LDV Measurements of Axial Drop Velocity in Evaporating, Dense Sprays

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LDV Measurements of Axial Drop Velocity in Evaporating, Dense Sprays

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The axial component of the drop velocity was measured by laser Doppler velocimetry (LDV) within steady hexane-into-nitrogen sprays from a cylindrical nozzle at gas temperatures from 300 to 500 K. Also varied were the injection velocity and the gas-to-liquid density ratio. It was found that the gas temperature had no effect on the mean centerline velocity for distances smaller than 200 and greater than 650 nozzle diameters. At short distances, the core of the spray is not sensitive to the gas temperature; at long distances, the large amount of entrained gas renders inconsequential the degree of vaporization. Beyond 300 nozzle diameters, so much gas has been entrained that the mean axial velocity approaches the fully developed incompressible jet structure. The approach is accelerated by higher gas temperatures and gas-to-liquid density ratios. The axial drop velocity fluctuation amplitude responds to variations in gas temperature similarly to the mean axial drop velocity. Skewness and flatness indicate nearly Gaussian distributions near the axis and rapid increases beyond the half-radius and differ somewhat from those of incompressible jets, possibly because small drops vaporize fast and large ones do not follow the flow as closely as the small ones.

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The breakup of liquid jets is achieved through a large variety of atomizers for a large variety of applications. The breakup increases the surface-to-volume ratio of the liquid and, thus, increases the rates of mass, momentum, and heat transfer, and the vaporization rate. In the case of diesel engines, poppet, pintle, and multihole nozzles are used , the most common being the latter, which usually consists of a group of cylindrical holes from 100 to 300 microns in diameter.

When a liquid is focused through a cylindrical hole into a gas, many modes of breakup are observed. In the one relevant to internal combustion engines, no outer intact length is observed and the jet starts to diverge at nozzle exit. This regime, which has been termed the atomization regime, is reached at high injection velocities, on the order of 100 m/s for the fuel and conditions of engine applications.

Due to their practical importance, many aspects of atomizing jets have been studies extensively. In the 1930s, significant data were gathered on global quantiles, such as downstream drop size distribution, tip penetration rates, and average spray angles. More recent efforts have attempted to determine the structure of atomizing jets. For example, the outer part in the immediate vicinity of the nozzle exit, and the inner part in the same region, have been studies in detail. Recently, laser techniques have been used to measure drop velocity, drop size distribution, and liquid volume concentrations in sprays from air-blast atomizers, but so dilute as to transmit more than 90% of the light.

The application of laser techniques to diesel-type spray is made difficult by the high number density of droplets. Nevertheless, measurements of drop velocity by laser Doppler velocimetry (LDV) in nonevaporating, steady, diesel-type, dense sprays produced by single-hole cylindrical nozzles injecting into compressed nitrogen atmospheres at room temperature have recently been reported by this group. In experiments by Wu et al., measurements were made in regions of the spray where the light transmission was as low as 2%. However, successful simultaneous measurements of drop size distribution have not yet been possible in such sprays due to the high drop number density.

In this paper, we describe an extension of the latter work to vaporizing conditions, where the sprays are injected into compressed nitrogen atmospheres, which were heated to temperatures.

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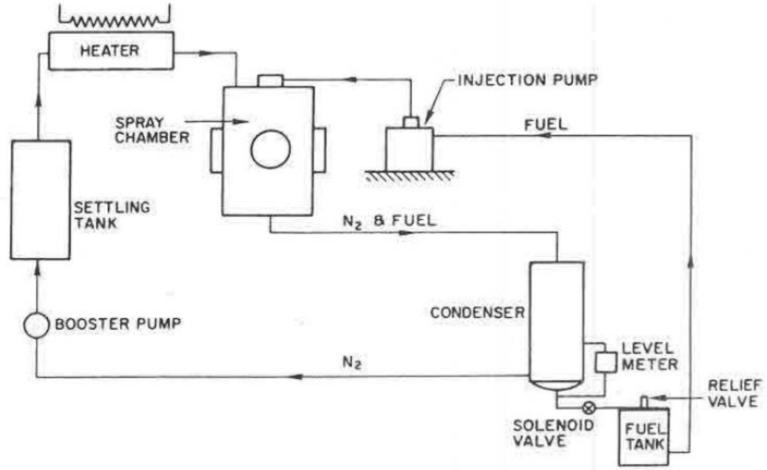

Fig. 1 Schematic of the spray apparatus.

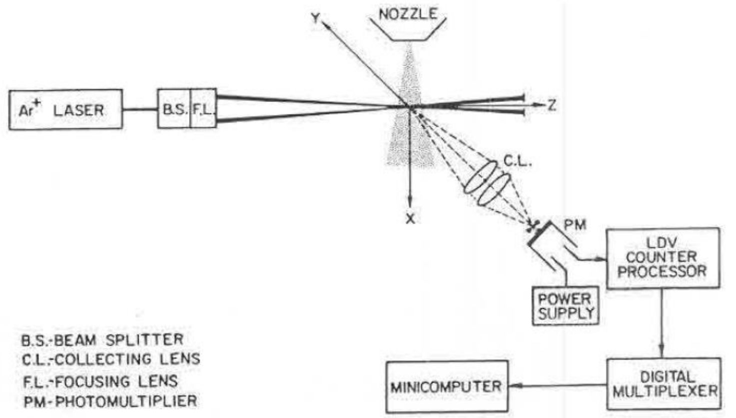

Fig. 2 Schematic of the LDV apparatus.

Table 1 LDV operating conditions

Laser wavelength	488 nm
Fringe spacing	2.45 $\pm \mu m \pm 0.5\%$
Probe volume dimensions	$0.2 \times 0.2 \times 0.2$ mm
Number of fringes	8 (usually)
Laser power	0.2–1.75 W
Frequency shift	5 MHz (usually)

Table 2 Spray conditions

ρ_g/ρ_l	T_g, K	P_g, MPa	ΔP, MPa	X/d
0.025	350	1.726	11	200, 300, 400, 650
0.025	450	2.219	11	200, 300, 400, 650
0.025	550	2.713	11	200, 300, 400
0.0144	300	0.854	11	400
0.0144	350	0.996	11	300, 400, 650
0.0144	400	1.137	11	400
0.0144	450	1.281	11	300, 400, 650
0.0144	500	1.425	11	400
0.0144	550	1.566	11	300, 400, 650
0.0144	350	0.996	33	650
0.0144	450	1.281	33	400, 650
0.0144	550	1.566	33	400
Liquid temperature 320 K ± 5 K				

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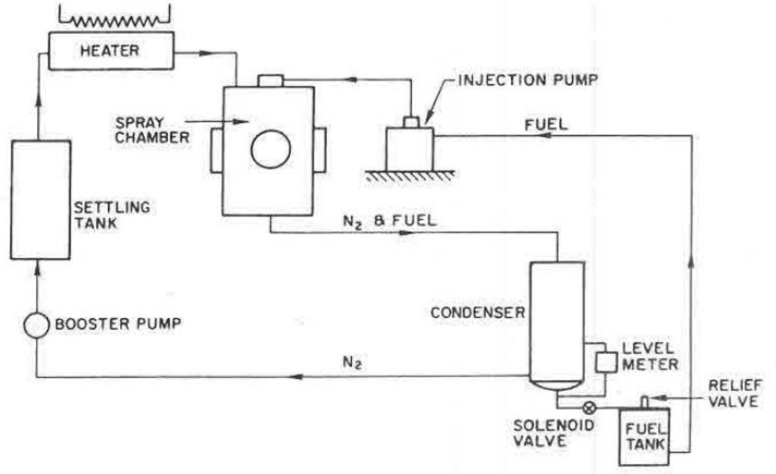

Fig. 1 Schematic of the spray apparatus.

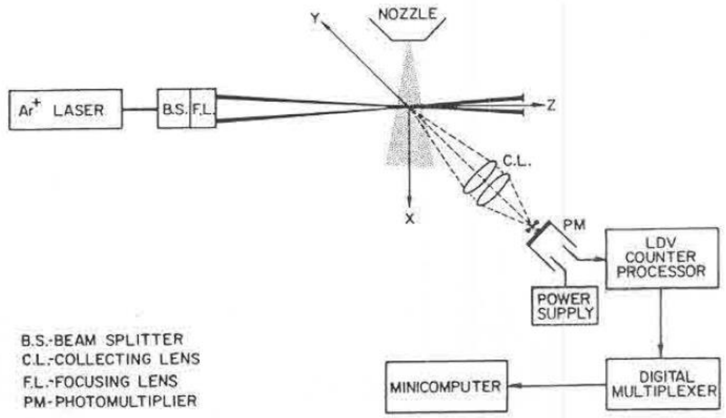

Fig. 2 Schematic of the LDV apparatus.

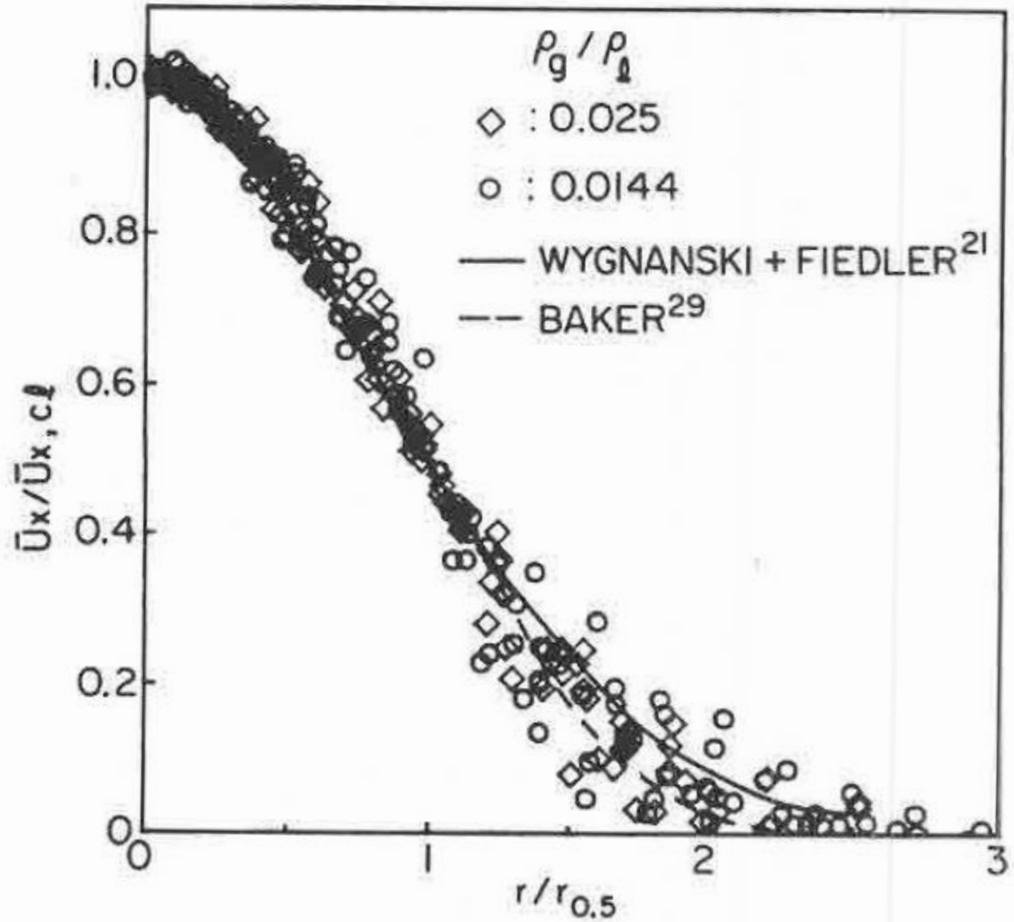

Fig. 8 Self-similar profile of the mean drop axial velocity for all the data of Table 2.

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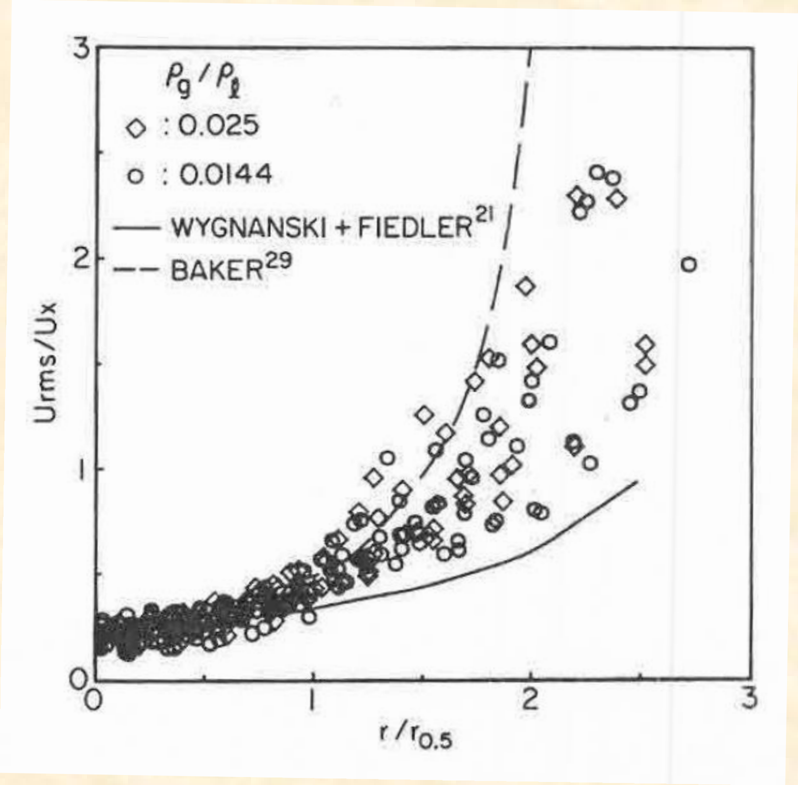
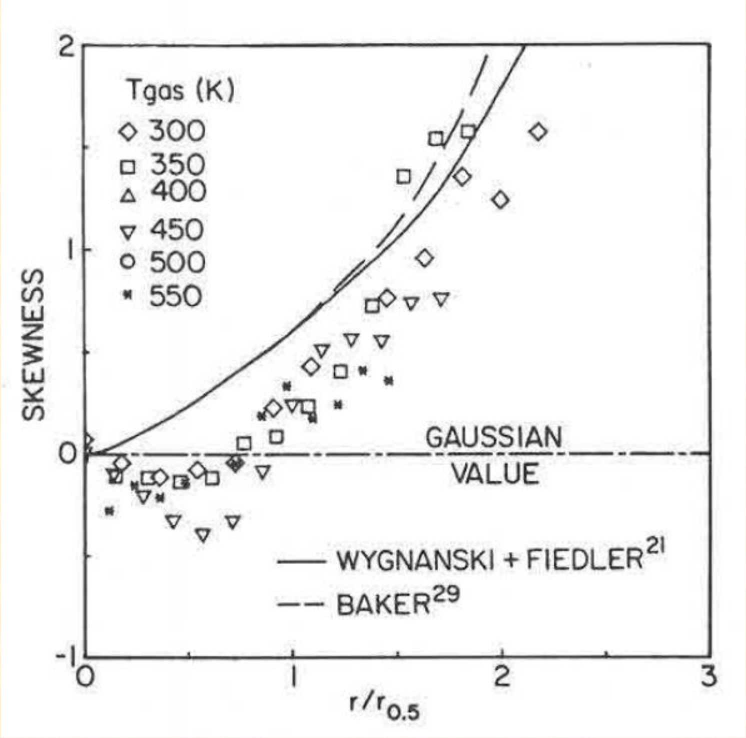
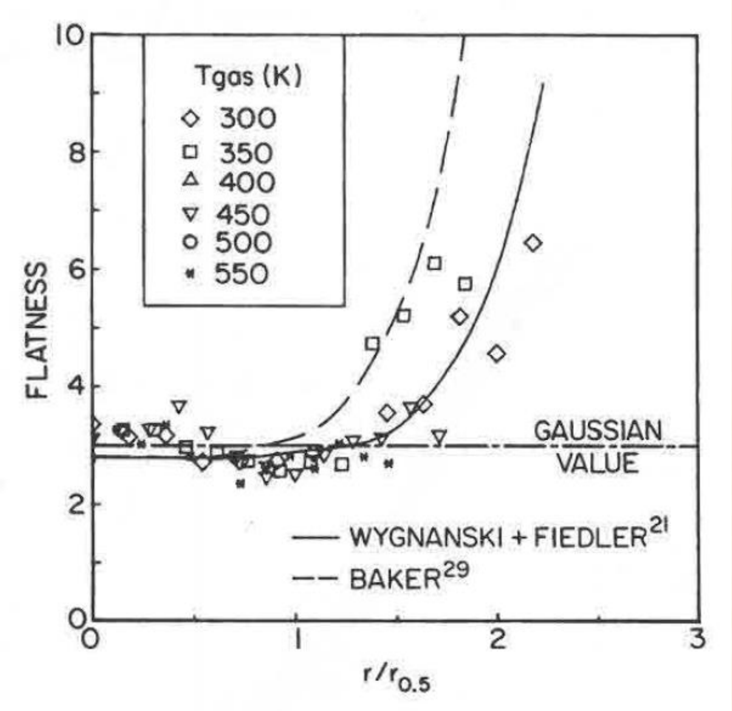


Self-similar profile of the relative fluctuation amplitude for all the data of Table 2.



Self-similar profile of the skewness: $X/d = 400$; gas-to-liquid density ratio of 0.0144.



Self-similar profile of the flatness: $X/d = 400$; gas-to-liquid density ratio of 0.0144.

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