



AIChE Spring Meeting
Orlando, FL
23-27 April 2005

On the Development of an Electrical Tomographic System for Monitoring the Performance of a Heavy Metal Precipitation Step during Nuclear Fuel Reprocessing

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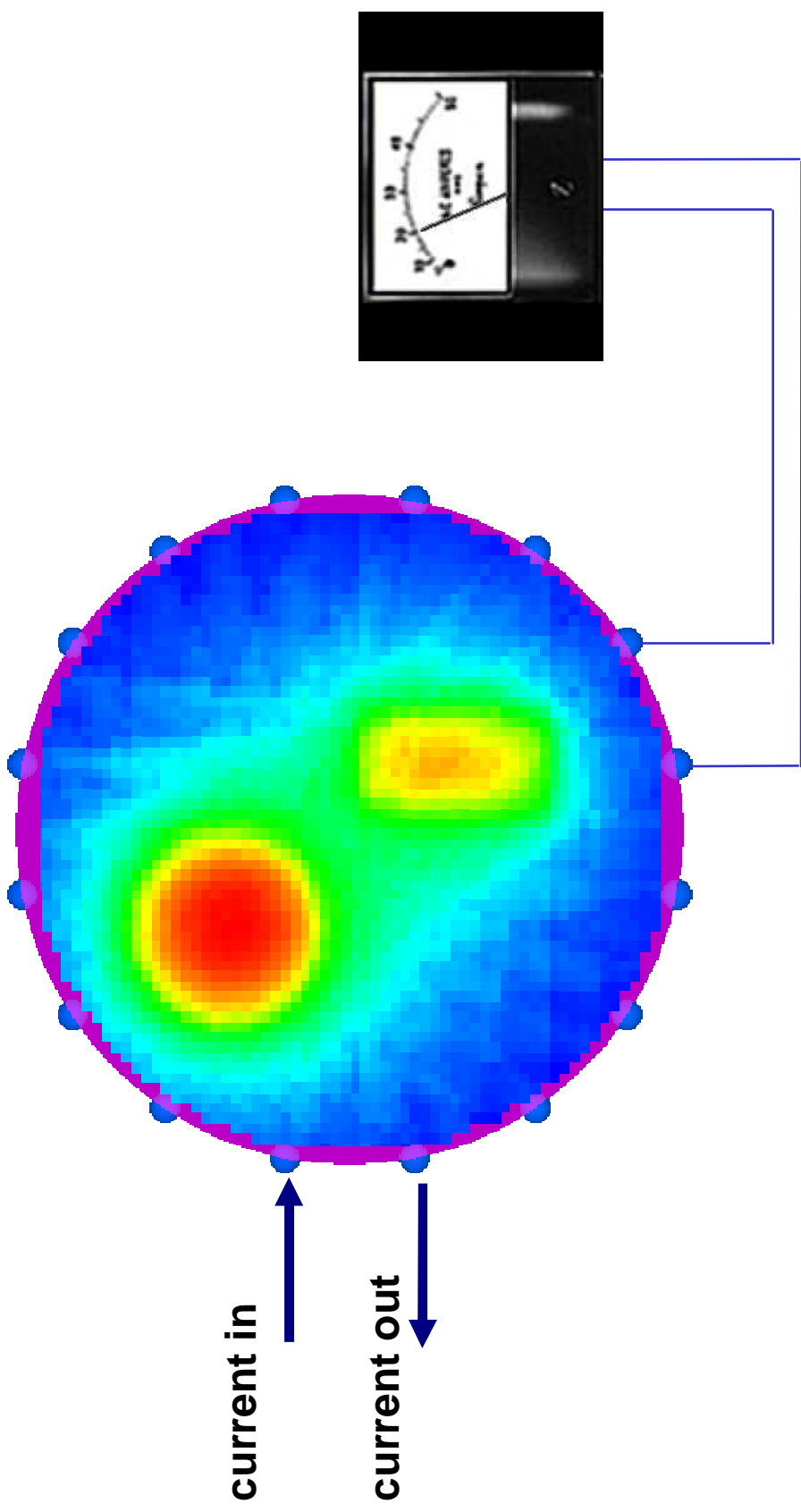


Contents

- Principles of ERT
- THORP
- Feasibility Trial
- Development Programme
 - Sensor
 - Hardware
 - Software
- Testing



ERT Principles



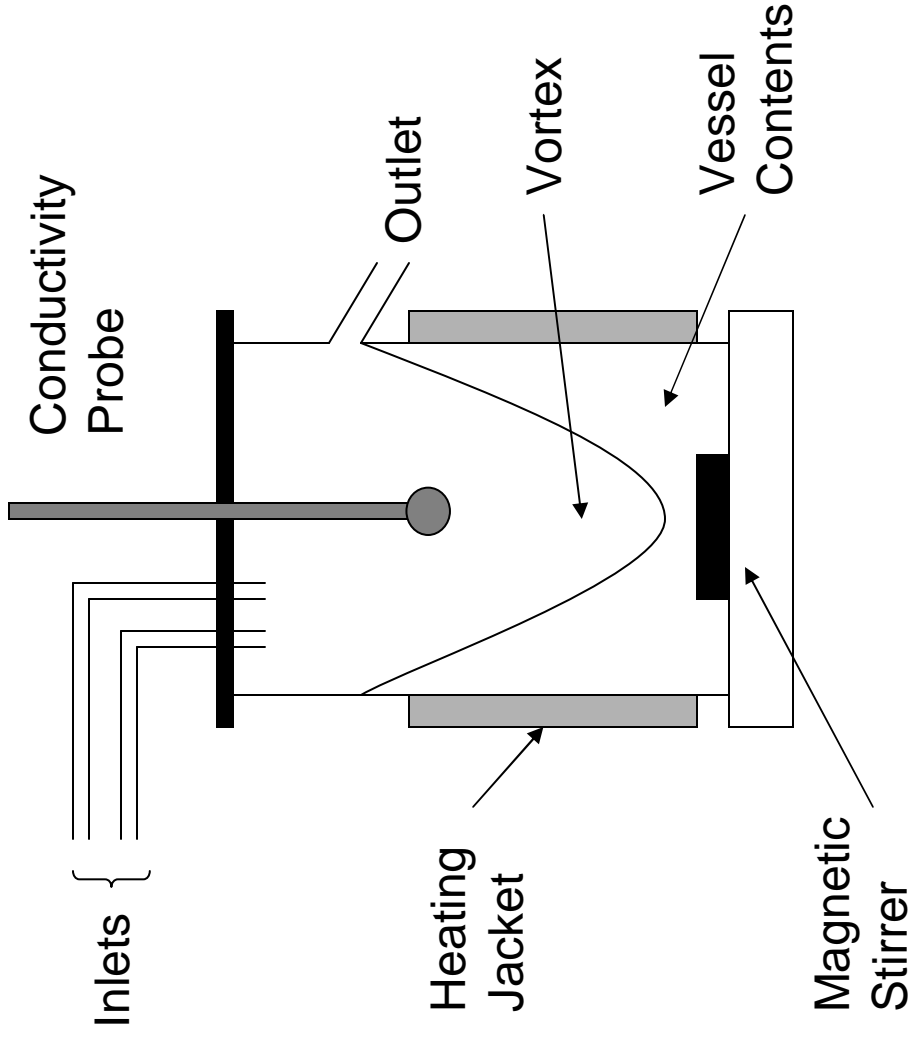


Thermal Oxide Reprocessing Plant **[THORP], Sellafield**

- Includes continuous stirred tanks into which reactants are added to produce a heavy metal precipitate
- Stirring must be continuous and of the right intensity to ensure the precipitation process proceeds as intended
- Tanks are operated with a deep vortex, the presence and depth providing valuable information on the performance of the precipitation step



Precipitation Vessel



- Glass vessel with metal heating jacket
- 2 overhead feeds (metal salt in nitric acid and an organic acid)
- Magnetic stirrer – 400 rpm
- Product overflow
- Standard conductivity probe located at top of vortex



Feasibility Trial

- Replica vessel at University of Leeds
- Filled with tap water
- Fitted with temporary 'PCB' sensor
- Measurements collected using standard ITS P2000 in linear measurement protocol

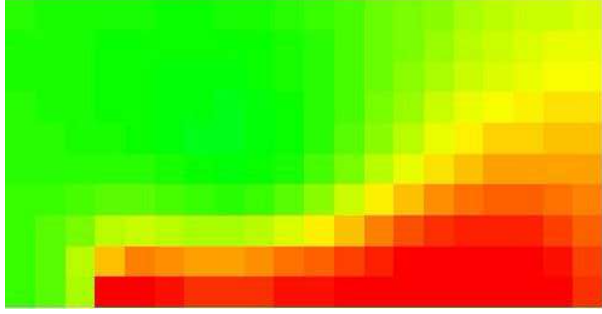




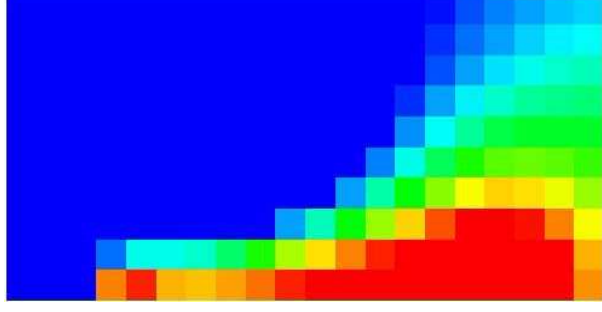
Feasibility Trial - Summary



200 rpm



300 rpm



400 rpm

Conclusion

- Successful detection of vortex in tap water

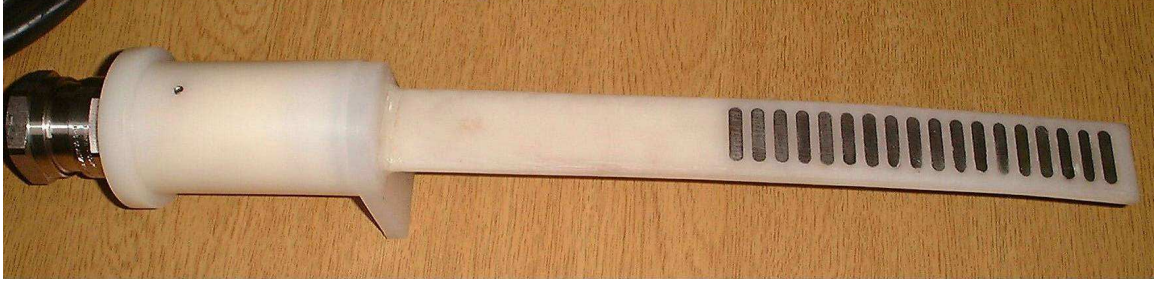


Some of the Challenges

- Process liquor – 3.5M nitric acid ($\sigma \approx 600$ mS/cm), radioactive and abrasive
 - Impact on quality of electrical measurements
 - Sensor materials of construction
- Plant layout
 - instrumentation 30 m away from sensor
 - PC 30 m from instrumentation
- Software / Data Outputs
 - User friendly / simple user interface
- 24/7 operation required

Sensor Development

- Resistant to:
 - High chemical reactivity
 - Radiation
 - Abrasion
- Minimise disturbance of the flow regime
- Polyvinylidene Fluoride (PVDF) and 316L Stainless Steel
- Electrodes fitted into precision laser-cut recesses and attached using micro screws
- Single strand conductor crimped to back of electrode and laid in laser-cut channel which is then filled with molten PVDF
- Top section re-shaped to allow for easier handling
- Cables sheathed in Viton





Instrumentation design and manufacture



Hardware Development

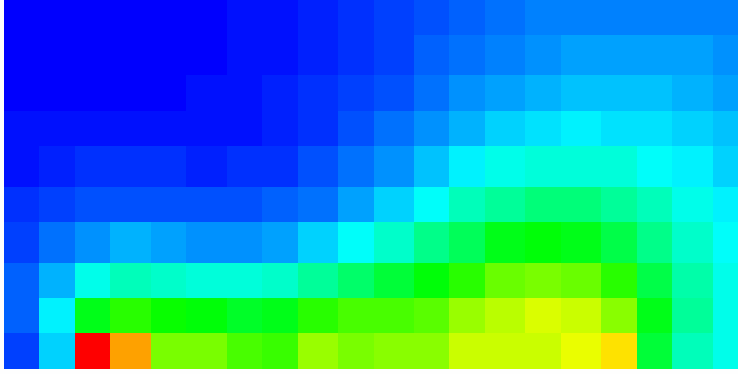
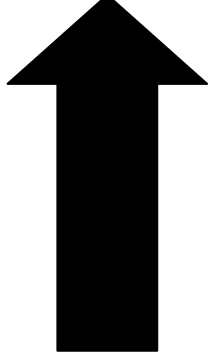
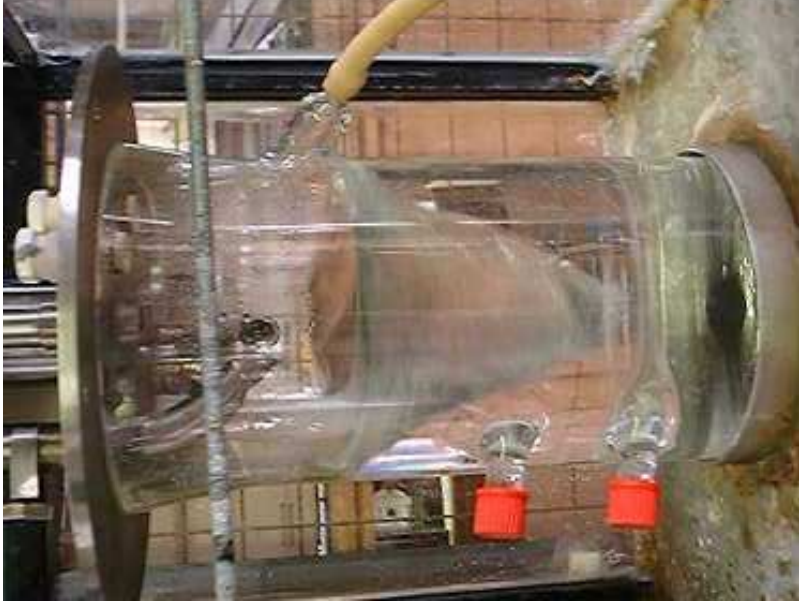
- Based on ITS P2000 ERT instrumentation platform
- Pre-amplifier circuit was fitted to measurement board
- Full impedance measurements
- Lower current injection frequency
- Optimisation of hardware delay times
- Conductivity range tested up to 750 mS/cm



Software Development and Data Interpretation



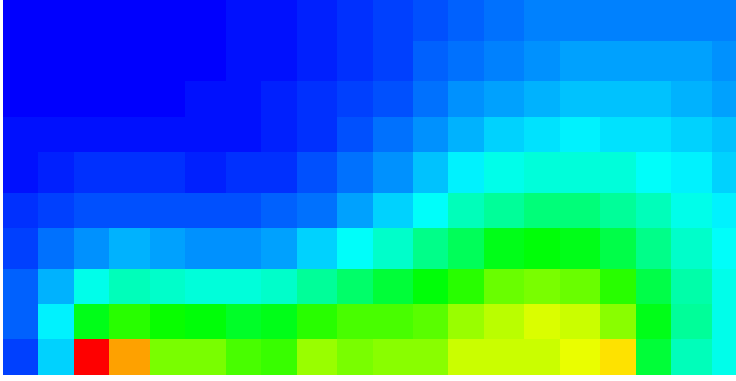
Vortex Raw Image



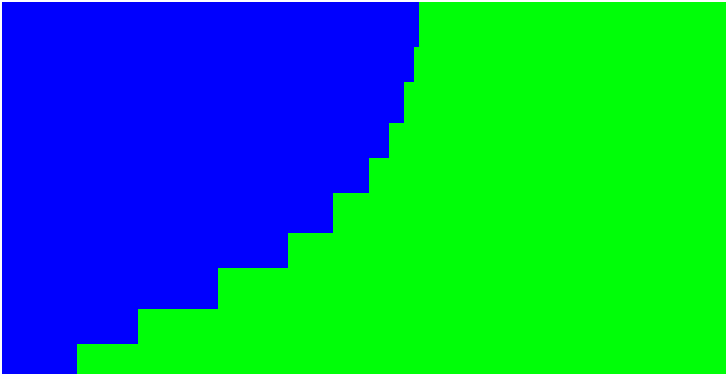


'Processed' Vortex Image

- Reconstructed image displayed on a colour-scale to show conductivity range across image
- Mean conductivity of 10 columns calculated [0,1]
- Represents liquid content at 10 axial positions
- Plotted as bar chart with green colour to indicate liquor and blue to indicate air



Raw Image

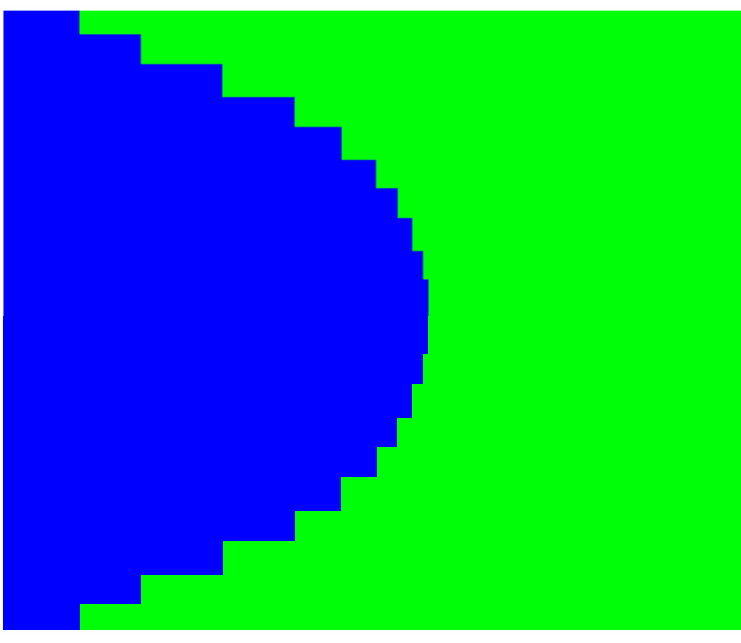
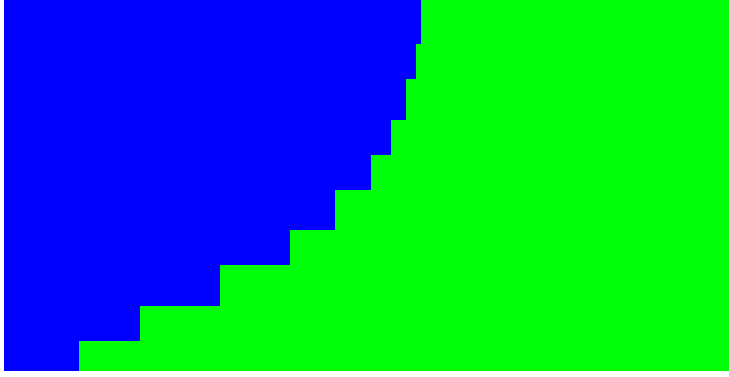


Processed Image



Vortex Display

- Flip image around vertical axis
- Merge 'mirror' images to obtain complete vortex image





Vortex Finder User Interface

The screenshot displays the Vortex Finder software interface. At the top left, the title bar reads "ITS Vortex Finder Version 3.1 (c) 2004" and "File Engineer". The interface is divided into several sections:

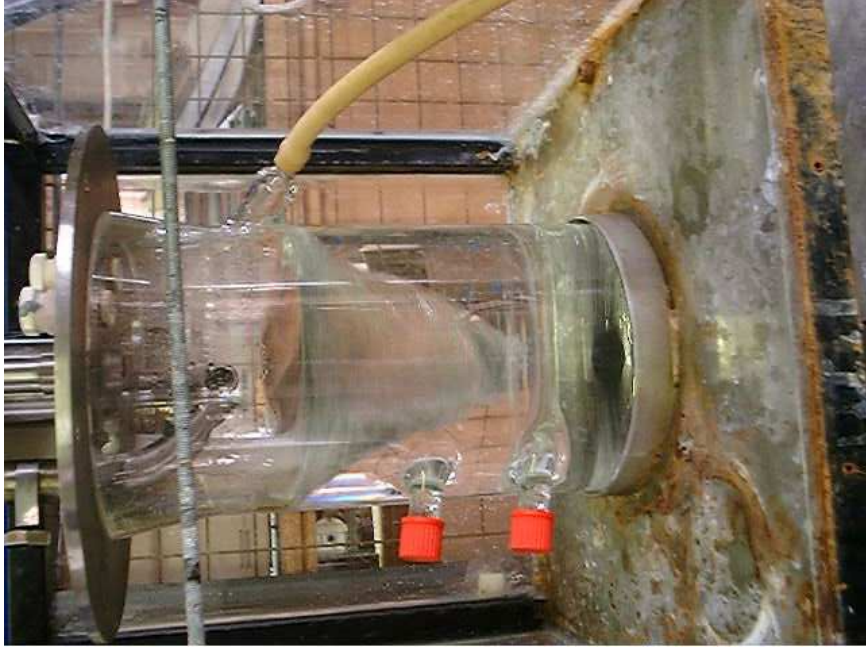
- Vortex image:** A 2D heatmap showing a vortex core in red, surrounded by yellow and green regions.
- Interface level trace:** A line graph showing the vortex level over time, with a red horizontal line indicating the current level.
- Current status:** A vertical bar with three segments: red (labeled "Shallow"), yellow (labeled "Normal"), and blue (labeled "Deep"). A horizontal line indicates the current status is "Normal".
- Control Panel:** Includes a "Start" button, a "Lower threshold" slider set to 20, an "Upper threshold" slider set to 80, and a "No. of incidents" field set to 5. The "Time of the last incident" is 21/05/04 19:08:33.
- Frame Information:** A text box displays "Frame 175: Level 42, Abnormal 0, Shallow 5, Deep 0".
- Buttons:** A green "OK" button is located at the bottom right.

Annotations with arrows point to the following elements:

- Vortex image** (points to the 2D heatmap)
- Interface level trace** (points to the line graph)
- Current status** (points to the vertical bar)
- Lower threshold** (points to the 20 slider)
- Upper threshold** (points to the 80 slider)



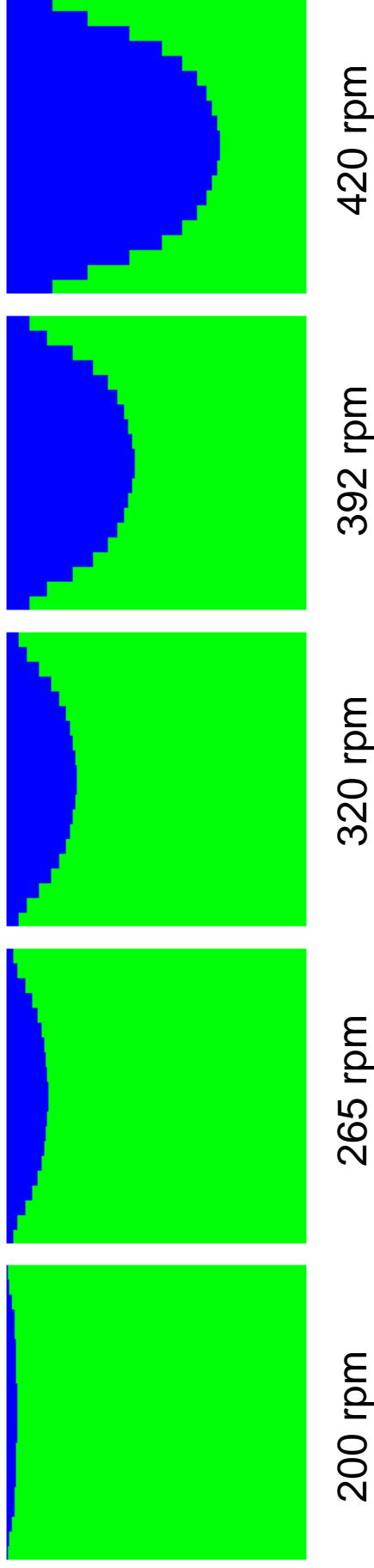
System Testing



- Replica vessel at University of Leeds
- Filled with 6M nitric acid
- Fitted with sensor and 30 m cable between sensor and P2000*
- Measurements collected using ITS Vortex Finder software



System Testing



Steady state vortex images at increasing rates of agitation

- Client acceptance test successfully completed
- System delivered to client for plant installation and trial



Acknowledgements

- **BNFL / Nexia Solutions**
 - Martin Wright, Dominic Rhodes, Steven Stanley
- **University of Leeds**
 - Mi Wang, Mark Bennett
- **Industrial Tomography Systems**
 - Changhua Qiu, Ken Primrose



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