General Principles of Fixed Water Fire-extinguishing Systems

Water is an ideal extinguishing medium for many fire applications. It is readily available, has great heat absorbing capabilities and can be used on a variety of fires. There are several mechanisms involved in the extinguishment of a fire with water.

First, there is the cooling of the flame temperature when water passes through the combustion zone and absorbs heat through evaporation. Cooling of the flame temperature results in a reduction in the amount of radiant heat released by the fire, and therefore, a reduction in the amount of heat radiated back to the fuel surface.

Secondly, there is the cooling effect of the fuel surface by the direct impingement of water droplets on the surface. With a reduction of the radiant heat received at the fuel surface and the additional cooling of the fuel surface by direct contact with the water droplets, there is a reduction in the amount of combustible gases released. With sufficient cooling of the flame temperature and/or the fuel, the rate of pyrolysis or vaporization of combustible vapors will be reduced to a point which combustion will no longer be self-supporting. Water has the important additional effect of when it evaporates it turns into steam.
The steam, which is in the immediate vicinity of the chemical reaction, displaces the air that supplies oxygen for the combustion process and results in a smothering of the fire.

Thirdly, it wets the adjacent commodities around the outside perimeter of the fire base in order to avoid catching fire.

Fixed automatic water extinguishing systems are normally include water sprinkler systems. These systems utilize fixed piping systems with distributed arrays of nozzles located in the overhead, which are supplied from dedicated water supply. However, the particular fire hazards and safety concerns vary depending on the particular type of space being protected. There is no one size fits all.

Accordingly, the system designs, as well as the requirements, vary depending upon the space to be protected and the type of system to be installed. However, unlike water spray systems, water sprinkler systems are designed for automatic activation. Since these systems are automatically actuated, the distribution system must be pressurized at all times. To accommodate the automatic release, the sprinkler nozzles used are of the “closed” type and fitted with individual heat sensitive links or bulbs that allow the nozzle to open when the temperature of the air in the vicinity of a particular nozzle exceeds a certain pre-determined “activation” temperature. Since each individual nozzle has its own activation mechanism, only those nozzles in the immediate vicinity of the fire will receive temperatures sufficient for activation and will open.

Normally, the nozzles located directly above or next to the fire source, as well as the nozzles around the outside perimeter of the fire base, will be opened.
Those nozzles located directly over or near the fire source serve to control the fire by wetting the flames and fuel source, while the nozzles around the perimeter of the fire serve to pre-cool any surrounding combustible materials.
Sprinkler system design requirements generally differ depending on the type of occupancy being protected, the storage configuration and commodity type, the type of sprinklers (e.g. standard spray sprinklers, early suppression fast response sprinklers, control mode specific application sprinklers, etc.) being used and the mode of installation (e.g. at ceiling level or in racks, etc.). For the purpose of evaluating the design criteria referenced in this overview, we are only interested in sprinklers installed using what is known as the density area method.

The density area method requires that for the purpose of hydraulic design all of the sprinklers within an area prescribed by the installation standard (AMAO i.e. Assumed Area of Operation) are assumed to have operated and be discharging water simultaneously at a minimum density, or flow rate per unit of protected floor area, prescribed by the installation standard. The design criteria published in the sprinkler system installation standards is generally based on a large scale fire tests and recorded loss history.

When designing a sprinkler system it is necessary to quantify the fuel load that will be present within the AMAO (Assumed Area of Operation). Sprinkler system installations generally do not directly consider the fuel load as a heat release rate only but rather as a combination of commodity type, storage height and storage configuration (e.g. Block stacked, stored on solid shelves or in open racking arrays). One of the key elements in determining the design of the sprinkler system is the classification of the stored goods into commodity classifications or groupings of products with similar burning characteristics. Engineering calculations are best performed in areas where an understanding exists as to relationships between parameters. Calculation methods are widely used with regard to only one aspect of sprinkler systems: water flow through piping. There are only being proposed in conformance with the requirements of the standard, the system designer can begin a series of calculations to demonstrate that the delivery of a prescribed rate of water application will be accomplished for the maximum number of sprinklers that might be reasonably expected to operate. This number of sprinklers, which must be supplied regardless of the location of the fire within the building, is the basis of the concept of the remote design area.
The designer needs to demonstrate that the shape and location of the sprinkler arrangement in the design area will be adequately supplied with water in the event of a fire.
Occupancy hazard classification is the most critical aspect of the sprinkler system design process. If the hazard is underestimated, it is possible for fire to overpower the sprinklers, conceivably resulting in a large loss of property or life.

Hazard classification is not an area in which calculation methods are presently in use, however. The proper classification of hazard requires experienced judgment and familiarity with LPC (**Loss Prevention Council**) British standards **BS 5306 Part 2** (Rules of Automatic Sprinkler Installations.

Once the hazard or commodity classification is determined and a sprinkler spacing and piping layout has been proposed in conformance with the requirements of the standard, the system designer can begin a series of calculations to demonstrate that the delivery of a prescribed rate of water application will be accomplished for the maximum number of sprinklers that might be reasonably expected to operate. Water is provided only for the number of sprinklers in the design assumed area of operation, since no water is needed for the sprinklers that are not expected to open. The actual number of sprinklers in the design area depends, of course, on the spacing of the sprinklers.

Once the minimum pressure at the most remote sprinkler is determined, the hydraulic calculation method proceeds backward toward the source of supply. If the sprinkler spacing is regular, it can be assumed that all other sprinklers within the design area will be flowing at least as much water, and the minimum density is assured. If spacing is irregular or sprinklers with different K-factors are used, care must be taken that each sprinkler is provided with sufficient flow.

As the calculations proceed toward the system riser, the minimum pressure requirements increase, because additional pressures are needed at these points if elevation and friction losses are to be overcome while still maintaining the minimum needed pressure at the most remote sprinkler. These losses are determined and their values added to the total pressure requirements. Total flow requirements also increase backward toward the source of supply, until calculations get beyond the design area. Then there is no flow added other than hose stream allowances.

It should be noted that each sprinkler closer to the source of supply will show a successively greater flow rate, since a higher total pressure is available at that point in the system piping. This effect on the total water demand is termed hydraulic increase, and is the reason why the total water demand of a system is not simply equal to the product of the minimum density and the design area. When calculations are complete, the system demand will be known, stated in the form of a specific flow at a specific pressure.

Not enough water released / water does not reach the fire

Inadequate water discharge from a sprinkler system can be the result of a number of issues. For instance, inadequate water flow and/or pressure from the municipal water supply can result from changes in demand of the system over time or from partially-closed upstream valves or obstructions in upstream piping.

The water supply to a sprinkler system is one of the most important factors a factory owner should consider when evaluating a system. Obviously, if there is no water supply, the system is useless.
Often, inadequate spray density is simply the result of what is referred to as shielding of the sprinkler water flow. Shielding can be caused by obstructions to sprinkler spray from such things as building components, large equipment, piping racks, cable trays, rack shelving or storage piles (to name a few).
Any time a fire is allowed to grow unimpeded by cooling or wetting from sprinklers, a fire can quickly overwhelm a fire sprinkler system and essentially spread uncontrolled. Therefore, it's important to identify and correct areas within a building that may be shielded from the spray of fire sprinklers.
Another possible reason for inadequate water discharge from a sprinkler system is excessive internal corrosion of piping, which should be addressed during periodic inspection, testing and maintenance.

Much of a sprinkler system's overall performance relative to controlling the fire is dictated by the available water supply, assuming that the proper design was applied to the hazard being protected. The basic principle of a hydraulically designed water based fire sprinkler system is that the peak flow and pressure demand is no greater than the available supply. If an inadequate flow and/or system pressure is delivered, the sprinkler system is likely to operate improperly, possibly allowing the fire to spread out of control.

The hydraulic demand at a system reference point, such as the base of riser (BOR), can be graphically compared to the available supply to determine the adequacy of the water supply.
The design margin or "buffer" is the pressure difference in the available supply curve and the system hydraulic demand point, in kPa. The model codes governing the design of automatic sprinkler systems are silent regarding the minimum design buffer, leaving the size of the margin to the discretion of the designer.
Usually when the system is not meeting design specifications, the water supply is worse. Final acceptance testing is a bad time to find out the water supply does not meet system demands, but it can be just as devastating prior to installation. The typical proposed solution is to conduct another flow test; does that truly indicate that the system can perform during the worst case scenario?

Summary

The successful operation of a fire sprinkler system relies heavily on the characteristics of the available water supply. An inadequate water supply can cause improper operation during a fire event leading to unnecessary fire damage. Internationally recognized fire standards are available as best engineering practices for automatic fire protection systems. Implementing the features of these standards will reduce the potential for an inadequate sprinkler system water supply to remain undiscovered.