

Introduction to Sprays

Sprays are an important constituent of many natural and technological processes and range in scale from the very large dimensions of the global air-sea interaction and the dynamics of spillways and plunge pools to the smaller dimensions of fuel injection and ink jet systems. In this chapter we first examine the processes by which sprays are formed and some of the resulting features of those sprays. Then since, the combustion of liquid fuels in droplet form constitute such an important component of our industrialized society, we focus on the evaporation and combustion of single droplets and follow that with an examination of the features involved in the combustion of sprays.

In general, sprays are formed when the interface between a liquid and a gas becomes deformed and droplets of liquid are generated. These then migrate out into the body of the gas. Sometimes the gas plays a negligible role in the kinematics and dynamics of the droplet formation process; this simplifies the analyses of the phenomena. In other circumstances the gasdynamic forces generated can play an important role. This tends to occur when the relative velocity between the gas and the liquid becomes large as is the case, for example, with hurricane-generated ocean spray.

Several prototypical flow geometries are characteristic of the natural and technological circumstances in which spray formation is important. The first prototypical geometry is the flow of a gas over a liquid surface. When the relative velocity is sufficiently large, the interfacial shear stress produces waves on the interface and the breakup of the waves generates a spray that is transported further into the gas phase by the turbulent motions. Ocean spray generated in high wind conditions falls into this category as does annular, vertical two-phase flow. In some fuel injectors a coflowing gas jet is often added to enhance spray formation. Section (Nod) provides an overview of this class of spray formation processes.

A second, related configuration is a liquid pool or ocean into which gas is injected so that the bubbles rise up to break through the free surface of the liquid. In the more quiescent version of this configuration, the spray is formed by process of break-through (see section (Noc)). However, as the superficial gas flux is increased, the induced liquid motions become more violent and spray is formed within the gas bubbles. This spray is then released when the bubbles reach the surface. An example of this is the spray contained within the gas phase of churn-turbulent flow in a vertical pipe.

A third configuration is the formation of a spray due to condensation in a vapor flow. This process is governed by a very different set of physical principles. The nucleation mechanisms involved are beyond the scope of this book.

The fourth configuration is the break up of a liquid jet propelled through a nozzle into a gaseous atmosphere. The unsteady, turbulent motions in the liquid (or the gas) generate ligaments of liquid that project into the gas and the breakup of these ligaments creates the spray. The jet may be laminar or turbulent when it leaves the nozzle and the details of ligament formation, jet breakup and spray formation are somewhat different in the two cases. Sections (Noe) and (Nof) will summarize the processes of this flow configuration.

One area in which sprays play a very important role is in the combustion of liquid fuels. We conclude this chapter with brief reviews of the important phenomena associated with the combustion of sprays, beginning with the evaporation of droplets and concluding with droplet and droplet cloud combustion.