

**Hydraulic Calculations for Sprinkler Systems**

**YASHKUMAR SHAH**

<https://www.ny-engineers.com/blog/hydraulic-calculations-for-sprinkler-systems>

Hydraulic calculations are a particularly important step when designing fire protection systems, since they ensure the flow rate established through the piping network will be enough to control fires effectively. Calculation procedures are established in model codes: automatic sprinkler systems are subject to NFPA 13 (National Fire Protection Association) in the USA, while the the international standard is EN 12845.

In simple terms, the hydraulic calculation procedure verifies three basic elements of a fire suppression system:

* Water delivery requirements for suppression of a possible fire
* Available water supply
* The piping network and its associated friction losses

Water Supply for Fire Protection

A water flow test is often used to determine the water supply available, where a fire hydrant is opened to record pressure and flow values. This information may also be publicly available from some municipal water authorities.

When a municipal water supply is not available or impractical, the piping network may be designed to draw water from another source, which can be either open or closed.

* Lakes, ponds and rivers are examples of open sources.
* Underground, above-ground and elevated tanks are examples of closed sources.

When water is obtained from a static supply such as a lake or buried tank, pressure must be added to have an effective water supply for fire protection. This is accounted for during the hydraulic calculation procedure, and the pressure boost is normally achieved with a fire pump or pressurized tank.

Piping System Configurations

Most piping networks in fire suppression systems can be classified into three types, based on how individual pipes are arranged: tree, loop, or grid. They are summarized as follows:

Tree

As implied by its name, this configuration uses a main piping line that branches out into progressively smaller pipes, providing water for individual sprinklers and other fire protection elements. This is similar to how a tree has a trunk from which all branches grow.

Loop

This configuration also has a main pipe from which all others branch out. However, the main pipe returns to its starting point, completing a water loop.

Grid

This configuration uses two main lines running parallel to each other, and smaller piping segments are connected to both. Since there is more than one route for water to reach a given point in the system, friction is reduced.

Regardless of the piping configuration, design standards normally require the Hazen-Williams method to determine friction losses through the system. The calculation procedure is simpler for tree and loop configurations, to the point that a manual procedure is feasible; on the other hand, grid systems normally require software to analyze and balance water flow through all possible paths. Regardless of piping configuration, computer design is the standard practice for modern fire protection systems, since software allows component changes and recalculation in just a fraction of the time required with manual procedures.

Get a reliable sprinkler system design with optimized costs.

The potential intensity and extent of fire is determined based on building occupancy and height, as well as the materials stored and their arrangement. Fire protection codes normally provide tables and typical values to aid in the design procedure, which are based on decades of testing complemented with detailed fire growth modeling. The NFPA 13 Handbook includes a supplement with the theory and procedures for hydraulic calculations.

Density-Based Sprinkler Demand

When designing a sprinkler system, occupancy hazard classification is the most critical aspect and the starting point for performance requirements. Consider a scenario where the hazard is underestimated: even if the sprinkler system is perfectly designed according to the hazard level considered, it may be unable to contain the fire, leading to significant human and material consequences.

The main challenge when analyzing the hazard classification of a building is the lack of a calculation procedure; the assessment is qualitative, and it depends on experience and familiarity with NFPA standards.

Based on the hazard classification, the designer can determine the sprinkler and piping layout. The next step is to determine the maximum number of sprinklers that could activate at once realistically, and calculate the required pressure to establish sufficient flow under that scenario. As a result, any scenario involving less sprinklers is also covered. The sprinkler count that is assumed for design calculations depends strongly on the hazard classification, but there is freedom for adjustment as considered suitable by the designer.

The NFPA provides graphs that establish the relationship between area covered and flow density, and the designer selects a combination of area and density that is considered suitable for the application. Exceeding the design requirements is acceptable, but specifying a system that falls below is not allowed.

System operation can range from high flow density over a small area, to low density over a large area.

In both cases the fire is expected to be controlled without triggering sprinklers outside of the design area.

How to Determine Flow Requirements

Flow calculation is very straightforward, since it is simply the product of coverage area and the flow density previously determined:

Q = Coverage Area x Flow Density

Note that most listed sprinklers have minimum flow requirements as part of their specifications, which are typically based on spacing. When flow requirements from the manufacturer exceed the values calculated through the area and density method, manufacturer requirements prevail.

How to Determine Pressure Requirements

Pressure calculation is more complex, since there is an energy conversion from pressure to kinetic energy in flowing water. There is a basic formula for water flow through an orifice, based on pressure inside the piping where the orifice is located:

Q = 29.83 x CD x d2 x √P

- CD is the discharge coefficient, based on characteristics of the orifice and determined experimentally.

- The letters d and P simply represent diameter and pressure.

Since sprinklers already have a design diameter, all factors other than pressure are combined into a “K-factor” to simplify calculations. The result is a much simpler version of the formula:

Q = K x √P

Once the required flow (Q) is known, the required pressure (P) can be calculated by simply rearranging the formula above:

P = (Q / K) 2

The NFPA 13 standard establishes a minimum pressure of 7 psi, even in cases where the calculation procedure yields a smaller value. This ensures that water will be sprayed with the proper shape under the sprinkler. There are also cases where the NFPA 13 standard specifies exceptions to the method. Chapter 7 covers exception, which apply in cases like the following:

Applications where dry systems are used.

Quick response sprinklers under flat smooth ceilings of limited height.

Non-sprinklered and combustible concealed spaces in the building.

Spaces that are broken down into a large number of compartments: an alternative method is proposed to allow a smaller number of sprinklers.

Dwelling units and adjacent corridors: a simplified procedure is provided, based on a four-sprinkler design area.

Conclusion

Automatic sprinkler systems are subject to stringent design requirements, which makes sense considering their role in fire suppression. Designing a sprinkler system that meets all code requirements at an optimal cost is a significant engineering challenge, which requires experience in fire protection and familiarity with standards.