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PRACTICAL PREPARED PROFESSIONAL

Course FP100 – BACKFLOW PREVENTERS (BFPs) 101 FOR AUTOMATIC FIRE SPRINKLER SYSTEM

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Introduction

If you have ever been exposed to automatic fire sprinkler system, there is a very good chance that you have heard the term backflow preventers (BFPs). BFPs are a critical requirement of automatic fire sprinkler systems and are found in all, with exception of a few cases (which will be discussed in this course), when the system is connected to potable (drinking) water supply. BFPs are placed on the fire line between the portable water supply and the sprinkler system. Although backflow preventers are used throughout various system, this course will focus on requirements of backflow for sprinkler system mainly in *NFPA 13 Standard for the Installation of Sprinkler Systems* with connection to portable water supply.

In this course, we will define backflow, codes requirements for backflow prevention, different backflow devices, effect of backflow on system demand, flow characteristics, friction loss, and finally testing requirements.

Backflow

Let's start by answering what is backflow? As the name suggest backflow is the flowing of water in the opposite direction than which is normally intended. In other words, it is flow reversal. In fire protection, water flows from the source to the supply i.e. from the city water distribution system through the fire line to the fire suppression system.

Backflow results in cross-connection, the process where potable water is connected to and contaminated by non-potable water. Water in sprinkler pipes is stationary and can be stagnant for years prone to bacteria growth. Furthermore, despite flushing during system testing, lube oil and metal shaving from fitting can be left in and introduced during retrofits. Also, pipes rated for fire protection usage may not be rated for carrying potable water.

Neither cross-connection nor backflow is of concern when the sprinkler supply water is off a non-potable water supply. Studies in both USA and Canada have found that the stagnant water present in sprinkler system is not deadly. However, in 1986 a thorough research according to American Water Works Association (AWWA) Research Foundation, an "international, nonprofit, scientific and educational society dedicated to providing total water solutions assuring the effective management of water", concluded that sprinkler water does not meet Federal Safe Drinking Water Act (a federal mandated regulation to provide quality for drinking water).

There are two types of backflow: backpressure backflow and backsiphonage.

What is backpressure backflow and its affects?

- Occurs when the pressure in the system is greater than the pressure in the supply
- Water flows from high pressure area to a low pressure area (from the sprinkler system back to the water supply)
- Other examples of backpressure:
  - when the fire pumper pressurizes the system via a fire department connection
  - hot water expansion in a boiler due to high temperature
  - a reduction of pressure in water distribution system due to increase demand ex. water main break, fire trucks using a fire hydrants

What is backsiphonage and its affects?

- Results when pressure is negative
- A vacuum is created which draws water from contaminated sources
- Water is sucked from the system back into the supply. Example, a fire pump or fire pumper drafting water from a supply source allows for contaminates around the supply line to be sucked into the system.
- Joint connections of underground water pipe can also suck in dirt and other contaminate i.e. when the sewer line is located close to the water line leakage in sewer can be drafted into potable water (there are minimum requirements by health code to keep certain distances between water line and other utilizes ex. https://law.lis.virginia.gov/admincode/title12/agency5/chapter590/section1150)

Statue Requirements

There are statue (laws and regulation) in affect that require prevention of contamination of portable water supply. These take form of codes such as building code, fire code, plumbing code, health code etc. Additionally, local jurisdiction can adopt standards that contain special requirement for how to handle backflow.

A well know code that requires backflow protection in potable water supply is the International Plumbing Code (IPC). IPC requires portable water to be protected by backflow assemblies when connected to a fire sprinkler system. *NFPA 13 – Standard of Installation of Sprinkler System &- NFPA 24 – Standard of Installation of Private Fire Services Mains and Their Appurtenances* (provide installation and testing guidelines) are the most commonly adopted reference standards by codes (example for ICC building codes see Chapter 35 Reference Standards). Remember, a standard is a guideline while statue, codes are required by law. Only by reference through the code can the standard become law and enforceable.

There are exceptions to incorporating BFP devices (note that BFP and BFP device are used synonymously and mean the same thing). For example, jurisdictions that have adopted the International Building Codes (IBC), can utilize chapter 9 which allows for sprinkler system with BFPs where ‘limited areas system’, system containing fewer than 20 sprinkler heads are allowed to be connected directly of domestic water line. Additionally IBC codes do not require certain residential fire sprinkler system to have BFP devices. Note, this is only true for system posing low hazard - see below for explanation of hazards. Additionally, where there are conflicts between two codes, then the most stringent requires are applied.

The Right Device?

- A backflow preventer device is used to mitigate backflow and/or backsiphonage. This is accomplished internally via hydraulically means inside the device through mechanical components utilizing spring load check valves. BFP device for automatic sprinkler system must be listed for fire protection and acceptable to authority having jurisdiction (AHJ). Two popular devices to prevent backflow are double check backflow detector assembly (also known as double check valve) and reduced pressures principle assembly (also known as reduced pressures zone assembly or RPZ).

Above is shown Ames Double Check valve with OS&Y valves. Image from http://www.amesfirewater.com/pages/hi_res.asp?imgId=327)

Above is shown Watts Reduced Pressure backflow assembly with OS&Y valves. Image from http://www.watts.com/pages/view_image.asp?imgId=893

Double Check Valve Assembly

The double check valve assembly is the most simplest of the devices with the least amount of friction loss for a given water flow. However, these devices are good only against backpressure. They contain two check valves with control valves on both sides, and four test ports utilized to isolate and test the different chambers to determine the device is preventing flow in the wrong direction*.

Note that although the backflow devices contains check valves, a single check valve is not considered a device for backflow means. There is no redundancy to prevent reverse flow and it makes it is difficult to test for backflow without opening it for inspection.

For many years, backflow devices were not required on fire protection systems connected to potable water and as such many existing systems may contain only an alarm check valve. Mostly all codes and standards today require that all new systems have means to protect against backflow via a BFP device. For existing systems, as to whether or not they need to be retrofitted with BFP, refer to your state and local jurisdiction codes. Care must be taken when changing and retrofitting system with BFPs as it adds friction loss to the system and can compromise the designed system.

*Isman, Kenneth. 2007. Layout, Detail and Calculation of Fire Sprinkler Systems. National Fire Sprinkler Association, Inc

Double Check Valve Assembly

NFPA 13 2016 states:

Retroactive Installation. When backflow prevention devices are to be retroactively installed on existing systems, a thorough hydraulic analysis, including revised hydraulic calculations, new fire flow data, and all necessary system modifications to accommodate the additional friction loss, shall be completed as a part of the installation.

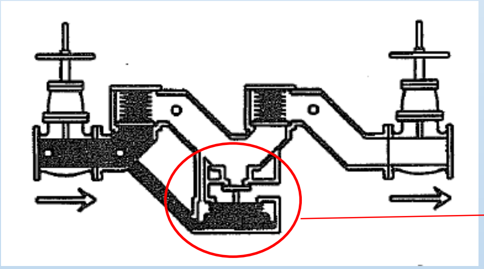
More discussion on this in the *Flow characteristics and friction loss* section.

Reduced Pressures Zone Assembly

RPZs are a more robust devices. They are capable of rectifying both the backpressure and backsiphonage conditions. These devices consists of two check valves, shutoff valves and test ports, similar to the double check valve assembly with the inclusion of having a hydraulically operated mechanical pressure differential relief valve located between the check valves and below the first check valve.

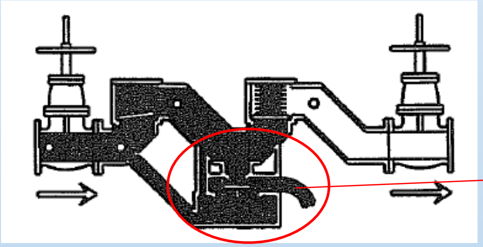
Reduced Pressures Zone Assembly

- Image below from *Layout, Detail and Calculation of Fire Sprinkler Systems.* National Fire Sprinkler Association, Inc 2007



pressure differential relief valve

Above: Arrows indicate water flowing backwards. Water is prevented from flowing past the first check valve.



pressure differential relief valve

Above: Arrows indicate water flowing backwards. If the first check valve fails (check valve on downstream side of the system), the chamber opens and discharges water out of the assembly. This prevents stress on the upstream check valve and ensures the contaminated water from flowing back into the potable water. RPZs have higher friction loss. Furthermore, because these devices discharge water out of the device care for placement of these devices and drainage must be taken into account. A large sized RPZ device can discharge a lot of water and should have a drain pipe routed to a drain.

The Right Device?

Use on the type of devices depends on the severity of health hazard present. International Plumbing Code (IPC) classifies hazard as either low or high. Low hazard is defined as “an impairment of the quality of the potable water to a degree that does not create a hazard to the public health but that does adversely and unreasonably affect the aesthetic qualities of such potable water for domestic use”. A double check valve backflow is required against low hazard.

The Right Device?

For High hazards, IPC requires use of reduced pressures principle assembly. A high hazard is “an impairment of the quality of the potable water that creates an actual hazard to the public health through poisoning or through the spread of disease by sewage, industrial fluids or waste” ex. antifreeze system or auxiliary system attached to the sprinkler system utilizing the water for heat exchanger(s) heating and cooling.

The Right Device?

- There can be multiple backflows present in a single fire sprinkler system. For example, a double check BFP device may be present on the supply line. If an antifreeze system is fed of this sprinkler system to protect an outdoor area open to cold climate, then a RPZ must be installed prior to connection of the antifreeze solution (see details in NFPA 13). Now, you could have installed one RPZ right at the incoming supply line, on the fire line instead of the double check valve, however in doing so, the entire system will have to adjust for the increased friction loss present through the RPZ. The pressure loss through an RPZ for same flow compared to a double check can be double.

NFPA 13 examples of RPZ with antifreeze

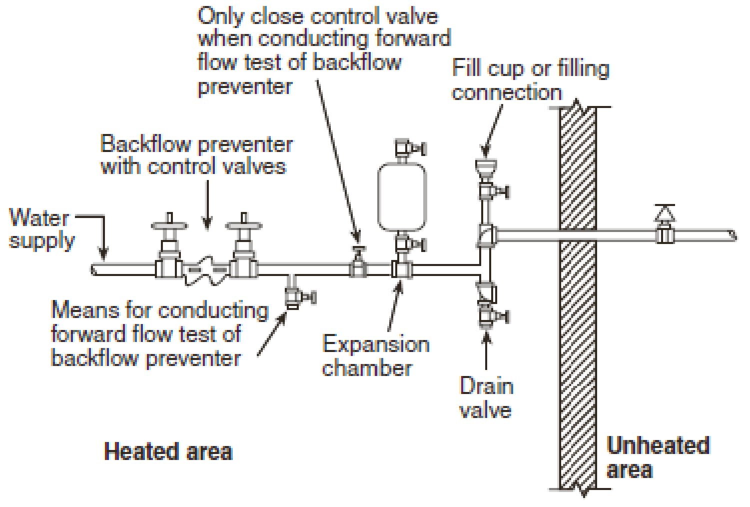


FIGURE 7.6.3.3 Arrangement of Supply Piping with Backflow Device.

The Right Device?

Fire protection water supply is typically not metered. If a water meter is present, friction loss for it must be accounted for in the hydraulic calculation when determining system demand. Many times, desired with a BFP device is a detector which comes as one assembly through the manufacturer. The entire assembly is known either as Double Check Detector Assembly or Reduced Pressure Detector Assembly. The additional detector allows to detect any unauthorized use of water or leaks in the fire line.

A hydraulic evaluation must be made whenever adding or changing devices in existing and new sprinkler systems.

Location and Connection to System

The purpose of BFP is to prevent reverse flow. For systems fed of public potable water, connection should be made as close as possible to the public supply. In warm climates not exposed to freezing conditions, the backflow device can be located outside of the building open to the environment. Typically, we find control valves such as OS&Y or butterfly on both sides of the BFP device. This allows for easy maintenance and replacement and testing of the BFP. These valves must be locked with chains or supervised electrically via tamper switches to prevent anyone from closing them. Closing them will shut off the main water supply to the entire fire suppression sprinkler system.

In colder climates, location of BFP is typically inside the building, in a sprinkler room heated to maintain at least 40F. The fire line enters the building typically via a stub-in flange and the BFP connection is made either on or as close as possible.

The pipe up to suction side of backflow must meet plumbing code and health code requirements as it is potable water ex. be either galvanized pipe or ductile iron. Do not use black steel pipe on suction side of BFP. Black steel pipe rusts easy and can contaminate the potable water supply. Pipe on discharge side can be any listed pipe ex. black steel since contaminates will be prevented from entering back into the potable water supply system via BFP.

Location and Connection to System

With reference to a fire pump, BFP can be located either on the discharge or suction side of fire pump. If installed on discharge side care must be taken to account for high flow from the pump which will increase pressure loss through the BFP. Furthermore, with this arrangement there are greater chances of cross-connection (contamination of the potable water supply) and AHJ should be consulted. If installed on suction, NFPA 20 requires BFP device to be located away from the pump suction flange, 10 times the diameter of the pipe (ex if the suction pipe is 6”, the distance from the flange the discharge flange of BFP to be minimum 60”) or 50ft if utilizing butterfly valve on the BFP, to allow for reduction in turbulence and smooth flow into the pump. For diesel engine fire pump utilizing cooling water for the pump, a RPZ must be used.

Location and Connection to System

Each manufacturer of the BFP supplies specification (cut sheet) of their device. The document indicates whether or not backflow device can be installed in vertical or horizontal orientation. Other key things to note are size, type of connection (flange or grooved ends), direction and orientation, length, types of valves. Check designed plans for tight wall spots and other equipment. Verify clearance, access and working space to conduct test and replace for future. Confirm that the device must be listed for use ex. use with potable water, type of health hazard. Some jurisdiction require backflow preventer to be listed for fire protection use. Confirm device is UL or FM approved as required by code and adopted standard. NFPA 13 requires BFP to be listed for fire protection use.

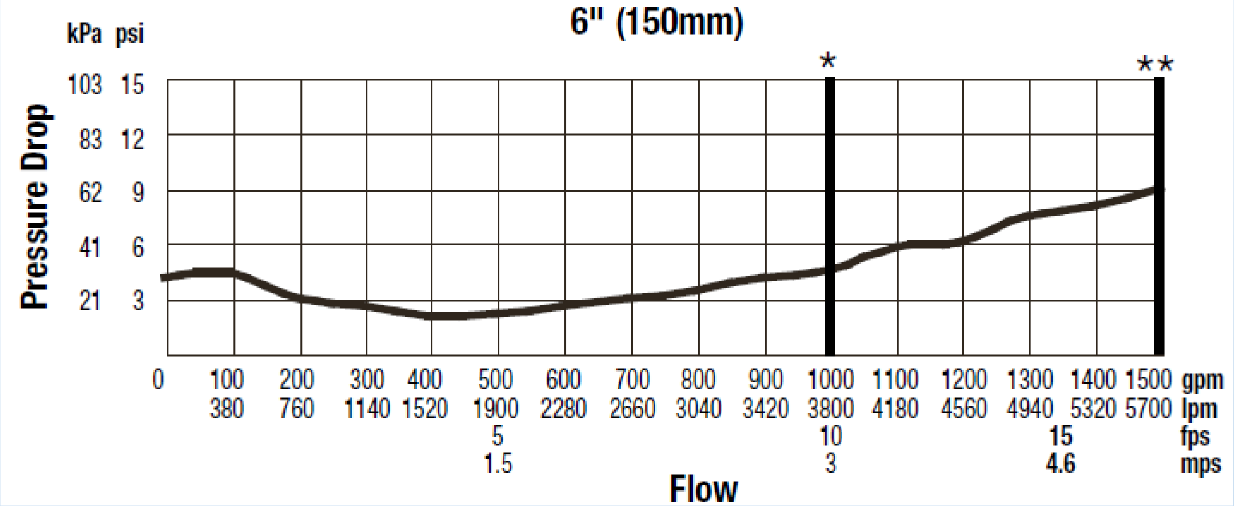
See Ames cut sheet link

See Watts cut sheet link

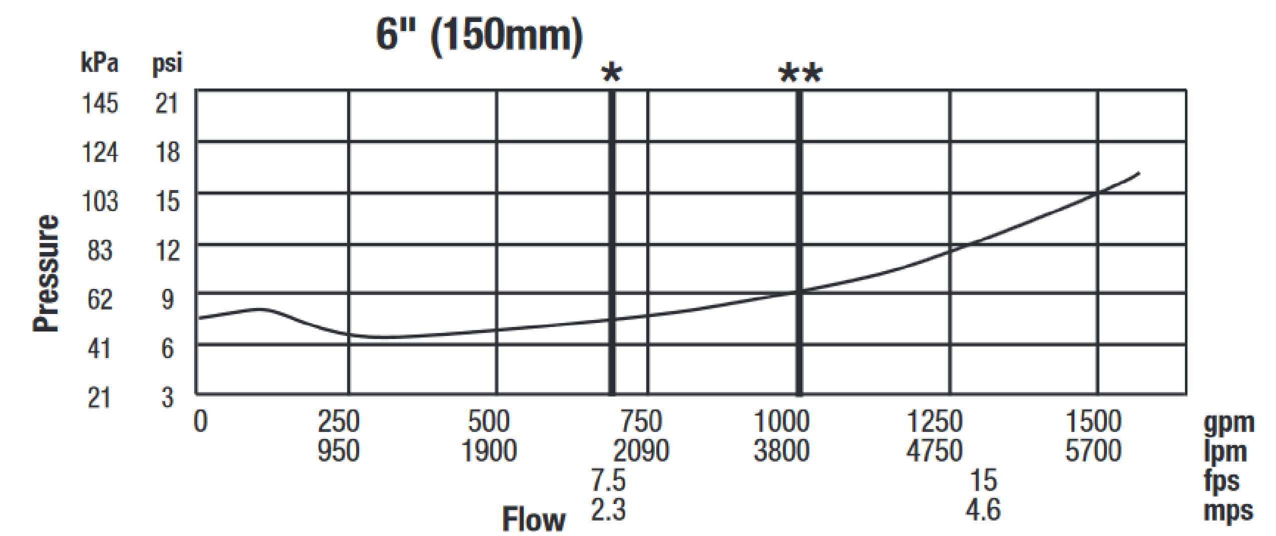
Flow Characteristics and Friction Loss

On drawings the designer must provide information about backflow preventers which must include manufacturer, size, and type. A cut sheet from the manufacturer must be provided for AHJ review and inspection. All BFP add friction loss to the fire sprinkler system. When water moves flow through BFP device, the check valves and controls create resistance to the flow. Unlike other fittings where a standard equivalent length is provided to determine friction loss such as a 1” sch 40 tee equates to 5ft per NFPA 13, friction loss through BFP are dependent on rate of flow. To evaluate this, locate the graph in cut sheet. Based on size of BFP to be used ex. 6”, 8”, 10” see the appropriate curve to determine pressure drop.

Flow Characteristics and Friction Loss



Above is graph of Watts 6” Double Check Detector Assembly.



Above is graph of (Example of graph from Watts 6” Reduced Pressure Zone Assembly)

Flow Characteristics and Friction Loss

Use the flow in gpm along the horizontal axis calculated via the remote area for the system including any hose allowance and read the highest psi loss in the vertical axis going back to 0 flow. Add this pressure loss to your system demand.

Why not use the pressure at the highest flow? As you can see from the graph the pressure fluctuates with flow. By using the highest psi loss along the curve, you have accounted for the worst case scenario as the flow is not going to jump immediately to system demand ex 1000gpm. The flow will increase as the number of sprinkler heads open thereby we must take the worst case.

Common Mistakes!!!

- You must examine the overall system demand to verify that addition of BFP friction loss does not overcome available pressure from the source. In past, very old buildings allowed sprinkler system without any BFP device.
- If the adopted codes require addition of a backflow device then a hydraulic examination must be performed to make sure adequate supply pressure is available. This also applies to replacement of BFP. See the two graphs above for double check vs RPZ. For the same flow RPZ has higher friction loss, almost double.

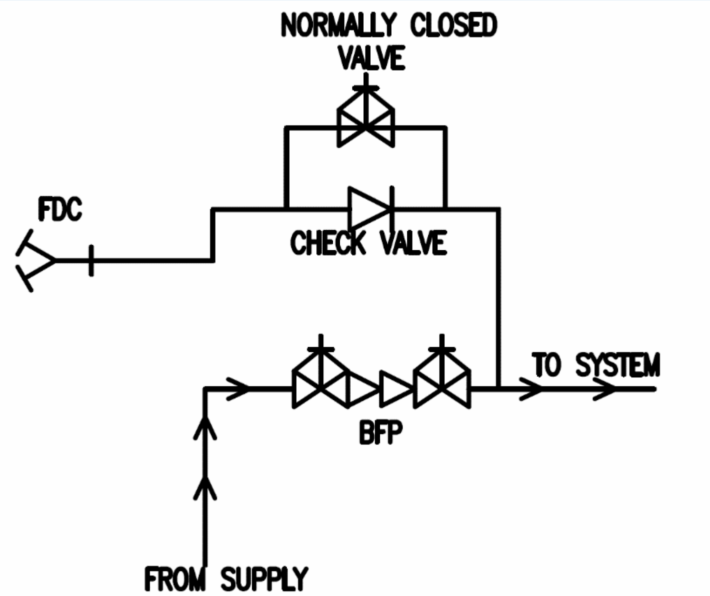
Inspection Maintenance and Testing

- NFPA 25 is the standard for Inspection, maintenance and testing of BFP. When adopted by code, the referenced standard must be followed. Care must be taken to which edition is referenced by the code.
- It is not necessarily that the newest edition is referenced and therefore cannot be enforced.
- BFP test must be performed by a qualified person. Control valves on the BFP are required to be inspected monthly. These must either be chain locked or electrically supervised via tamper switches. Make sure working drawings show locks or tamper on BFP control valves to avoid delays during inspection.
- For RPZ, the differential valve must be inspected weekly to ensure it is not discharging.
- Listed or approved pipe stands/hangers must be utilized to support the BFP.
- BFP assemblies are required to be opened and internally inspected every 5years.
- All the components must be operated to ensure they move freely and are in good condition.

Inspection Maintenance and Testing

- Finally, there must be a means to test backflow. The standard requires conducting a forward flow test (flowing water through the BFP device from supply in direction of the system) at a minimum flow rate of the system demand.
- The testing component can be achieved in several ways. Most commonly test hose outlets are provided downstream on discharge side of the BFP. Typically this contains 2-1/2” outlets with hose valves (each capable of flowing 250gpm).
- Based on the system demand and inside hose total flow must be flowed. So, if system demand is 600gpm, you need at least three - 2-1/2” outlets (hose valves which can flow up to 750gpm). The test hose valves should be monitored with tamper switch or have chain/locks.
- At times, fire department connection (FDC) or pump test header can also be used for BFP testing if the arrangement is design in. A bypass is made around the FDC check valve containing a control valve.

Inspection Maintenance and Testing



- In the above figure, the control valve at FDC is normally closed. During the test, the valve is opened and water will flow from bypass out through the FDC. There are certain cases where the discharge flow from the test is far off and cannot be determined at the drain. In this case a closed loop flow can be acceptable if a flowmeter or sight glass is incorporated into the system to ensure flow.

Inspection Maintenance and Testing

- Test must be conducted at initial installation, repair, relocation and annually thereafter. Test is required to make sure BFP is functioning as designed, no obstruction are present, the clapper is operation and control valves are open. Remember BFP is the main connection to the system. A shut off valve, closed clapper or obstruction can leave the entire fire protection system compromised. The above is an example of a forward flow test. Currently, NFPA 25 requires only a forward flow test. This means the testing is to ensure there is appropriate flow though the backflow in order to meet the system design. There is no requirements for testing the pressure loss through the BFP.

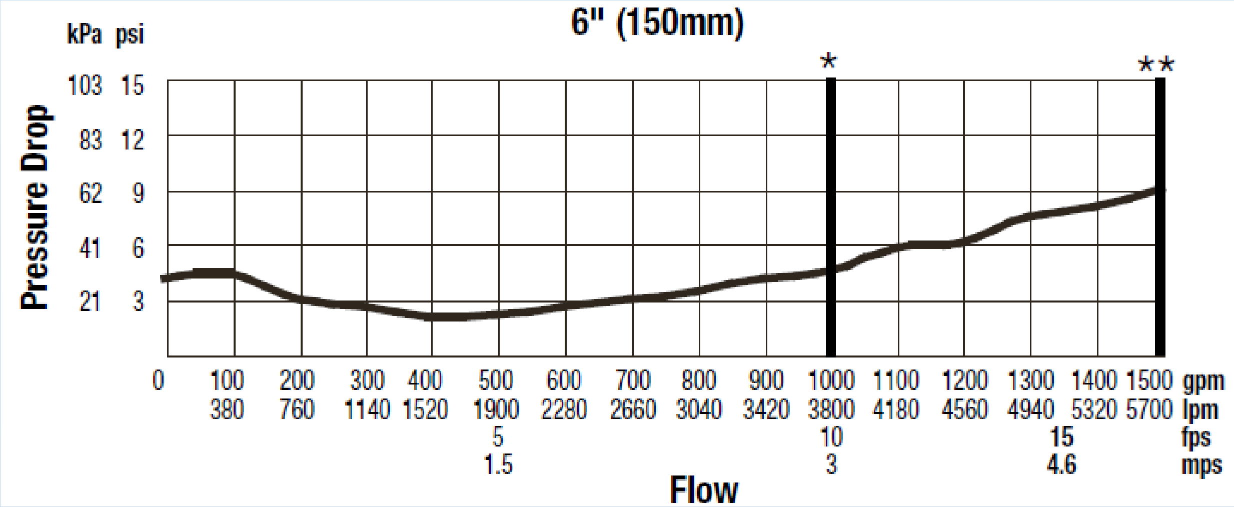
Following is procedure for testing backflow preventers:

- Step 1: Call out the test before testing. Alert the local fire department or local monitoring company (you don't want fire department showing up!).
- *Step 2: Read and record the gauges on suction and discharge side.
- Step 3: Open the test valve slowly and flow water. Confirm that an alarm indicator on the FACP is indicated for flow.
- *Step 4: When the flow is steady read and record the gauge on suction and discharge side. The different between the two is friction loss through the BFP.
- Step 5: Measure the flow using pitot tube at the hose outlets and calculate flow. Recall the formula $Q = 29.83cd^2\sqrt{p}$ where c is coefficient, d is diameter of hose in inches, p is pressure in psi measured from pitot tube and Q is flow in gpm. We will use the pitot tube reading to calculate the flow.
- *Step 6: Close the valves and again read and record the gauge on suction and discharge side.
- *Step 7: Use the calculated flow and the delta value of the pressures (i.e. pressure at discharge gauge of BFP minus pressure at suction gauge of BFP).
- *Step 8: Using the manufacturer curve locating the appropriate flow and pressure. Verify that for the flow rate during the test, the delta psi calculated is below the psi for the manufactured curve. If not, then further investigation is required.

*Testing for pressure loss is not currently required by NFPA 25. The test requires that the flow rate flowed should be equivalent to the system demand flow rate including any hose demands and downstream hydrants. If the AHJ chooses they can adopt more stringent methods requiring pressure check. The pressure differential allows a view of the conditions of the check valve.

Example:

- A backflow test was performed. Water was flowed through two 2-1/2 hose valves (inside diameter 2.25inch) with a smooth well rounded outlet (coefficient of discharge factor of 0.9). The pitot reading was 7psi. BFP supply gauge reads 50psi while gauge on discharge side reads 43psi. The remote area system demand is 520gpm at 38psi. Is the BFP functioning properly?
- Below is manufacture curve for double check backflow preventer



Answer

- Start with $Q = 29.83cd^2\sqrt{p}$
- $Q= 29.83 \times 0.9 \times 2.25^2 \times \sqrt{7}$
- Q = 359.60gpm
- Because there are two hose valve the total flow is 2 x 359.60gpm = 719.2gpm
- *The pressure loss through the BFP is 50psi – 42psi =8psi
- Therefore, at a flow if 719.2gpm the pressure lost is 8psi. Flow through BFP is also achieved as the system demand of 520gpm is lower than 712gpm.
- *However, looking at the graph the flow at the manufacturers curve at 719.2gpm the friction loss through the BFP should be close to 5psi (highest friction loss going back to 0 flow). This indicates that there appears to be more resistance created by the backflow preventer check vales then proposed by the manufacturer and further investigation is required.

*Testing for pressure loss is not currently required by NFPA 25.

Inspection Maintenance and Testing

You will also have noticed that this forward flow test doesn't test the backflow mechanism rather the functionality of the BFP spring load valve operating to allow adequate flow of water at a given pressure. In the past, NFPA 25 standard had requirements for backwards flow test, however this was removed from NFPA 25 as the scope covered functionally of the fire protection system instead of health safety. Although this appears to be contradictory for reasons of having the backflow (to prevent contamination of potable water supply), it is the NFPA committees stance that BFP testing for the fire protection system is to ensure adequate flow is present. AHJ and Health department should be consulted to make sure if there are more stringent requirements.

Summary

Backflow preventer are a critical component of an automatic fire suppression system. Not having a clear of understanding of how they work, their installation and testing can render the entire sprinkler system compromised thus leaving the occupants and property unprotected. AHJ, engineers and contractors must thoroughly examine BFP during design, installation and testing to verify compliance with codes and standards.

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