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Integration of Hydronic Thermal Transport Systems with Fire Suppression Systems

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ABSTRACT

The challenge of conforming to ANSI/ASHRAE Standard 62-1999 *in an energy-efficient manner has led some HVAC practitioners to the conclusion that using dedicated outside air systems in conjunction with sensible cooling at terminal units offers the best solution. Although these systems are very feasible in most applications, they may have a higher installation cost than the long-favored all-air variable air volume (VAV) systems they are intended to replace. Thus, there is resistance to the use of air-water systems to solve ventilation and off-design humidity problems.*

This paper will explore the potential for integrating hydronic distribution systems with fire suppression systems in an effort to mitigate the first-cost penalty associated with the installation of air-water systems. This concept, which was first used in the late 19th century and further developed in the 1970s, may have a place in helping to make air-water systems first-cost competitive with all-air VAV systems in many cases. Specific issues to be explored will include code and standards compliance, cost implications, and design considerations.

INTRODUCTION

The challenge of conforming to *ANSI/ASHRAE Standard 62-1999* in an energy-efficient manner has led some HVAC practitioners to the conclusion that using dedicated outside air systems in conjunction with sensible cooling at terminal units (air-water systems) offers a good solution. There are many benefits to air-water systems (Mumma 2001), the complete details of which are beyond the scope of this paper. One of the most significant benefits is that the process of controlling space humidity (humidification and dehumidification) is separated from the process of controlling the space temperature. There is also a “natural” fit between the latent loads in a space and the ventilation function, as humidity control is closely linked to occupancy. Once the requirement for dehumidification at the terminal unit is eliminated, “high” temperature chilled water at 55ºF to 60°F (13ºC to 15°C) can be used effectively for sensible cooling at a terminal unit (Shank and Mumma 2001). This has two important consequences.

1. More efficient sources of the chilled water can be used, which can greatly increase the overall energy efficiency of the air-water system arrangement and reduce operating costs (Mumma and Shank 2001).
2. If the chilled water temperature is above the indoor dew-point temperature, the chilled water piping may not have to be insulated to control condensation. This can greatly reduce the first cost of the hydronic distribution system, provided that the thermal losses are deemed to be acceptable.

Although air-water systems are technically feasible for many common cooling applications (Conroy and Mumma 2001), they have not been widely applied in the United States. This is due, in part, to the higher installation costs for these types of systems as compared to an all-air variable air volume (VAV) system. One way to mitigate these higher installation costs is through system integration. Integration involves the “interrelating of normally separate subsystems…to save first cost and/or energy operating costs, based on integrating compatible functions” (Meckler 1987). One seldom-used integration technique is the dual use of sprinkler piping for both fire protection and hydronic distribution for cooling. Traditionally separated, hydronic distribution systems and fire protection systems have evolved more or less independently of one another. In today’s building industry, sprinkler systems

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and hydronic piping systems are usually designed by different engineers and almost always installed by different subcontractors.

The use of sprinkler piping for controlling the temperature of buildings is not a new idea. It has been reported that Henry S. Parmelee installed a dual-use system in a New Haven, Connecticut, piano factory as early as 1874. This system allowed steam into the sprinkler piping to heat the factory, with the piping system functioning essentially like a giant radiator. Additional systems were reportedly installed by Parmelee around 1910 using hot water as the heating medium. However, after that time, interest in this technique waned to the point that it was nearly forgotten (Webb and Meckler 1979).

In the 1970s, Gershon Meckler designed several major building projects that incorporated integrated sprinkler systems. All of these gave many years of service, and a few are still in operation.

- The Social Security Administration Regional Program Service Centers in Philadelphia and Chicago used sprinkler piping to circulate nonrefrigerated (70°F/21°C) water to the office lighting fixtures throughout the building. The water was cooled by a closed-circuit fluid cooler and absorbed heat from the lights via copper tubing attached to the back of the fixtures. This arrangement effectively removed 70% of the heat of light from the building before it became a load on the air-conditioning systems.
- The Social Security Administration Metro West facility in Baltimore uses sprinkler piping as the return for a 55°F (13°C) chilled water system serving fan coil terminal units. The design also includes a modular piping arrangement that allows terminals to be added or moved easily to accommodate changes in space use. A liquid desiccant dehumidifier provides ventilation air to the facility.
- The Monroe County Courthouse and Government Center Addition in Stroudsburg, Penn., uses the sprinkler system to distribute water to water-source heat pump terminal units.
- The Veterans Administration Hospital nursing home addition in Washington, D.C., used the sprinkler system to distribute hot water for heating.

CODES AND STANDARDS

The National Fire Protection Association (NFPA) has specifically allowed the dual use of sprinkler piping for other purposes since the 1978 edition of the *NFPA 13 Standard* was published. Section 4.6 of the current standard (NFPA 1999) states the requirements for nonfire protection connections and auxiliary equipment. Not all of these limitations apply to the chilled water application illustrated below. In brief, they include the following:

- The primary duty of such a combined system is fire protection, and all portions of the combined system must comply with the other provisions of NFPA 13.
- All components of the auxiliary system must be rated for the working pressure of the sprinkler system (175 or 300 psi) but not necessarily listed for fire protection service.
- During a fire, water for sprinklers must not pass through auxiliary equipment or piping on its way from the fire water source.
- The system must be a closed-loop circulating system.
- Dielectric fittings are required for all joints of dissimilar metals.
- There must be shutoff valves between the sprinkler system and all auxiliary equipment and piping to ensure continuous availability of the sprinkler system while other parts of the system are being serviced.
- The water cannot be at a temperature higher that 120°F (49°C) and if water at over 100°F (38°C) is used, intermediate or high temperature sprinklers must be used.
- Special signage is required at fire control valves warning the operator to use other valves provided for servicing the auxiliary equipment.
- There can be no additives to the water that would inhibit the fire fighting characteristics of the water.
- Operation of the auxiliary system must not inhibit sprinkler alarms or cause false alarms under any mode of operation.

None of the major model building codes specifically addresses the dual use of sprinkler piping, although provisions may have been added by local jurisdictions. As always, it is important to coordinate with the local code official when considering this type of integration.

INSTALLATION COST IMPLICATIONS

The primary benefit of integrating the sprinkler system with hydronic distribution is the reduced cost compared to installing the two systems separately, as is normally the case. Consider the following simple example for an office building located in Washington, D.C. The building has six stories with a rectangular footprint measuring 120 ft × 90 ft (36.6 m × 27.4 m). A sprinkler system will be designed for light hazard classification with a maximum coverage area of 225 ft^2 (20.9 m^2) per sprinkler using the hydraulic calculation method (0.10 gpm/ft^2 at the most remote 1500 ft^2). A separate chilled water system serving multiple fan coil terminal units will also be designed. Sensible design cooling loads of 12 $Btu/h{\cdot}ft^2$ (38 W/m^2) for the north and interior zones and 30 $Btu/h{\cdot}ft^2$ (95 W/m^2) for east, west, and south perimeter zones were assumed, along with a chilled water distribution rate of 3 gpm/ton (0.5 Lps/kW). (Note that the loads are low because they do not include latent loads or the sensible loads associated with ventilation air.) Finally, an integrated system will be shown. Installation costs for the three systems were estimated using *Means Cost Data* (Means 1998) and applying correction factors for Washington, D.C.

Figure 1 shows a simple sprinkler piping layout for a typical open-plan office space. There is a single sprinkler riser located at the building core and a single sprinkler main running down the center of the floor plate along the long dimension. Sprinkler branches are located 15 ft (4.6 m) apart with sprinklers located at 15 ft (4.6 m) on center along the branches. The estimated installation cost of the piping system (schedule 10 threaded steel), including the riser but not including the sprinkler drops or any of the front end piping and accessories associated with the fire service supply, is estimated to be $44,500, about $0.69 per square foot ($7.39 per square meter).

Figure 2 shows a chilled water piping layout for a typical floor and was generated assuming a maximum water pressure drop of 4 ft w.c./100 ft (3.9 kPa/10 m) of pipe. The hydronic risers are located at the center of the floor plate with a looped distribution scheme. The piping (schedule 40 steel) serves 20 ceiling-mounted fan coil terminal units. The estimated installation cost of the piping system, including the risers but not including the runouts to the terminal units or any of the front end piping and accessories associated with the chilled water plant, is $47,000, about $0.73 per square foot ($7.80 per square meter).

Figure 3 shows an integrated piping layout for a typical floor. The sprinkler riser also serves as the return riser for the circulating system. This is connected to a pair of parallel sprinkler mains running down the center of the floor plate along the long dimension. Each of the mains is connected to every other branch line, which are located 15 ft (4.6 m) apart. A check valve in the connection to the "supply" main prevents chilled water from short-circuiting through this connection. There is also a chilled water supply riser connected to each floor's supply main. Terminal units are connected to the distribution system by runouts connected to each of the alternating supply and return branches. The piping (schedule 40 steel) is sized for sprinkler duty and then checked against the chilled water flow duty with the larger pipe size used. The estimated installation cost of this piping system, including the risers and additional check valves but not including the sprinkler drops, the runouts to the terminal units, or any of the front end piping and accessories associated with the fire service supply or the chilled water plant, is $50,800, about $0.78 per square foot ($8.44 per square meter).

In a building that has both systems installed, as in Figures 1 and 2, the total cost of the two independent piping systems would be approximately $91,500, about $1.42 per square foot ($15.19 per square meter). When an integrated system is used to serve both functions, as in Figure 3, there is an installation cost savings of $40,700, or $0.63 per square foot ($6.75 per square meter). For a typical mid-rise office building costing $75 per square foot ($807 per square meter) to construct, this represents about one percent of the total building cost. Note that there will be additional costs for configuring the sprinkler

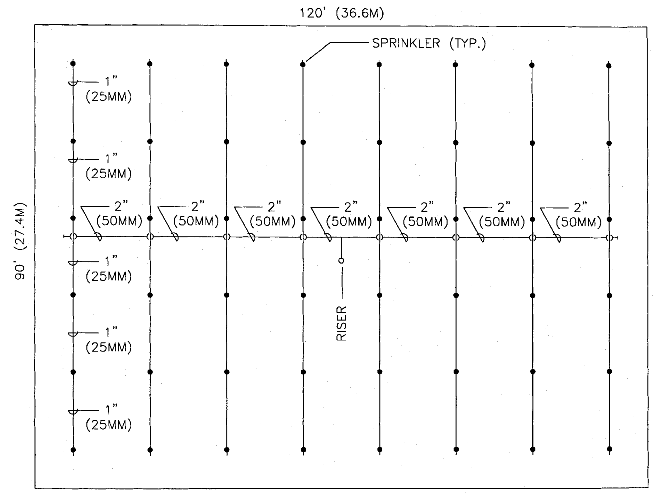

Figure 1 *Typical sprinkler system floor plan.*

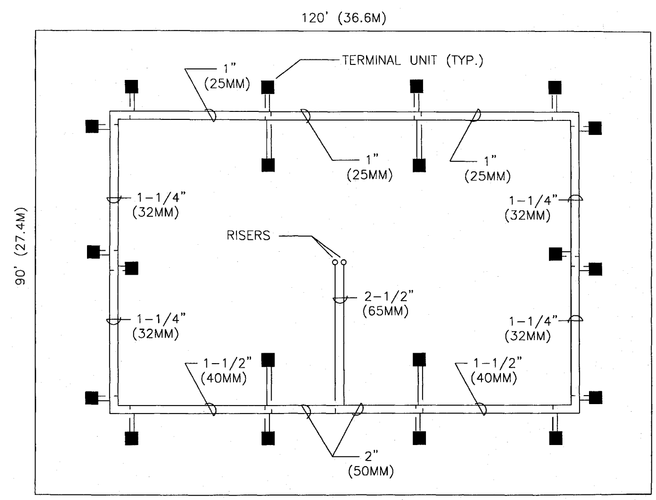

Figure 2 *HVAC system floor plan.*

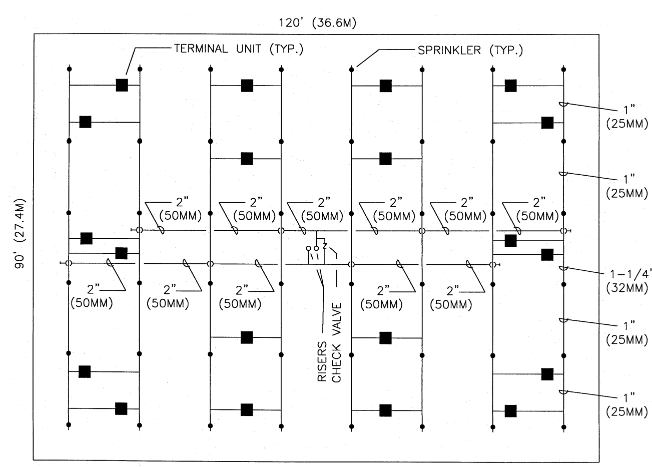

Figure 3 *Integrated sprinkler/HVAC system floor plan.*

system to perform both functions (i.e., controls), but in general, both functions can be achieved for about half the price of two individual systems. The integrated system also can provide a degree of flexibility to accommodate future changes to the HVAC system due to the uniform and all-inclusive layout of sprinkler piping. Adding or relocating terminal units and tapping into the nearest sprinkler branch lines can easily accommodate changes in space usage, zoning, or loads. Additional outlet valves can be provided on a regular basis to accomplish this.

DESIGN CONSIDERATIONS

When designing and installing an integrated sprinkler system, careful attention must be given to meeting the NFPA requirements described above, as well as the normal details associated with designing quality sprinkler and hydronic systems. Of great importance is the early involvement and approval of the building code official who will ultimately approve the installation. This is essential due to the doubts that may arise from this atypical application and the concern that this integration may somehow hinder the effectiveness of the sprinkler system. It is important to remember that the life safety functions of the system must always come first.

Close coordination between the different design disciplines and/or consultants is also important. The requirements of the sprinkler system are determined first, and then the hydronic requirements are added to it. The HVAC designer must verify pipe sizes and set lower limits on branch piping if hydraulic calculations performed by the installer will result in reduced sizes. The sprinkler designer must convey the importance of the designed layout to the contractor and clearly indicate the alternating pattern of branch lines on the plan. During the construction administration phase, both the sprinkler designer and the HVAC designer must check the fabrication drawings carefully to ensure the intent has been satisfied. The HVAC designer must also be sure to specify the correct pressure ratings and follow through with the submittal process for HVAC equipment included in the system.

Normally during construction, two different contractors will be involved in constructing the integrated system. Close coordination between these two subcontractors will be essential for a successful installation, and the respective duties of each should be clearly defined in the project manual. As usual, the sprinkler contractor will handle the sprinklers, branches, mains, and all aspects of the fire water service main piping and head end equipment. It is suggested that these duties extend up to and include the shutoff valves that will isolate the auxiliary piping from the sprinkler piping and accessories. All other piping and equipment for the auxiliary system should be the domain of the HVAC contractor.

A properly sized expansion tank is required to accommodate for thermal expansion of the water and piping in the closed-loop system. Where no fire pump is installed, provisions for makeup water should be handled independently of the fire service main in order to eliminate the risk of false alarms at the fire alarm check valve. A makeup water pump and flow-limiting valve combination can be used to maintain the water level in the system expansion tank. In cases where a fire pump is provided, the fire water supply assembly jockey pump can provide makeup water and maintain system pressure. In either case, a flow-limiting valve set at 8 to 10 gpm (0.5 to 0.6 Lps) is needed at the makeup or jockey pump to limit the flow of the makeup water to less than the flow volume of a single sprinkler. A greater flow will produce a waterflow alarm in the normal fashion.

Where the building is also equipped with a fire alarm system, additional requirements related to sprinkler annunciation must be considered. This usually requires that in addition to the main water flow alarm, the discharging head must also be annunciated by floor and by zone if the floor plates are large. This will require the addition of controls to stop the HVAC circulation pumps and close valves in order to get the system to "settle down" so that the appropriate flow switch can signal the location of the fire. One method of doing this is shown in Figure 4. A double check valve arrangement allows the normal circulating flow to bypass the annunciating flow switch. When a sprinkler discharges, the main fire alarm valve is tripped and a signal is sent to stop the circulating pumps. Often, the water will continue to circulate for some time, delaying the annunciation response. Additional valves can be added in the auxiliary piping, which will close on a sprinkler flow alarm and stop the flow more quickly. When the circulation stops, water flow will be reversed to the discharging head, causing the water to flow past the flow switch and annunciate the location.

Figure 5 illustrates a riser diagram for a complete integrated system. The HVAC circulating pumps and heat exchanger are connected to the combined sprinkler/return riser and the supply riser serving the floors of the building. In cases where sprinkler annunciation is required, normally opened valves should be provided to isolate the HVAC equipment from the risers. The fire water source is also connected to the combined sprinkler/return riser. In this case, a fire pump/jockey pump combination is shown. These pumps are oper-

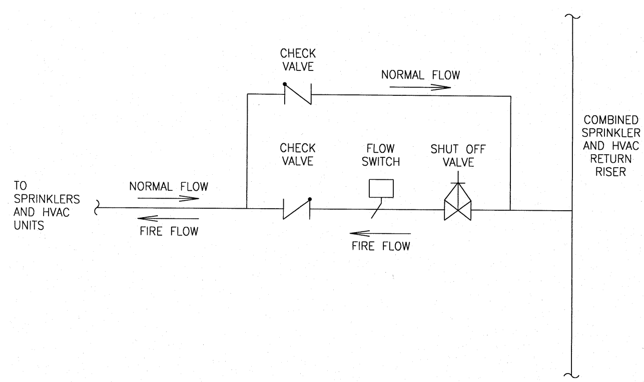

Figure 4 *Annunciation arrangement for integrated sprinkler system.*

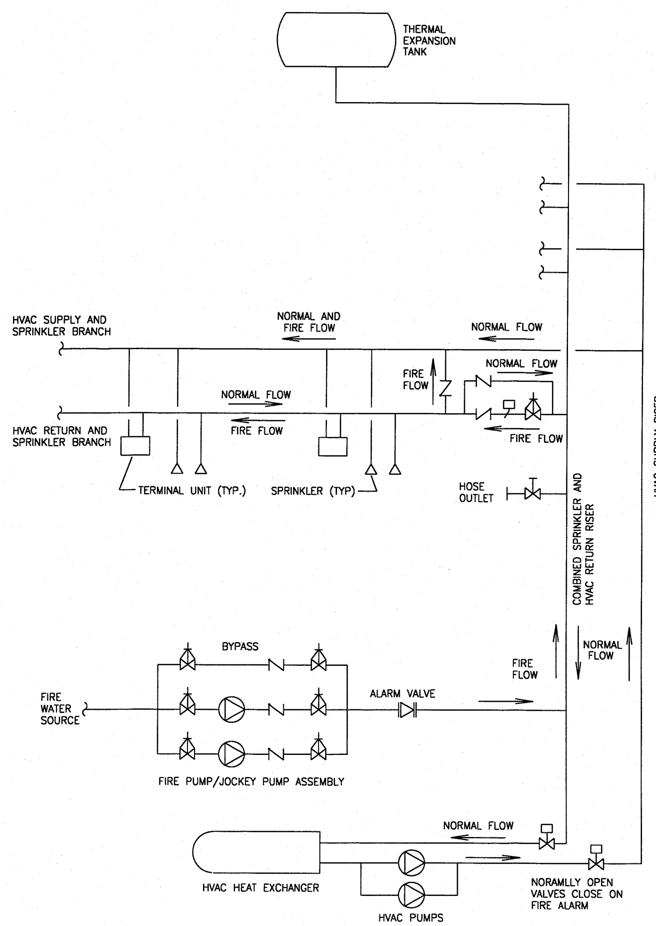

Figure 5 *Integrated sprinkler system riser diagram.*

ated based on maintaining the desired pressure in the integrated system. The expansion tank is shown at the high point of the system and is connected to the combined sprinkler/ return riser.

At each floor the mains will be connected to each riser to supply a network of branch piping, such as that shown in Figure 3. The supply and return mains will include a check valve to allow the flow of fire water from the return main to the supply main but will prevent flow from the supply main to the return main during normal operation. An annunciation valve assembly, such as the one shown in Figure 4, is also needed at each floor if annunciation by floor is desired. Hose outlets can also be provided at each floor if desired.

During normal operation, one or more HVAC pumps will be operating to circulate water between the cooling plant and the terminal units. At each floor, the arrangement of check valves prevents flow across the flow switch or between the supply and return mains. The terminal units take water from the loop as required to satisfy the cooling (or heating) requirements of each unit.

When a sprinkler begins to discharge, the flow triggers the alarm valve and sends a signal to the fire alarm panel. This signal also triggers the shutdown of the HVAC pumps and the closing of the main isolation valves. Once the system pressure drops below the set pressure, the fire pump will begin to operate. Within a short time, the HVAC circulation flows will settle down and the flow to the discharging heads will be established along the desired path, from the fire pump, through the annunciating flow switch, and to the affected sprinklers. The affected sprinkler zone will then be indicated at the fire annunciator panel.

CONCLUSIONS

The integrated hydronic distribution and fire suppression system can be a useful technique for distributing chilled water for comfort cooling. This method, although not widely used or well known, is an acceptable practice in accordance with National Fire Protection Association (NFPA) standards and model building codes. By integrating two functions into a single piping system, the perceived cost penalty for air-water systems can be greatly reduced, if not eliminated. The design and installation of such integrated systems requires close coordination between designers, contractors, and code officials.

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