Spray Combustion

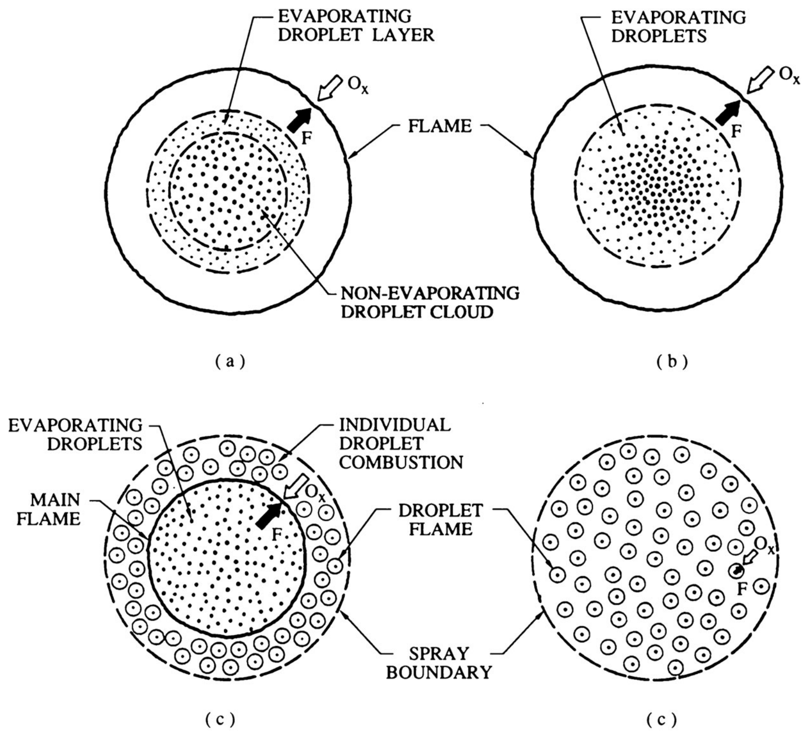

Figure 1: Four modes of droplet cloud combustion: (a) Cloud combustion with non-evaporating droplet core (b) Cloud combustion with evaporating droplets (c) Individual droplet combustion shell (d) Single droplet combustion. Adapted from Chiu and Croke (1981).

Consider the combustion of a spray of liquid droplets. When the radius of the flame front around individual droplets is small compared with the distance separating the droplets, each droplet will burn on its own surrounded by a flame front. However, when r_{flame} becomes comparable with the interdroplet separation the flame front will begin to surround a number of droplets and combustion will change to a form of droplet cloud combustion. Figure 1 depicts four different spray combustion scenarios as described by Chiu and Croke (1981) (see also Kuo 1986). Since the ratio of the flame front radius to droplet radius is primarily a function of the rate of the combustion heat release per unit mass of fuel to the latent heat of vaporization of the fuel, or $\mathcal{Q}/\mathcal{L}$ as demonstrated in the preceding section, these patterns of droplet cloud combustion occur in different ranges of that parameter. As depicted in figure 1(a), at high values of $\mathcal{Q}/\mathcal{L}$, the flame front surrounds the entire cloud of droplets. Only the droplets in the outer shell of this cloud are heated sufficiently to produce significant evaporation and the outer flow of this vapor fuels the combustion. At somewhat lower values of $\mathcal{Q}/\mathcal{L}$ (figure 1(b)) the entire cloud of droplets is evaporating but the flame front is still outside the droplet cloud. At still lower values of $\mathcal{Q}/\mathcal{L}$ (figure 1(c)), the main flame front is within the droplet cloud and the droplets in the outer shell beyond that main flame front have individual flames surrounding each droplet. Finally at low $\mathcal{Q}/\mathcal{L}$ values (figure 1(d)) every droplet is surrounded by its own flame front. Of course, several of these configurations may be present simultaneously in a particular combustion process. Figure 2 depicts one such circumstance occuring in a burning spray emerging from a nozzle.

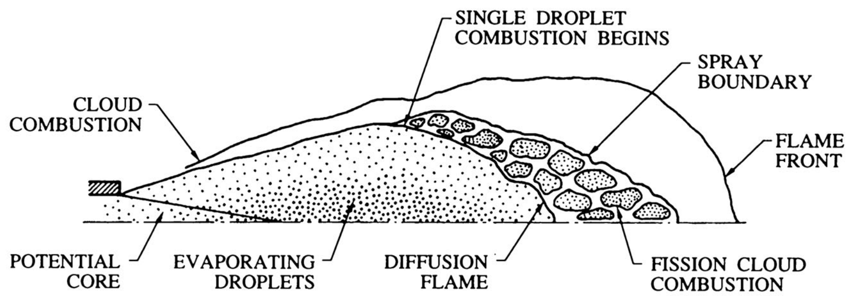

Figure 2: An example of several modes of droplet cloud combustion in a burning liquid fuel spray. Adapted from Kuo (1986).

Note that though we have focused here on the combustion of liquid droplet sprays, the combustion of suspended solid particles is of equal importance. Solid fuels in particulate form are burned both in conventional boilers where they are injected as a dusty gas and in fluidized beds into which granular particles and oxidizing gas are continuously fed. We shall not dwell on solid particle combustion since the analysis is very similar to that for liquid droplets. Major differences are the boundary conditions at the particle surface where the devolatilization of the fuel and the oxidation of the char require special attention (see, for example, Gavalas 1982, Flagan and Seinfeld 1988).