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Quick Opening Devices
(Dry Pipe Valve Accelerators)

A Technical Analysis:

Mechanical vs. Electronic Dry Pipe Valve Accelerators

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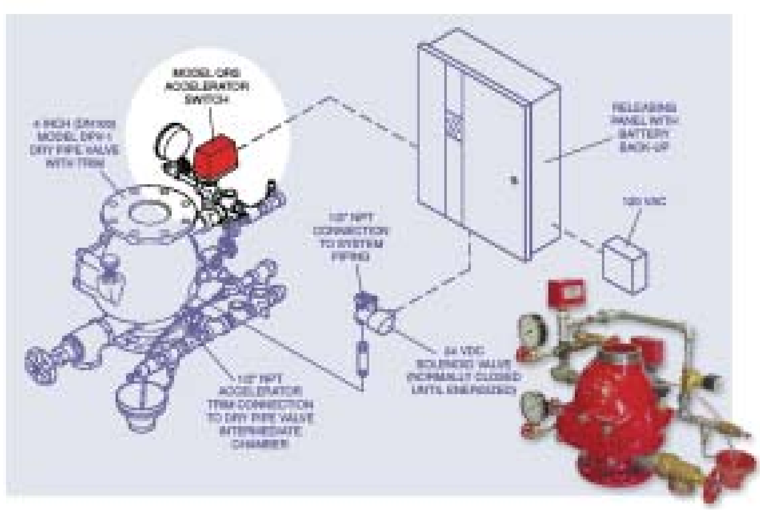

Introduction

Quick Opening Devices (QOD) are predominately used in dry pipe sprinkler systems to speed the operation of the dry pipe valve (trip time), resulting in quicker water delivery time (trip time + transit time). There are two principal types of quick opening devices - accelerators and exhausters. This paper will focus on the accelerator in its different forms, both mechanical and electrical, for the purpose of providing a comparative analysis of function, performance, and maintenance.

How long does it take for a dry pipe sprinkler system to discharge water from an open sprinkler? A previous paper entitled "Variables That Affect The Performance Of Dry Pipe Systems"[1] clearly identifies the many factors involved with establishing the answer to this question. However, the previous paper does not fully explore the variables of performance between mechanical and electronic accelerators, nor does it consider the different delivery times of each.

The use of mechanical accelerators has been the traditional method of meeting the water delivery time required by NFPA standards, and the use of accelerators has far outweighed the use of exhausters. The principle behind an accelerator is simply the implementation of a device that is more sensitive to air pressure loss than a traditional dry pipe valve. Mechanical accelerators are more sensitive to air pressure loss by means of restricted orifices and many moving parts intended to detect a small pressure imbalance. Unfortunately, mechanical accelerators are fine tuned devices that require frequent maintenance to function properly and prevent false operation of the dry pipe valves that fill the sprinkler system unnecessarily.

Electronic accelerators have recently been introduced to the market. Their simplicity in function, dependability, and lack of required maintenance is expected to revolutionize the concept of accelerators to quicken the water delivery time of dry pipe sprinkler systems.

Definitions

Quick Opening Device — A Quick Opening Device is defined by Underwriters Laboratory as "a device that generally consists of one of the following two constructions that are intended to reduce the time delay between the operation of the first sprinkler and the entrance of water into the sprinkler piping of a dry pipe system:

a) **Accelerator** - A device intended to induce dry pipe system air into a chamber of a dry pipe valve to reduce the trip time
b) **Exhauster** - A device intended to discharge dry pipe air directly to atmosphere."[2]

Dry Pipe Valve - The water control valve that separates the water supply (in a heated area) from the system piping exposed to potential freezing temperatures.

Dry Pipe Sprinkler System - A fire sprinkler piping system charged with pressurized air or nitrogen on the system side of a dry pipe valve.

Inspector's Test Valve - A remotely located test valve (from the water supply) to simulate the operation of a single sprinkler to measure the water delivery time.

Trip Time - The time between the opening of the inspectors test valve and the activation of the dry pipe valve.

Transit Time - The time between the dry pipe valve trip and water delivery to the inspector's test valve.

Water Delivery Time - The total time between the opening of the inspector's test valve and the water delivery to the test valve (Trip + Transit).

Accelerator Performance

Additional information is necessary to understand the criteria for an Accelerator to qualify as a Quick Opening Device per UL1486.2 Besides the normal mechanical and corrosion tests, a performance test is required that mandates the device must operate before the pressure drops 5 psi (0.34 bar) in a simulated system 1.6 times greater than the volume for which the device is rated. For example: If a device is rated for a maximum volume of 1500 gallons (5678 l), the test for activation within a 5 psi (0.34 bar) drop would be performed with a 2400 gallon (9085 l) system (1500 gallons x 1.6). The initial system air pressure for three different tests will be 50 (3.4 bar), 35 (2.4 bar) and 25 psi (1.7 bar). At the 25 psi (1.7 bar) start pressure, the loss of 5 psi (0.34 bar) will take as long as 62 seconds in a 2400 gallon (9085 l) test as shown in Figure 1. The test is conservative with respect to the device's rating; the 2400 gallon (9085 l) test certifies the performance of a 1500 gallon (5678 l) rating of the device that is also shown in Figure 1.

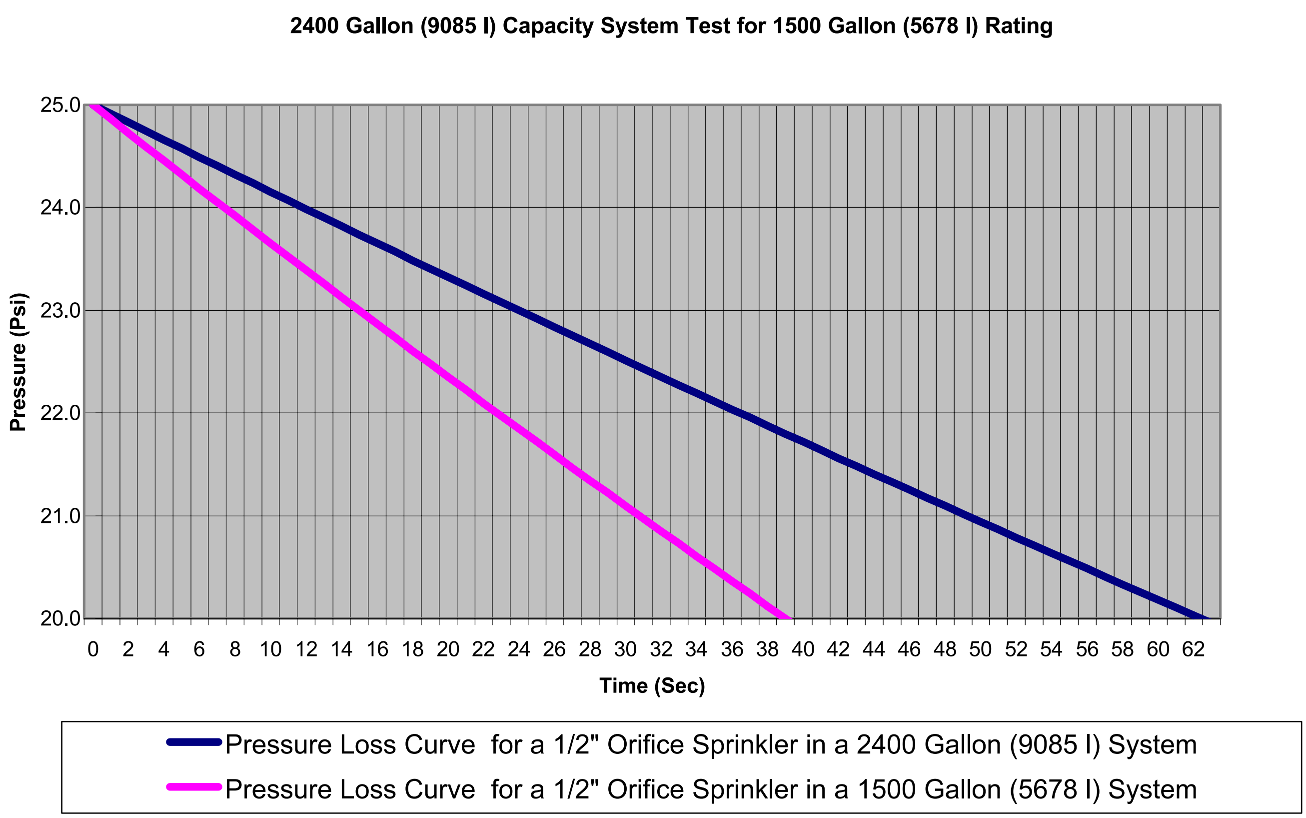

Figure 1- Air Loss Curves

Not all accelerators are alike, and their performance can vary significantly. The time required for an accelerator to activate within a given system volume may vary as much as 47 seconds between brands and types. Table 1 demonstrates the activation time performance of the Tyco QRS electronic accelerator, the Tyco ACC-1 mechanical accelerator, and a third (Brand X) mechanical accelerator. For reference, data for the third accelerator was compiled through the testing of a purchased unit, and is not from published values. From Figure 1, a maximum time of 40 seconds (5 psi (0.34 bar) drop) is allowed for a 1500 gallon (5678 l) system starting at 25 psi (1.7 bar) air. Performance of the third accelerator approaches the limit at 34 seconds, while the ACC-1 came in at 15 seconds, only to finish a distant second to the QRS performance of 3 seconds.

Initial Air Psi (bar)	Accelerator Activation Time (sec)											
	806 Gallon (3028 l) System			970 Gallon (3672 l) System			1330 Gallon (5034 l) System			1500 Gallon (5678 l) System		
	QRS	ACC-1	Brand X	QRS	ACC-1	Brand X	QRS	ACC-1	Brand X	QRS	ACC-1	Brand X
15 (1.03)	3	8	11	3	11	12	3	14	21	3	16	26
25 (1.7)	3	7	12	3	11	13	3	12	29	3	15	34
50 (3.4)	3	6	12	3	7	16	3	11	32	3	12	50

Table 1 - Accelerator Activation Times

In addition to the actual accelerator activation time, UL1486 allows a maximum 5 seconds for the accelerator to trip the dry pipe valve.

The lesson here is that accelerators vary in their performance, but are all Listed as “quick opening devices” when qualified to laboratory test requirements such as UL1486. With respect to activation times, perhaps it is more important that a quick opening device operate within a given time frame and not a given pressure drop. Working within this constraint would assure a more timely water delivery time (trip time + transit time).

It is also interesting to note that although a test starting at 25 psi (1.7 bar) in most cases will be the most demanding, since it represents the slowest air decay rate as the test begins, the Brand X mechanical accelerator unexpectedly operates slower at higher initial pressures. This further compromises the potential water delivery time (trip time + transit time).

Accelerator Use Requirements

When are accelerators required by NFPA 13[3]? Contrary to popular belief, accelerators are not required exclusively on the basis of system volume. Accelerators are an option if the system exceeds a 500 gallon capacity and requires more than 60 seconds for water delivery. The inspector's test criteria simulates single sprinkler activation through a test valve - from the time the inspector's test valve is fully opened (simulating a sprinkler operation) to the time water flows from the inspector's test valve. A quick glance at Table 2 summarizes the 2002 edition of NFPA 13 criteria for dry pipe sprinkler system performance. Table 2 clearly states that if the system is capable of water delivery in 60 seconds or less, accelerators are not required. (Consequently, one might assume that a system of 500 gallons or less not requiring the water delivery would deliver water within 60 seconds if subject to the same test at the inspector's test valve.)

System Size Gal. (Liters)	Quick Opening Device Required?	Required Water Delivery Time to Inspectors Test Connection
0 – 500 Gal. (0 – 1893 L)	N	None
500 – 750 Gal. (1893 – 2839 L)	N	60 Sec
	Y	None
Over 750 Gal. (2839 L)	N	60 Sec

Table 2 - Summary of NFPA 13 Requirements

A good example that illustrates the installer's decision process when determining the need for an accelerator is a system having a capacity of 700 gallons (2650 l). Most installers would not put an accelerator on the system during the initial installation of the system. After the system is complete, a water delivery test is performed to establish the actual water delivery time. As can be seen from Table 2, a water delivery of 60 seconds or less will not require an accelerator, and the installation will be adequate. If the water delivery is 85 seconds, an accelerator would be required, and the contractor would be forced (by code) to install one at that time. No further time testing is required after an accelerator is placed on a system with a capacity between 500 (1893 l) and 750 gallons (2839 l). Also note that systems above a 750 gallon (2839 l) capacity do not require accelerators but do mandate the 60 second water delivery time.

Accelerator Types

As referenced in the introduction, this paper addresses two types of Accelerators — the first is the Mechanical Accelerator and the second will be the Electronic Accelerator. No analysis would be complete unless the cost difference is also evaluated. The comparative Tyco Fire Products published list price of a 4 inch (100 mm) dry pipe valve, complete with trim, low and high air pressure alarm switches and accelerator, is US$3,559.00 (Mechanical Accelerator), and US$5,289.00 (Electric Accelerator).

The comparative analysis of function, performance, and maintenance is discussed below.

Mechanical Accelerator

Figure 2 shows a typical example of a mechanical accelerator and its connections to a dry pipe system. The following description will detail the operational sequence of a Tyco ACC-1 mechanical accelerator. An understanding of the principles of this device applies to virtually all mechanical accelerators.

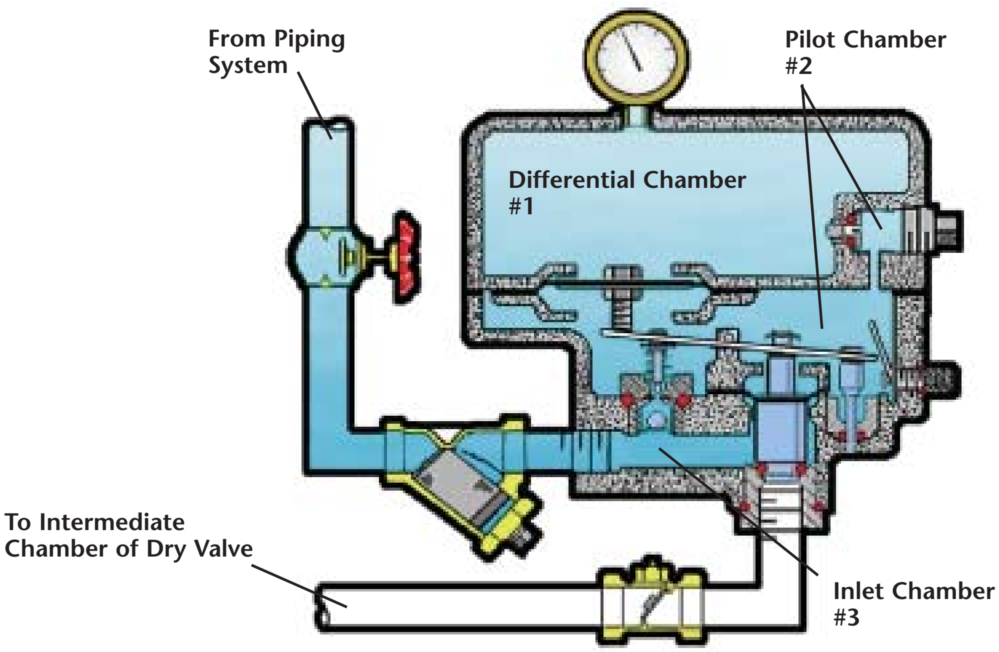

Figure 2 - Tyco ACC-1 Accelerator as Installed in the Set Position

To better understand the details of operation, Figure 3 is an enlarged view of the accelerator. There are 3 separate pressure chambers involved with this mechanical accelerator. Chamber #1 is called the Differential Chamber, Chamber #2 is called the Pilot Chamber, and Chamber #3 is the Inlet Chamber. All three chambers are connected by communicating ports. The restricted orifice between Chamber #1 and #2 is smaller than the orifice between Chamber #2 and #3. Therefore, loss of air pressure from the system (#3) drops the air pressure in Chamber #2 faster than the air can escape from Chamber #1. This imbalance will cause this accelerator to activate when the pressure differential is approximately 2 psi (0.14 bar) higher in Chamber #1 than in Chamber #2.

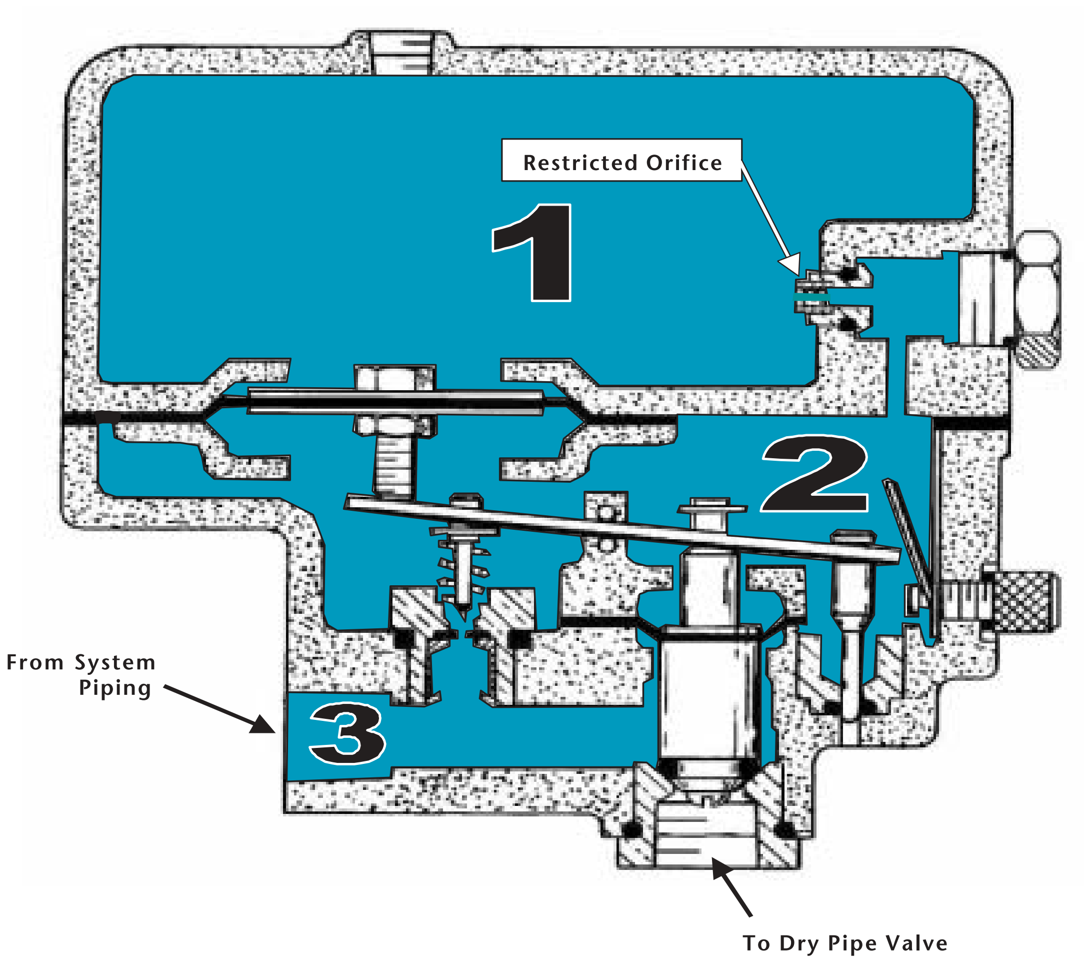

Figure 3 - Section View of a Mechanical Accelerator

The sequence of operation for a mechanical accelerator is shown in Figures 4 to 6. Reviewing these figures reveals the orifices, passageways, and moving parts associated with mechanical accelerators, as well as the numerous potential points of required maintenance necessary for proper operation. Any obstruction of the communicating ports between the chambers will cause either a false trip or will prevent the accelerator from operating. If the unit is not trip tested as required on regular intervals (quarterly per NFPA 25)[4], moving parts may become frozen or obstructed and produce a false trip or will fail to trip at all. Frequent maintenance is required to keep mechanical accelerators in proper operating condition.

'False trips' in Mechanical Accelerators generally occur at night. This is commonly due to obstructions in the restricted orifice between Chambers #1 and #2. The dry valve and accelerator are located in a heated area, and higher air pressure from elevated daytime temperature (heat expands air to cause higher pressures) is trapped in Chamber #1. As night falls and the temperature cools in the unheated building, the system air pressure drops (air decompresses when it is cooled). If the higher pressure in Chamber #1 is blocked by an obstruction, pressure cannot be relieved into chamber #2, and an imbalance results. The device will trip when the pressure differential is approximately 2 psi (0.14 bar) between the two chambers.

Example: First, assume an unheated warehouse where a dry pipe system has been installed due to cold winter temperatures. Now assume a normal system air pressure automatically maintained at a minimum pressure of 40 psi (2.8 bar) and an ambient temperature of 70F (21C) during the summer. As the daytime temperature slowly increases to 100F (38C), the pressure slowly rises in the system to 54 psi (3.7 l). Likewise, Chambers #1, #2, and #3 slowly increase to 54 psi (3.7 l). Chamber # 3, however, increases even more slowly due to the communicating port (between the chambers) being partially clogged. As night falls, so does the ambient temperature. The system rapidly cools, but most of the excess pressure is trapped in Chamber #1 due to the inability of the restricted orifice to compensate (balance the chamber pressures) because of its being obstructed. With a differential between Chambers #1 and #2, where Chamber #1 is at a higher pressure than Chamber #2, the accelerator will false trip when the differential reaches an approximate 2 psi (0.14 bar) difference.

False trips of accelerators can also be attributed to the failure of anti-flooding devices within the accelerator, and excessive drain-back water after a dry pipe sprinkler system is reset. In all cases, the false trip is a result of the inability of the restricted orifice to compensate (equalize) normal pressure variations between two chambers. Ironically, in the mechanical accelerator, it is the restricted orifice that is critical to maintaining the pressure variation within the accelerator due to a sprinkler operation and for the proper operation of the device.

Mechanical Accelerator Operation

Figures 4, 5, and 6 show the sequence of events that cause a mechanical accelerator to operate under normal conditions. Figure 4 shows the mechanical accelerator in the set position. In this position, the air pressure in the system (#3) is equal to the air pressure in Chambers #1, and #2.

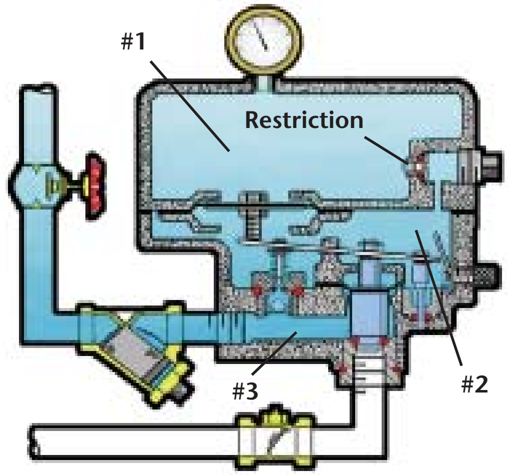

Figure 4 - Section View of a Mechanical Accelerator in the Set Position

Figure 5 illustrates the initial air movement that occurs when a sprinkler activates on the dry pipe system. The activation begins to drop the air pressure in the system piping and the connecting trim piping that feeds system air pressure to the inlet chamber of the accelerator. The depletion of air in the inlet chamber is equalized to the pilot chamber (#2) faster than the pressure can equalize between the differential chamber (#1) and the pilot chamber due to the restricting orifice through which the two chambers communicate. This causes a pressure imbalance.

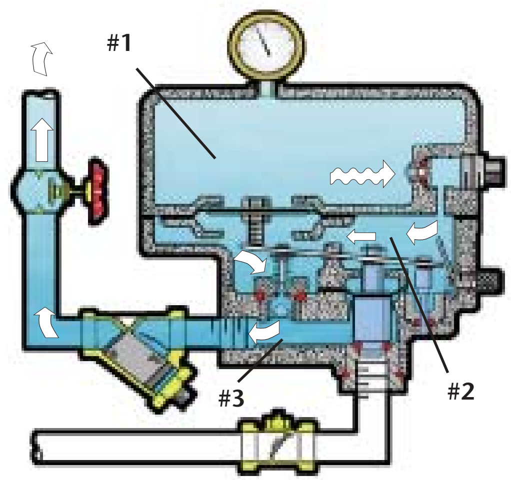

Figure 5 - Air Movement In a Mechanical Accelerator Upon Sprinkler Activation

When the air pressure in the differential chamber (#1) is approximately 2 psi (0.14 bar) higher than the pilot chamber (#2), the diaphragm between the two will be forced downward by the pressure imbalance, causing the accelerator to trip as shown in Figure 6, clearing the exhaust valve, and sending a burst of the residual system air pressure through the now unobstructed exhaust valve opening to the underside of the dry pipe valve clapper (through the intermediate chamber of the valve), causing the dry pipe valve to activate.

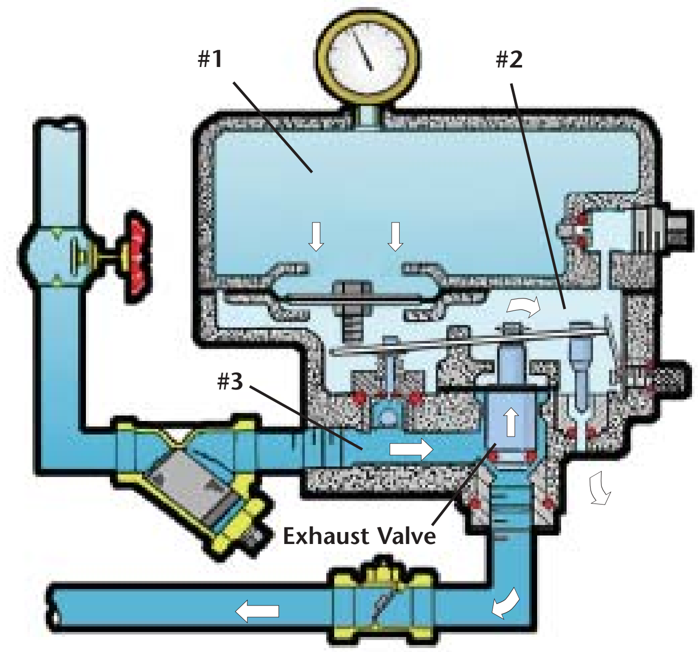

Figure 6 - Upon 2 psi Differential Pressure (Chamber 1 & 2) - Accelerator Trips

Mechanical Accelerator Maintenance

From the diagrams, it is easy to see why frequent maintenance is required and necessary with mechanical style accelerators. By count, there are 3 sliding pistons, two diaphragms, two restricted passageways, and one restriction that all have to be in operating condition for the accelerator to function properly. Without this maintenance, it is likely that the mechanical accelerator will cause false trips or worse, cause a failure in a fire condition. Too many mechanical accelerators that are necessary to qualify installations are soon removed from service due to maintenance issues. Removing an accelerator from service is a violation of the code, and will most likely place the water delivery of the dry pipe system into an unacceptable time period. An increase in delivery time above those shown in Table 2 (above) is unacceptable and could cause a system failure.

Negative issues with mechanical type accelerators are compounded further when problems are encountered during the resetting procedure. NFPA 13 requires anti-flooding devices to protect the restricted orifices after a system trip, and NFPA 13 also requires provisions to prevent drain back water from entering restricted orifices. Failure to follow the requirements of NFPA 13, or to maintain the devices associated with the provisions required by NFPA 25, can result in an accelerator that cannot be properly set. The result again is the unacceptable removal of the accelerator from service.

Electronic Accelerator

To afford simplicity and dependability to Quick Opening Devices, Tyco Fire Products has introduced the Model QRS Electronic Accelerator. The accelerator utilizes the Model QRS Quick Release Switch manufactured by Potter Electric Signal Company. The concept for this device was to make it sensitive enough for a fast reaction to loss of system air pressure due to sprinkler activation, yet automatically adjust to differentiate between a sprinkler activation and small or slow changes to system air pressure.

The innovation of the QRS switch revolves around a unique concept of comparing air pressure loss to elapsed time. Many devices can sense pressure loss to preset pressure intervals, but this device compares and reacts to a rate of pressure decay of 0.1 psi (0.007 bar) per second or greater. The following demonstrates how dramatic sprinkler activation is to air pressure/time measurements. Figure 7 shows the same air loss curve as in Figure 1, but it has been abbreviated to show the first 5 seconds of operation of a 1500 gallon (5678 l) system.

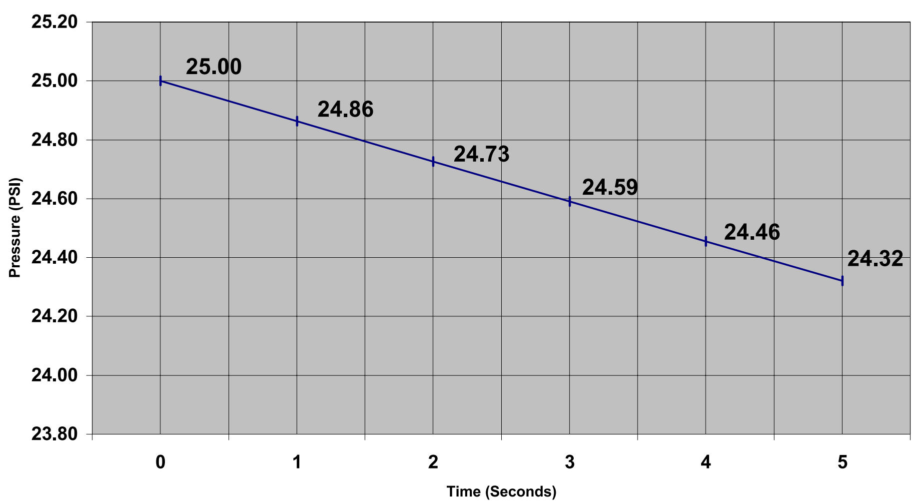

Figure 7 - Air Loss Curve -Detail

As shown in Figure 7, the pressure loss in the first five seconds is 0.14 (0.010 bar), 0.13 (0.009 bar), 0.14 (0.010 bar), 0.13 (0.009 bar) and 0.14 psi (0.010 bar) (rounded off to the 100ths) respectively. After 3 consecutive readings at the rate of 2 readings per second, and validating a pressure drop of at least 0.1 psi (0.007 bar), the QRS switch will send a signal to the control panel that will then activate the dry pipe valve. Keep in mind that a 1500 gallon (5678 l) dry pipe system is a large system, and that a sprinkler orifice with a K-factor of 5.6 (80) is normally the smallest sprinkler orifice size allowed. Smaller systems or larger orifice sizes will have faster pressure losses than shown in Figure 7. The average trip time for the Model QRS is 3 seconds for system volumes from 50 gallons (189 l) to as high as[T1] 2400 gallons (9085 l). In 3 seconds, the system shown in Figure 7 will have only lost 0.41 psi (0.03 bar), but the decay will have been rapid enough to activate the QRS switch.

To show how dramatic the 0.1 psi (0.007 bar) air loss is to a system as compared to normal pressure fluctuations, Figure 8 demonstrates a 1500 gallon (5678 l) system with an air leak equivalent to a 1/4" (6.3 mm) drilled hole in the riser piping. The 1/4 inch (6.3 mm) hole produces an air pressure loss of approximately 0.05 psi (0.003 bar) per second, which would not trip the QRS switch. Temperature changes from day to night occur at a much slower rate than 0.05 psi (0.003 bar) per second and would also not trip the QRS switch. Pressure losses due to system leaks would also be much slower than 0.05 psi (0.003 bar) per second. In fact, per NFPA 13, the allowable loss is no more than 2 psi (0.14 bar) in 24 hours starting at 40 psi (2.8 bar). This air loss equals an air decay rate of 0.000023 psi (1.5 x 10-6 bar) per second.

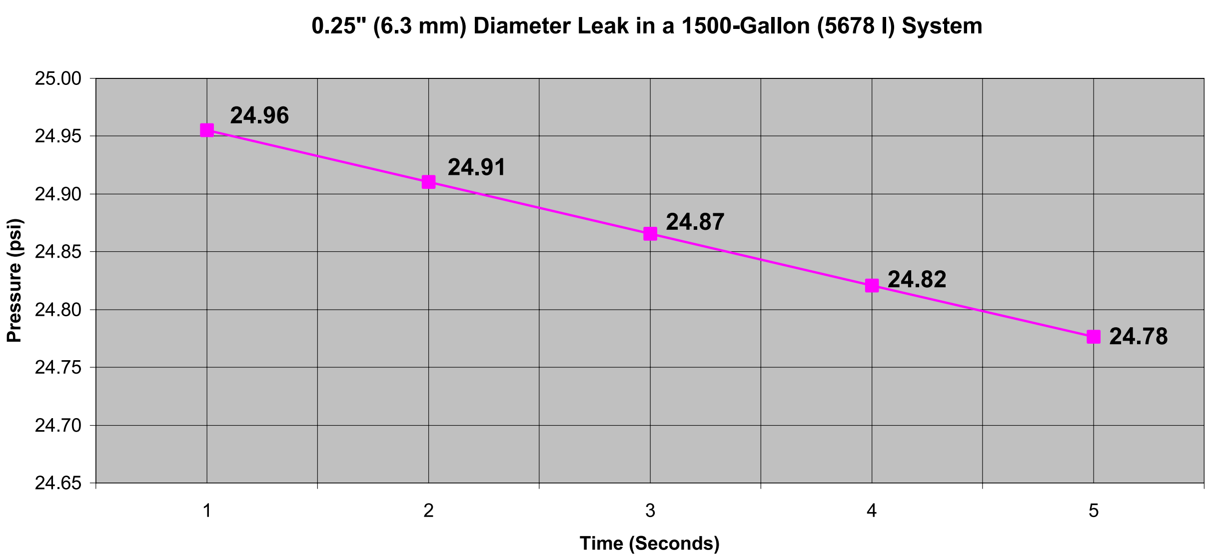

Figure 8- Air Leak Curve -Detail

Electronic Accelerator Operation

In contrast to all manufacturers' mechanical accelerators, electronic accelerators have no moving mechanical parts to stick or become obstructed, and no small-restricted orifices to become clogged. In addition, resetting the accelerator is accomplished by simply pushing the reset button on the accelerator control panel. Figure 9 shows a section of the QRS switch and the pressure transducer that senses the air pressure. Again, there are no moving parts or communicating chambers are common in a mechanical accelerator.

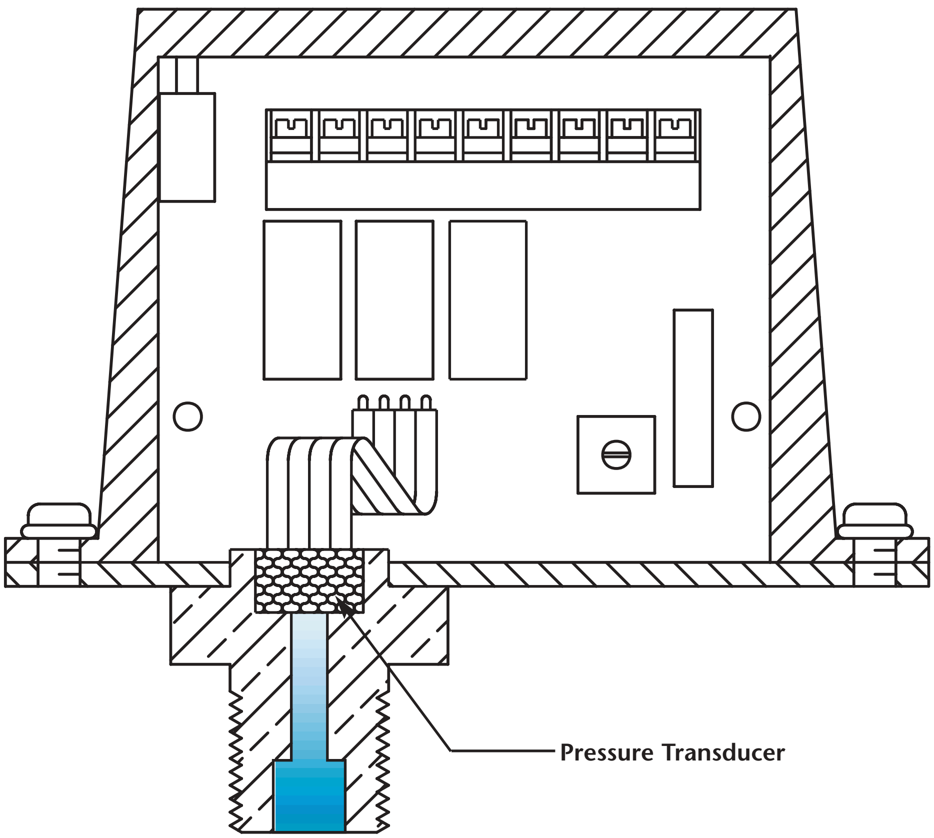

Figure 9 - Section of QRS Switch

The sequence of operation for the QRS switch is detailed in Figures 10 and 11. Figure 10 shows the switch and the associated solenoid valve working together in the set position. In the set position, the system air pressure is isolated from the dry pipe valve intermediate chamber by the solenoid valve. Normal pressure fluctuations in the system air pressure, due to either temperature changes or air leaks, do not affect the QRS switch. This is especially true since the Electronic Accelerator does not use a restricted orifice that may be subject to clogging.

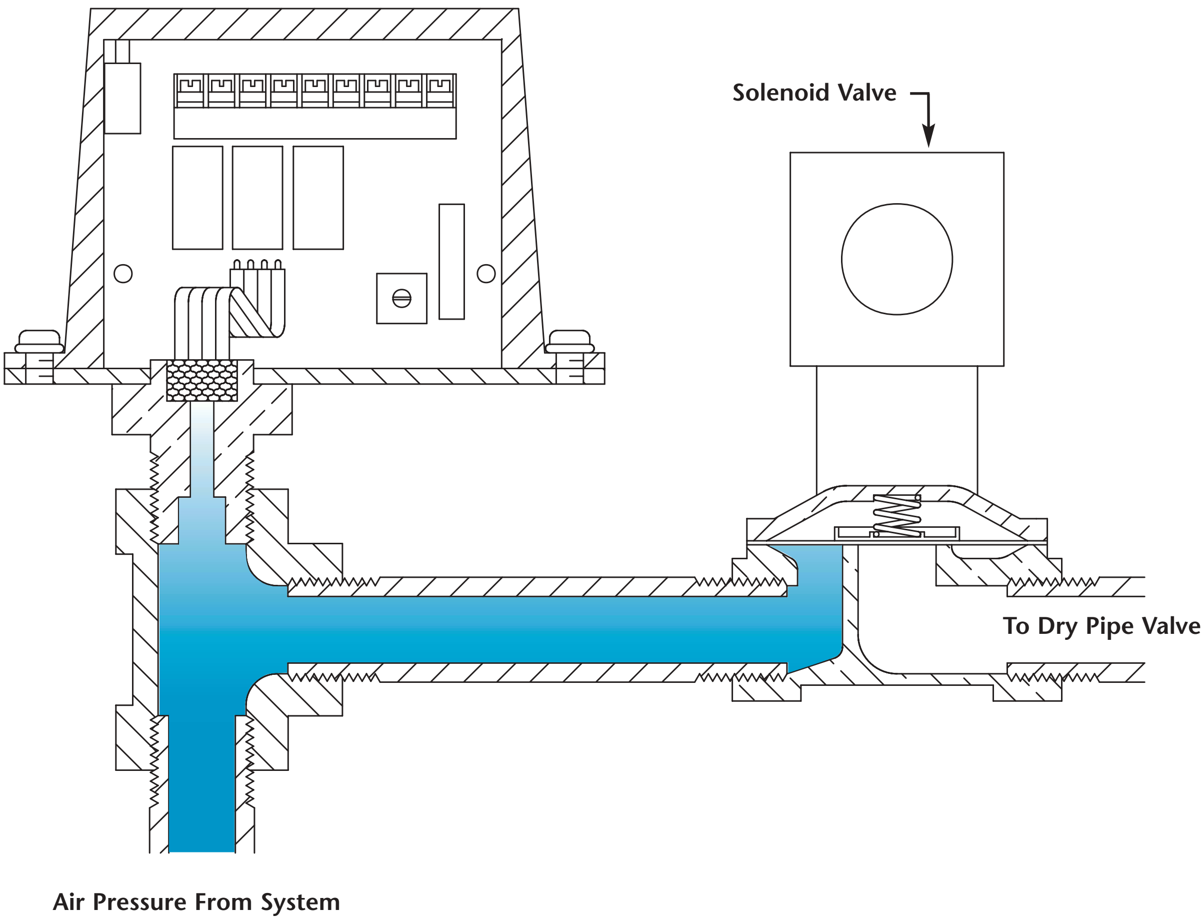

Figure 10 - QRS Switch and Solenoid Valve in the Set Position

Figure 11 shows the switch and the associated electric solenoid valve in the activated position. The activated position is a result of a sprinkler activation in the system that caused a pressure loss of 0.1 psi/sec (0.007 bar/sec) or greater. The switch sends an electric signal to activate the solenoid valve causing the residual system air pressure to be released to the intermediate chamber and underside of the clapper in the dry pipe valve. The release of pressure will activate the dry pipe valve.

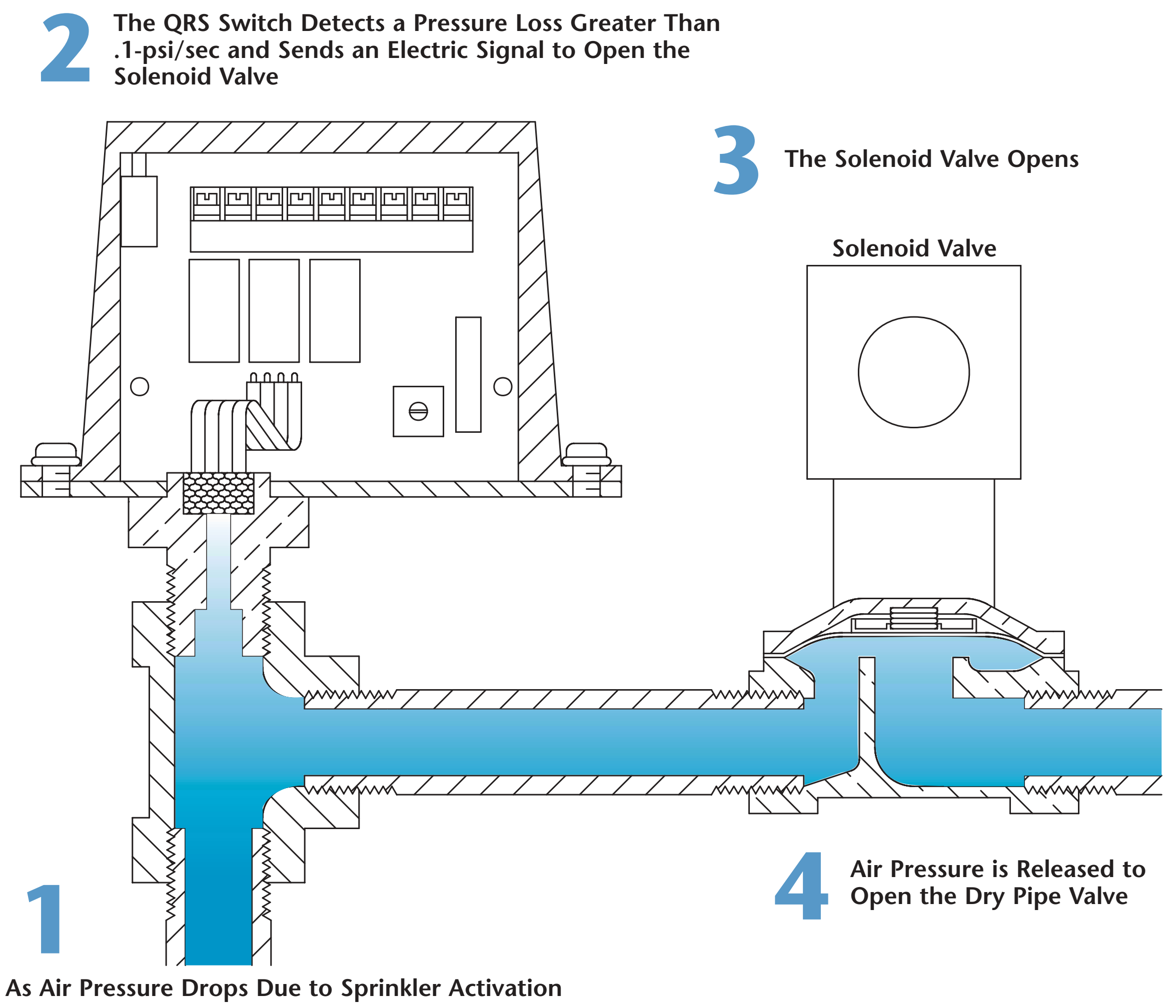

Figure 11 - QRS Switch and Solenoid Valve in Activated Position

The graph in Figure 12 shows the various system sizes, initial air pressures, and sprinkler K-factor combinations that will result in a minimum 0.1 psi (0.007 bar) per second air decay upon activation of a sprinkler. The graph incorporates a safety factor to assure that if all of the variables are applied, the appropriate minimum air decay to activate the QRS will be attained. Within the combinations permitted by the graph, the QRS switch will always activate in 1.5 seconds. Coupled with the control panel and dry pipe valve, the dry pipe valve will operate within 4 seconds. The maximum allotted 4 second trip time is certainly much quicker than can be expected with a Mechanical Accelerator, especially considering that the laboratory testing allows for up to 5 psi (0.34 bar) pressure drop. It is interesting to note when combining information from Table 1 and Figure 1, and using the starting pressure of 25 psi (1.7 bar), the Brand X Mechanical Accelerator operated in 34 seconds (Table 1) which represents a 4.5 psi (0.31 bar) drop in pressure (Figure 1) that is with the allowable 5 psi (0.34 bar) drop permitted by UL1486.

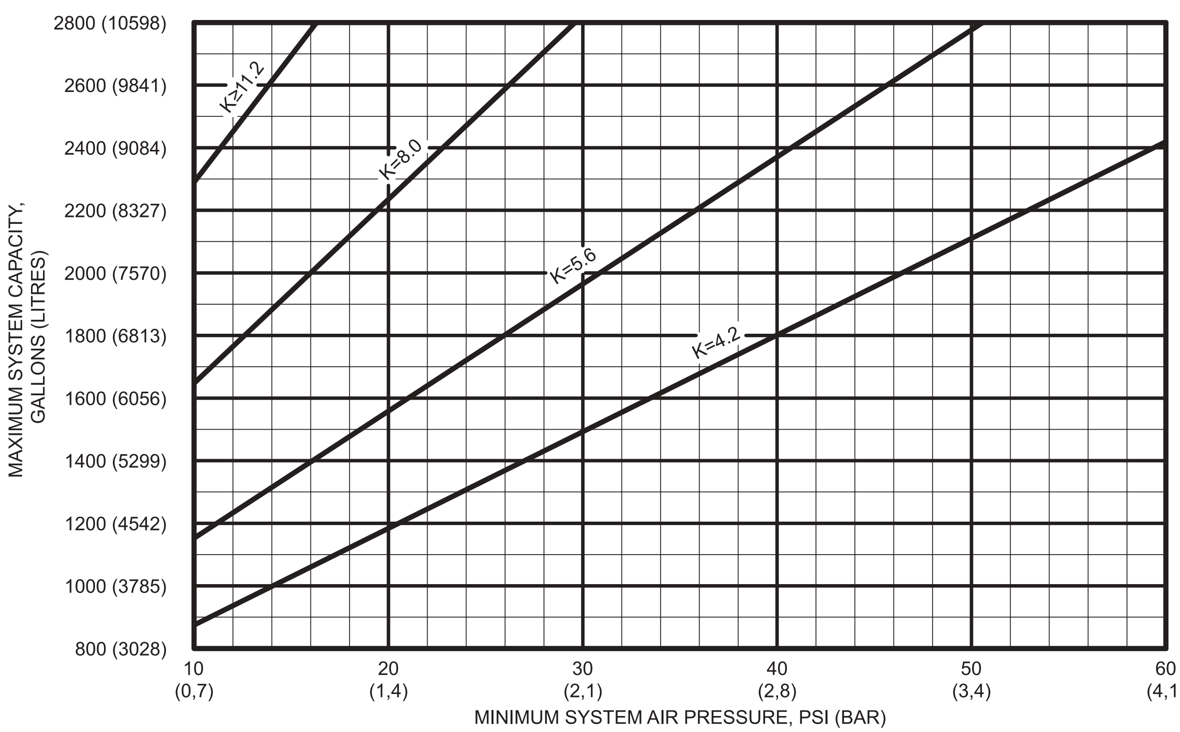

Figure 12 - K Factors That Result in 0.1 psi (0.007 bar) Drop/Second

Summary

The simplicity and dependability of the QRS switch as a substitute for the mechanical accelerator are keys. The following list is a summary of some of the key benefits of the Electric Accelerator:

* Facility Operator costs decrease due to less frequent maintenance issues.
* Fewer maintenance issues insure that the accelerators (critical to many systems) remain in service.
* Faster operation improves the performance of larger dry systems.
* With no moving parts in the pressure sensing area (QRS switch), maintenance and dependability are improved dramatically.
* Without a restricted orifice, false trips due to temperature changes are eliminated.
* Without a restricted orifice, maintenance and resetting issues related to anti-flooding devices and drain-back do not apply.
* Built-in low and high air pressure switches: small leakage will trigger supervisory alarm vs. the activation that might occur with a clogged restriction in a mechanical accelerator.
* Proven electronic technology used with electrically operated deluge and preaction systems.
* Consistent operating times improve water supply analysis and dry system performance.
* Accurate dry pipe valves trip times will assist in calculating dry pipe system performance.
* Insurance Risk assessment improvement due to dependability of service.

References:

1. Variables that Affect the Performance of Dry Pipe Systems - Tyco Fire and Building Products, Cranston RI - http://tyco-fireproducts.com/TFP_Gem/literature.php - Technical Reports and White Papers

2. Underwriters Laboratory - Northbrook, Illinois - UL 1486 Quick Opening Devices for Dry Pipe Valves for Fire Protection Service, April 29, 1997

3. National Fire Protection Association - Quincy, Massachusetts - NFPA 13 Installation of Sprinkler Systems, August 8, 2002.

4. National Fire Protection Association - Quincy, Massachusetts - NFPA 25 Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems. January 31, 2002

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Mr. Golinveaux's areas of interest include the research, design and applications of automatic fire sprinklers as well as their history. His interest in the fire sprinkler industry was sparked by his father's 27 years in the fire service.

Beginning as a designer in the early 1980's and later as a design manager for a fire protection firm in California, he applied local and national standards to develop working drawings for automatic fire sprinkler systems. Mr. Golinveaux became active and continues his involvement today through his membership on numerous committees such as the National Fire Protection Association (Member of NFPA 13 Discharge & Installation), International Conference of Building Officials, Society of Fire Protection Engineers and Southern Building Code Congress International. By 1991, Mr. Golinveaux's strong application knowledge of the automatic fire sprinkler industry afforded him the opportunity to work on the East Coast as the Director of Technical Services for Central Sprinkler Company. Mr. Golinveaux was responsible for the technical responses to worldwide production of automatic fire sprinkler system components. He continued his involvement in the industry and represented Central on many national committees including the National Fire Protection Research Foundation, Research and Advisory Council on Fire Suppression Futures and Underwriters Laboratories Industry Advisory Committee for automatic sprinklers. Mr. Golinveaux's many talents and wealth of knowledge were recognized by Central where he was Senior Vice President of Engineering and was directly responsible for the Production Plant with over 600 employees, the Engineering/R & D, Quality Control and Technical Services operations. Currently, Mr. Golinveaux is Senior Vice President of Research and Development for Tyco Fire & Building Products, which represents Central, Gem and Star branded products.

In addition to the support of the industry through his numerous committee memberships, Mr. Golinveaux also contributes his time as a speaker for national education seminars sponsored by organizations such as the Society of Fire Protection Engineers, Universities, Highly Protected Risk (HPR) Insurance Companies, National Apprenticeship and Training, and Trade Associations as well as state and local fire authorities. He has educated many on the latest sprinkler technology and its associated codes and standards.

Mr. Golinveaux has authored "A Technical Analysis: The Use and Maintenance of Dry Type Sprinklers", "A Technical Analysis: Variables That Affect the Performance of Dry Pipe Systems", and "A Technical Analysis: Listings and Applications of Residential Sprinklers". He has contributed to the NFPA Fire Protection Handbook 19th Edition as well as the 2002 Automatic Sprinkler System Handbook. He is also named on numerous U.S. Patents relating to automatic sprinklers.

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