Application of in-line holography to drop size measurement in dense fuel sprays

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The requirement to measure drop size distributions in the dense sprays produced by large fuel oil atomizers used in power generation has led to the consideration of holography as a possible means by which this might be achieved. The successful measurement of drop size distributions in fuel sprays is one of several tasks with the final objective of establishing the relationship between the degree of atomization and solids emission in oil-fired plants so that the latter may ultimately be controlled by design improvements.

The choice of holography as a possible tool for atomizer development was made on the basis of several attractive features. First, when used with a Q-switched laser, it enables a 3-D record of an array of high velocity drops to be frozen in time. This recording can subsequently be reconstructed and analyzed at leisure without the risk of coalescence, evaporation, or general deterioration of the sample, a shortcoming inherent in many other techniques. Second, because of its potentially large depth of field, the data required to characterize a spray will be significantly less than when using conventional high speed photography, in which a number of planes of focus must be investigated. An additional advantage over photography lies in the fact that each drop can be focused before measurement, thereby removing errors that might arise from the measurement of out-of-focus drops. A final attraction of holography, brought about by the quasi-monochromaticity and brightness of the laser light, lies in its potential ability to operate in combusting systems.Although the technique has been proven in a variety of dilute aerosols, its application to high density sprays with typically more than one drop per mm³ is uncertain. Consequently, a program of work has been undertaken to resolve this uncertainty.

Experiments were carried out in a large atomizer test facility using a conventional in-line holographic arrangement (Fig. 1). The atomizer used was of the swirl pressure jet type passing 1 kg sec⁻¹ of a water-glycerol mixture, having the same viscosity as residual fuel oil at firing temperature, at a pressure of 5.8 MN m⁻², and producing a hollow cone spray. A Nikon 35-mm motorized camera was housed in a 20-cm diam tube through which was passed a purging airflow to prevent drops from entering and fouling the camera. Coherent light of 694.3-nm wavelength was provided by a series 2000 JK pulsed ruby laser, which, when Q-switched, delivered a single pulse of 25-30-nsec duration in the TEM₀₀ mode at an energy output of 20-25 mJ. A correctly aligned spatial filter of less than 50-µm diam was produced by focusing the laser beam on some 0.2-mm brass shim and operating the laser in the non-Q-switched mode.

From order of magnitude calculations involving the atomizer throughput and an estimate of the Sauter mean diameter of the spray, it was concluded that the complete half cone of spray would undoubtedly give rise to noisy holograms. This conclusion was based on a criterion, developed by Royer, in which he related holographic image quality to the degree of light obscuration. The question was, therefore, could a realistically sized sample volume be isolated within the spray that

(a) provided good quality holograms, and
(b) allowed a representative spray sample to be investigated?

To answer this question the experimental arrangement was equipped with a means by which spray samples of various thicknesses could be isolated for holographic study. Laser light was piped into the region of interest via a length of 50-mm bore tube, and the forward diffracted light was fed to

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After publication of this paper the authors became aware of British Patent Specification 850,452 (1968), where the essentials of contrast generating arrangements as treated in their paper were already disclosed. According to the inventor, F. H. Smith, a working model was made at the time by Cooke, Troughton & Simms, Ltd.