

The Leader in Global Imaging Applications

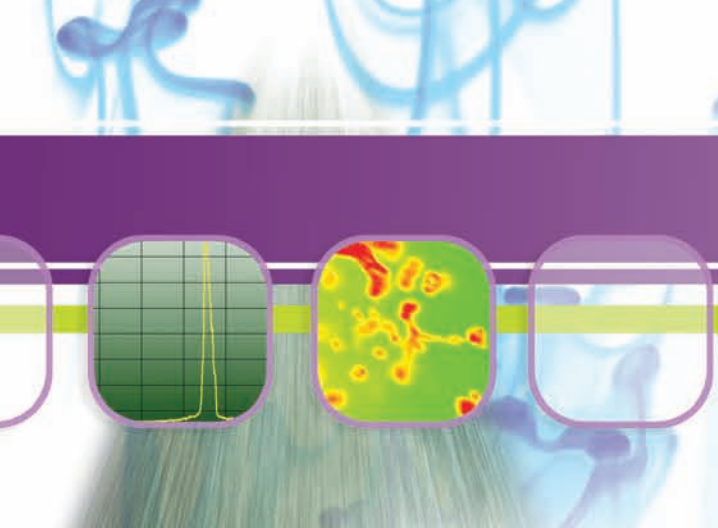


FLUID MECHANICS

Multiphase Flow Measurements



TRUST. SCIENCE. INNOVATION.



TSI's Global Imaging Systems, driven by the *INSIGHT 3G*™ Software Platform, feature the most advanced tools and widest range of measurement techniques for detailed analysis of multiphase fluid flow properties. Measured parameters include droplet size and velocity in sprays, object size–shape–velocity analysis (including diameter, Feret diameter, ellipticity, and area) in bubbly, particle laden, or liquid-liquid multiphase flows, and void fraction.

Measurement Solutions in Sprays

There are two primary categories of spray measurements: small scale measurements of the individual droplet sizes and velocities, and large scale measurements that quantify the geometric properties of the spray and the instantaneous velocity field throughout the spray.

Global Sizing and Velocimetry (GSV) is an interferometric technique that measures the size of droplets from the spacing of the defocused fringe pattern. A laser light source is used to illuminate the droplets in a planar region within the spray, and the scattered light is collected on a scientific, frame-straddling CCD camera. The TSI GSV System is based on both the Lorenz-Mie theory and the Finely Stratified Sphere Scattering Model, and incorporates patented algorithms, a unique camera slit arrangement, and a carefully chosen viewing angle that eliminates the influence of changes in refractive index within the droplet. These innovations allow droplet size–velocity measurements in sprays with inhomogeneous droplets, at higher densities than other interferometric methods, and with only a single camera.

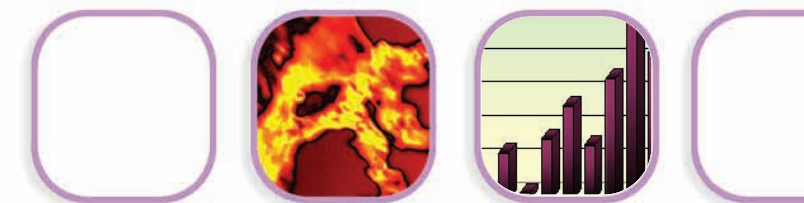
The larger scale spray measurements use the Spray Analysis and Patternation algorithms built into *INSIGHT 3G* software. Using laser illuminated images of the full spray, measured parameters include the spray cone angle and penetration, as well as the spray Pattern Factor. The Pattern Factor quantifies the symmetry and repeatability of the spray, and can be analyzed in both sectors (angular analysis) and rings (radial analysis). Measurements can be phase-locked to allow temporal analysis of pulsed sprays. High speed cameras can also be used to provide time-resolved details of the evolution of a single spray event.

Measurement Solutions in Other Multiphase Flows

In other types of multiphase flows, such as liquid-liquid, bubbly, or particle laden flows, the *INSIGHT 3G* program features a host of image processing and analysis algorithms to quantify a range of key flow parameters.

One critical aspect of multiphase flow measurements is the ability to separately analyze the flow properties of the individual fluid phases. Numerous methods are implemented into the *INSIGHT 3G* software platform to provide this phase separation and analysis. The velocity field in the continuous phase can be measured using Particle Image Velocimetry (PIV) and other related techniques. The dispersed phase is removed from this analysis either through experimental methods, such as wavelength shifting using fluorescence techniques, or through computational methods, including image filtering, intensity separation, size separation, and image masking. The *INSIGHT 3G* program features a processing pipeline that simplifies algorithm setup, even for complex, multi-step image processing, arithmetic, and analysis algorithms. The entire image analysis process can then be executed with a single mouse click, taking you straight from raw data images to quantitative results.

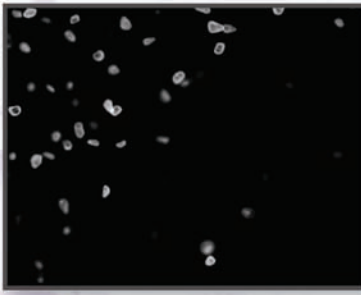
Separate analysis of the dispersed phase allows measurement of the object (bubble, particle, droplet, etc) velocity, as well as a range of size and shape parameters, including the mean diameter, the Feret diameter, major and minor axis diameters (ellipticity), and area. The total area occupied by the dispersed phase, or the void fraction, can also be easily measured.



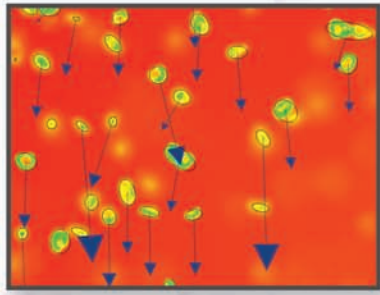
Measurement Example: Measurement of size and velocity in particle laden (sand-air) flow



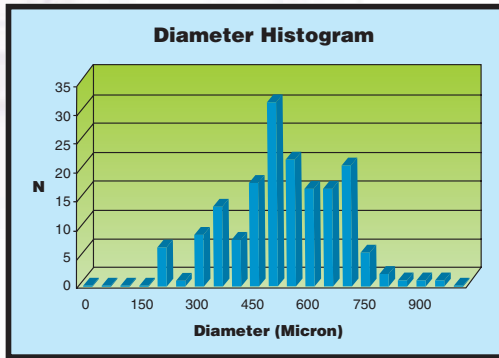
Raw Image:
Captured with uniform backlighting



Pre-processed image:
Grayscale intensity inversion with background subtraction

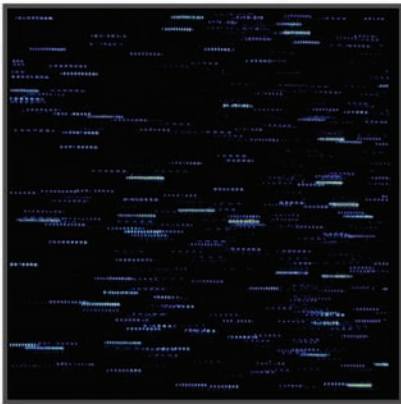


Processed image:
Showing best fit ellipse and individual particle velocities

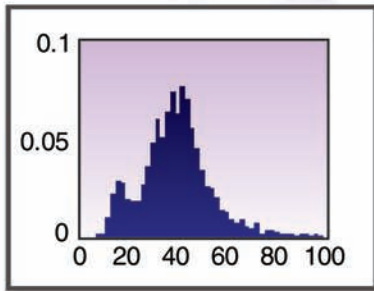


Statistical analysis showing the particle diameter distribution in the flow

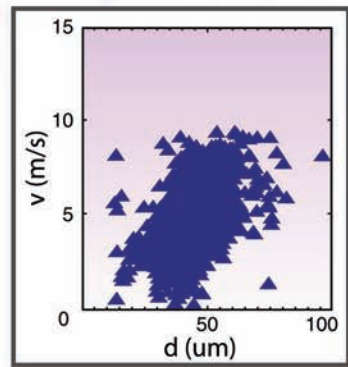
Measurement Example: GSV measurements in a spray



Raw Image: Showing the defocused fringe pattern of the individual droplets



Results: Diameter histogram of individual droplets in a region of the spray



Results: Size-velocity correlation of the individual droplets in the spray

TSI Incorporated serves a global market by investigating, identifying and solving measurement problems. As an industry leader in the design and production of precision instruments, TSI partners with research institutions and customers around the world to set the standard for measurements relating to aerosol science, air flow, indoor air quality, fluid dynamics and biohazard detection. With headquarters based in the U.S. and field offices throughout Europe and Asia, TSI has established a worldwide presence in the markets we serve. Every day, our dedicated employees turn research into reality.

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