

only supply for the low zone was from the city water mains. Thus, should the city water mains be unavailable (as was the situation following the collapse of WTC 1 on September 11, 2001), there would still have been sufficient water to control four six-cubicle fires in the mid or high zones, but there would have been no water to control a fire in the lowest 20 floors.

4.4.4 Supplemental Manual Operations and Related Procedures

The City of New York has a challenge, in common with other large cities, involving firefighting operations among the ever-growing number of high-rise office buildings. The Fire Department of the City of New York (FDNY) addressed this challenge by developing a standard set of procedures for dealing with high-rise office building fires. In 1986, the FDNY developed *Fire Fighting Procedures* and *Fire Operations for High-Rise Office Buildings* to meet the challenge (FDNY 1990). Among the procedures and operations outlined in the manual were the methods used by the FDNY to supplement automatic sprinkler systems and standpipe systems within high-rise office buildings.

The NYC Building Code required all new high-rise buildings to have a primary water supply and a secondary water supply to supplement the fire protection water demands (NYCBC 1968). In buildings over 90 m (300 ft) in height, a manual fire pump, or combination of manual fire pumps must be installed as a secondary water supply. However, fire department connections (FDC) were also required as an auxiliary water supply. Therefore, in buildings over 90 m (300 ft) in height, the FDNY procedures included connecting to the FDC to provide a tertiary supply to the automatic sprinkler systems and standpipe systems in high-rise office buildings (NIST NCSTAR 1-1D and 1-1G). A system of color-coded caps identified whether the FDC supplied a standpipe system, automatic fire sprinkler system, combined sprinkler and standpipe system, or a high pressure supply for upper floor level systems. Specific procedures and recommended pressures were outlined in the *Fire Fighting Procedures* and *Fire Operations for High-Rise Office Buildings* manual developed by the FDNY (FDNY 1990).

The FDNY had two types of pumper engines, conventional and high-pressure. The conventional pumpers contained two-stage pumps with either 4 m³/min (1 000 gal/min) or 8 m³/min (2 000 gal/min) capacity. The high-pressure pumpers contained a third stage capability that can supply 2 m³/min (500 gal/min) at 4.8 MPa (700 psi). Whether used singly or supplementarily, these pumpers have the capability of supplying floors in high-rise buildings up to 110 stories. The *Fire Fighting Procedures* and *Fire Operations for High-Rise Office Buildings* manual suggested supplying the standpipe systems with at least two pumpers at two different siamese connections to ensure that an adequate water supply was added to the system.

The *Fire Fighting Procedures* and *Fire Operations for High-Rise Office Buildings* manual outlined the recommended pump pressures to be used based on floor level and nozzle type attached to the hose lines. The pressures were based on calculations that took into account nozzle pressure, friction loss of three lengths of 2½ in. hose, head loss, system friction losses, and the friction loss of two lengths of 3½ in. hose supplying the siamese FDC.

The WTC 7 building maintenance and engineering staff was familiar with the locations of emergency equipment and the required actions to support the systems in an emergency situation. Such actions during a fire event included starting the manual fire pump on the first floor. Other emergency actions included closing isolation valves to support systems in the case of a ruptured pipe. The WTC 7 operations and