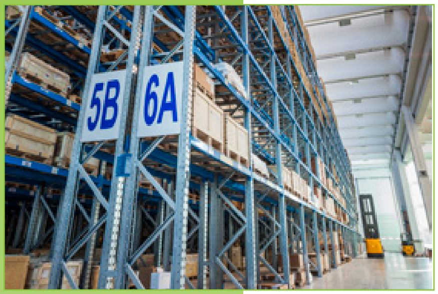
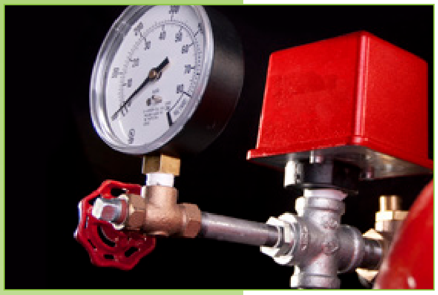




# Water Delivery Time

## Comparing Traditional Higher Air Pressure to Lower Air Pressure Dry Pipe Fire Sprinkler Systems

Johnson Controls

## *Contents*

## Introduction:

Dry pipe sprinkler systems, filled with pressurized air or nitrogen and typically found in areas prone to freezing temperatures, utilize one of two primary types of dry pipe fire protection valve technologies available on the market today: differential clapper-type valves and differential latch-type valves. Clapper-type valves work using an approximate one-to-six differential of air to water pressure (exact ratios may vary by manufacturer). System air pressure holds back water on the opposite side of the valve clapper until the air pressure drops to the point where water pressure can be overcome by the system air pressure. Systems using these valves are traditionally higher air pressure systems. Differential latch-type valves typically use a lower differential and therefore lower system air pressure on the assumption that the valve will trip faster if the system air pressure is lower and will speed water delivery. These valves use a latch to hold a clapper closed. When air pressure drops, an actuator trips and permits a latch to release the clapper and allow water to flow into the system.

"NFPA 13 Standard for the Installation of Sprinkler Systems" (NFPA 13) requires water delivery within certain time limitations as a function of system volume, or in some cases, upon multiple sprinkler activations. The premise is that quicker water delivery will enhance fire control ability, as water can be delivered before the fire sprinklers are overwhelmed by the increasing fire size. At least two types of differential latch-type dry pipe valves on the market promote the use of lower air pressure dry pipe fire sprinkler systems. These valves are marketed as an alternative to differential clapper-type valves, requiring higher air pressure for use in dry pipe systems, asserting systems requiring lower air pressure in system piping will save costs on air compressor sizing and decrease water delivery time. These assertions are based on (1) conditions allowing for a smaller, less expensive air compressor to be used that can be attributed to lower system air pressure and (2) a belief that if there is lower air pressure in the system, there is less resistance to water entering the system and flowing to the most remote point. With the National Fire Protection Association (NFPA) standard requirement to pressurize a dry pipe sprinkler system to the minimum required pressure in 30 minutes, air compressor costs may offer an advantage, especially where high water supply pressures exist; however, the ability for lower air pressure to quicken water delivery over traditional higher air pressure valves is debatable.

Using its SprinkFDT fluid delivery time software, Johnson Controls simulated two differential latch-type valves, "Low Pressure Valve A" and "Low Pressure Valve B," alongside the TYCO Model DPV-1 differential clapper-style dry pipe valve. Simulations with all valves were performed both with and without an accelerator, a device intended to further quicken a dry pipe valve opening should the valve be unable to meet the required water delivery time. The intent was to compare and contrast the performance of each valve in complying with water delivery times required by NFPA 13. The results clearly demonstrate there are circumstances in which lower system air pressure may not result in faster overall water delivery times.

## Low Pressure Valve A:

Technical literature for Low Pressure Valve A indicates system air pressure needs to be between 13 and 18 pounds per square inch (psi) for all water supply pressures. For purposes of comparison and based on the assumption that lower air pressure speeds water delivery, 13 psi was used in the simulations performed without an accelerator. Technical literature for Valve A also shows the valve will trip when air pressure decays to 7 psi (i.e. the time it takes for the system air pressure to reduce from 13 to 7 psi).

Valve A may be equipped with an optional mechanical dry pipe valve accelerator. The accelerator technical literature indicates system air pressure must be 18 to 30 psi. For comparison purposes and based on the assumption that lower air pressure accelerates water delivery, 18 psi was used in the simulations performed with an accelerator.

Technical literature for the accelerator further indicates that the device trips within an air pressure differential of 3 to 5 psi (i.e. essentially a drop in system air pressure of 3 to 5 psi). Due to the mechanical nature of the accelerator, the operating range of air pressure decay is likely related to system volume, because larger systems result in slower operation; therefore, a larger system drops 5 psi, while a smaller system drops 3 psi. Consideration should also be given to the timeframe required for the accelerator to trip the dry pipe valve, which can result in another 1 psi drop in air pressure. For purposes of comparison, the conservative assumption is that with the mechanical accelerator installed, the dry pipe valve will trip when air pressure decays by 4 psi. (i.e. the time it takes for system air pressure to reduce from 18 to 14 psi).

## Low Pressure Valve B:

Technical literature for Low Pressure Valve B indicates required system air pressure must be between 8 and 28 psi as a function of water supply pressures of 20 to 300 psi, and the fastest water delivery time is achieved by staying within the specified range as a function of water pressure. Specified pressure ranges for typical water pressures of 50 to 175 psi are as follows:

| Water psi | Minimum Air psi | Maximum Air psi |
|---|---|---|
| 50 | 12 | 16 |
| 75 | 13 | 17 |
| 100 | 15 | 19 |
| 125 | 16 | 20 |
| 150 | 17 | 21 |
| 175 | 18 | 22 |

For purposes of comparison and based on the assumption that lower air pressure speeds water delivery, the minimum air pressure was used in the simulations performed without an accelerator. Technical literature for Valve B indicates the valve will trip at a water-to-air ratio of 14:1.

Valve B was may be equipped with an optional mechanical dry pipe valve accelerator. According to the accelerator technical literature, when using the device, the system air pressure must be a minimum of 15 psi, which affects water supplies less than 100 psi based on the aforementioned air pressure ranges for Valve B. Technical literature for the accelerator further indicates that the device should trip a dry pipe valve in 24 seconds for what is assumed to be a 5.6K sprinkler on a 1,430-gallon system, which is the system capacity used in the comparison simulations.

The comparison simulates a single sprinkler operating with K-factors of 5.6, 8.0, and 11.2, as well as four sprinklers operating with those same K-factors. By means of extrapolation using available technical data and adding a one-second safety factor for the combined accelerator and dry pipe valve operation, the anticipated operating times for Low Pressure Valve B when equipped with an accelerator are as follows:

| | K=5.6 | K= 8.0 | K=11.2 |
|---|---|---|---|
| **Qty. 1** | 25 sec. | 17 sec. | 12 sec. |
| **Qty. 4** | 6 sec. | 4 sec. | 3 sec. |

## Comparison:

Using valve performance data for Valves A and B derived from each valve's respective technical literature, a comparison was conducted of the two low pressure valves to a higher air pressure system using the TYCO Model DPV-1 Dry Pipe Valve. The DPV-1 has a water-to-air trip ratio of 5.5:1 and may be equipped with the optional VIZOR electronic accelerator, which has an operating time of two seconds, independent of system volume or sprinkler K-factor.

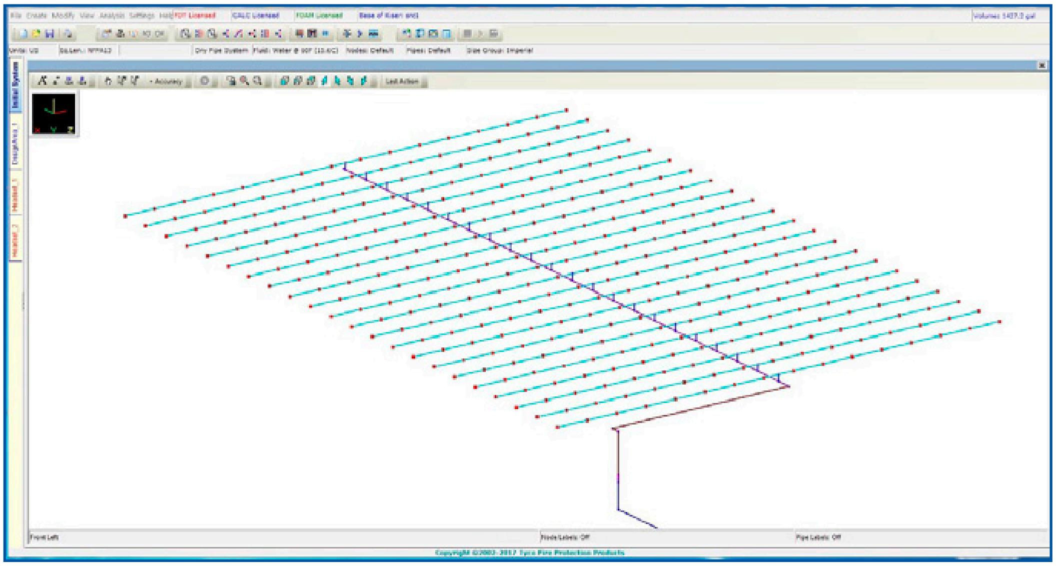
A tree-style system was simulated with SprinkFDT using three common water supply characteristics for static and residual pressure at 1,300 gallons per minute. These characteristics are detailed in the comparison chart summarizing the simulation data found on pages six, seven, and eight of this paper. The design area used to first determine whether the systems could be hydraulically validated was 2,438 square feet (sf), derived from an initial square footage of 2,500 sf, adding 30 percent increased square footage for a dry system and deducting 25 percent square footage for 286°F sprinklers. On the basis of a NFPA 13 classification of "Extra Hazard I," the following variables were examined using sprinklers with K-factors of 5.6, 8.0 and 11.2: (1) all K-factors with and without an accelerator and (2) all K-factors with the operation of one and four sprinkler heads.

Adhering to standard sprinkler system design, the system was first hydraulically calculated, thereby eliminating sprinkler options that did not provide the required water delivery. The comparison charts help demonstrate the process a designer might use: (1) select the optimum sprinkler K-factor, (2) eliminate the use of a dry pipe valve accelerator if possible and (3) identify the potential advantage of using a four-sprinkler test manifold versus a one-sprinkler test connection – all of which can be optimized through the use of SprinkFDT, as was done for this comparison. SprinkFDT is a UL Listed software program for calculating fluid delivery time. The software accurately calculates dry valve trip time and water delivery time to the remote sprinkler(s). The pass/fail results shown in the comparison charts are based on NFPA 13 water delivery requirements for dry pipe systems.

The comparison results also validate circumstances in which differential clapper-style valves in higher air pressure systems can meet water delivery times, where, in the same circumstances, differential latch-type valves in lower air pressure systems cannot. As the charts show, the differential-style DPV-1 valve met water delivery times without an accelerator in 8 of 12 simulations, and with the VIZOR electronic accelerator in 12 of 12 simulations, a combined record of 20 passes in 24 total simulations. Valve A passed 16 of 24 simulations, and passed only 6 without an accelerator. Valve B passed 15 of 24, including only 3 without an accelerator. Additionally, the simulation results illustrate the higher air pressure valve tripped faster than both lower air pressure valves in all 12 simulations without accelerators. This demonstrates that although there was higher air pressure in the system, the DPV-1 valve reached its set trip point and began delivering water sooner than the lower pressure valves. The water transit times (the time from valve trip to water delivery) for the higher air pressure DPV-1 were also comparable to those of the lower air pressure valves, with faster times in 6 of 12 simulations. Without an accelerator, the DPV-1 delivered water faster than both low pressure valves in 12 of 12 simulations.

In simulations with an accelerator, the DPV-1 was paired with the TYCO VIZOR electronic accelerator, set to a standard trip time of two seconds, which was unmatched by the trip times of the mechanical accelerators used on the low-pressure valves. The DPV-1 met the water delivery time requirements in 12 of 12 simulations performed using accelerators. Valve A passed in 10 of 12 instances and Valve B passed 12 of 12. The improved percentage of passed simulations reinforces the impact an accelerator can have on lowering trip times and overall water delivery times. Comparing only water transit times to determine the impact of lower versus higher system air pressure, the data reveals the DPV-1 valve had a faster transit time in 6 of 12 simulations. Comparison of water delivery times shows the DPV-1 with the VIZOR electronic accelerator had a faster overall water delivery time in 12 of 12 simulations, which in part can be attributed to the faster trip time of the electronic accelerator.

In running the simulations, it was noted that in a higher air pressure dry pipe system, the probability of water flowing into the system branch lines was less than in lower air pressure systems, due to higher resistance from the system air pressure.  Higher air pressure in the branch lines forced water to take the path of least resistance to forward motion, moving it more quickly toward the inspector's test connection. Because of reduced resistance from system air pressure in the lower air pressure systems, water transit times and, consequently, water delivery times were at times negatively impacted.



**2,500 square foot, tree-style system designed in SprinkFDT**

## *Model DPV-1 Dry Pipe Valve and Vizor Dry Pipe Valve Accelerator*

**System Capacity Description**

***Design Density*** **= 0.30 gpm/sf over 2438 sf — *Hose Demand* = 500 gpm — *System Capacity* = 1430 Gallons — *Feed Main* = 6 inch pipe, Sch. 10 — *Cross Main* = 6 inch pipe, Sch.10 – *Riser Nipples* = 2-1/2 inch pipe, Sch. 40 — *Branch Line* = 2-1/2 inch pipe, Sch.10 — *352 Sprinklers* covering 35,200 sf**

| Water Supply Characteristics | Initial Air Pressure, psi | K-Factor | Accelerator | Valve Trip Time | Water Transition Time | Fluid Delivery Time | Extra Hazard I Required Delivery Time | Number of Remote Operated Sprinklers | Pass<br>Fail |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Seconds | | | | | |
| 50 psi static 45 psi residual at 1300 gpm | 15 | 5.6 | No | DOES NOT MEET HYDRAULIC DEMAND | | | 60 | 1 | |
| | | | Yes | | | | | | |
| | | | No | | | | 45 | 4 | |
| | | | Yes | | | | | | |
| | | 8.0 | No | 52.2 | 31.2 | 83.5 | 60 | 1 | Fail |
| | | | Yes | 2.0 | 33.8 | 35.8 | | | Pass |
| | | | No | 13.0 | 26.4 | 37.4 | 45 | 4 | Pass |
| | | | Yes | 2.0 | 25.9 | 27.9 | | | Pass |
| | | 11.2 | No | DOES NOT MEET HYDRAULIC DEMAND | | | 60 | 1 | |
| | | | Yes | | | | | | |
| | | | No | | | | 45 | 4 | |
| | | | Yes | | | | | | |
| 80 psi static 65 psi residual at 1300 gpm | 20 | 5.6 | No | DOES NOT MEET HYDRAULIC DEMAND | | | 60 | 1 | |
| | | | Yes | | | | | | |
| | | | No | | | | 45 | 4 | |
| | | | Yes | | | | | | |
| | | 8.0 | No | 40.3 | 29.3 | 69.6 | 60 | 1 | Fail |
| | | | Yes | 2.0 | 30.4 | 32.4 | | | Pass |
| | | | No | 10.1 | 24.2 | 34.3 | 45 | 4 | Pass |
| | | | Yes | 2.0 | 23.9 | 25.9 | | | Pass |
| | | 11.2 | No | 26.8 | 26.9 | 53.7 | 60 | 1 | Pass |
| | | | Yes | 2.0 | 27.5 | 29.5 | | | Pass |
| | | | No | 6.7 | 24.1 | 30.8 | 45 | 4 | Pass |
| | | | Yes | 2.0 | 23.4 | 25.4 | | | Pass |
| 120 psi static 95 psi residual at 1300 gpm | 30 | 5.6 | No | 65.3 | 29.8 | 95.1 | 60 | 1 | Fail |
| | | | Yes | 2.0 | 31.2 | 33.2 | | | Pass |
| | | | No | 16.3 | 23.5 | 39.8 | 45 | 4 | Pass |
| | | | Yes | 2.0 | 23.6 | 25.6 | | | Pass |
| | | 8.0 | No | 45.5 | 27.4 | 72.8 | 60 | 1 | Fail |
| | | | Yes | 2.0 | 28.3 | 30.3 | | | Pass |
| | | | No | 11.4 | 22.2 | 33.5 | 45 | 4 | Pass |
| | | | Yes | 2.0 | 21.9 | 23.9 | | | Pass |
| | | 11.2 | No | 30.3 | 25.1 | 55.3 | 60 | 1 | Pass |
| | | | Yes | 2.0 | 25.5 | 27.6 | | | Pass |
| | | | No | 7.6 | 21.6 | 29.2 | 45 | 4 | Pass |
| | | | Yes | 2.0 | 21.0 | 23.0 | | | Pass |

**Summary data of DPV-1 simulations performed using SprinkFDT software**

## *Dry Pipe Valve "A" and Dry Pipe Valve Accelerator*

**System Capacity Description**

***Design Density*** = 0.30 gpm/sf over 2438 sf — ***Hose Demand*** = 500 gpm — ***System Capacity*** = 1430 Gallons — ***Feed Main*** = 6 inch pipe, Sch. 10 — ***Cross Main*** = 6 inch pipe, Sch.10 – ***Riser Nipples*** = 2-1/2 inch pipe, Sch. 40 — ***Branch Line*** = 2-1/2 inch pipe, Sch.10 — ***352 Sprinklers*** covering 35,200 sf

| Water Supply Characteristics | Initial Air Pressure, psi | K-Factor | Accelerator | Valve Trip Time | Water Transition Time | Fluid Delivery Time | Extra Hazard I Required Delivery Time | Number of Remote Operated Sprinklers | Pass<br>Fail |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Seconds | | | | | |
| **50 psi static 45 psi residual at 1300 gpm** | 13 with out Accelerator<br>18 with Accelerator | 5.6 | No | DOES NOT MEET HYDRAULIC DEMAND | | | 60 | 1 | |
| | | | Yes | | | | | | |
| | | | No | | | | 45 | 4 | |
| | | | Yes | | | | | | |
| | | 8.0 | No | 56.5 | 30.8 | 87.3 | 60 | 1 | Fail |
| | | | Yes | 31.9 | 31.5 | 63.4 | | | Fail |
| | | | No | 14.1 | 26.8 | 40.9 | 45 | 4 | Pass |
| | | | Yes | 8.0 | 26.3 | 34.3 | | | Pass |
| | | 11.2 | No | DOES NOT MEET HYDRAULIC DEMAND | | | 60 | 1 | |
| | | | Yes | | | | | | |
| | | | No | | | | 45 | 4 | |
| | | | Yes | | | | | | |
| **80 psi static 65 psi residual at 1300 gpm** | | 5.6 | No | DOES NOT MEET HYDRAULIC DEMAND | | | 60 | 1 | |
| | | | Yes | | | | | | |
| | | | No | | | | 45 | 4 | |
| | | | Yes | | | | | | |
| | | 8.0 | No | 54.1 | 28.6 | 82.7 | 60 | 1 | Fail |
| | | | Yes | 31.9 | 28.8 | 60.7 | | | Fail |
| | | | No | 13.5 | 25.6 | 39.1 | 45 | 4 | Pass |
| | | | Yes | 8.0 | 25.0 | 33.0 | | | Pass |
| | | 11.2 | No | 36.0 | 26.8 | 62.8 | 60 | 1 | Fail |
| | | | Yes | 21.2 | 26.8 | 48.0 | | | Pass |
| | | | No | 9.0 | 26.0 | 35.0 | 45 | 4 | Pass |
| | | | Yes | 5.3 | 25.3 | 30.6 | | | Pass |
| **120 psi static 95 psi residual at 1300 gpm** | | 5.6 | No | 75.7 | 28.6 | 104.3 | 60 | 1 | Fail |
| | | | Yes | 22.2 | 29.2 | 51.4 | | | Pass |
| | | | No | 18.9 | 24.6 | 43.6 | 45 | 4 | Pass |
| | | | Yes | 5.6 | 23.7 | 29.3 | | | Pass |
| | | 8.0 | No | 52.7 | 26.8 | 79.5 | 60 | 1 | Fail |
| | | | Yes | 15.5 | 27.0 | 42.5 | | | Pass |
| | | | No | 13.2 | 24.3 | 37.5 | 45 | 4 | Pass |
| | | | Yes | 3.9 | 22.6 | 26.5 | | | Pass |
| | | 11.2 | No | 35.1 | 25.3 | 60.4 | 60 | 1 | Fail |
| | | | Yes | 10.3 | 24.9 | 35.3 | | | Pass |
| | | | No | 8.8 | 24.7 | 33.5 | 45 | 4 | Pass |
| | | | Yes | 2.6 | 22.5 | 25.1 | | | Pass |

**Summary data of Valve A simulations performed using SprinkFDT software**

## *Dry Pipe Valve "B" and Dry Pipe Valve Accelerator*

**System Capacity Description**

***Design Density*** = 0.30 gpm/sf over 2438 sf — ***Hose Demand*** = 500 gpm — ***System Capacity*** = 1430 Gallons — ***Feed Main*** = 6 inch pipe, Sch. 10 — ***Cross Main*** = 6 inch pipe, Sch.10 – ***Riser Nipples*** = 2-1/2 inch pipe, Sch. 40 — ***Branch Line*** = 2-1/2 inch pipe, Sch.10 — ***352 Sprinklers*** covering 35,200 sf

| Water Supply Characteristics | Initial Air Pressure, psi | K-Factor | Accelerator | Valve Trip Time | Water Transition Time | Fluid Delivery Time | Extra Hazard I Required Delivery Time | Number of Remote Operated Sprinklers | Pass<br>Fail |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Seconds | | | | | |
| 50 psi static 45 psi residual at 1300 gpm | 15 | 5.6 | No | DOES NOT MEET HYDRAULIC DEMAND | | | 60 | 1 | |
| | | | Yes | | | | | | |
| | | | No | | | | 45 | 4 | |
| | | | Yes | | | | | | |
| | | 8.0 | No | 86.5 | 30.3 | 116.8 | 60 | 1 | Fail |
| | | | Yes | 19.2 | 31.6 | 50.8 | | | Pass |
| | | | No | 21.6 | 27.6 | 49.2 | 45 | 4 | Fail |
| | | | Yes | 4.8 | 26.2 | 31.0 | | | Pass |
| | | 11.2 | No | DOES NOT MEET HYDRAULIC DEMAND | | | 60 | 1 | |
| | | | Yes | | | | | | |
| | | | No | | | | 45 | 4 | |
| | | | Yes | | | | | | |
| 80 psi static 65 psi residual at 1300 gpm | 15 | 5.6 | No | DOES NOT MEET HYDRAULIC DEMAND | | | 60 | 1 | |
| | | | Yes | | | | | | |
| | | | No | | | | 45 | 4 | |
| | | | Yes | | | | | | |
| | | 8.0 | No | 81.2 | 28.6 | 109.8 | 60 | 1 | Fail |
| | | | Yes | 17.0 | 30.0 | 47.0 | | | Pass |
| | | | No | 20.3 | 25.9 | 46.2 | 45 | 4 | Fail |
| | | | Yes | 5.0 | 24.5 | 29.5 | | | Pass |
| | | 11.2 | No | 54.1 | 26.9 | 81.0 | 60 | 1 | Fail |
| | | | Yes | 12.0 | 27.0 | 39.0 | | | Pass |
| | | | No | 13.5 | 26.4 | 39.9 | 45 | 4 | Pass |
| | | | Yes | 3.0 | 25.0 | 28.0 | | | Pass |
| 120 psi static 95 psi residual at 1300 gpm | 16 | 5.6 | No | 85.2 | 28.6 | 113.8 | 60 | 1 | Fail |
| | | | Yes | 25.0 | 29.0 | 54.0 | | | Pass |
| | | | No | 21.3 | 24.4 | 45.7 | 45 | 4 | Fail |
| | | | Yes | 6.2 | 23.8 | 30.0 | | | Pass |
| | | 8.0 | No | 59.3 | 26.8 | 86.1 | 60 | 1 | Fail |
| | | | Yes | 17.3 | 26.9 | 44.1 | | | Pass |
| | | | No | 14.8 | 23.9 | 38.7 | 45 | 4 | Pass |
| | | | Yes | 4.3 | 22.9 | 27.2 | | | Pass |
| | | 11.2 | No | 39.5 | 25.2 | 64.7 | 60 | 1 | Fail |
| | | | Yes | 11.5 | 25.0 | 36.4 | | | Pass |
| | | | No | 9.9 | 24.3 | 34.1 | 45 | 4 | Pass |
| | | | Yes | 2.9 | 22.9 | 25.8 | | | Pass |

**Summary data of Valve B simulations performed using SprinkFDT software**

## Conclusion:

The simulation data provided by SprinkFDT indicates the traditional higher air pressure system using the TYCO Model DVP-1 Dry Pipe Valve, with or without the VIZOR Dry Pipe Valve Accelerator, provided quicker water delivery times for each variable than Valve A and Valve B. When measured against the NFPA 13 pass/fail criteria, the traditional high air pressure system outperformed the low air pressure system arrangements. This conclusion is based upon comparisons for one system piping arrangement with variables of only three water supply conditions; however, the simulations demonstrate that the belief that lower air pressure dry systems quick water delivery over traditional higher air pressure systems is debatable or even not at all likely. The results also reinforce the fact that apart from system air pressure, other factors, such as water supply, system volume, system design, sprinkler head sizes and the use of an accelerator, affect water delivery time in a dry pipe system. A low-pressure valve should not be considered a fool-proof answer to meeting water delivery times or avoiding the need for an accelerator. Multiple contributing factors may make a differential-style or a low-pressure valve more suitable for a given system design.

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