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PREFACE: FLASH–BOILING ATOMIZATION

Spray formation by flash boiling is one of the most effective and promising mechanisms for generating fine, accurate, uniform-droplet sprays at low injection pressures. When a high vapor pressure liquid is injected through an atomizer, flash boiling within the atomizer may occur. The liquid introduced into the atomizer may be composed of a single-component, gas-dissolved liquid (effervescent) or a bi-/multi-component mixture. Under some circumstances, the sudden depressurization of the liquid results in an intense generation of vapor nuclei that rapidly evaporate, resulting in turn in a rapid disintegration (atomization) of the liquid bulk into tiny and fairly uniform droplets.

Depending on the initial conditions, heterogeneous nucleation (usually at a lower degree of superheat) or homogeneous nucleation (usually at a higher degree of superheat) is involved. Finer sprays are usually achieved when the superheating degree is increased, and thus for some applications homogeneous nucleation is definitely preferred.

Spray formation of a bi-component liquid is widely used in domestic applications such as sprays for eliminating odors, controlling insect pests, various medical uses, printing, and painting. Compared to spray formation by mechanical means, spray formation by flash boiling is characterized by a much smaller mean diameter, higher homogeneity, wider cone angle, and shorter penetration depth for the same operating pressure. These characteristics are needed for a variety of uses, including internal combustion engines, in which shorter penetration depth is important to avoid wall impingement. In a well-designed gasoline direct injection system, the fuel must vaporize and mix well with the cylinder charge before the spark onset in order to limit unburned and partially burned hydrocarbon emissions to an acceptable level. Moreover, the complete evaporation of the fuel can make the ignition process more robust and diminish cyclic variations. In today's fuel injection systems, it is common practice to use a highly elevated fuel pressure in combination with a swirl nozzle in order to produce the desired small drop sizes. Spray formation by flash boiling provides the opportunity to generate the desired spray at a low injection pressure that is a paramount requirement in internal combustion engines.

The effervescent atomization technique has recently been proposed in order to meet the increasing demand for smaller drops and avoid safety problems associated with high injection pressure systems. It involves a mixture of fuel and dissolved gas. The dissolved gas evaporates into rapidly-growing gas bubbles that in turn promote the disintegration of the liquid fuel. This technique has been found quite attractive for direct injection engines because it enhances atomization and increases spray angle for rapid fuel-air mixing.

Flash–boiling atomization is a highly complicated process that involves a number of fundamental issues, including thermodynamic instabilities, bubble nucleation in different mechanisms (surface and bulk), effects that pertain to the atomizer's and aperture's

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geometries, simultaneous growth of bubbles of different sizes under mixed constraints (inertia, thermal conductivity, and mass diffusion), building of surface forces during the dynamic rapid liquid disintegration process (dynamic and static surface tension), droplet formation in several different mechanisms, rapid evaporation, possible condensation, droplet coalescence, different regimes of two-phase flow (continuous liquid and continuous vapor), ambient air entrainment into a mixed-phase jet, spray shape, and jet penetration. The rapid processes occur simultaneously in a tiny volume, thus presenting enormously difficult challenges in measuring and collecting high-quality data in real flash–boiling atomization systems.

This volume is dedicated to the worldwide, continuous, intense, and remarkable efforts of researchers in exploring this promising and fascinating field in both theoretical and experimental multiple-spaces.

I wish to thank Professor Chaim Elata for pioneering this research area forty years ago and offering a number of major concepts that have contributed to our fundamental understanding of the flash–boiling atomization process.

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