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Tomoflow R5000

The ***Tomoflow R5000*** is a non-intrusive multiphase flow analysis system based on Electrical Capacitance Tomography (ECT). With a Tomoflow R5000 package including ***Flowan*** software you can:

- Image flows of non-conducting fluid/fluid and fluid/solid mixtures,
- Measure the velocity at any point or over any zone in the flow-field,
- Investigate the details of flow structures,
- Measure the flowrate of a dispersed phase as a function of time and space,
- Measure the volume of moving structures within the section.

The Tomoflow R5000 multiphase flow analysis system consists of a Capacitance Measurement Unit (CMU), real-time data acquisition and image reconstruction software, and off-line multiphase flow analysis software.

Capacitance Measurement Unit - TFL R5000

The Tomoflow R5000 is a very-high-speed multiplexed Capacitance Measurement Unit (CMU) which can operate at excitation frequencies in the range 1 to 10MHz. It can be used for imaging, analysing and measuring flows of a mixture of two non-conducting materials and is based on the use of Electrical Capacitance Tomography. Data can be captured at rates up to 5000 image frames per second. For operation at lower frame rates, the measurement noise level can be improved by averaging measurement frames at the expense of the image frame data rate. Typical measurement noise levels at 500 fps. are 0.02fF rms.

The CMU contains 16 independent capacitance measurement channels and a further 16 driven guard channels. The unit is fully-software-configurable and can operate with up to 16 electrodes in a single measurement plane (for operation as a high-resolution ECT imaging system) and up to 8 electrodes in each of 2 separate measurement planes (for operation as a high-speed flow analysis system). A wide range of measurement protocols to be configured. For example, multiple electrode excitation can be used to improve measurement sensitivity in addition to the normal single electrode excitation mode.

The TFL R5000 is intended for use with a range of multi-electrode capacitance sensors containing sets of driven guard electrodes and can image either the pure capacitive (loss-free) component of the sensor contents or the conductive (lossy) component. This additional information allows the moisture content and distribution of the material inside the sensor to be measured.

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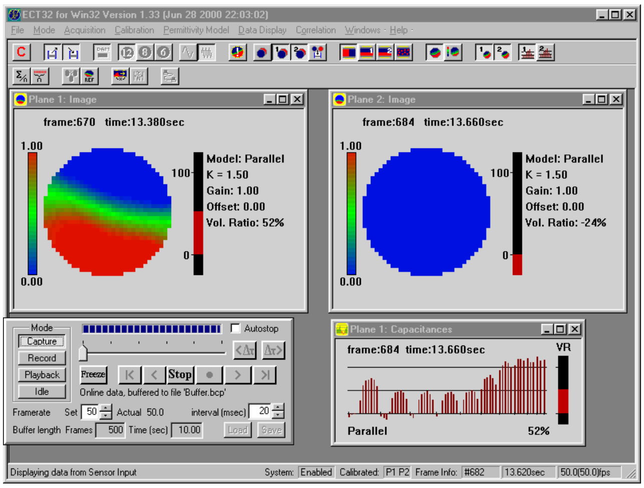
Image capture and reconstruction software

The TFL R5000 system is supplied with a comprehensive suite of control and analysis software which includes the following:

ECT32-3 Control and Imaging software



ECT32-3. ECT32-3 is a comprehensive on-line software suite for controlling and processing data from Tomoflow and PTL ECT systems. The software runs on the Windows operating systems. The images can be shown on the screen in real-time, then recorded and played back at user-defined speeds. Data files can be used for flow analysis using ***Flowan****.

Sensor Toolkit

Sensor Toolkit is the normal mode of operating the CMU in flow measurement and analysis mode. It produces stored data files which can be read and processed by the Flowan flow analysis software (see below).

IU2000. The IU2000 Image Utility sofware is an extensive set of off-line tools for processing and viewing captured ECT image data.

Matect. Matect software is a set of off-line Matlab utilities for displaying and modifying sensitivity maps and for generating images using these maps and transforms.

Makemap. Makemap software suite calculates accurate sensitivity maps for circular ECT sensors with either internal or external electrodes.

C/KTool: This software generates sensor characteristic files from sets of calibration files and allows any non-linearities in the sensor characteristics to be corrected.

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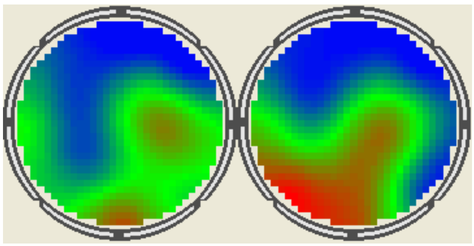
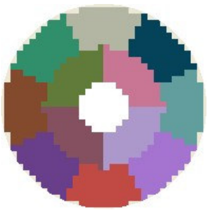
Flowan off-line Multiphase Flow Analysis Software

Image flows of fluid/fluid and fluid/solid mixtures

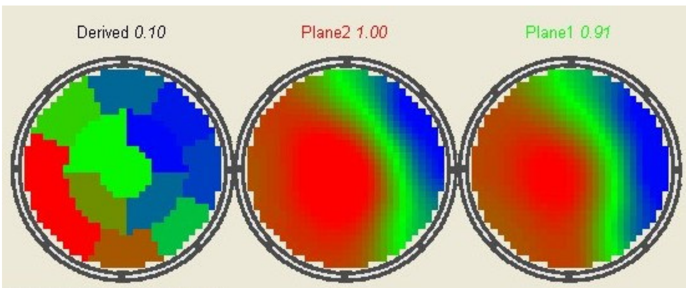
Data from the Tomoflow R5000 system may be saved to file for off-line flow structure analysis using Tomoflow's Flowan multiphase flow analysis software. Example results are given here for several flow conditions in a 50mm diameter pipe. The sensor used is a twin-plane unit with 3cm long electrodes axially separated by 10cm driven guard electrodes. The sensor is shown in the photograph mounted on a 50mm perspex pipe ready to be mounted in the test rig.



Images of flows are shown as circular maps with a grid of 32x32 pixels using a colour scale from blue (pixel empty) to red (pixel full). The example alongside shows the arrival of a slug front in a horizontal flow of plastic pellets in air. In this case the leading plane is on the right. Flowan automatically establishes the direction of flow .

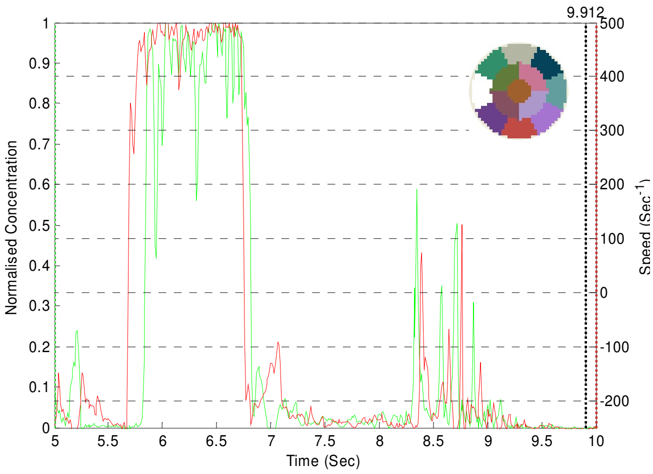


Each image plane can be divided into a number of zones – arranged appropriately for the flow conditions. The example alongside shows a typical 13 zone division.



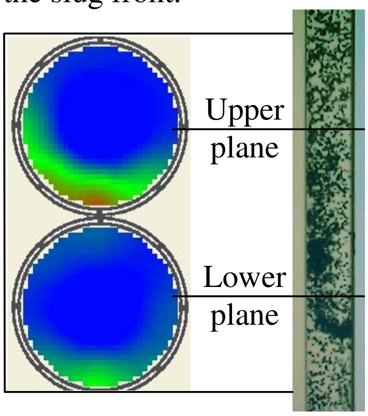
Flowan can calculate a number of average parameters for each zone, including average concentration and average flowrate. The example shows average concentration (left) over several 10s of seconds, compared with the instantaneous images (middle & right).

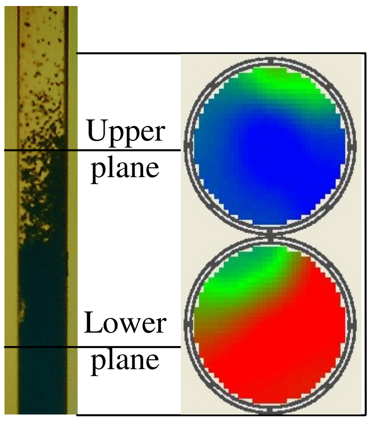
For each zone of each image plane the concentration may be plotted against time. The example below shows the area-average concentration in zone 2 (left hand zone highlighted in white) of plane 1 in red, and zone 2 of plane 2 in green. The flow shown is an upward flow of plastic pellets blown by air at about 2 m/s. The average flowrate of plastic beads is 750kg/hr upwards.



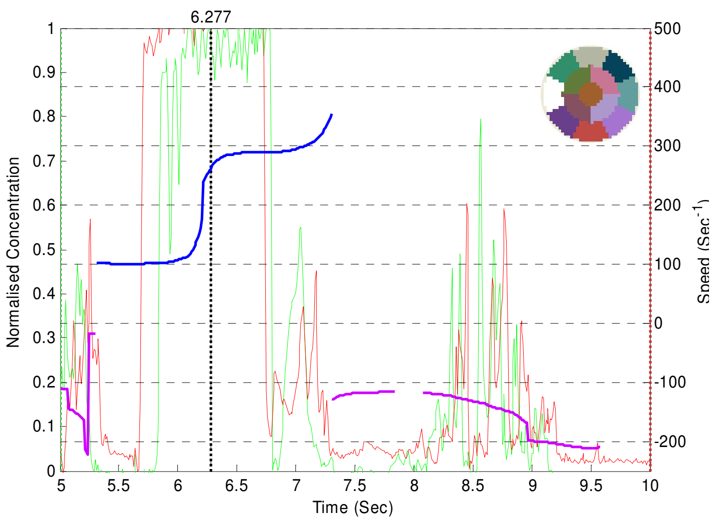
The first half of the graph shows upflow - an upward-going slug with concentration going from near 0 to near 1 in a short space of time at plane 1 (red line) slightly before arrival at plane 2 (green line). It can be seen that the rear of the slug is travelling faster than the front. On the second half of the graph the green line shows concentration events at plane 2 (upper) preceding their arrival at plane 1 (lower plane - red line).

Comparison of high speed photography with the image cross-sections shows that the downward going ‘rope’ of solids (left hand side of page) is on one side of the pipe – which is not obvious from the side-on photography. The diagram on the right hand side of page shows the arrival of the slug front.



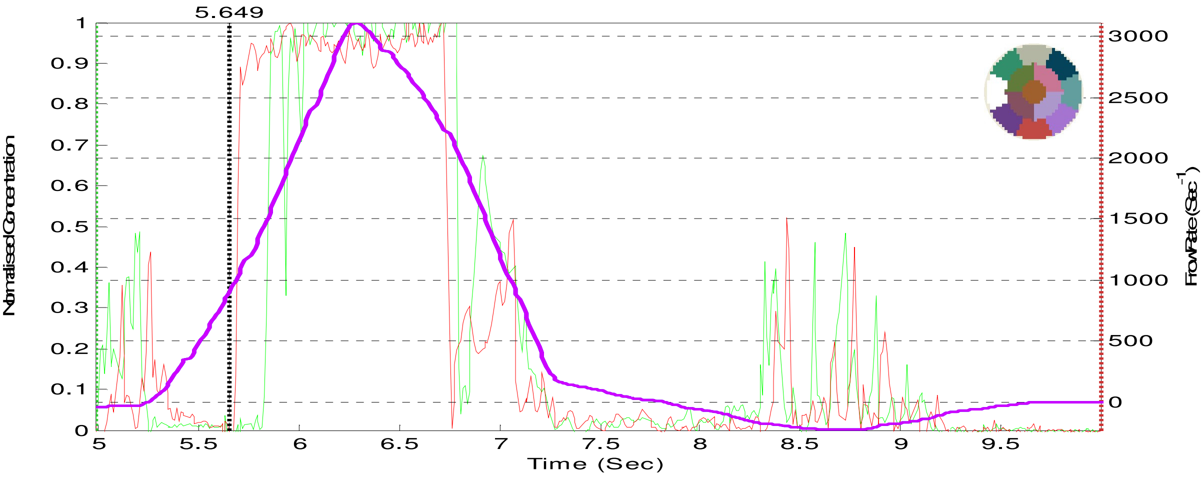


Measure the velocity at any point or over any zone in the flow-field

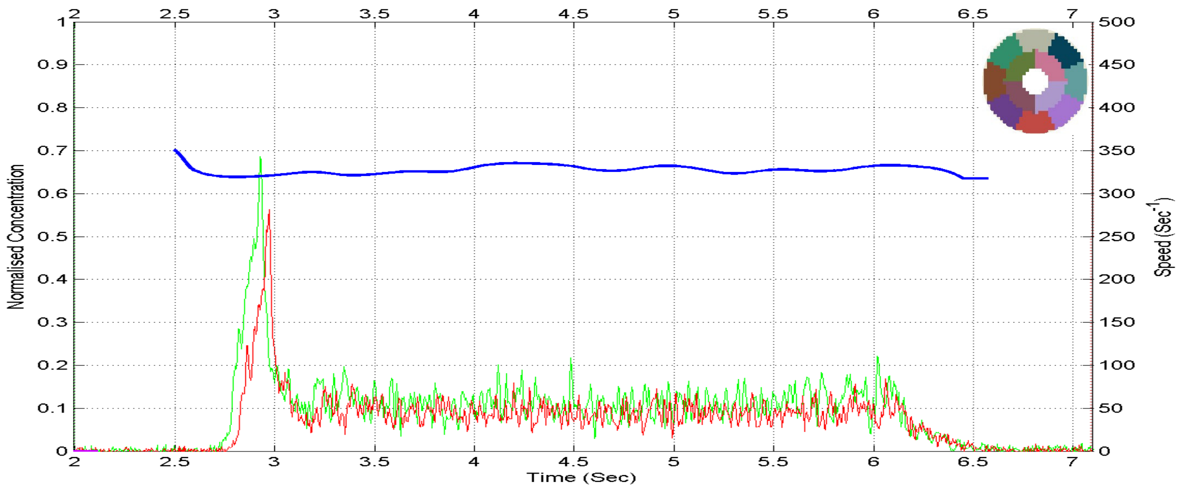


The velocity at each point in time within each zone is calculated by correlating the instantaneous concentration of one plane with the same zone in the other plane. The result is plotted as a second graph with axes in cm/second on the right hand side of the graph. The blue line shows positive velocities (in this case upwards) and the mauve line shows downward velocities. It can be seen in this case that the slug front is moving at 100cm/s bur the tail is progressing at 300 cm/s.

Measure the flowrate of a dispersed phase as a function of time and space



The flowrate within the cross section can be found by integrating the product of the velocity and the concentration at each point in time. This gives the flowrate per zone, and all zones can then be summed to give total flowrate. Total flowrate (cm^3/second) as a rolling 1 second average is shown as the mauve line in the example above. For an average flowrate in this case of 750 tonnes per hour (about $350cm^3$/sec) the peak rate is over $3000cm^3$/sec - almost 10 times the average rate. Such details can be critical in controlling industrial processes.



Comparisons have been made for downward gravity flows through the same 5cm diameter sensor, using plastic beads, small spheres and coffee powder. The results above show the drop of plastic beads from a funnel under gravity. The concentrations at plane 1 and plane 2 are given here for the central zone, together with the velocity (blue line) for that zone. It can be seen that there is an initial plug of beads which pass between the two planes, dispersing slightly as it does so. The velocity is fairly constant since the beads are dropping freely under gravity.

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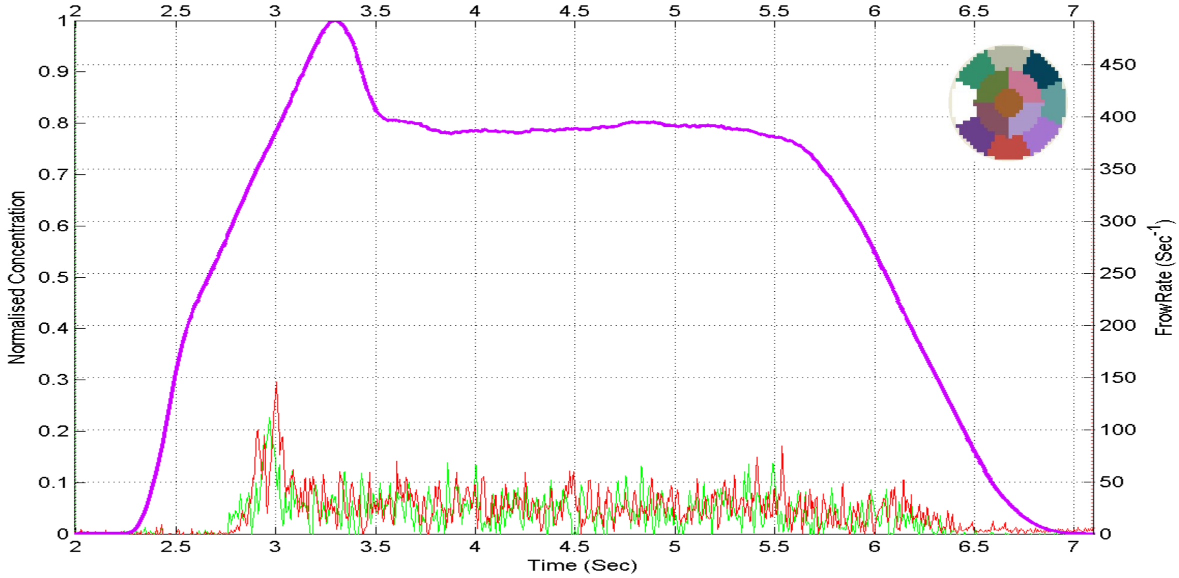
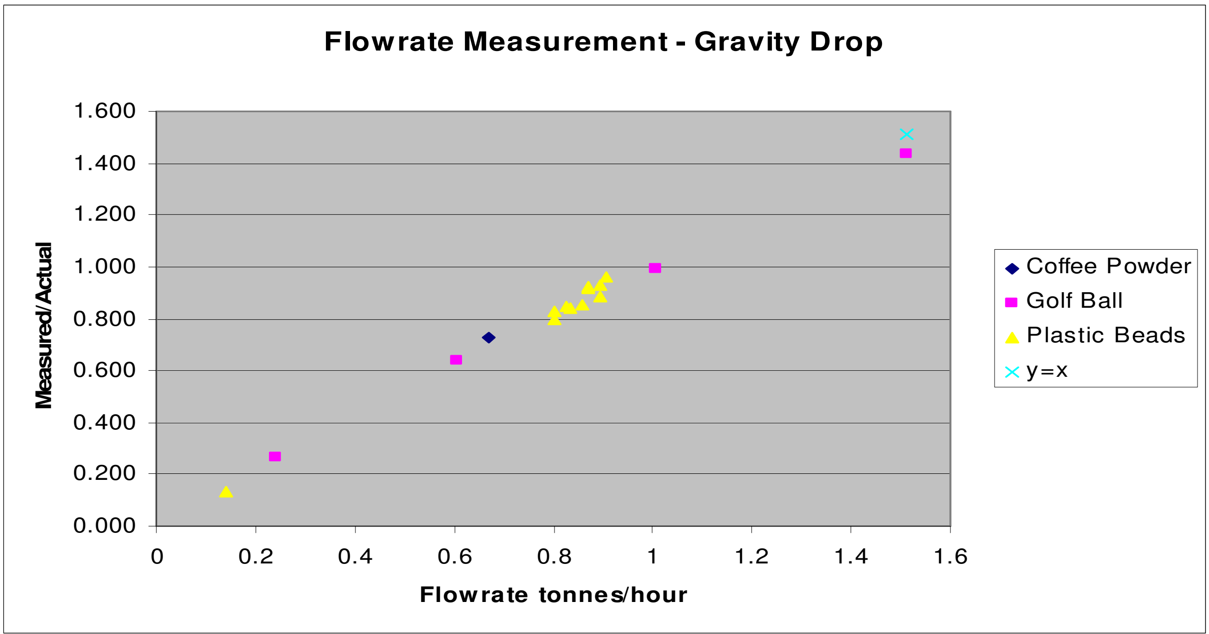
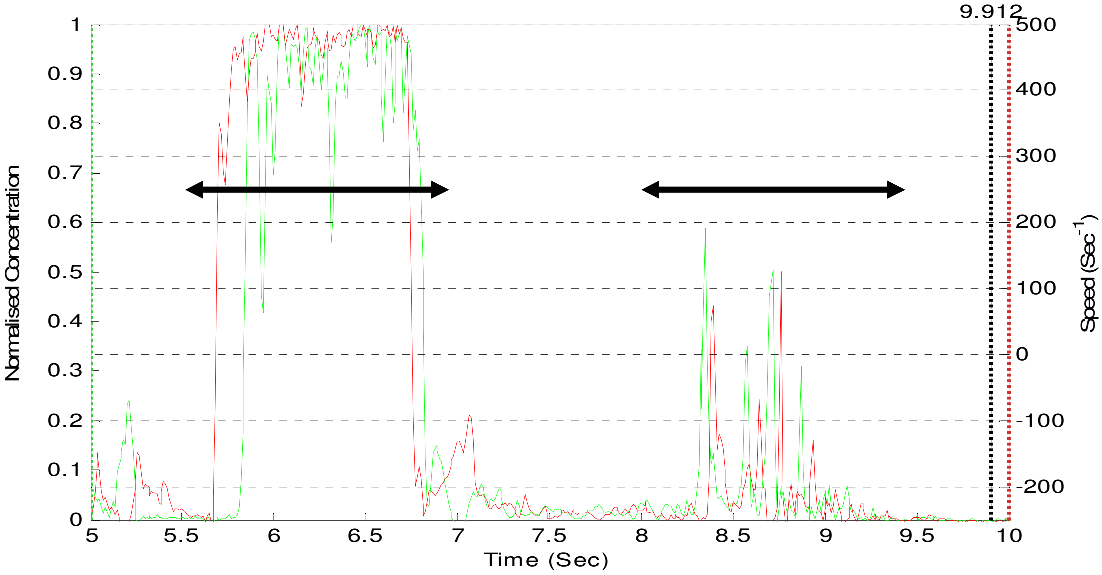


The next figure (above) shows the overall flowrate in mauve (cm^3 per second, right hand scale, summed over all zones) for the same case of plastic beads falling under gravity, this time shown with the concentrations in the two planes within the zone at the left hand side of the pipe. It can be seen that the concentration in this zone is greater in the second plane (red) – confirming the results earlier that the initial plug is dispersing towards the edges of the pipe. Integrating the flowrate for the entire record gives a total of 1464 cm^3, compared to the actual value of 1490 cm^3 – an error of less than 2%.



A summary of test results (above) for a range of flows indicates that Flowan calculates volumetric flow, converted here to mass flow rate, within typically a few percent of the true rate.

Measure the volume of moving structures within the section



Up 3392 cm^3 ***Down 252 cm^3***

In addition to being able to integrate the total flowrate, the volume of individual structures within the flow may be calculated. For example in the slug flow shown above, the volume of the upgoing slug between about 5.5 and 7 seconds is 3392 cm^3, equivalent to a 2 metre long plug of solids moving at about 200 cm/s over 1 second. The downward flow, although lasting just as long from about 8 to 9.5 seconds, only contains 252 cm^3.

Summary

Tomoflow ***Flowan**** brings a new level of sophistication to multiphase flow structure research. Tomoflow Ltd can either supply ***Flowan**** software for use with existing PTL twin-plane ECT systems or we can provide complete multiphase flow measurement systems.

Please contact us for further information, pricing and delivery:

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