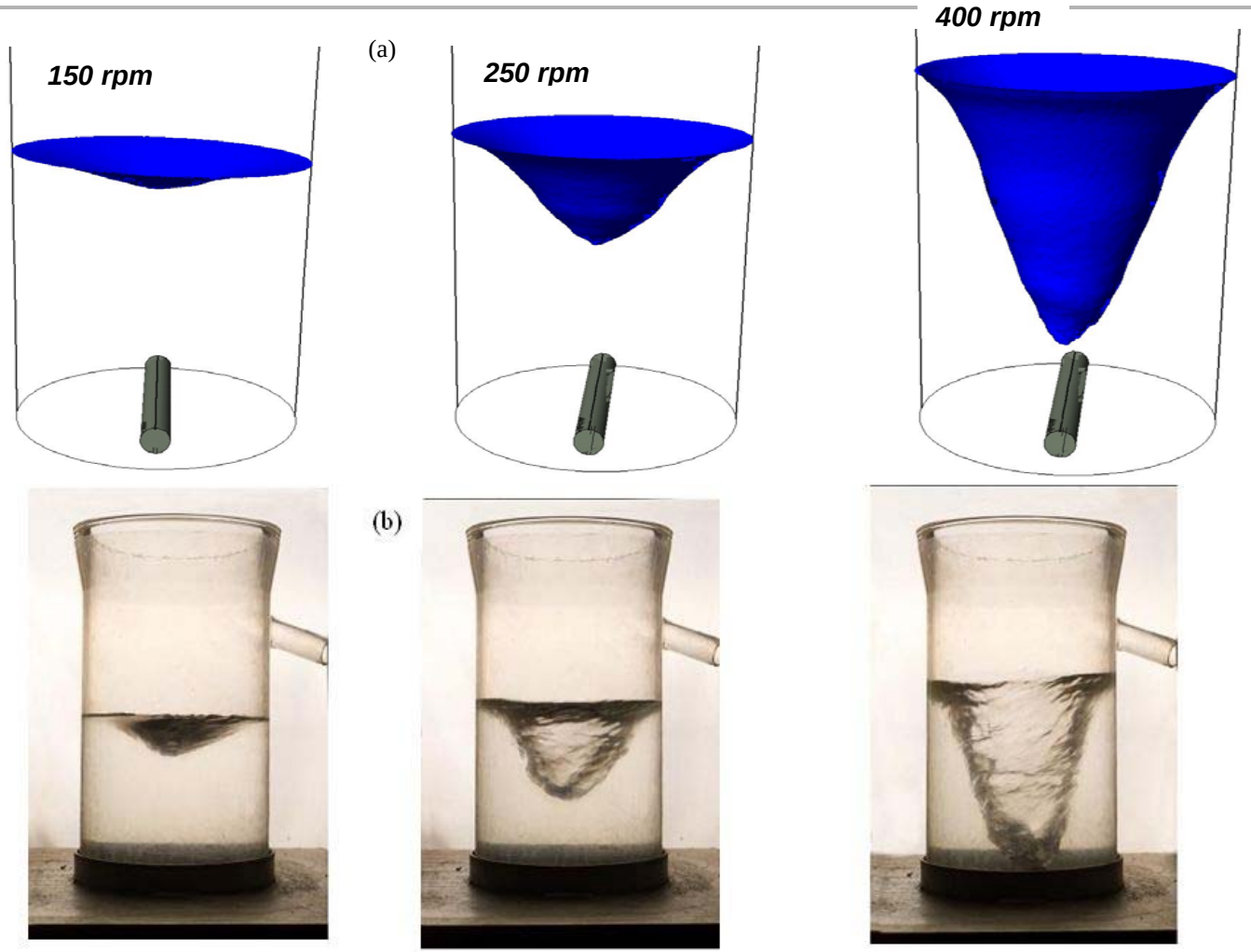
Predicted liquid surface profiles / flow fields



Comparison: Predicted vs Measured



Validation



Case Study 3

Electrical imaging of solid liquid suspensions

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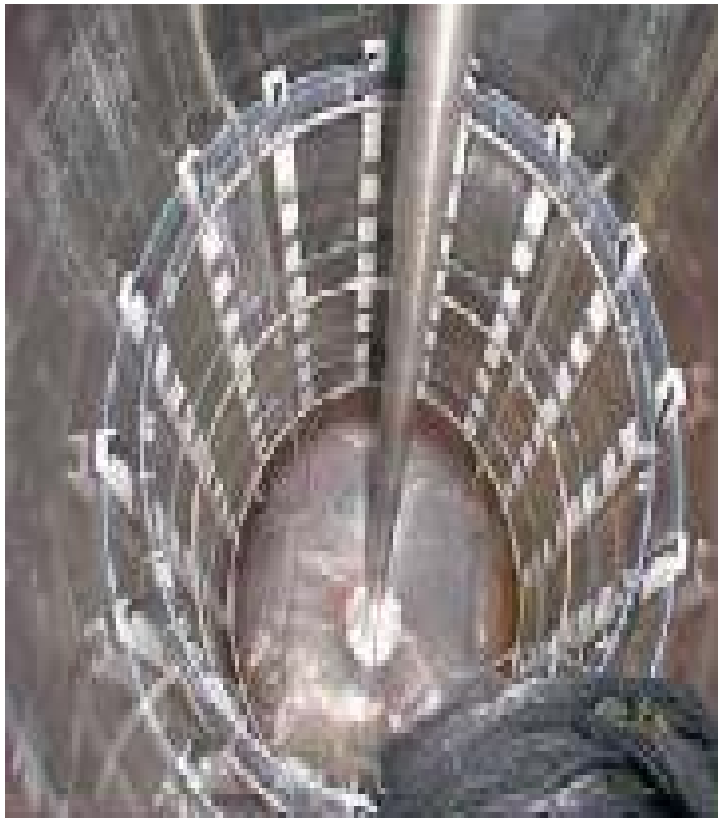
Nuclear expertise intelligently applied

Date: 16/01/08

Electrical Imaging of Solid Suspensions

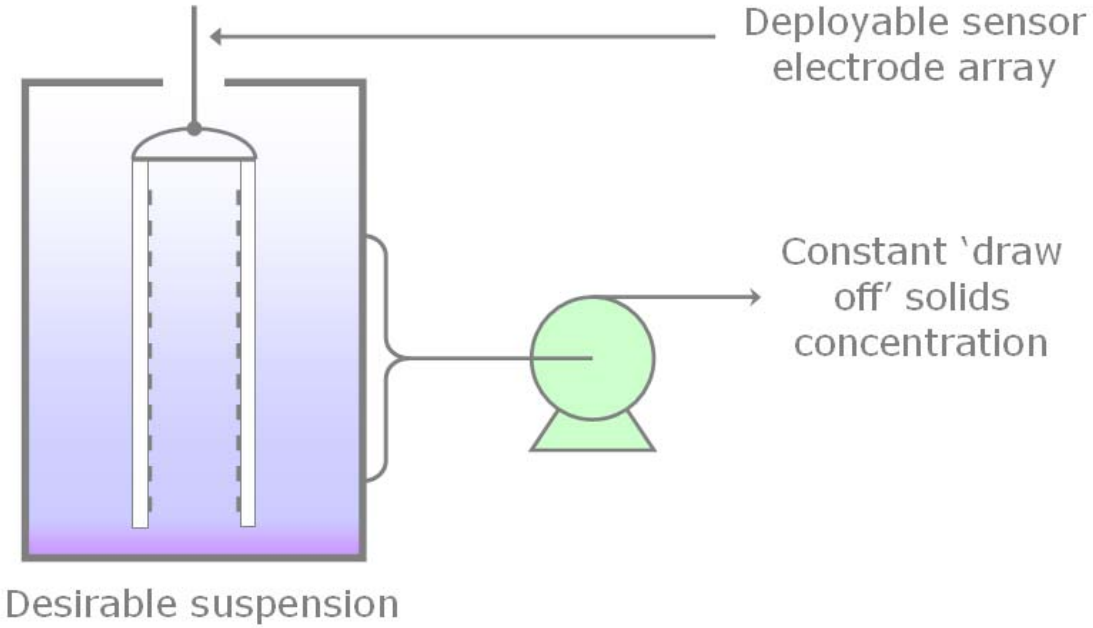
Ring Arrays

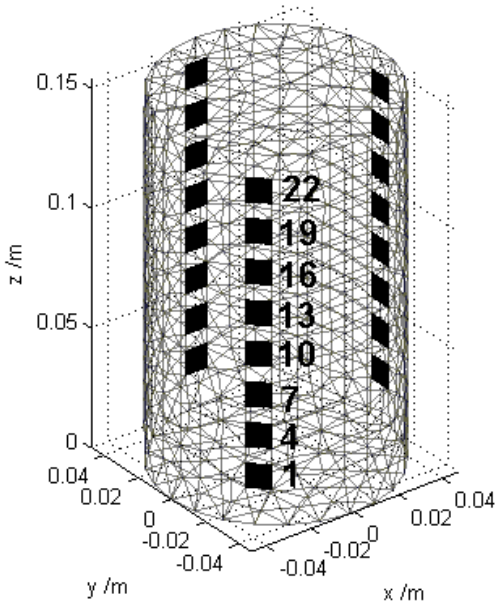


Linear Arrays

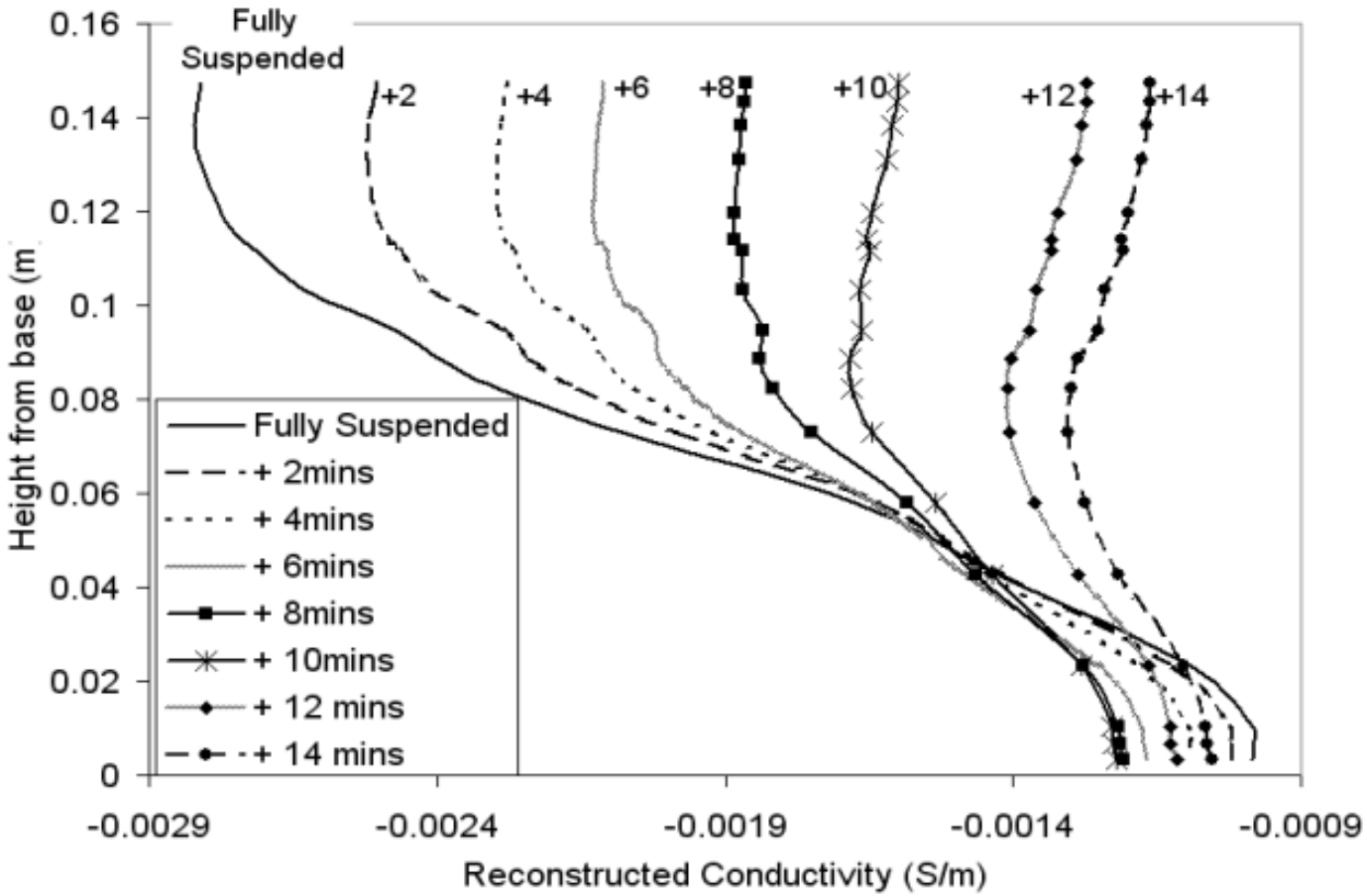
Electrical Imaging of Solid Suspensions

Linear Arrays

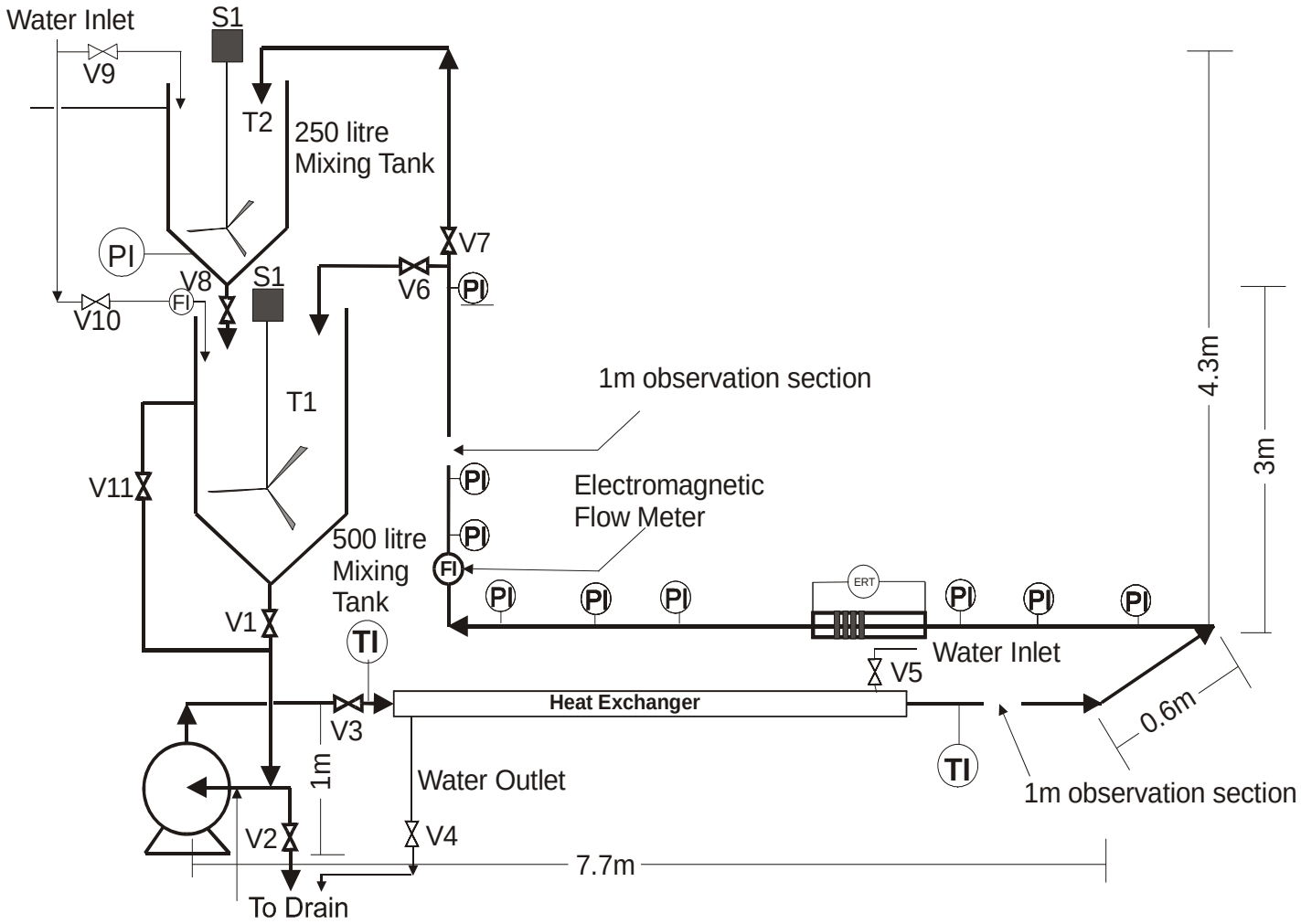




Electrical Imaging of Solid Suspensions



Typical Flow loop



Case Study 4

Non Electrical Imaging

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Date: 16/01/08

What is RadBall?

RadBall is a deployable radiation mapping device which can **locate**, **quantify** and **characterise** radiation hazards from a single position.

Polymer plastic

+

Collimation sheath

=

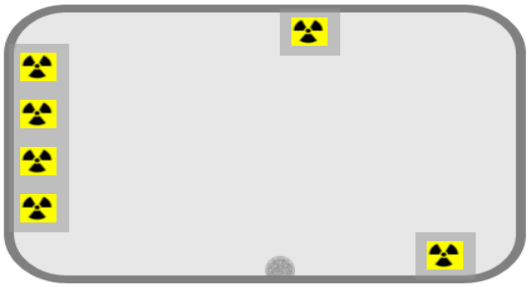
DEPLOYABLE RADIATION MAPPING DEVICE

RADBALL

What can it be used for?

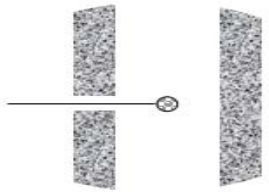
Nexia Solution will offer a radiation mapping service based on the RadBall device

- Radiation mapping in:
  - Active cells
  - Glovebox
  - Confined spaces
  - Hard to reach parts of the plant
  - Plants with high radiation levels



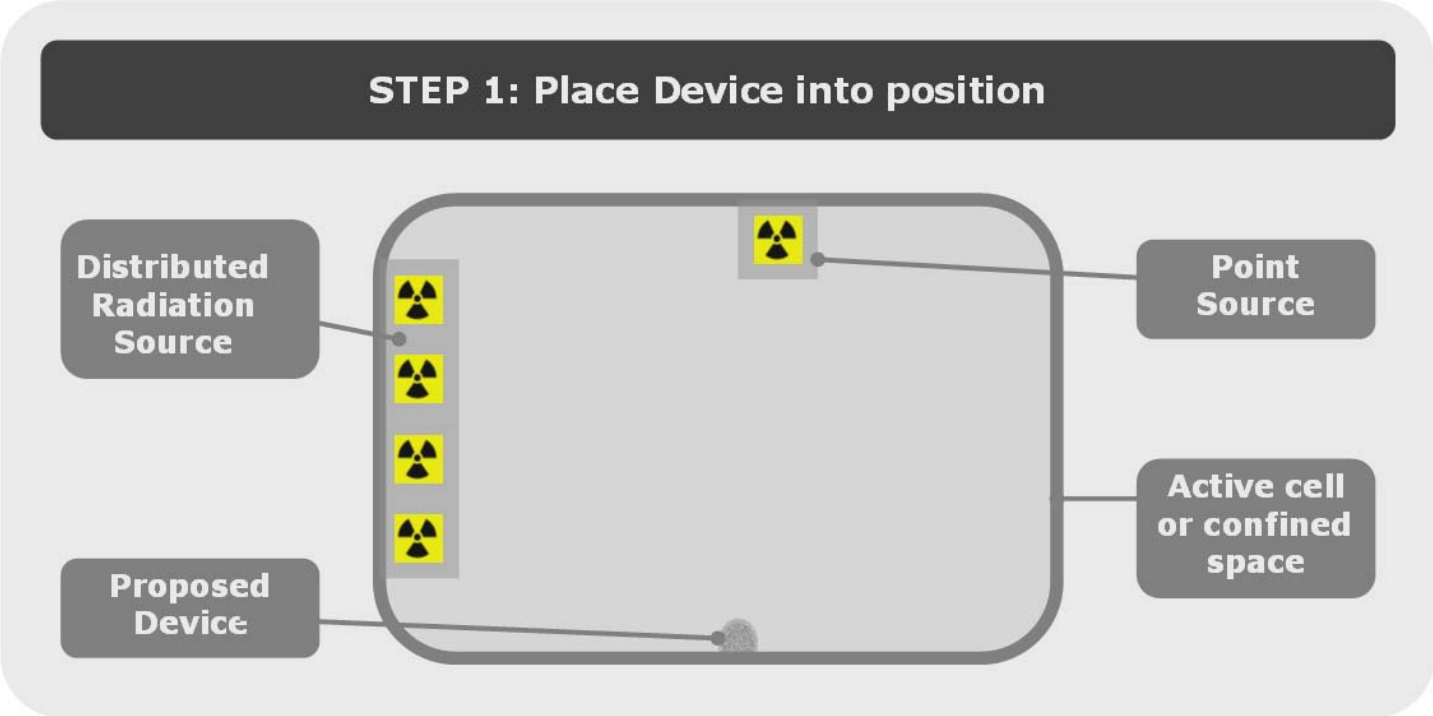
Cell/glovebox

- Quality control for decontamination efforts
  - Before and after surveys
  - Detection of untreated areas

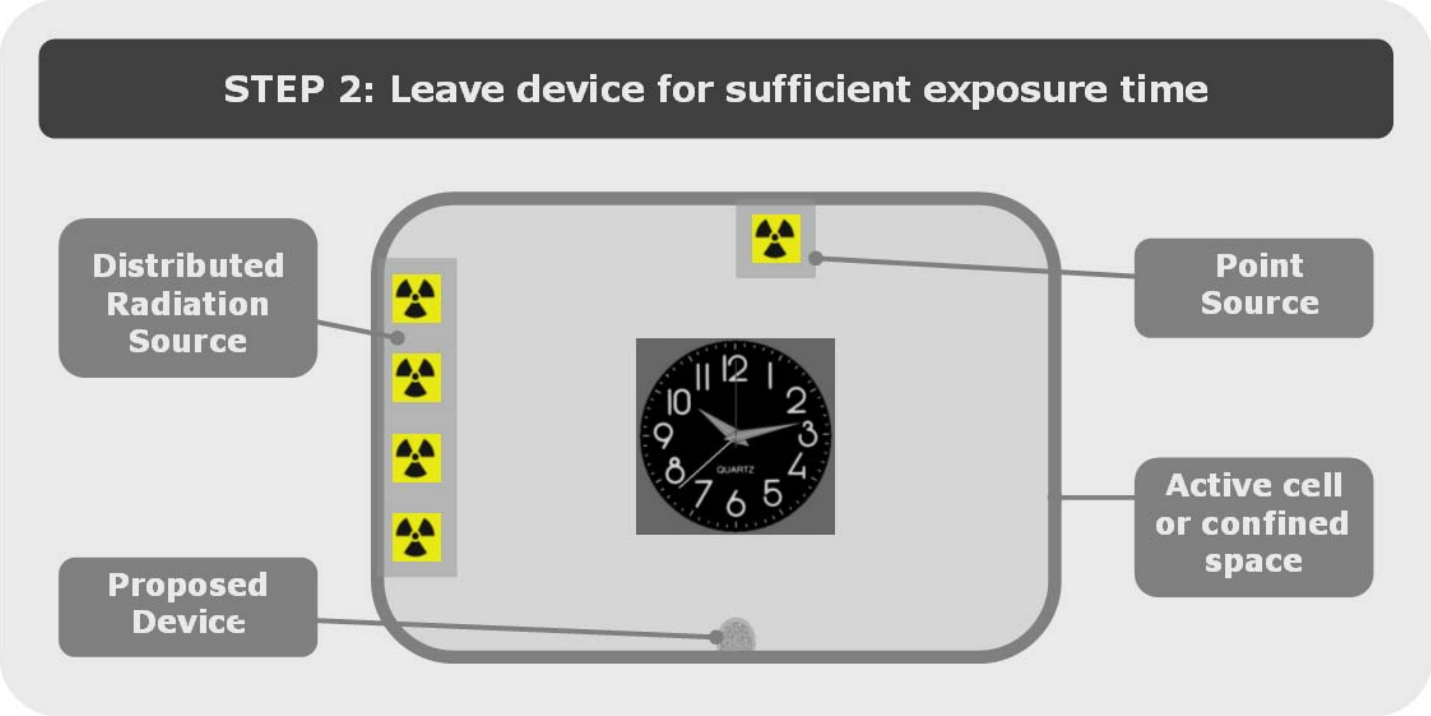


Through a drilled hole

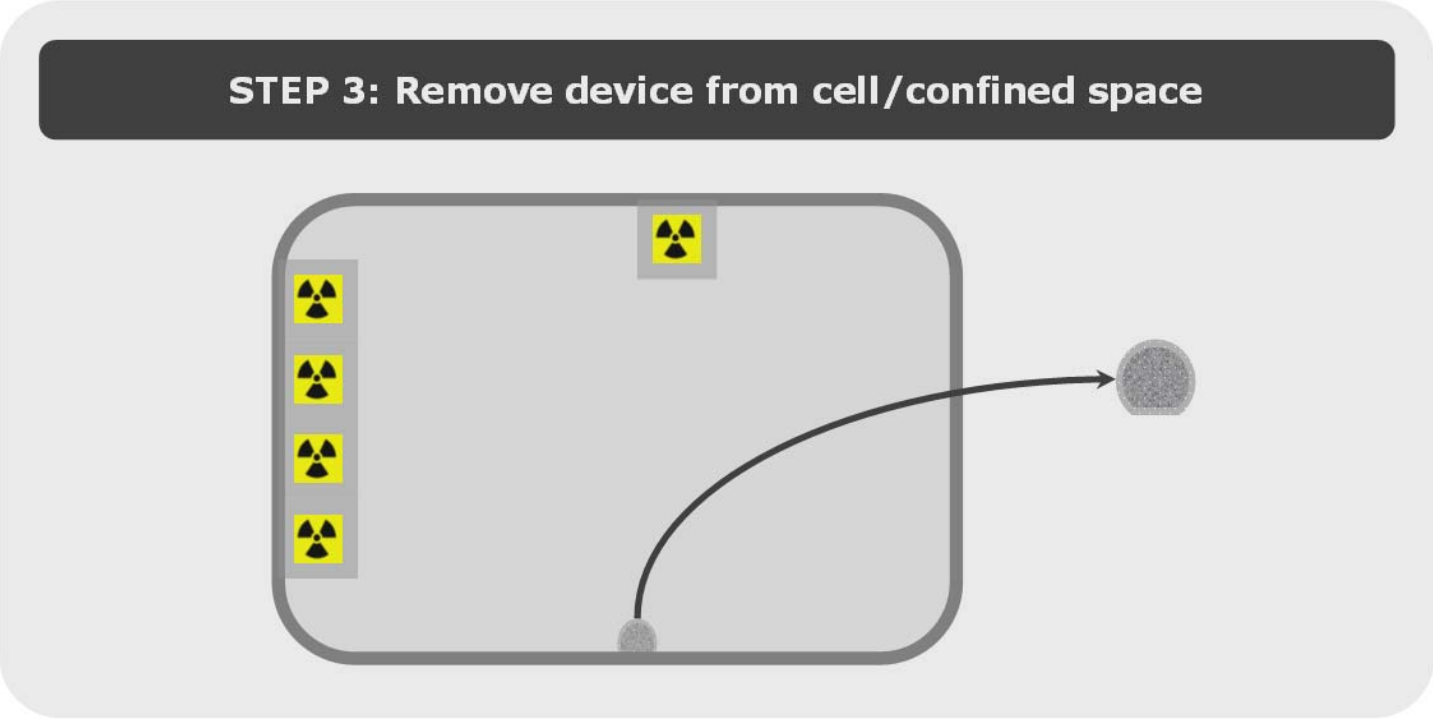
How does it work?



How does it work?

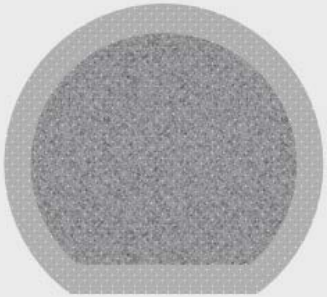


How does it work?



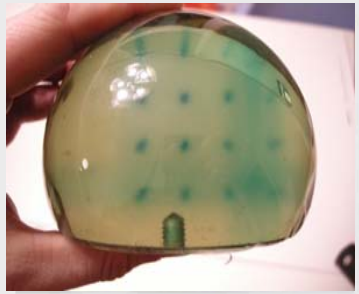
How does it work?

STEP 4: Remove collimation sheath



Proposed device

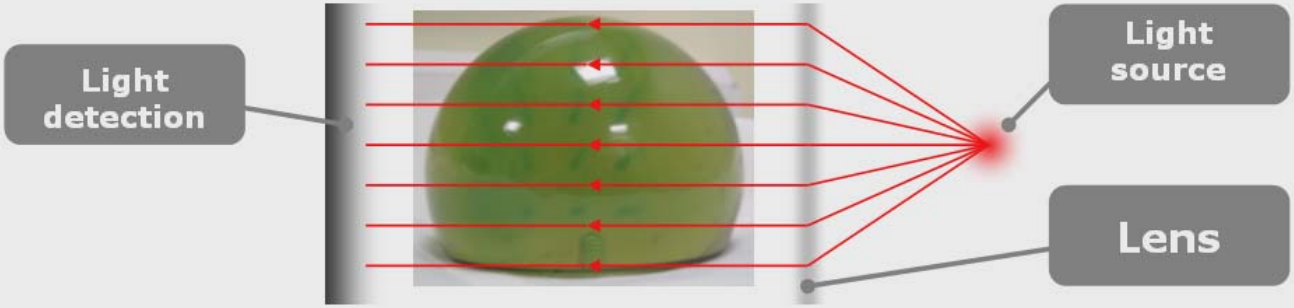
Collimation sheath



Polymer plastic

How does it work?

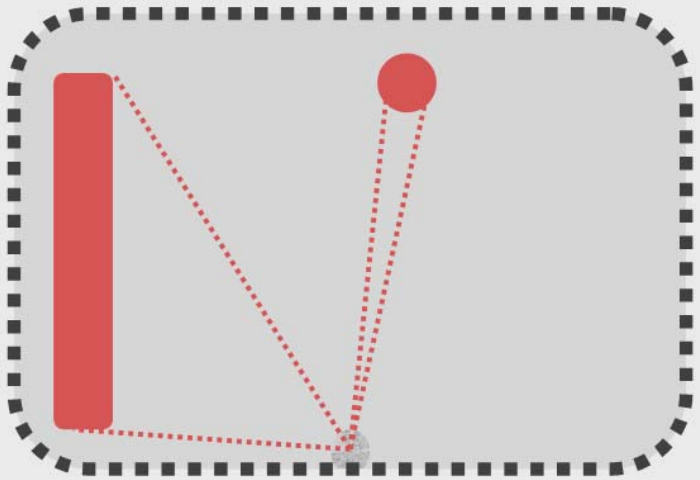
STEP 5: Analyse polymer plastic matrix



Polymer plastic sample is rotated to obtain 3D information

How does it work?

STEP 6: Radiation hazards located and characterised

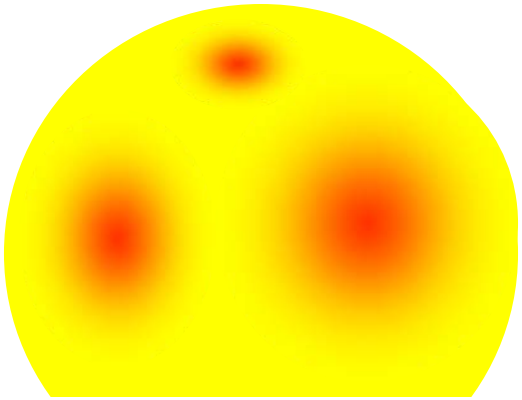


Radiation is located, quantified and characterised

What is the output (basic)?

BASIC OUTPUT:

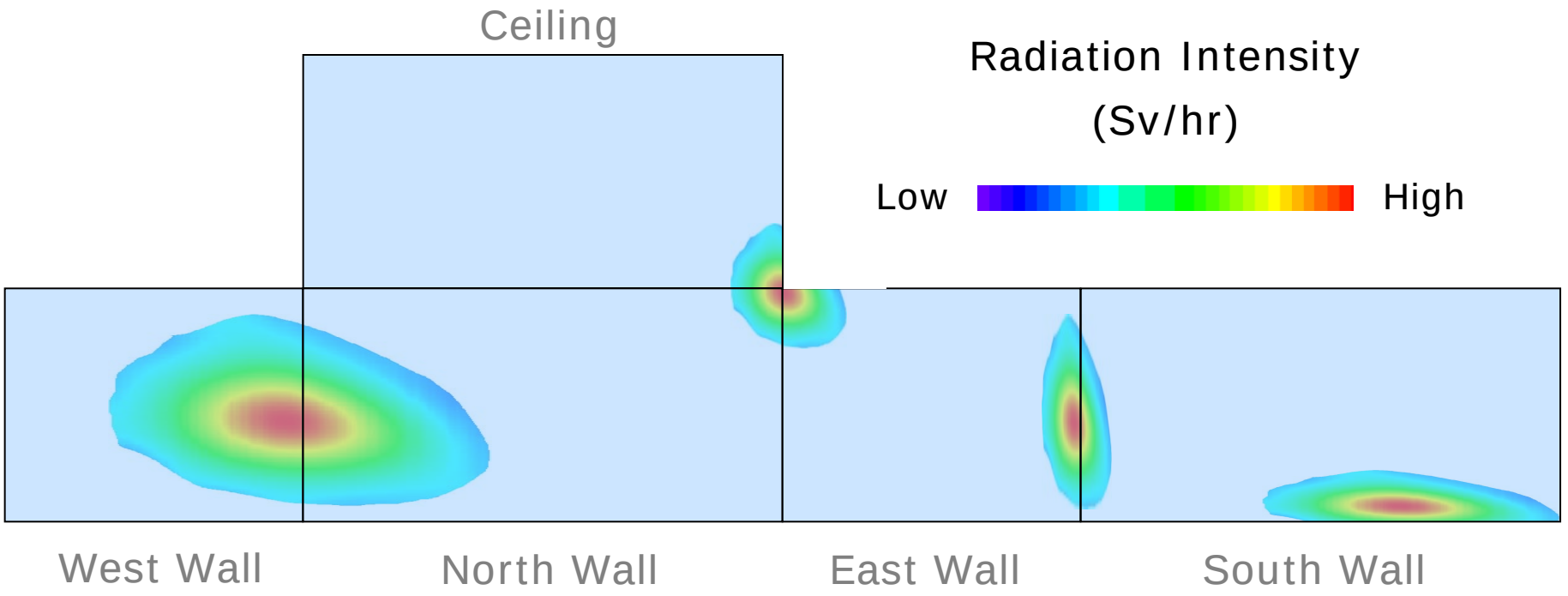
Radiation deposited on the device
From a particular direction
+
An estimate of the incident
radiation energy



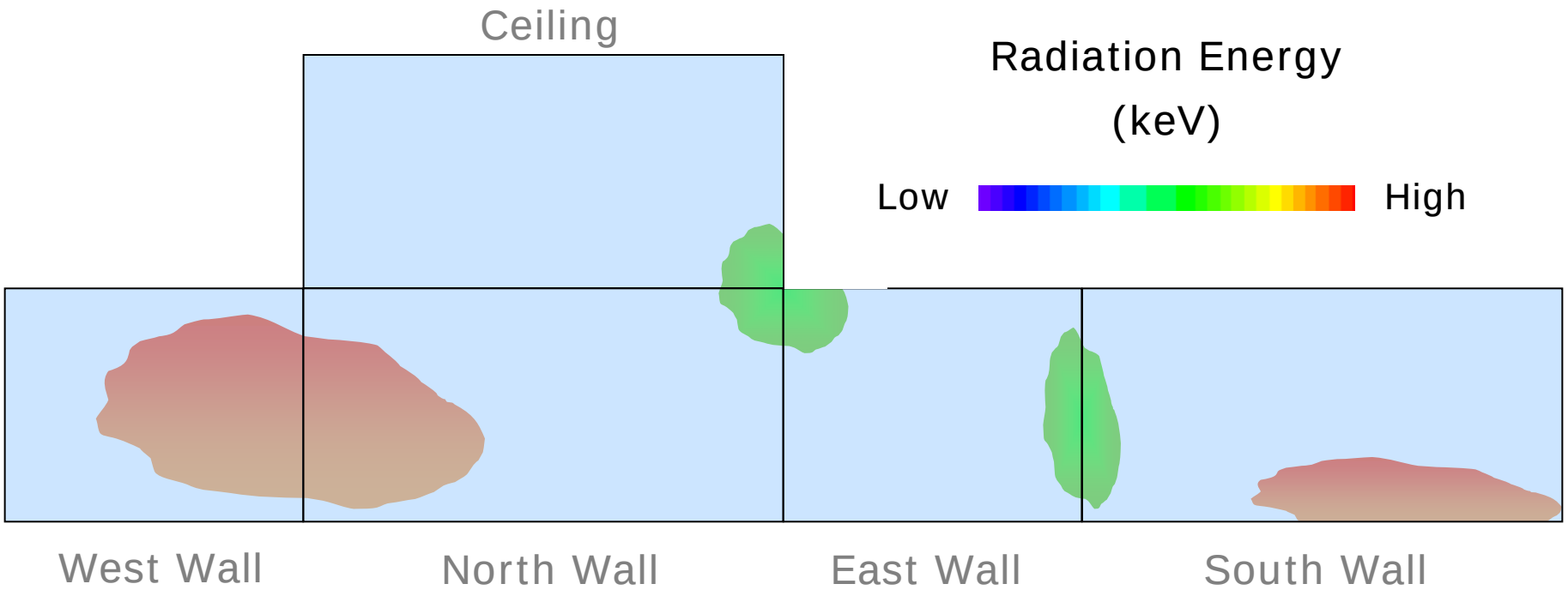
Radiation Intensity (Sv/hr)

Low — High

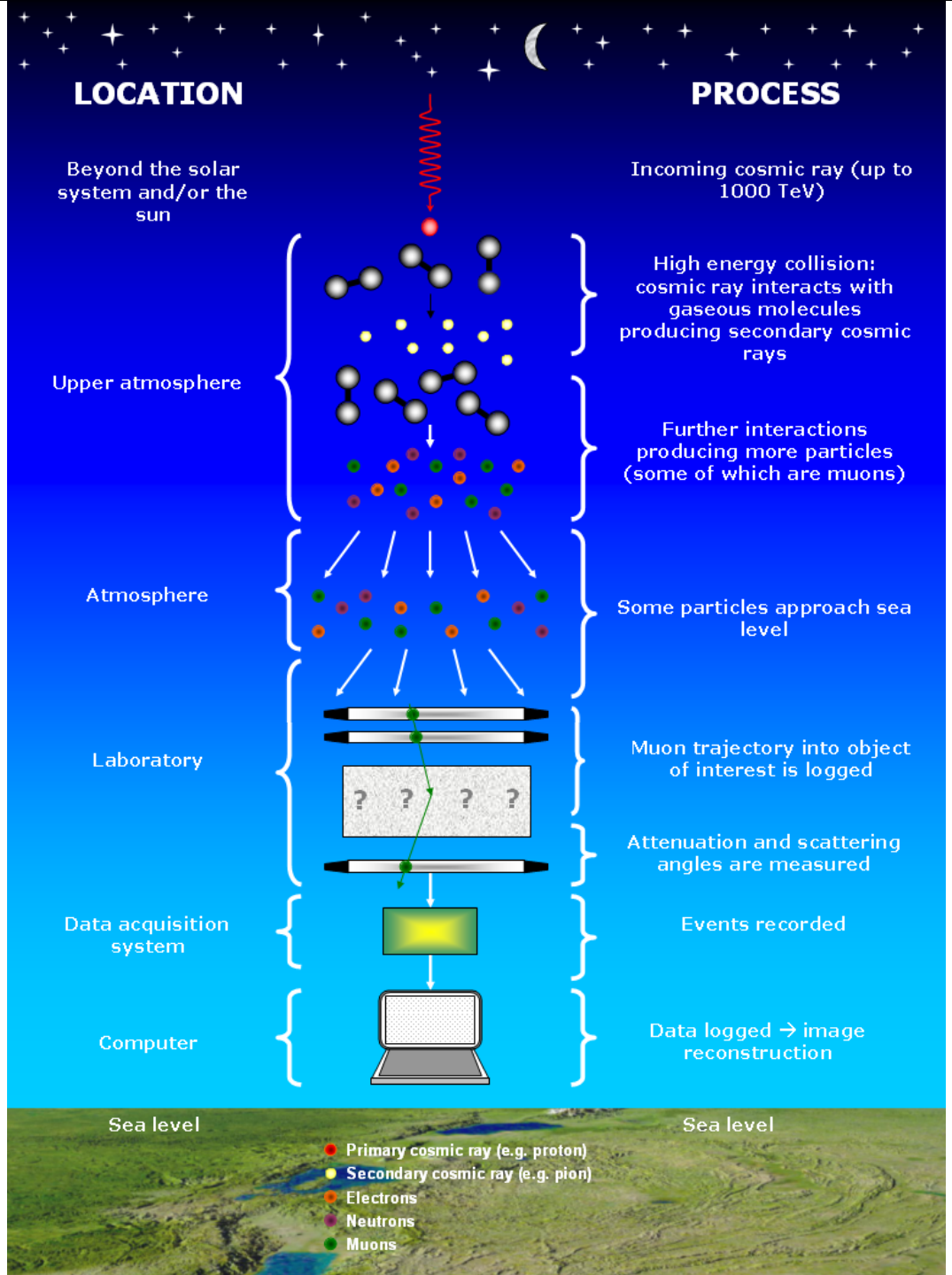
What is the output (enhanced)?



What is the output (enhanced)?

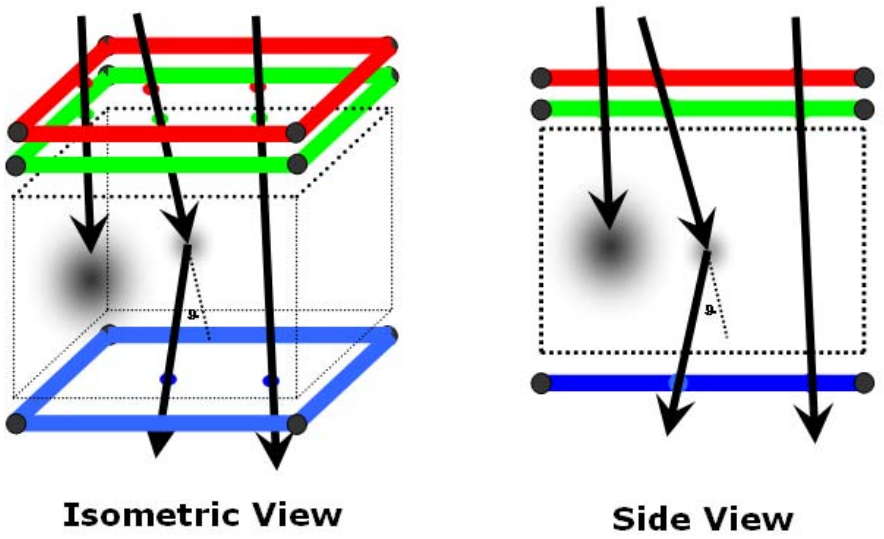


Others Imaging Techniques


LOCATION
PROCESS
Beyond the solar system and/or the sun
Incoming cosmic ray (up to 1000 TeV)
High energy collision: cosmic ray interacts with gaseous molecules producing secondary cosmic rays
Upper atmosphere
Further interactions producing more particles (some of which are muons)
Atmosphere
Some particles approach sea level
Laboratory
Muon trajectory into object of interest is logged
Attenuation and scattering angles are measured
Data acquisition system
Events recorded
Computer
Data logged → image reconstruction
Sea level
Sea level
Primary cosmic ray (e.g. proton)
Secondary cosmic ray (e.g. pion)
Electrons
Neutrons
Muons

Imaging in the nuclear industry

Prototype Muon Camera



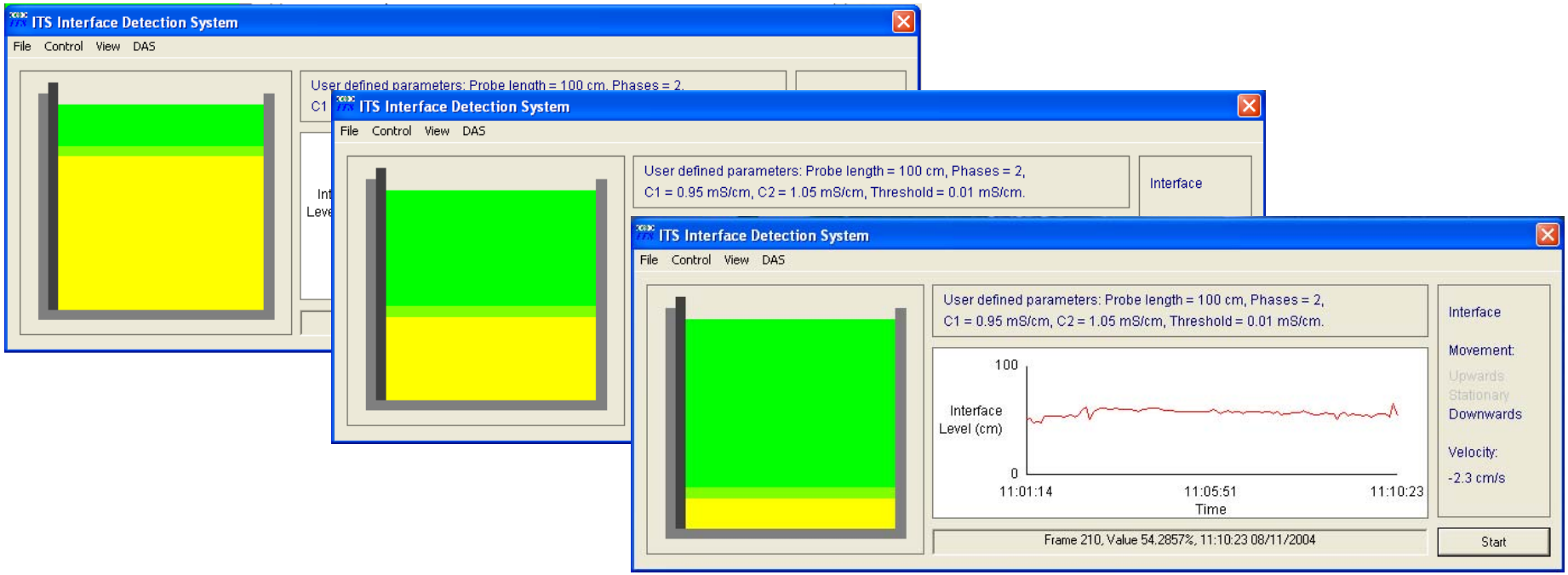
Isometric View

Side View

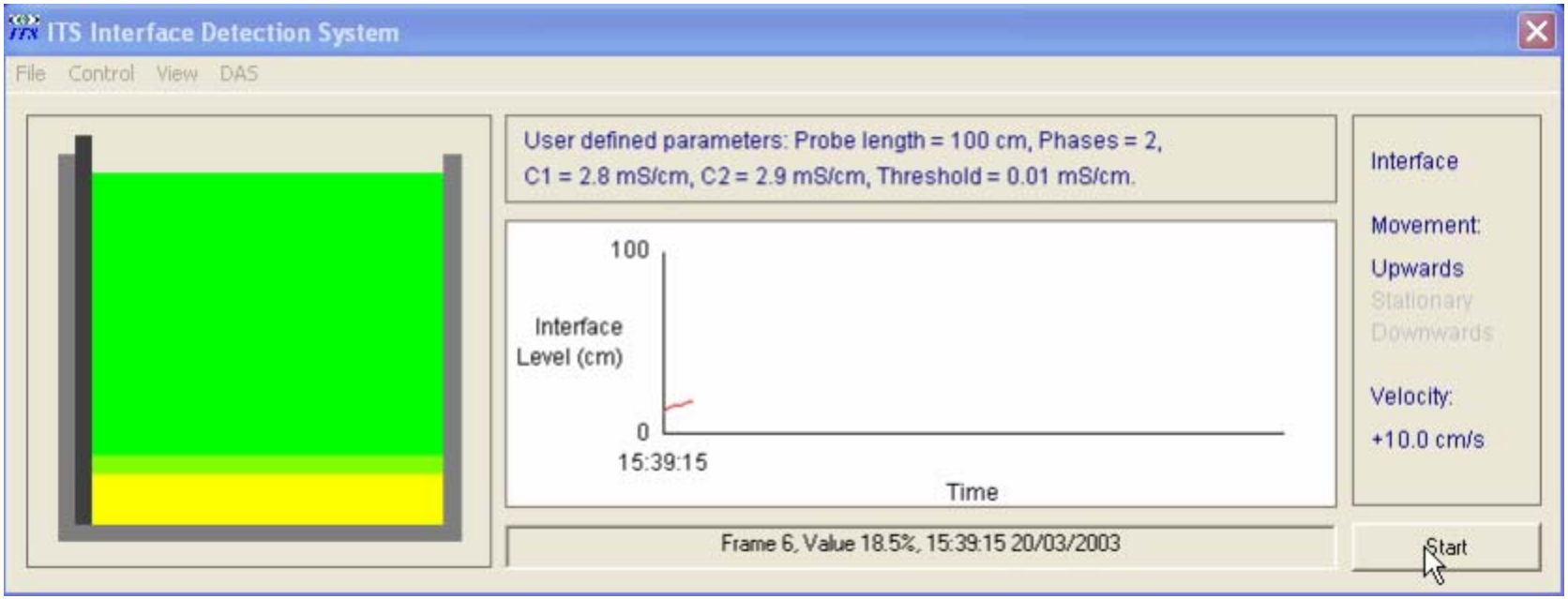
The detector panels are placed around the domain of interest, preferably above and below. The muon trajectories are tracked into the domain of interest where they are either stopped, scattered or unaffected. This provides a means to locate, quantify and characterise the heavy metal (i.e. Plutonium and Uranium) contents of the vessel or silo through spatial muon flux and scattering angle measurements.

Imaging and Remote Sensing Capability

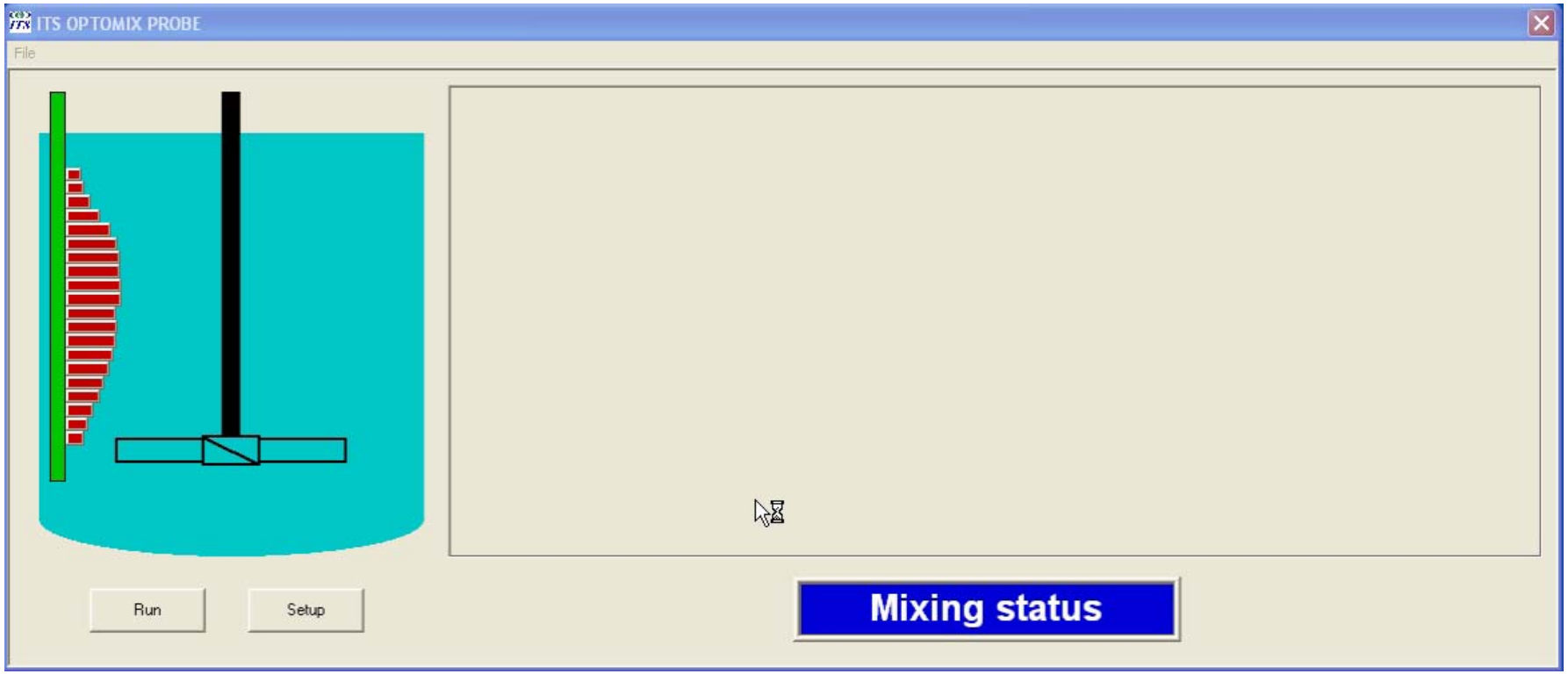
Case Study: Process Measurement, level detection during sludge transfer



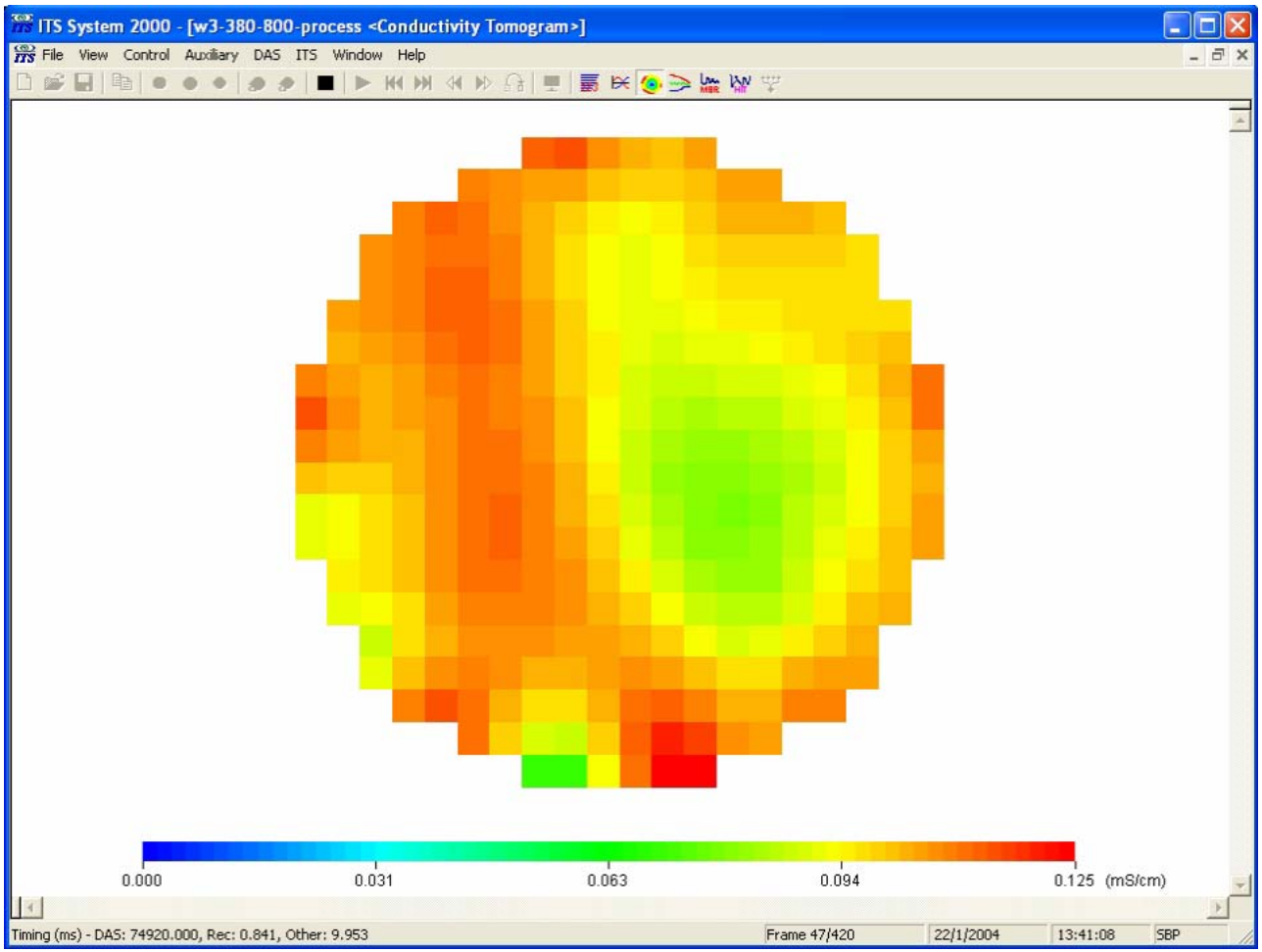
Interface Detection Video



Mixing Video



Filtration Video



Drift Flux CFD

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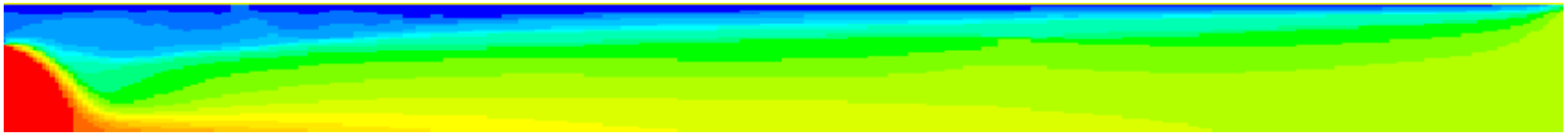
Glass Particles in Model Settling Tank



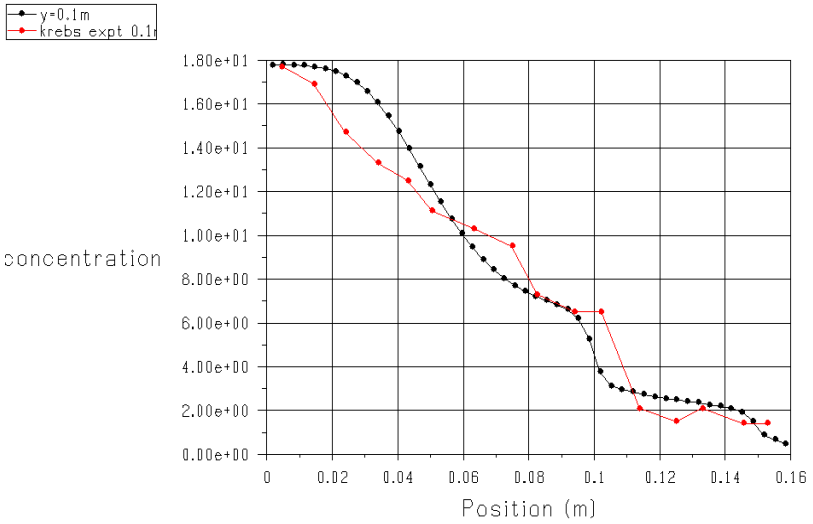
Total concentration (red ~ 19 kg/m^3)

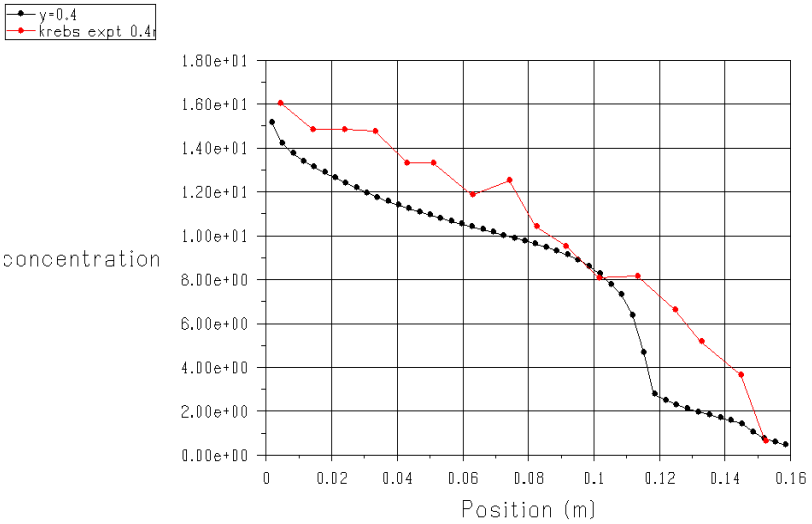
Concentration in 20-30 μm range.

Concentration in 60-70 μm range.

Concentration in 90-100 μm range.

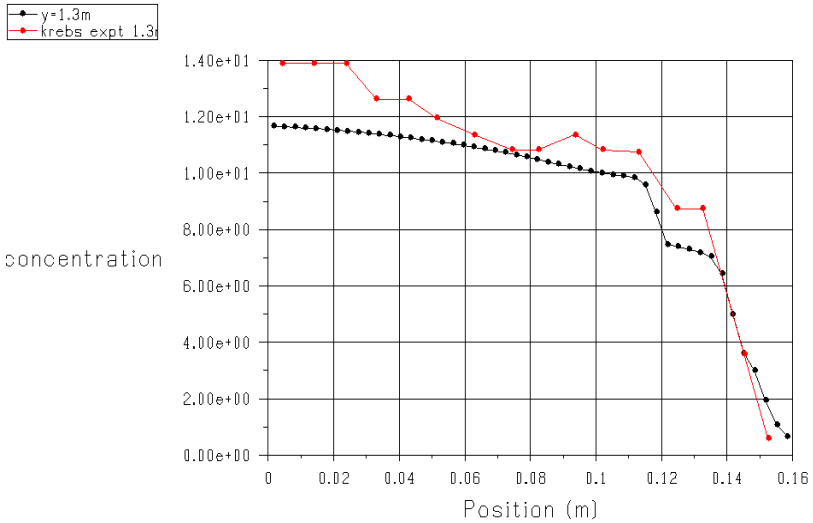
Concentration in Model Settling Tank

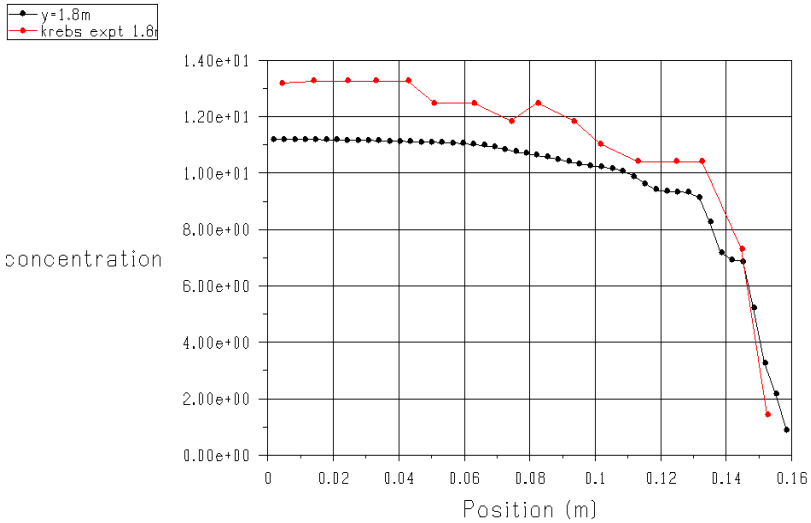




Total concentration at 0.1m along tank (left) and 0.4m along tank (right). Red is experiment, black calculated.

Concentration in Model Settling Tank



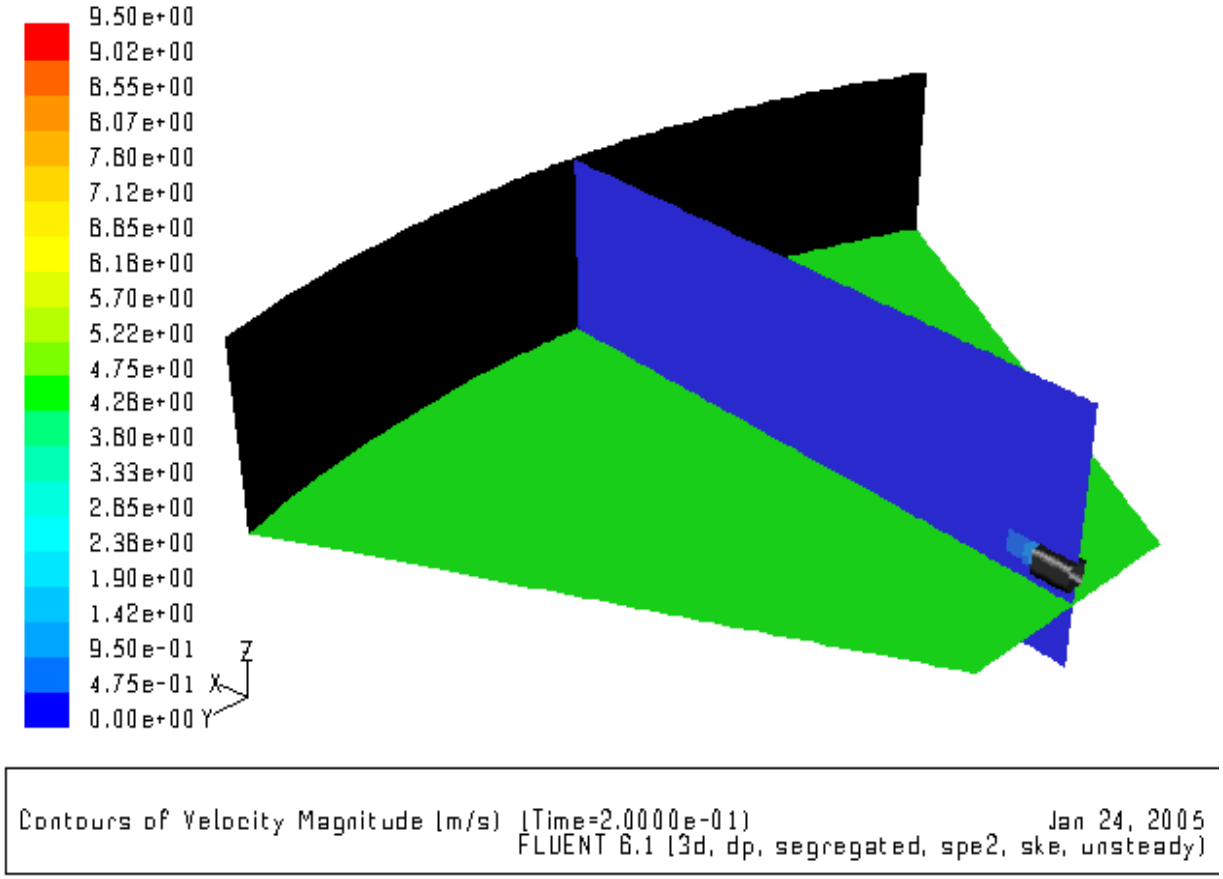


Total concentration at 1.3m along tank (left) and 1.8m along tank (right). Red is experiment, black calculated.

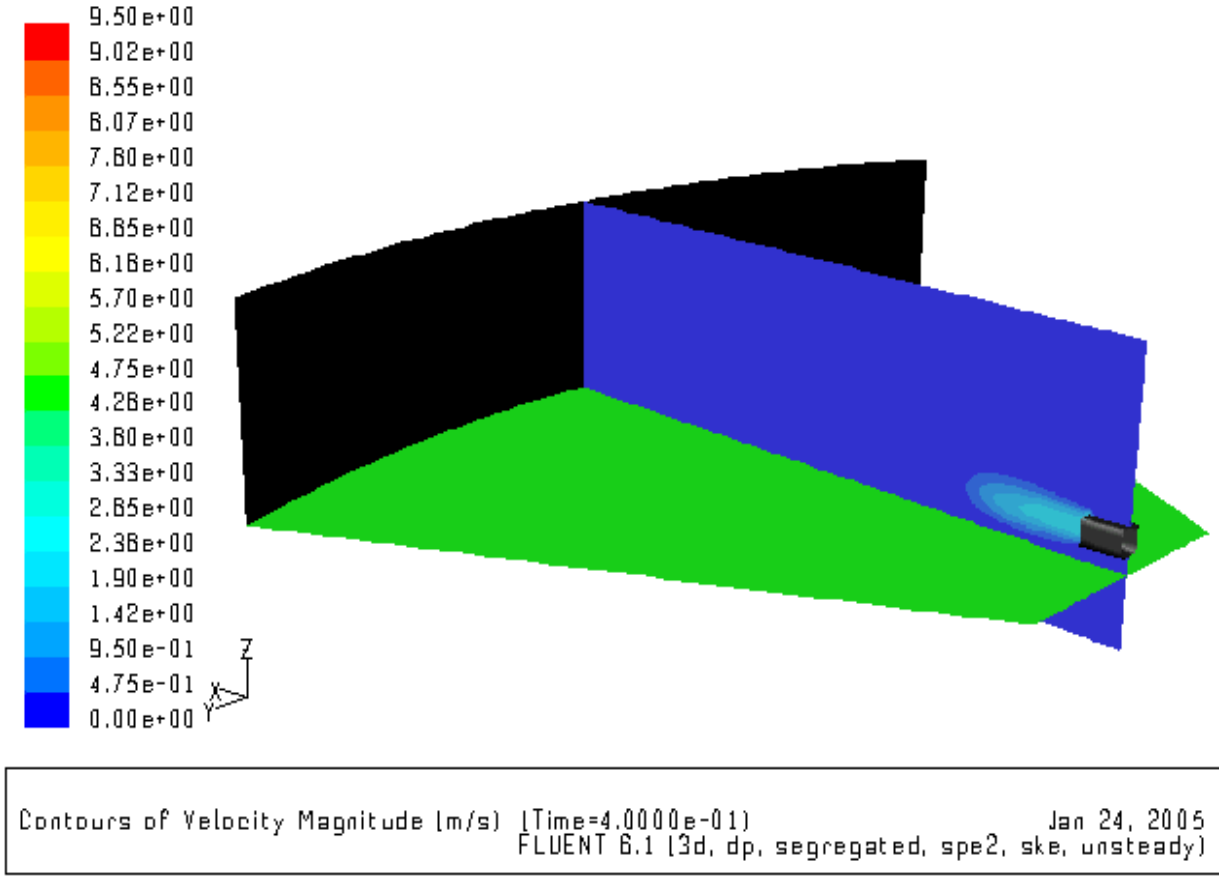
Glass Particles in Settling Tank - Scalars

Evolution of concentration over first 85 seconds.

Sludge Erosion (Horizontal Jet - SAGE226)



Sludge Erosion (Horizontal Jet - kaolin)



Windscale Pile 1 Safety

- **The Challenge**

To show that the unlikely event of self-heating due to uranium hydride oxidation in the core of Windscale Pile 1 will not lead to a fire.

To enable a reduction in the cost of surveillance and emergency response cover.

To enable physical intrusion into the core, leading to cost effective decommissioning options.

Windscale Pile 1 Safety

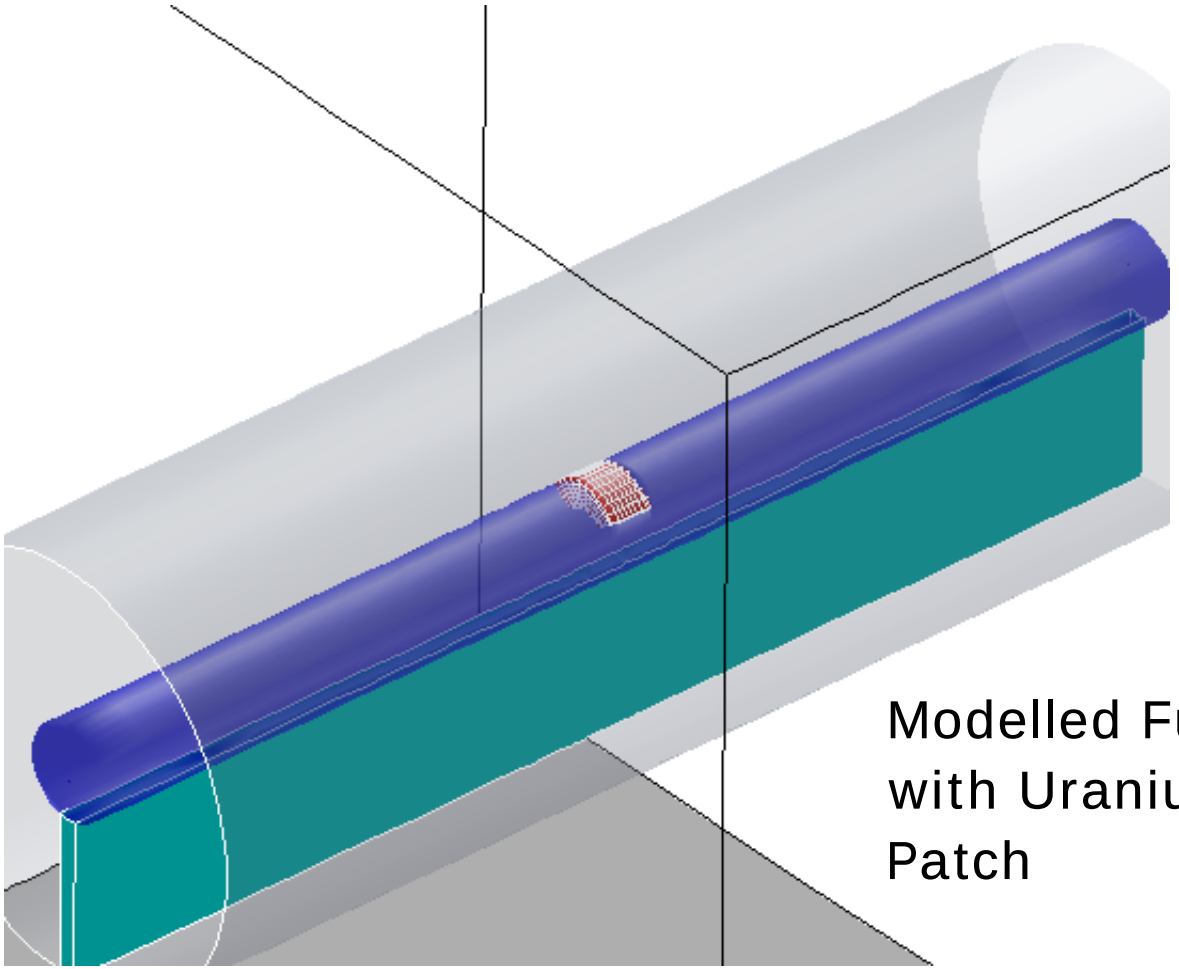
- **The Solution**

Using Computational Fluid Dynamics (CFD) technology and the latest data available for the chemistry of hydride:

The behaviour of the core was predicted under quiescent and accident scenarios;

Rigorous examination of the work was carried out, being reviewed by national and international experts.

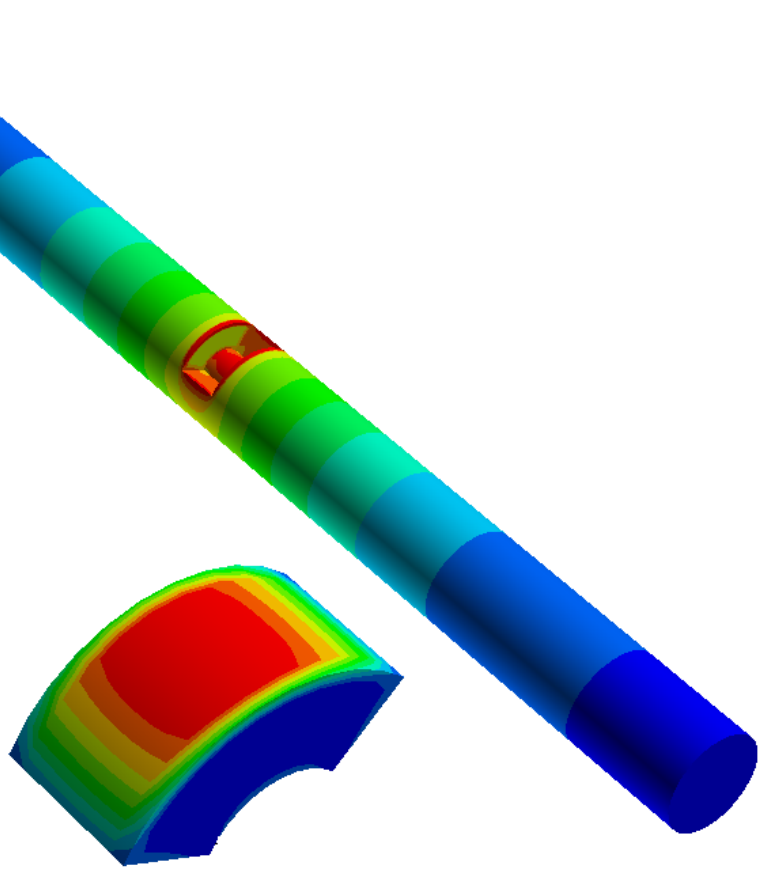
Windscale Pile 1 Safety



Modelled Fuel Element with Uranium Hydride Patch

Windscale Pile 1 Safety

Predicted hydride and fuel element temperatures



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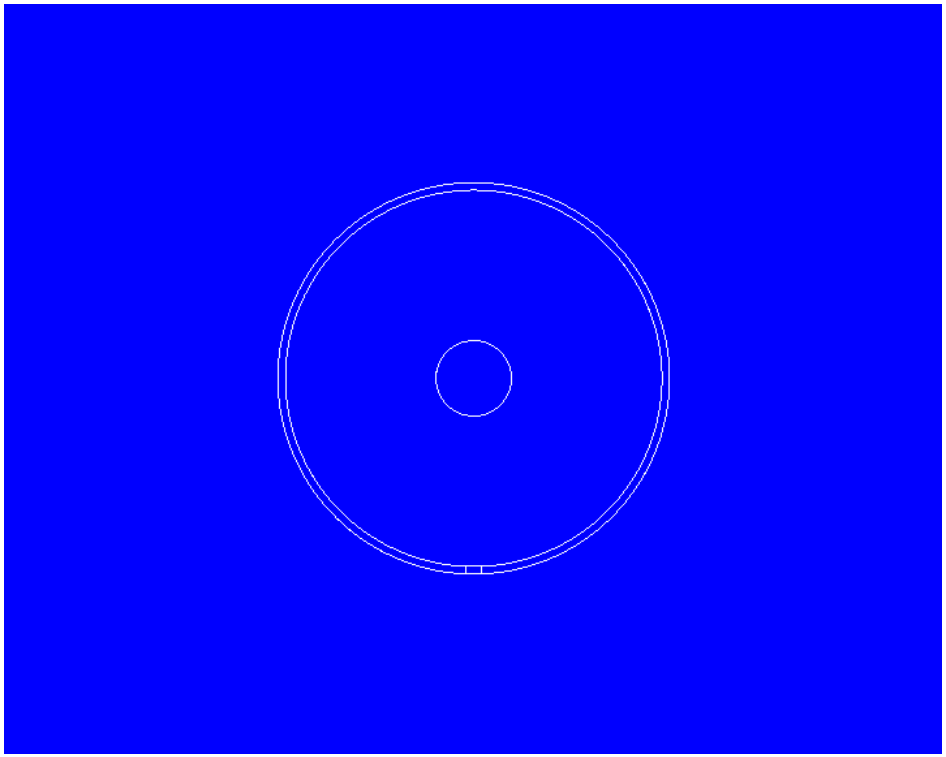
Additional work has now included the presence of stored energy in the graphite core:

Predicted stored energy power density in graphite surrounding a fuel channel



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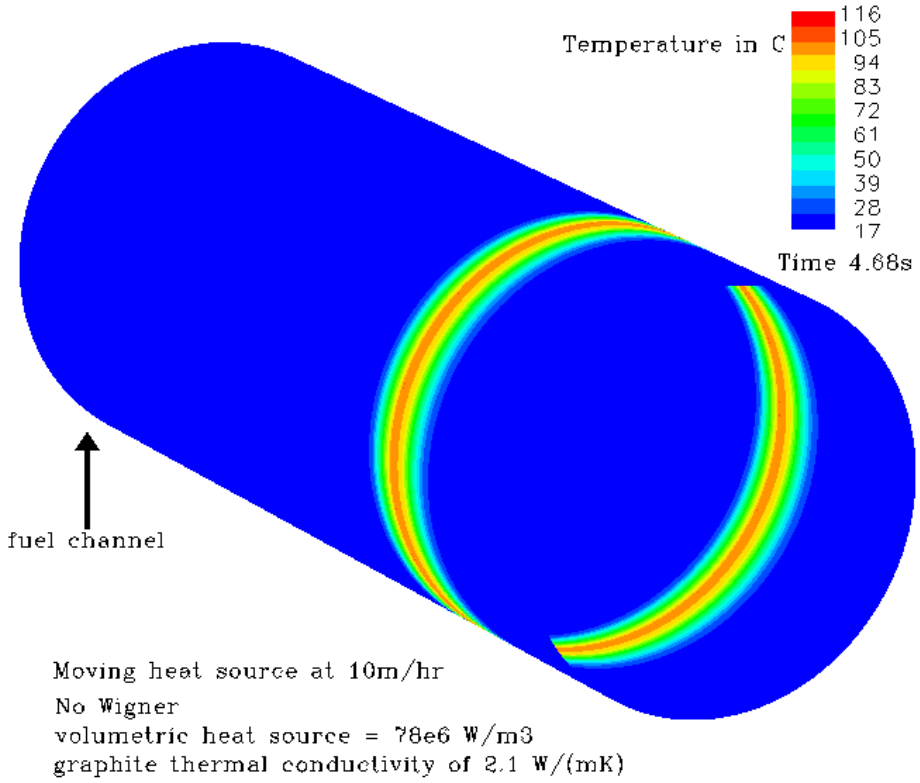
Moving heat sources have been represented for decommissioning:



Predicted fuel channel wall temperature distribution

Windscale Pile 1 Safety

- **The Benefit**

Reassessment of current safety management arrangements leading to a saving of thousands of pounds per year.

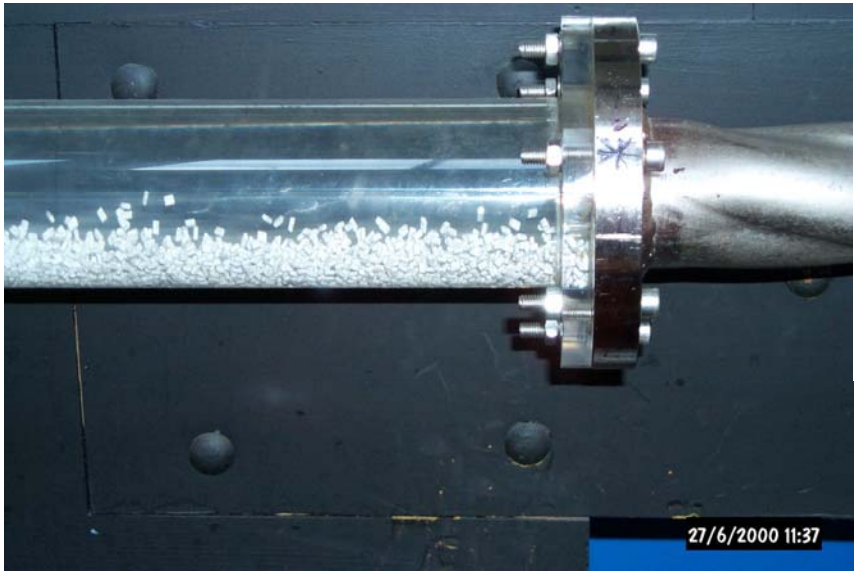
The work has shown that large quantities of inert gas are not required for decommissioning, saving millions of pounds and making the process safer and quicker.

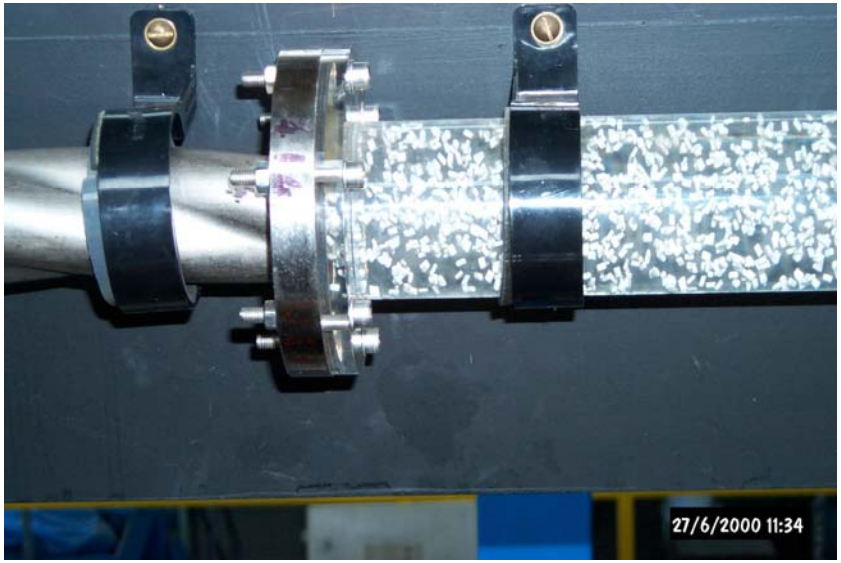
Swirly Flow

Settling, Pumping Power and Wear

- Circular section encourages particles to collect at the bottom of a pipe. Fluid velocity must be high enough to prevent this
  - N.B. pumping power $\propto$ velocity^3
- High velocity causes pipe wear
  - impact wear
  - Ploughing wear
  - N.B.
    wear per tonne $\propto$ velocity$^{2.5}$
    wear per annum $\propto$ velocity$^{3.5}$

Slurry Transfer

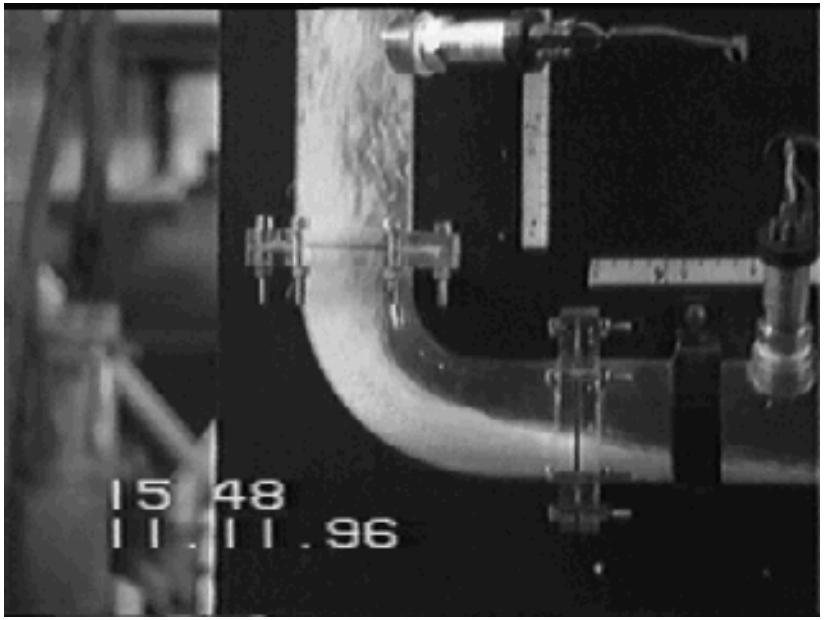




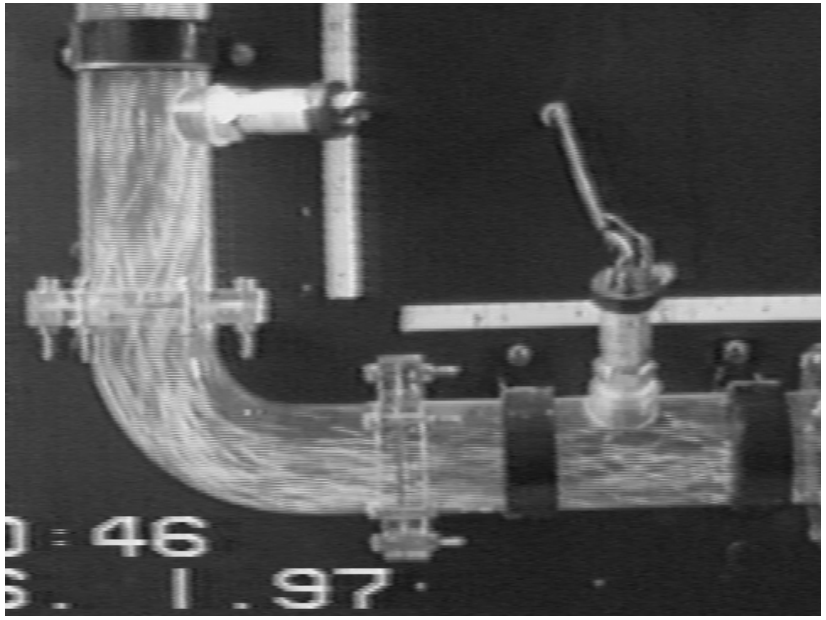
Slurry Transfer

Slurry Transfer

Slurry Transfer



Original



Swirl

Imaging and Tomography at Sellafield in the UK

Dominic Rhodes & Tim Tinsley
Nexia Solutions

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Nuclear expertise intelligently applied