The Case for Interior High-Rise Breathing Air Systems

BY JOSEPH D. RUSH III

Improvements in fire codes and fire safety standards have been beneficial to the fire service and the communities they protect. The resulting reduction in fires nationally has often led to a false sense of security. Fire departments are increasingly expected to accomplish tasks with a continually decreasing workforce. When large-scale incidents occur, such as a high-rise fire, readily available resources deplete rapidly. It is imperative that fire service professionals embrace new technologies that offer the potential to improve job performance in a cooperative effort with community leaders to reduce risks within the community.

Leaders in the fire service agree that hauling self-containing breathing apparatus (SCBA) cylinders up countless floors wastes highly trained personnel on a menial but necessary task. An in-building high-rise breathing air system is a practical solution to this logistical nightmare, especially when we will be dealing with many more mega high-rise structures (greater than 420 feet) in the near future.

The Firefighter Air Systems (FFAS), which is leading the way in what may prove to be the most revolutionary innovation to hit the fire service in decades, can reduce the amount of staffing necessary for the labor-intensive task of maintaining an adequate supply of SCBA at high-rise fires, underground tunnels, and other all-hazard threats that may afflict a structure and put more demands on our air-management needs.

During the First Interstate Bank fire in Los Angeles, 383 firefighters from 64 companies used 600 air bottles in three hours and 39 minutes to bring the fire under control. The general consensus is FFAS brings a readily available supply of air within close proximity to the fire scene, allowing for a safer and more efficient use of personnel. FFAS saves time, resources, and lives. In the end, it reduces the loss of life and property, "eliminating the need to carry out this assignment frees resources for fire attack, rescue operations, ventilation, evacuation, search and rescue, lobby control, and other critical tasks."

During the One Meridian Plaza fire in Philadelphia, approximately 100 firefighters were used for support operations, including refilling SCBA cylinders. Three firefighters from Engine Company 11 died when they ran out of air on the 28th floor. (2) The fire started on the 22nd floor of the 38-story building. The three firefighters who perished were attempting to ventilate the center stair tower when they became disoriented and exhausted their air supply before they could reach safety. The crew from Engine Company 11 was six floors above the fire, but heavy smoke conditions filled the upper floors. Eight members of a search team ran out of air on the 38th floor while trying to exit to the roof; they, too, had run out of air and became disoriented. Fortunately, they were rescued by a crew that was sent by helicopter to the roof.

Search and rescue operations in high-rise buildings often take place several floors or more above a fire. FFAS offers two models with a quick SCBA connection on either a rupture containment system (RCS) or a rapid fill system (RFS) that can enable firefighters to refill their SCBA cylinders while on their backs and in operation even in toxic environments.

These systems, which may be in the stairwells (RFS) or in a room off the corridor (RCS) near a stairwell, will enable firefighters easy access to air whether remaining in operation or exiting the building through a hazardous atmosphere. In a scenario similar to the One Meridian Plaza fire, both search and rescue teams would have had readily accessible air in the stairwells. Search and rescue teams as well as ventilation teams were as many as 16 stories above the fire. This exemplifies the versatility of FFAS. It not only brings an air supply closer to the work area, but it also provides a ready source of air to trapped or evacuating firefighters.

Air management is an important issue that impacts supervision and accountability on the fireground. National Fire Protection Association (NFPA) 1404, Standard for Fire Service Respiratory Protection Training, requires that a standard operating procedure (SOP) be established that includes an individual air-management program. That program is to include a determination of each member's rate of air consumption.

Gagliano, et al., discuss the importance of this issue in Air Management for the Fire Service. They note that the low-air alarm is an indication that 75 percent of the user's air has been depleted and he is working on the remaining 25 percent. Using the low-air alarm as the cue to exit the work area can be extremely risky considering the varied rate at which individuals expend their air.

Researchers from the University of Waterloo (Canada) developed two scenarios to test how much air firefighters used
during high-rise operations. The research determined that within 11-12 minutes, 50 percent of the firefighter's low-air alarms activate, even while working at a self-selected pace. Some used air so rapidly that their low-air alarms activated in as little as eight minutes.5

Coleman and Turiello quote Associate Professor of Fire Science Glenn Corbett of John Jay College of Criminal Justice:

One of the biggest factors that limit firefighting and rescue in a complex structure is having enough replacement air cylinders at the staging area. The firefighter air system eliminates that factor and allows them to operate much more effectively during fire suppression and rescue. (2, p. 9)

The labor intensity of high-rise firefighting operations coupled with the logistical challenges of providing firefight-
ers with a readily available air supply can place demands on fire departments that often exceed their resources. It is estimated that for every four firefighters battling a high-rise fire, four firefighters are needed every seven floors to support the operation. In that case, a fire on the 21st floor of a building would require 12 additional firefighters to support each four firefighters performing suppression activities. Experts estimate that as many as half of the personnel operating at high-rise fires are used to fill and transport air cylinders to the staging area. (2)

**FFAS: MECHANICS**

The mechanics of Firefighter Air Systems are relatively simple. They are described by many fire service experts as "standpipes for air." Most of the system's components mirror those of a standard cascade system that's merely integrated into the building's infrastructure. Its modular design allows for several variations of the two base models, enabling building owners and local fire departments to build systems that meet the operational needs of the authority having jurisdiction (AHJ).

The RCS refills SCBA cylinders in the customary way: Air cylinders are removed from the firefighter's SCBA harness and refilled in a rupture containment chamber, or interior air fill station, that encapsulates the entire cylinder. The RFS refills SCBA air cylinders while they remain on the firefighter's back, using an interior air-fill panel.

**FFAS: COMPONENTS**

There are seven components to FFAS: the exterior mobile air-connection panels (EMAC), the interior air-fill station, the interior air-fill panel, the air-storage system, the air-monitoring system, the system isolation valve, and the piping distribution system. Systems are generally designed with air-fill stations or air-fill panels. A more specific description of each component follows.

1. **The exterior mobile air-connection panel** consists of a locked box mounted on the exterior of the building or on a remote monument. The fire department mobile air unit connects to the FFAS using a high-pressure air hose, providing the building with a continuous supply of air. Moisture and carbon monoxide (CO) levels as well as the system's pressure can be monitored from this panel (photo 1).

2. **The interior air-fill station (chamber)** consists of a stationary air unit that allows for refilling of SCBA air cylinders in a rupture containment chamber. The interior air-fill station includes an air-control panel in addition to a quick-fill connection. Interior air-fill stations are placed in fire-rated locations, such as cache rooms, every three to five floors. It is recommended that the stair-identification system used be consistent throughout the district—i.e., RCS/5th Floor Corridor off Stair A (photos 2-3).

3. **The interior air-fill panel** consists of a locked box mounted in the stairwell on every other floor. The box includes an air-control panel and a quick-fill connection. Rapid refilling of SCBA air cylinders is done while they are still on the firefighter's back and, if

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(4) Interior air-fill panel. (5) Air-storage system.

necessary, still in use. The quick-fill connection attaches to the RIC/UAC on the SCBA harness. Interior air-fill panels allow for at least two air cylinders to be filling simultaneously (photo 4).

4 The air-storage system consists of a bank of large air cylinders and a booster pump much like any other cascade system. The bank supplies firefighters with a continuous delivery of air prior to the arrival of the fire department's mobile air unit. Depending on the system's design, this component can provide refills for between 50 and 250 SCBA cylinders. The piping alone holds enough compressed air to fill several SCBA cylinders prior to the arrival of the fire department's cascade unit (photo 5).

5 The air-monitoring system's primary function is to continuously monitor the FFAS pressure, moisture, and CO levels. If moisture or CO levels exceed the minimum acceptable levels, the system shows red flashing lights and digital readouts at key components. In addition, a supervisory signal is sent to the fire command center and an independent web monitoring station. In the event of an inadvertent overpressurization of the system, the air-monitoring system also acts as a pressure relief. The air-monitoring systems meet or exceed NFPA standards and mirror those installed in other stationary and mobile cascade systems. Testing and inspection requirements are usually specified within the local code. Generally, they are conducted annually by a third party at the building owner's expense. Some codes call for the fire department to observe the process (photo 6).
Group. (1) The NFPA steered this code development. IAPMO IGC 220-2005 was adopted into its Uniform Plumbing Code (UPC) in 2006 and is contained within Appendix F. The document was written to provide a framework for FFAS adoption. This had a positive impact at the time, but most fire, building, and plumbing officials still do not know anything about FFAS.

Now, FFAS is being required more often by amendments to the code at the state or local levels. Some states allow the local AHJ to amend their own codes. Rescue Air System, Inc. provides expert analysis in this area and is available to consult in the code-writing and adoption process.

San Francisco, California; Boynton Beach, Florida; and Phoenix, Arizona are good examples of how FFAS has been adopted at the local level. These jurisdictions provide excellent examples of the various adoption possibilities.

San Francisco adopted FFAS through its city and county municipal code. Its code targets permitted applications on buildings 75 feet and greater and tunnels exceeding 300 feet after March 30, 2004. The fire department has the authority, through Administrative Bulletins, to update specifications, testing, and maintenance on the system.

Boynton Beach adopted FFAS by city ordinance. It falls under the fire protection and prevention requirements for high-rise buildings and consists of three short sentences. Specifications for the system's components references IAPMO IGC 220-2005. Maintenance and testing are to be performed annually at the owner's expense.

Phoenix adopted FFAS through its fire code, and it is listed under fire protection systems. The 10-page document spells out the requirements in detail. [personal interview, California State Fire Marshal (Ret.) R.J. Coleman]

**NFPA STANDARDS**

Several NFPA standards are applicable to FFAS; most are relevant in their current form. For example, NFPA 1404 specifies the minimum training and safety procedure required for respiratory protection use. As the equipment used by the AHJ changes, the training and safety procedures require modification. FFAS may change the fire department air management program, but the validity of the NFPA standard remains intact. Likewise, NFPA 1500 (2007 edition), *Standard on Fire Department Occupational Safety and Health Program*, specifies that fire departments establish a respiratory protection program. The fire department respiratory protection program may require modification as the AHJ is faced with changes, but

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**6 The system isolation valve** is placed alongside each interior air-fill station and interior air-fill panel. It enables the fire department to isolate the system manually or remotely from the fire command center (photo 7).

**7 The piping distribution system** is permanently installed stainless steel tubing. It delivers the compressed air to all the building interior air-fill stations and interior air-fill panels. The stainless steel tubing also acts as a conduit in the interior of the building between the exterior connection panel and the air-storage system. The entire piping distribution system is cross-connected with the exterior connection panels (photo 8).

The fire department keeps the keys to the exterior mobile air connection panel and the interior air-fill panel. Systems are generally charged to 4,500-5,000 pounds per square inch gauge (psig) and can contain enough air in the piping distribution system to fill several SCBA cylinders, depending on the building size, should owners elect not to add an air-storage system. Friction loss plays a very minimal role; in systems with five miles of ½-inch piping, it is virtually nonexistent.

**CODE ADOPTION**

The International Association of Plumbing Mechanical Officials (IAPMO) led the way in developing code language by establishing a Firefighter Breathing Air Replenishment Task Force. The NFPA Fire Protection Board reviewed and adopted the code language in 2005. IAPMO IGC 220-2005 was adopted into the Uniform Plumbing Code (UPC) in 2006, and IAPMO IGC 220-2010 was adopted in 2010. IAPMO IGC 220-2015 was adopted in 2011. This language is identical to NFPA 1404. The 2007 NFPA 1404 standard and NFPA 220-2015 standard are identical.

**8 (6) Air-monitoring system. (7) Isolation valve. (8) Piping distribution system.**
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NFPA 1500 does allows for rapid filling of SCBA cylinders during specially identified emergency situations and rapid refilling of SCBA cylinders while on the user if the following conditions are met: (a) National Institute for Occupational Safety and Health (NIOSH)-approved fill operations are used; (b) the risk assessment process has identified procedures for limiting personnel exposure during the refill process and has provided for adequate equipment inspection and member safety; and (c) an imminent life-threatening situation occurs that requires immediate action to prevent the loss of life or serious injury. (10) The argument could be made that all high-rise fires meet these conditions. NIOSH and the NFPA recommend personnel be protected during refilling but leave the determination to the AHJ.

NFPA 1500, "Annex-A, Explanatory Material," states that 12 cylinders have failed during refilling within the United States. Most of these failed cylinders had not been maintained properly. Some were being used beyond their Department of Transportation-defined hydrostatic test period. Some had not been retrofitted with a special neck ring that the manufacturer had recommended to reduce the possibility of failure. (10, p. 42)

SCBA cylinders are weakest during the filling procedure. This seems logical with the temperature change and stress the evolution causes; therefore, cylinders are manufactured to withstand this process.
BREATHING AIR SYSTEMS

NFPA 1981, Standard on Open-Circuit Self-Contained Breathing Apparatus (SCBA) for Emergency Services (2007 edition); NFPA 1989, Standard on Breathing Air Quality for Emergency Services Respiratory Protection (2008 edition); and NFPA 1901 (2009 edition), much like NFPA 1404 (2006 edition), NFPA 1500 (2007 edition), and NFPA 1852 (2008 edition), all have relevance to FFAS in their present form. As research is published, methods improve, and new technologies are developed, it is not unusual for an NFPA standard to be modified or broken into new standards. For example, the "use" of SCBAs was reassigned from NFPA 1404 to NFPA 1500; likewise, the "selection, care and maintenance" and "respiratory breathing air quality" were incorporated into the new standard, NFPA 1852. (4, p. 1)

Coleman proposes just such a modification to NFPA 1989. He proposes a new chapter entitled, "Firefighter Breathing Air Replenishment Systems Installed in Structures." Coleman argues that while IAPMO IGC 220, Appendix F describes FFAS, it has been adopted in only 14 states throughout the United States. Its adoption as an Appendix makes it even less effective. He further points out that often when FFAS is adopted by local ordinances, IAPMO IGC 200, Appendix F has not been adopted. For example, the Boynton Beach Fire Code references IAPMO IGC 200, whereas the San Francisco Fire Code makes no mention of it whatsoever.

The advantage of adding a new chapter to NFPA 1989 as proposed by Coleman would be twofold. First, the chapter would create much needed uniformity among installations while still providing flexibility where possible. Second, incorporating FFAS into a standard would allow for cross-referencing throughout the NFPA standards and other industry standards such as the Occupational Safety and Health Administration and NIOSH.

THE COST OF FFAS

It is estimated that FFAS adds one-eighth of one percent to the total construction cost of a building. Recently, a 65-story building in San Francisco was retrofitted for approximately $600,000. The system included two exterior points for mobile air connections, certified rupture containment air-fill systems every third floor, and an air storage system with a 100-cylinder capacity. Preconstruction plans can bring costs down considerably. In this example, it's estimated the price could have been reduced by 25 percent through preconstruction planning and value engineering.

In a cost comparison using a typical 20-story building, FFAS saves an estimated $785,568 over a 10-year period (compared with the installation of an equipment cache). It's estimated that FFAS would cost approximately $145,000 installed with yearly testing and certification fees of $2,200. By contrast, the same building with cache rooms (storage area on upper floors for firefighter tools and equipment) installed would cost an estimated $268,220. Initial construction costs of $188,000 would be increased by projected revenue losses on rentable square footage of $72,000 and additional testing and certification requirements on SCBAs and cylinders of $8,220. A KCS system typically uses much less square footage, and when a RFS is located in nonrentable space such as stair-
wells, it is more cost effective for the building owner.

Local fire departments incur no costs, as they are in no need to purchase additional equipment. FFAS uses technologies currently used by fire departments. All connecting valves and fittings are compatible. A potential for cost savings exists when considerations are given to health and safety benefits and the possibility that fire departments would have to stock and maintain fewer SCBA cylinders to fight high-rise fires.

The potential positive impact FFAS could have on the fire service, in high-rise buildings, as well as tunnels and mega structures, cannot be overstated. Efficiency and safety are increased if an air supply can be delivered in close proximity to the fire. Unfortunately, except for a handful of states, FFAS is still relatively unknown throughout the fire service and construction industries. Community and fire service leaders should take a long, hard look at the benefits this new technology offers.

REFERENCES

This article is based on a paper I prepared for the Federal Emergency Management Agency’s National Fire Academy’s Executive Officer Program.

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