

consumed in the fires that followed. The jet fuel in the aerosol would have burned out as fast as the flame could spread through it, igniting almost every combustible on the floors involved. Fuel that fell to the floor and did not flow out of the building would have burned as a pool or spill fire at the point where it came to rest.

The time to consume the jet fuel can be reasonably computed. At the upper bound, if one assumes that all 10,000 gallons of fuel were evenly spread across a single building floor, it would form a pool that would be consumed by fire in less than 5 minutes (SFPE 1995) provided sufficient air for combustion was available. In reality, the jet fuel would have been distributed over multiple floors, and some would have been transported to other locations. Some would have been absorbed by carpeting or other furnishings, consumed in the flash fire in the aerosol, expelled and consumed externally in the fireballs, or flowed away from the fire floors. Accounting for these factors, it is believed that almost all of the jet fuel that remained on the impact floors was consumed in the first few minutes of the fire.

As the jet fuel burned, the resulting heat ignited office contents throughout a major portion of several of the impact floors, as well as combustible material within the aircraft itself.

A limited amount of physical evidence about the fires is available in the form of videos and still photographs of the buildings and the smoke plume generated soon after the initial attack. Estimates of the buoyant energy in the plume were obtained by plotting the rise of the smoke plume, which is governed by buoyancy in the vertical direction and by the wind in the horizontal direction. Using the Computational Fluid Dynamics (CFD) fire model, Fire Dynamics Simulator Ver. 1 (FDS1), fire scientists at the National Institute of Standards and Technology (NIST) (Rehm, et al. 2002) were able to mathematically approximate the size of fires required to produce such a smoke plume. As input to this model, an estimate of the openings available to provide ventilation for the fires was obtained from an examination of photographs taken of the damaged tower. Meteorological data on wind velocity and atmospheric temperatures were provided by the National Oceanic and Atmospheric Administration (NOAA) based on reports from the Aircraft Communications Addressing and Reporting System (ACARS). The information used weather monitoring instruments onboard three aircraft that departed from LaGuardia and Newark airports between 7:15 a.m. and 9:00 a.m. on September 11, 2001. The wind speed at heights equal to the upper stories of the towers was in the range of 10–20 mph. The outside temperatures over the height of the building were 20–21 °C (68–70 °F).

The modeling suggests a peak total rate of fire energy output on the order of 3–5 trillion Btu/hr, around 1–1.5 gigawatts (GW), for each of the two towers. From one third to one half of this energy flowed out of the structures. This vented energy was the force that drove the external smoke plume. The vented energy and accompanying smoke from both towers combined into a single plume. The energy output from each of the two buildings is similar to the power output of a commercial power generating station. The modeling also suggests ceiling gas temperatures of 1,000 °C (1,800 °F), with an estimated confidence of plus or minus 100 °C (200 °F) or about 900–1,100 °C (1,600–2,000 °F). A major portion of the uncertainty in these estimates is due to the scarcity of data regarding the initial conditions within the building and how the aircraft impact changed the geometry and fuel loading. Temperatures may have been as high as 900–1,100 °C (1,700–2,000 °F) in some areas and 400–800 °C (800–1,500 °F) in others.

The viability of a 3–5 trillion Btu/hr (1–1.15 GW) fire depends on the fuel and air supply. The surface area of office contents needed to support such a fire ranges from about 30,000–50,000 square feet, depending on the composition and final arrangement of the contents and the fuel loading present. Given the typical occupied area of a floor as approximately 30,000 square feet, it can be seen that simultaneous fire involvement of an area equal to 1–2 entire floors can produce such a fire. Fuel loads are typically described in terms of the equivalent weight of wood. Fuel loads in office-type occupancies typically range from about 4–12 psf, with the mean slightly less than 8 psf (Culver 1977). File rooms, libraries, and similar concentrations of paper