IMI FLOW DESIGN

AUTOMATIC FLOW CARTRIDGES

Competition Analysis

"Not All Automatics Are Created Equal"

Engineering GREAT Solutions

IMI Hydronic Engineering

Improve the Performance of your Premium System Components...

In a construction project, when it comes to the major HVAC components in a Hydronic system such as the chillers, the pumps, and even the fan coil units, the various major stakeholders (e.g. Design Engineer, Mechanical Contractor, Balancing Contractor, Building Owners etc.) understandably tend to focus their attention in proportion to the cost of the equipment. The higher the cost of the component, the more attentionit receives. In such an economy of engineering resources, however, the lower-costbalancing valves may almost fall through the cracks. Yet, the rigorously compared and much-desired high performance ratings of the higher cost components entirely depend on the properly distributed flow throughout the system; that is to say, effective balancing valves are essential to achieve those impressive performance numbers for the high value equipment in the system.

Think System Design Flexibility...

In order to build optimized, robust, and cost-effective Hydronic HVAC systems, what is most often compromised is flexibility. In an ideal word, building designers and builders would expect “We plan what we do and do what we plan”. Yet the reality is that any project that is designed to last for years into the future will sooner or later undergo changes to the original plan and sometimes these changes occur right away. Automatic balancing valves are a simple way to provide the flexibility to handle changes. They not only save a lot of time and money at the point of commissioning in a very well planned building, but they are also the most flexible and adaptive to last minute design changes and, in some cases, errant pressure drop calculations or incorrectly sized control valves or pumps.

When fully understood, the flexibility inherent in automatic balancing valves provides much reassurance of dynamic system balancing to the Consulting/Design Engineer, the Installer, the Balancer, the Commissioning Agent, and the Building Owner of optimized system installation and operating costs. When a load is added or increased, or when a system is 90% balanced with the incorrect flow due to some oversight, such as a control valve that was inadvertently in the wrong position, the automatic valves respond by automatically adjusting the flow, giving the project’s major stakeholders much needed “peace of mind” that their system will operate as intended. Automatic valves save balance and commissioning time and provide reliable performance .

Think Energy Savings...

In these times, when we are all concerned about energy costs, environmental impact and energy conservation, having the right flow accuracy is critical. Below are theoretical equations that prove that there is an increase in energy consumption when the accuracy band is widened!

For fully turbulent flow, the pressure drop is proportional to the square of the flow:

$$\boldsymbol{\Delta P} \propto \boldsymbol{Q}^2$$

The pumping power is proportional to the flow multiplied by the pressure drop:

$$\boldsymbol{W} \propto \boldsymbol{Q}\ \boldsymbol{x}\ \boldsymbol{\Delta P}$$

ΔP = Pressure Drop in psi

Q = Flow in gpm

W = Power in W

k = Proportionality constant

Think Energy Savings... (Cont'd)

Combining these equations, the pumping power is proportional to the cube of the flow:

$$W \propto Q \, x \, Q^2 \quad \rightarrow \quad W = k \, x \, Q^3$$

For 5% overflow, this means that there would be 16% excess pump power. For 10% overflow, it's 33%. Meanwhile, 10% more flow typically means only about 2% more heat transfer.

Not All Automatics Are Created Equal...

The IMI Flow Design's valve rating system for Automatic Flow Control Valves provides real-world test data for anyone to see the difference between product claims and actual valve performance. We think the data speaks for itself; our customers can rest assured that the efficiency of their large expensive chillers will not be ruined by the poor performance of an economy valve. At IMI Flow Design, we work hard every day to earn our reputation for providing the best accuracy and reliability for our products. From innovative design to precision manufacturing to quality testing, our automatic valves are engineered to ensure correct design flow for HVAC systems to operate at peak efficiency thus optimizing a system's installed and operation costs.

The following pages summarize our ISO 9001 certified lab test results of the comparison of the IMI Flow Design automatic flow control valve to certain other automatic flow control valves in the industry from randomly collected competitor samples. All these samples have been tested in the IMI Flow Design flow laboratory and subjected to the same test conditions. The IMI Flow Design flow laboratory consists of precision instruments and a variable speed pump arranged in a piping configuration that is specifically designed to produce flow versus pressure results that are accurate. We have an annual third party calibration of the instruments to an accuracy of 0.25% on flow and 0.25% on pressure. The results are recorded and displayed in a Lab View environment according to the latest laboratory practices. The testing was not, however, conducted by an independent third party.

Balancing Valve Test Lab Summary

Attributes	System Effect	Score			
Performance		F	A	B	C
Accuracy					
Design Flow	Having an accurate design flow is important because too little flow means a terminal cannot produce its rated output. Too much flow, especially in many terminals, causes excess pumping energy, noise, and additional heat load.	5	2	1	3
Start Up Pressure	If the starting pressure of the valve cartridge is not true, then more pump pressure will be required to make the correct flow happen at all terminals. This attribute determines if the flow of the regulator cartridge starts to regulate at the low end of pressure range.	4	2	2	2
End of Pressure Range	Typically if a regulator goes out of range at high pressures, it overflows. Such overflow would occur at terminals near the pump, starving terminals further out in the system. This attribute determines if the flow of the regulator cartridge is maintained at its high end of the pressure range, which prevents overflow in the set pressure range.	5	2	2	4
Repeatability	Bad repeatability means consistently incorrect flows from the same cartridge. This might be due to the hysteresis caused by moving parts in the flow regulator cartridge design. It creates situations with intermittent bad performance. This is a nightmare for maintenance.	5	2	1	3
Stability	An unstable regulator could create cyclical variation of flow which could mean anything from chugging noises to visibly moving pipes (e.g. Pulsing, Water Hammer etc. in pipes).	4	3	4	1

F. IMI Flow Design
A. Competition A
B. Competition B
C. Competition C

1. Deficient
2. Inferior
3. Acceptable
4. Good
5. Excellent

Balancing Valve Test Lab Summary

Attributes	System Effect	Score			
Performance		F	A	B	C
Durability					
Dirty Systems	If the flow regulator cartridge does not have debris or dirt resistance design, there might be a change of clogging and thus lower flow than intended.	4	3	1	4
Degradation	Due to the material design of the wear and tear parts in a flow regulator cartridge, there might be a chance of cartridge failure. If the cartridge fails it might mean that the terminal gets no flow at all.	5	4	2	3
Consistency					
At a given flow	Consistency of the flow regulator cartridge to flow at the set design flow is critical for the system to work correctly and to give the Building Designer, Installing Contractor and Building Owner "peace of mind". If different cartridges produced for the same flow are not producing the flow as required, some of the floors might experience overflows and other floors underflow without being able to determine the correct reason for this.	5	2	2	4
Between one flow rate and another	This attribute measures the consistency of the manufacturer for all of their flow cartridges. If the cartridge for a particular flow, flows correctly and accurately, how confidently can you rely that cartridges for other flows will flow correctly and accurately.	5	2	2	2

F. IMI Flow Design
A. Competition A
B. Competition B
C. Competition C

1. Deficient
2. Inferior
3. Acceptable
4. Good
5. Excellent

Cartridge Design Comparision

IMI Flow Design

Design

The automatic flow regulator cartridge manufactured by IMI Flow Design, is made of stainless steel which provides good wear resistance. The profile for flow is achieved through the patented hybrid port design, which enables the flow to be restricted in both the width and the depth of the flow area that is cut into the flow regulator cartridge. The hybrid port design enables the flow regulator cartridge to maintain flow accuracy over the high end of the pressure range, where some other design regulating cartridge might fail. The hybrid port design also helps avoid a narrow flow path, thus giving it an excellent debris resistance, especially for low design flow applications. The need for a hybrid port is not as critical for larger flow regulator cartridges. All IMI Flow Design cartridges have a precision adjustment nut for presetting the springs. This presetting enables the flow regulator cartridge to accommodate the manufacturing tolerance in various components of the flow regulator cartridge and still enable the cartridge to achieve excellent flow accuracy and repeatability. IMI Flow Design's flow regulator cartridge for the flow samples tested is approximately 0.4 inches in diameter and 0.75 inches in stroke length. The greater stroke to diameter ratio enables great precision of design flow achievement. IMI Flow Design's cartridge does not have any rubber products used in the design of the flow regulating mechanism, which enables cartridge resistance to degradation in the system.

Flows Tested: 1 gpm and 2.5 gpm

Class[1]	1
Wear Components	Stainless steel
Debris Resistance	Excellent
Published Pressure Range	2-32 PSI
Published Flow Accuracy	± 5% (over 95% of the operating range)

Competition A

Design

The automatic flow regulator cartridge manufactured by Competition A is made of stainless steel which provides good wear resistance. The profile for the design flow is achieved through very thin flow slots, which are likely to catch debris in anything but a very clean system. The flow regulator cartridge from Competition A does not have an adjustment mechanism for the spring preset conditions, which might result in a poor flow accuracy due to other components manufacturing tolerance. The flow regulator cartridge from Competition A for the flow samples tested is about 0.3 inches in diameter with a stroke of about the same length, which may not give a precise flow profile. The Competition A cartridge does not have any rubber products used in the design of the flow regulating mechanism, which enables cartridge resistance to degradation in the system.

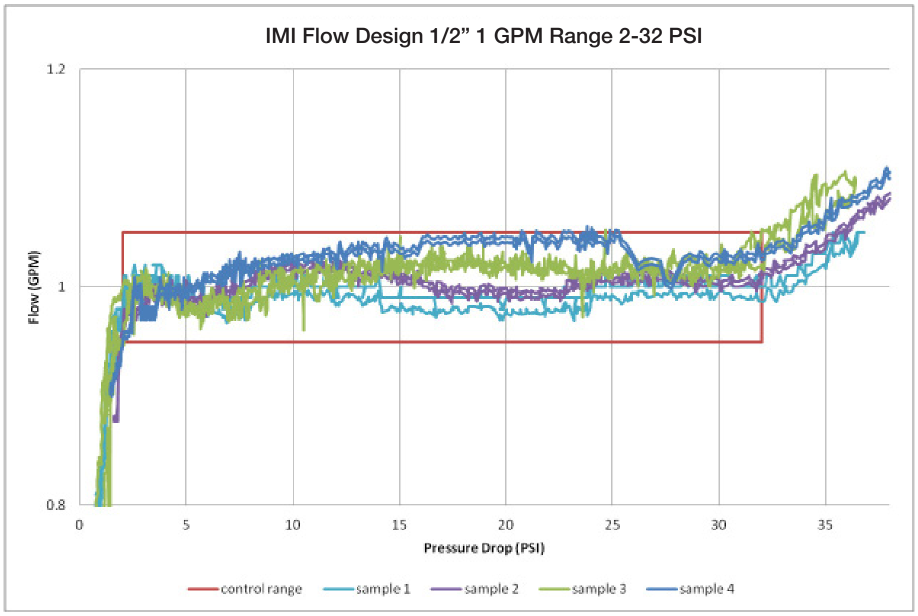
Flows Tested: 1 gpm and 2.5 gpm

Class[1]	1
Wear Components	Stainless steel
Debris Resistance	Moderate
Published Pressure Range	2-32 PSI
Published Flow Accuracy	± 5%

Note: {1}: Class 1 flow controllers use an orifice the size of which is varied directly in response to the imposed differential pressure. Class 2 flow controllers have a control orifice and a pressure responsive orifice. The differential pressure across the control orifice is meant to stay nearly constant.

1/2" Cartridge, 1 GPM

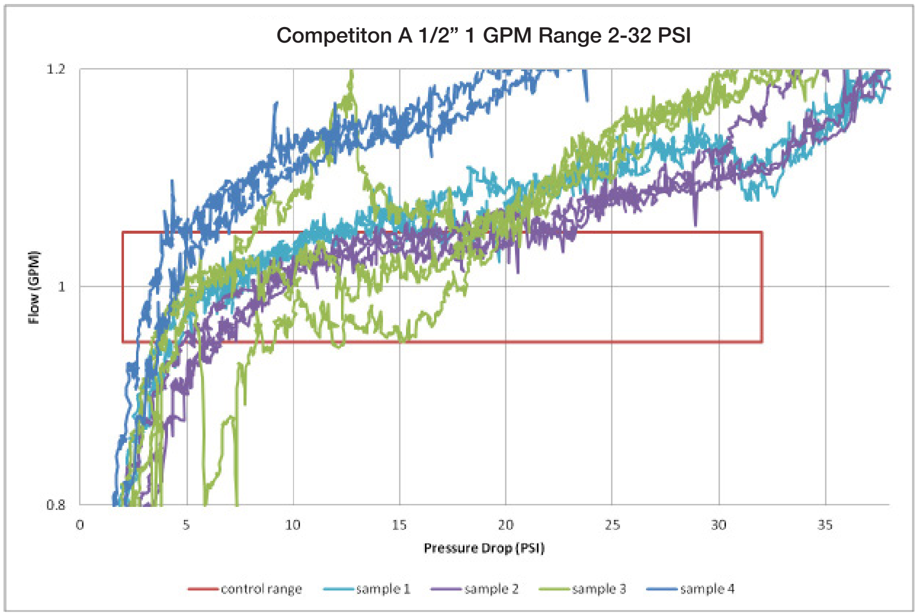
IMI Flow Design



Performance

The flow rises quickly to the control range at about 2 psi. The flow stays inside the ± 5% of target flow. The characteristic of suddenly dropping flow with rising pressure is not present. The rising pressure and falling pressure curves look very much alike. The flow increases in a linear fashion at the end of the control range.

Competition A

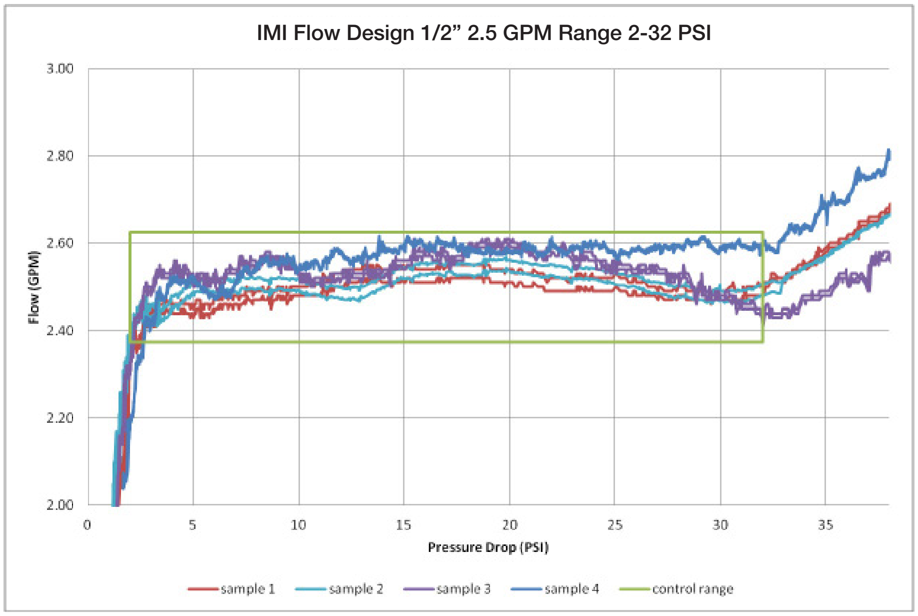


Performance

All four valve samples for 1 gpm flow did not fall within the ±5 percent flow accuracy box. At a startup pressure of 2 psi, all the valves had a flow below 95% of design. The average starting point was about 3.5 psi and the range was from 2.5 to 6 psi. The flow was over 105% of the rating on all the valves at the maximum pressure of 32 psi. The overflow average was about 13 % but the range was from 7% to 32% overflow. Most of the valves had good repeatability and stability for the samples tested on this particular flow rate.

1/2" Cartridge, 2.5 GPM

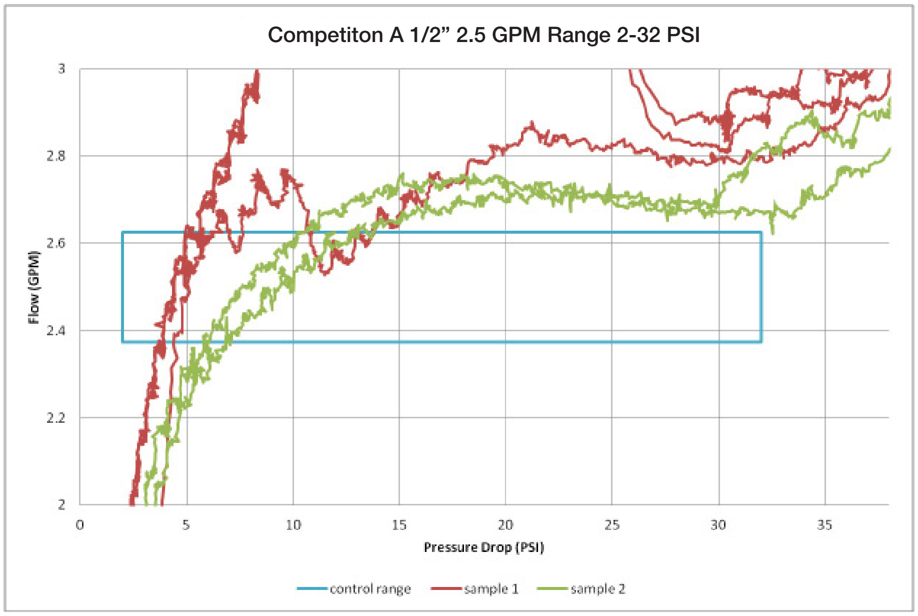
IMI Flow Design



Performance

The flow rises quickly to the control range at about 2 psi. The flow stays inside the ± 5% of target flow. The characteristic of suddenly dropping flow with rising pressure is not present. The rising pressure and falling pressure curves look very much alike. The flow increases in a linear fashion at the end of the control range.

Competition A

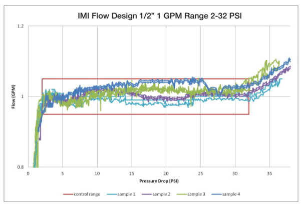


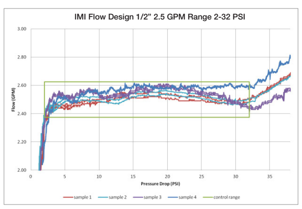
Performance

Both the valve samples for 2.5 gpm flow did not fall within the ± 5 percent flow accuracy box. None of the samples tested for 2.5 gpm from this manufacturer had flow regulation at 2 psi as published. The average starting point was about 3.5 psi and the range was from 2.5 to 6 psi. The flow was over 105% of the rating on all the valves at the maximum pressure of 32 psi. The overflow average was about 13 % but the range was from 7% to 32% overflow. Valves showed moderate to severe hysteresis for the samples tested for this flow rate.

Performance Summary

IMI Flow Design





Flow at Start Up Pressure:

The graphs for all the samples show that the flow rises quickly to the design flow just before the start of the pressure control range as desired.

Flow within the Operating Range:

As seen from the graphs , the flow remains within the ± 5% of the design flow accuracy box (red colored box). As stated earlier, keeping the flow accuracy within ± 5% in the operating pressure range enables tremendous pump energy savings and thus reduced operating costs.

A Flow at the End of Pressure Range:

As seen from the graphs, the flow at the end of the pressure range is still in the ± 5% flow accuracy box and increases in a linear fashion outside the operating pressure range, which gives the valves a good flow profile.

Hysteresis:

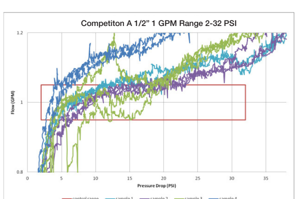
As can be seen from the graphs, the graphs for the rising and falling pressure look alike, so there is little or almost no hysteresis from the valve cartridge design, which enables great precision in flow accuracy and repeatability.

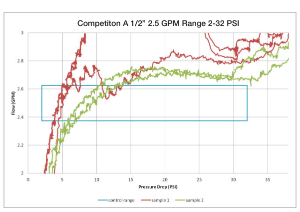
No. of Samples:

As noticed in the graphs, the flow curves for all the samples tested for the same flow, fall in the design flow accuracy box in the operating pressure range, thus giving the building stakeholder confidence, that any flow cartridge selected will flow at the stated flow. The flow profile is the same for samples for different flows.

For all the samples tested, the graphs do not show a characteristic of suddenly dropping the flow with rising pressure, which may lead to pulsing or water hammer, as can be seen in other manufacturers flow regulator cartridges tested.

Competition A





Flow at Start Up Pressure:

The graphs show that the flow is not regulated at start up pressure of 2 psi as stated. For most of the cartridges flow at start up pressure of 2 psi was below 95% of design flow.

Flow within the Operating Range:

As seen from the graphs, in all the tests, the flow did not fall within accuracy box of ± 5%

A Flow at the End of Pressure Range:

As seen from the graphs, at the end of the pressure range, there was significant overflow. As stated previously, overflow leads to excess pump power consumption without getting desired heat transfer.

Hysteresis:

As seen from the graphs, the Competition A flow regulator cartridge shows moderate to severe hysteresis. As discussed previously, this would mean, no reliability for the cartridge to flow in the way expected when the pressure in the system changes. There might be overflows and underflows in the same terminal unit at the same conditions without any known reasons.

No. of Samples:

Since the flow characteristics for most of the samples tested were outside the flow accuracy box, the building stakeholder might not be able to confidently select a valve and be confident that it will be flowing at the stated flow. The flow profile is inconsistent for samples for different flows.

Cartridge Design Comparision

IMI Flow Design

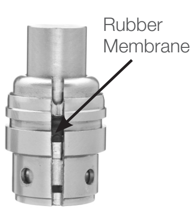
Design

The automatic flow regulator cartridge manufactured by IMI Flow Design, is made of stainless steel which provides good wear resistance. The profile for flow is achieved through the patented hybrid port design, which enables the flow to be restricted in both the width and the depth of the flow area that is cut into the flow regulator cartridge. The hybrid port design enables the flow regulator cartridge to maintain flow accuracy over the high end of the pressure range, where some other design regulating cartridge might fail. The hybrid port design also helps avoid a narrow flow path, thus giving it an excellent debris resistance, especially for low design flow applications. The need for a hybrid port is not as critical for larger flow regulator cartridges. All IMI Flow Design cartridges have a precision adjustment nut for presetting the springs. This presetting enables the flow regulator cartridge to accommodate the manufacturing tolerance in various components of the flow regulator cartridge and still enable the cartridge to achieve excellent flow accuracy and repeatability. IMI Flow Design's flow regulator cartridge for the flow samples tested is approximately 0.4 inches in diameter and 0.75 inches in stroke length. The greater stroke to diameter ratio enables great precision of design flow achievement. IMI Flow Design's cartridge does not have any rubber products used in the design of the flow regulating mechanism, which enables cartridge resistance to degradation in the system.

Flows Tested: 1 gpm and 2.5 gpm

Class[1]	1
Wear Components	Stainless steel
Debris Resistance	Excellent
Published Pressure Range	2-32 PSI
Published Flow Accuracy	± 5% (over 95% of the operating range)

Competition B



Design

The automatic flow regulator cartridge manufactured by Competition B, is made of stainless steel and some elastomer. The flow regulator cartridge is large and relatively complex. The flow profile is established through the use of a secondary pressure that is regulated. This need for secondary pressure regulation may result in late start up for flow regulation and some hysteresis during the operating pressure range. Also to separate the two pressure areas, there would be a need for a flexible membrane in the cartridge, which in this case is thin elastomer. This thin elastomer may be vulnerable to debris and dirt found in the system, plus it is less resistant to normal wear and tear and thus more degradation, compared to stainless steel parts.

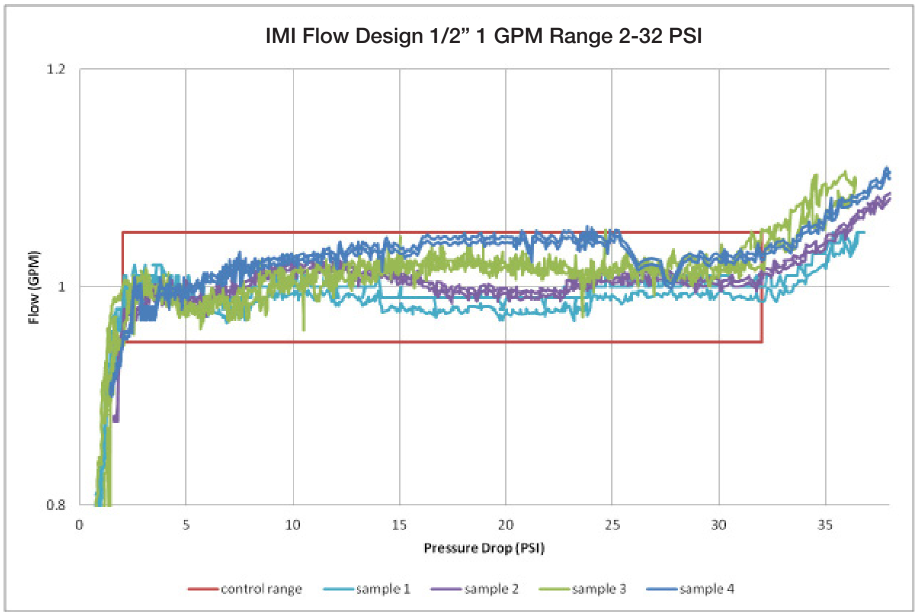
Flows Tested: 1 gpm and 2.5 gpm

Class[1]	1
Wear Components	Stainless steel, Elastomer
Debris Resistance	Poor
Published Pressure Range	2-60 PSI
Published Flow Accuracy	± 5%

Note: {1}: Class 1 flow controllers use an orifice the size of which is varied directly in response to the imposed differential pressure. Class 2 flow controllers have a control orifice and a pressure responsive orifice. The differential pressure across the control orifice is meant to stay nearly constant.

1/2" Cartridge, 1 GPM

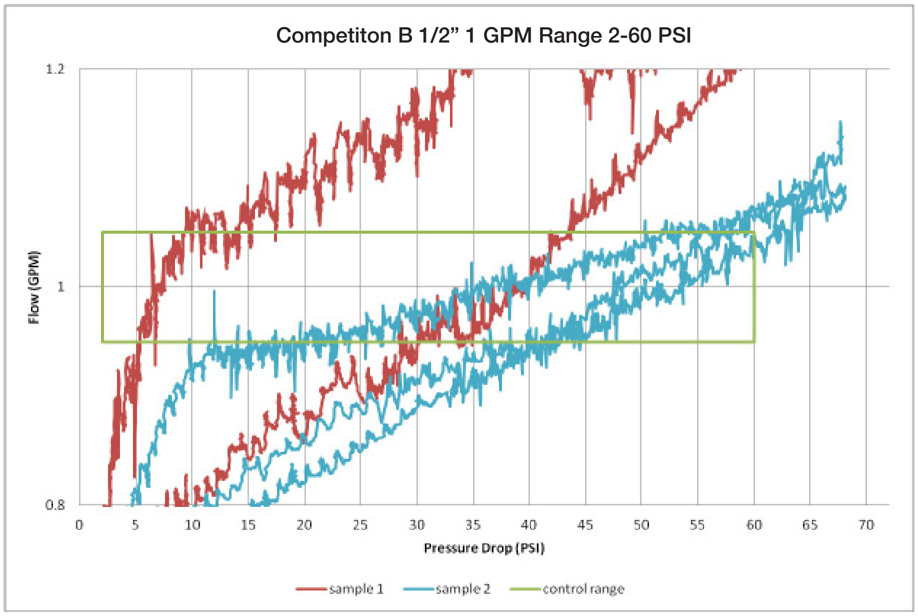
IMI Flow Design



Performance

The flow rises quickly to the control range at about 2 psi. The flow stays inside the ± 5% of target flow. The characteristic of suddenly dropping flow with rising pressure is not present. The rising pressure and falling pressure curves look very much alike. The flow increases in a linear fashion at the end of the control range.

Competition B

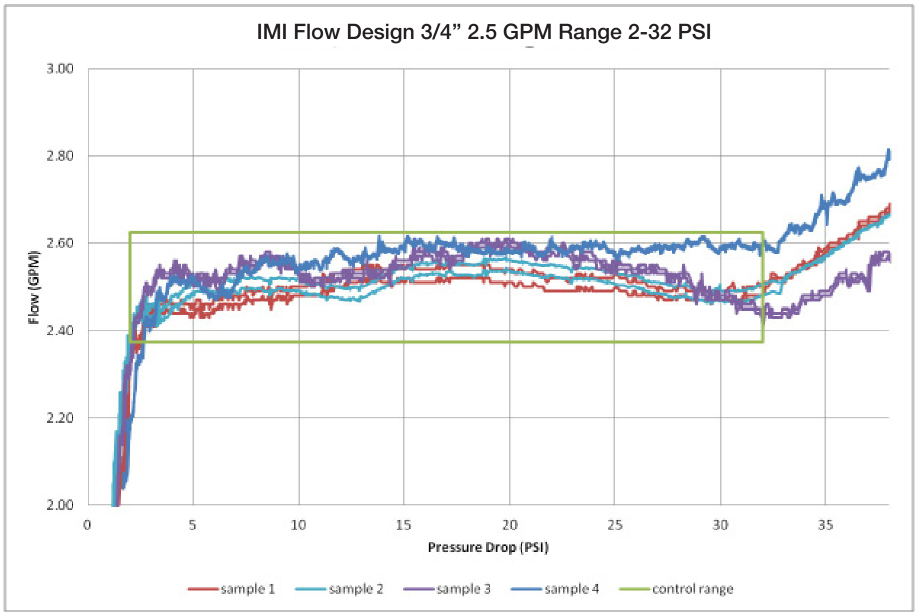


Performance

Both the samples tested for this manufacturer showed a very late start of flow regulation. The automatic flow regulator cartridges from this manufacturer indicated a 15% to 30% variation of flow with falling pressure versus rising pressure (significant hysteresis). The friction that is inherent in this design is shown with this lack of repeatability. One sample went well above the specified flow on the high end of the control pressure range.

3/4" Cartridge, 2.5 GPM

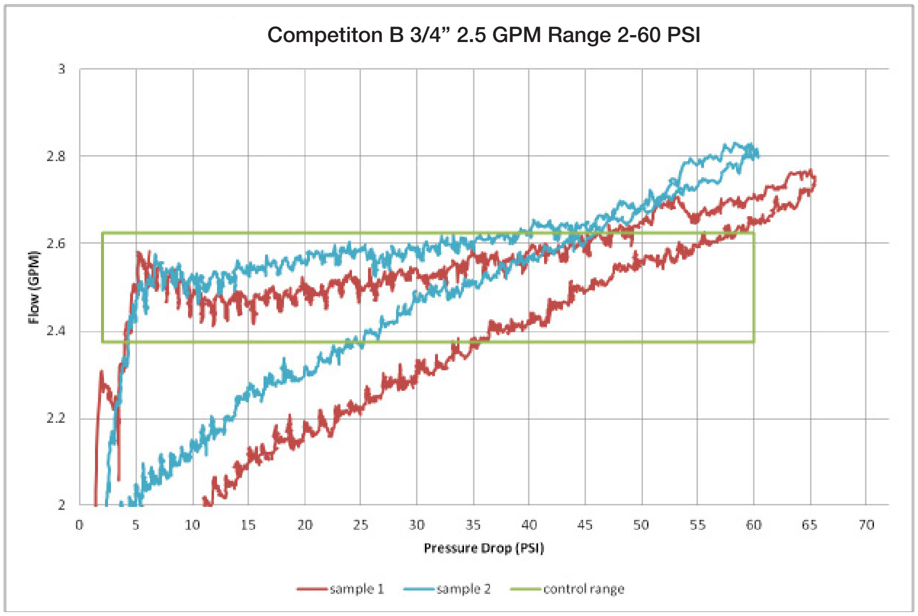
IMI Flow Design



Performance

The flow rises quickly to the control range at about 2 psi. The flow stays inside the ± 5% of target flow. The characteristic of suddenly dropping flow with rising pressure is not present. The rising pressure and falling pressure curves look very much alike. The flow increases in a linear fashion at the end of the control range.

Competition B

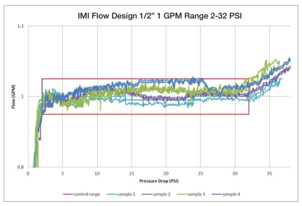


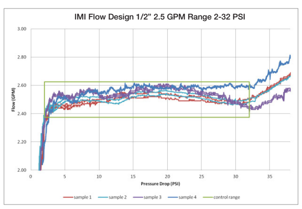
Performance

Both the samples tested for this manufacturer showed a very late start of flow regulation, specifically at increasing pressure. The flow valve samples tested for 2.5 gpm for this manufacturer indicated a 15% variation of flow with falling pressure versus rising pressure (significant hysteresis). The friction that is inherent in this design is shown with this lack of repeatability. Both the valve samples tested for this flow rate, showed significant overflow at the end of the operating pressure range.

Performance Summary

IMI Flow Design





Flow at Start Up Pressure:

The graphs for all the samples show that the flow rises quickly to the design flow just before the start of the pressure control range as desired.

Flow within the Operating Range:

As seen from the graphs , the flow remains within the ± 5% of the design flow accuracy box (red colored box). As stated earlier, keeping the flow accuracy within ± 5% in the operating pressure range enables tremendous pump energy savings and thus reduced operating costs.

A Flow at the End of Pressure Range:

As seen from the graphs, the flow at the end of the pressure range is still in the ± 5% flow accuracy box and increases in a linear fashion outside the operating pressure range, which gives the valves a good flow profile.

Hysteresis:

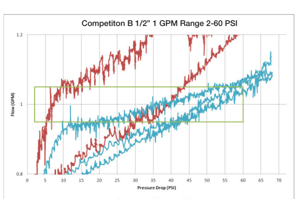
As can be seen from the graphs, the graphs for the rising and falling pressure look alike, so there is little or almost no hysteresis from the valve cartridge design, which enables great precision in flow accuracy and repeatability.

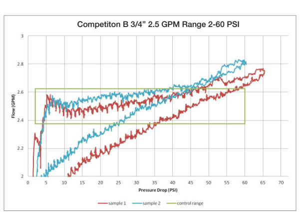
No. of Samples:

As noticed in the graphs, the flow curves for all the samples tested for the same flow, fall in the design flow accuracy box in the operating pressure range, thus giving the building stakeholder confidence, that any flow cartridge selected will flow at the stated flow. The flow profile is the same for samples for different flows.

For all the samples tested, the graphs do not show a characteristic of suddenly dropping the flow with rising pressure, which may lead to pulsing or water hammer, as can be seen in other manufacturers flow regulator cartridges tested.

Competition B





Flow at Start Up Pressure:

For the flow regulator cartridges tested, none of the cartridge for the required flow started at 2 psi as published.

Flow within the Operating Range:

As seen from the graphs, most of the flow regulator cartridges tested were out of the flow accuracy box (underflow overflow).

Flow at the End of Pressure Range:

The graphs show the flow is not regulated in its control range and also there is a significant overflow at the end of its control range.

Hysteresis:

From the flow regulator cartridge samples tested, there is between 15% to 30% flow variation with decreasing pressure compared to increasing pressure. This indicates significant hysteresis and thus a lack of repeatability of flow in the same cartridge sample.

No. of Samples:

The test results indicate that for different samples of the sample flow, the results varied. The flow profile is inconsistent for samples of different flows as well.

Cartridge Design Comparision

IMI Flow Design

Design

The automatic flow regulator cartridge manufactured by IMI Flow Design, is made of stainless steel which provides good wear resistance. The profile for flow is achieved through the patented hybrid port design, which enables the flow to be restricted in both the width and the depth of the flow area that is cut into the flow regulator cartridge. The hybrid port design enables the flow regulator cartridge to maintain flow accuracy over the high end of the pressure range, where some other design regulating cartridge might fail. The hybrid port design also helps avoid a narrow flow path, thus giving it an excellent debris resistance, especially for low design flow applications. The need for a hybrid port is not as critical for larger flow regulator cartridges. All IMI Flow Design cartridges have a precision adjustment nut for presetting the springs. This presetting enables the flow regulator cartridge to accommodate the manufacturing tolerance in various components of the flow regulator cartridge and still enable the cartridge to achieve excellent flow accuracy and repeatability. IMI Flow Design's flow regulator cartridge for the flow samples tested is approximately 0.4 inches in diameter and 0.75 inches in stroke length. The greater stroke to diameter ratio enables great precision of design flow achievement. IMI Flow Design's cartridge does not have any rubber products used in the design of the flow regulating mechanism, which enables cartridge resistance to degradation in the system.

Flows Tested: 1 gpm, 4.5 gpm and 7 gpm

Class[1]	1
Wear Components	Stainless steel
Debris Resistance	Excellent
Published Pressure Range	2-32 PSI
Published Flow Accuracy	± 5% (over 95% of the operating range)

Competition C

Design

The automatic flow regulator cartridge manufactured by Competition C, is made of brass and stainless steel, which gives it a fair wear resistance. The profile of the flow is achieved through a flow regulator cartridge design which features a piston that moves into a trumpet shaped cylinder. Competition B makes claims about the NON CLOGGING benefits of this design, but the piston itself is guided by a small center shaft that requires a very small clearance, which may also be subject to sticking due to dirt and debris in the system. The flow regulator cartridge from Competition C does have a spring adjustment mechanism that enables the cartridge for manufacturing tolerance of its components.

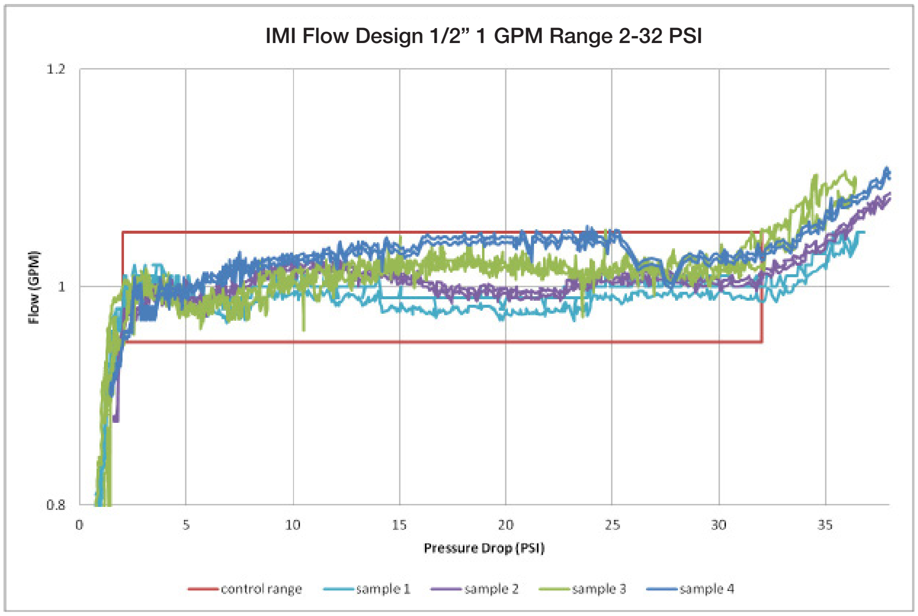
Flows Tested: 1 gpm, 4.5 gpm and 7 gpm

Class[1]	1
Wear Components	Brass, Stainless
Debris Resistance	Moderate
Published Pressure Range	2-45 PSI
Published Flow Accuracy	± 5%

Note: {1}: Class 1 flow controllers use an orifice the size of which is varied directly in response to the imposed differential pressure. Class 2 flow controllers have a control orifice and a pressure responsive orifice. The differential pressure across the control orifice is meant to stay nearly constant.

1/2" Cartridge, 1 GPM

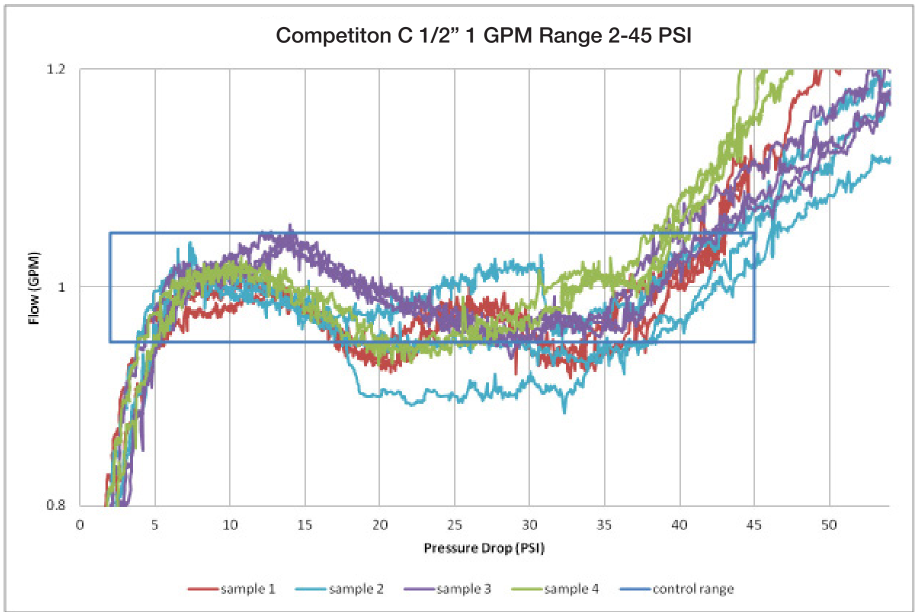
IMI Flow Design



Performance

The flow rises quickly to the control range at about 2 psi. The flow stays inside the ± 5% of target flow. The characteristic of suddenly dropping flow with rising pressure is not present. The rising pressure and falling pressure curves look very much alike. The flow increases in a linear fashion at the end of the control range.

Competition C

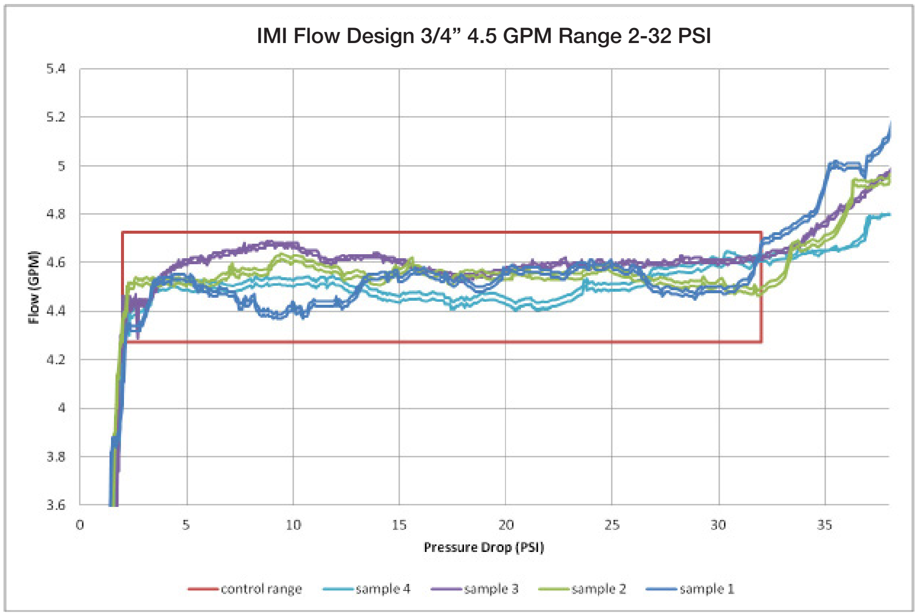


Performance

For the 1 gpm flow, most of the samples did not start regulating at 2 psi as published. The average starting point is around 4 psi. For 3 of the 4 samples tested, the flow at the end of the pressure operating range of 45 psi, was high by 10% to 20%. The one sample flow regulator cartridge, which did stay in the flow accuracy box range, had significant hysteresis (different flow at rising pressure point vs. falling pressure point) and did underflow in the middle of the pressure range. For all the flow samples (1 gpm, 4.5 gpm and 7 gpm) tested for this manufacturer, the 1 gpm automatic flow regulating cartridge was the most accurate.

3/4" Cartridge, 4.5 GPM

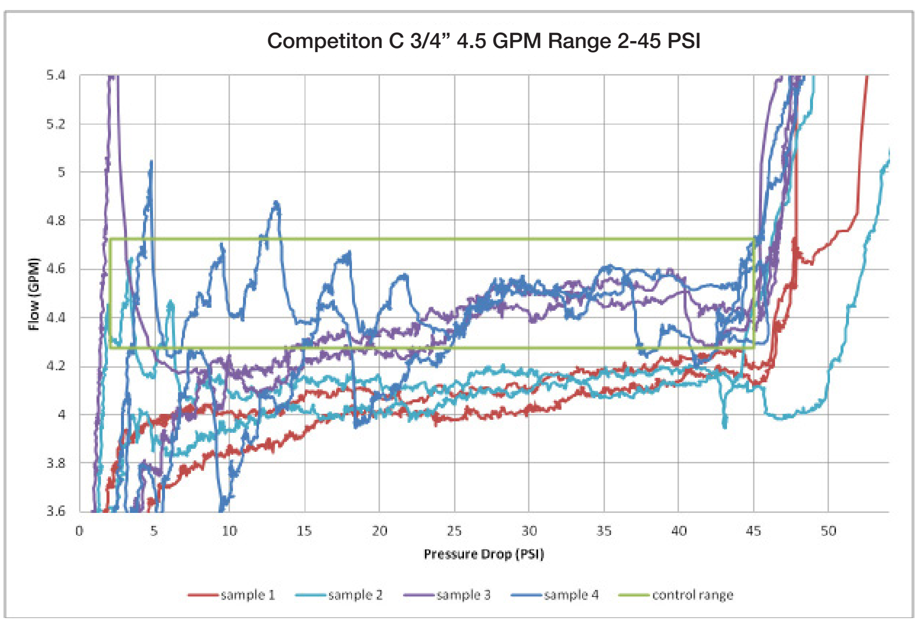
IMI Flow Design



Performance

The flow rises quickly to the control range at about 2 psi. The flow stays inside the ± 5% of target flow. The characteristic of suddenly dropping flow with rising pressure is not present. The rising pressure and falling pressure curves look very much alike. The flow increases in a linear fashion at the end of the control range.

Competition C

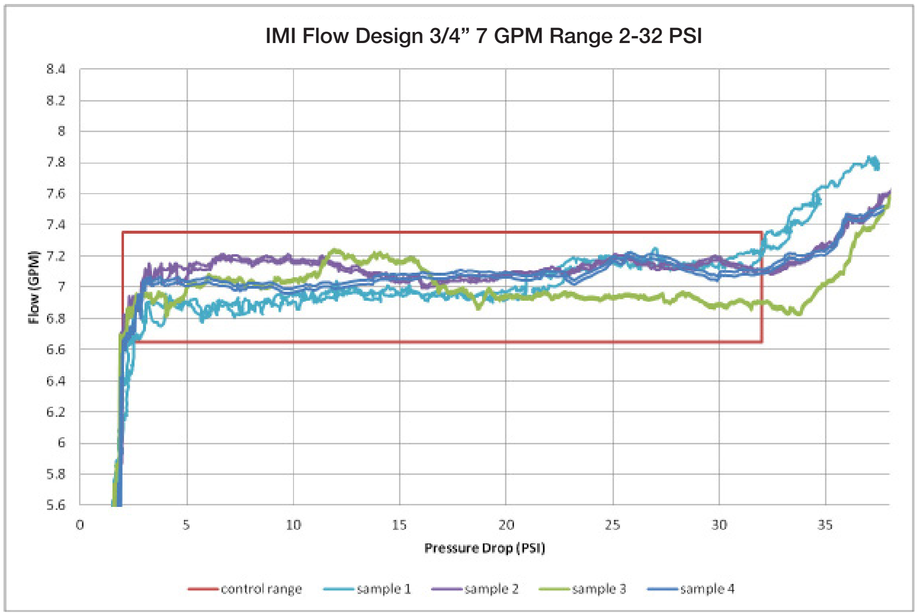


Performance

For all the 4 samples tested for this manufacturer's automatic flow regulator cartridge for 4.5 gpm, none of the flow cartridges started at 2 psi as published. The average underflow for these cartridges was about 7.5%. There seemed to be significant hysteresis and thus stability issues for these cartridges. There seems to be significant variation of flow at about the same pressure. There is a risk that the cartridge may interact with other components to cause vibration noise, pulsing and water hammer.

3/4" Cartridge, 7 GPM

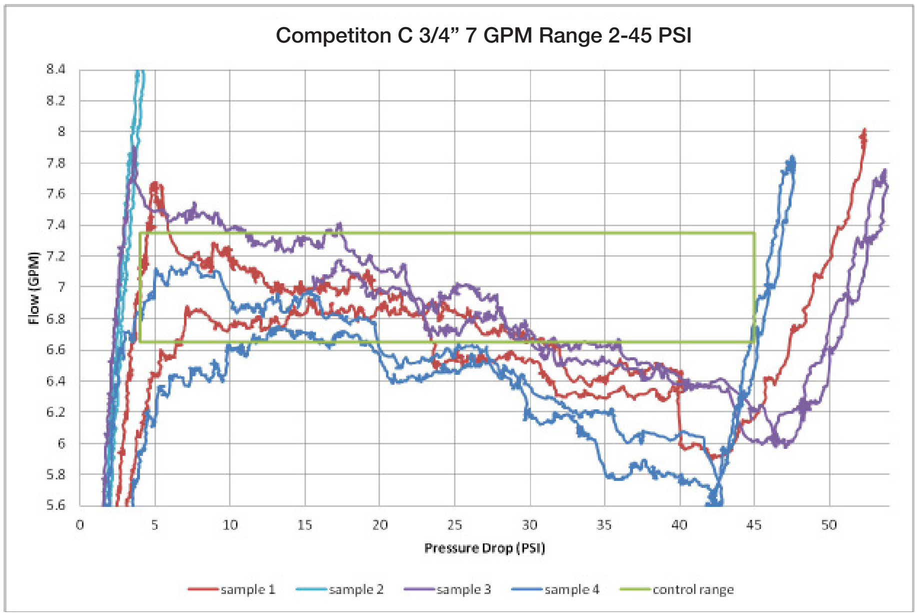
IMI Flow Design



Performance

The flow rises quickly to the control range at about 2 psi. The flow stays inside the ± 5% of target flow. The characteristic of suddenly dropping flow with rising pressure is not present. The rising pressure and falling pressure curves look very much alike. The flow increases in a linear fashion at the end of the control range.

Competition C

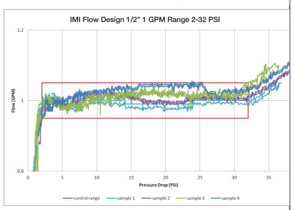


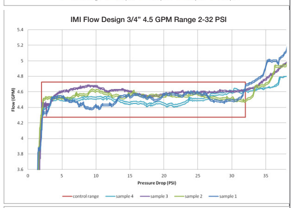
Performance

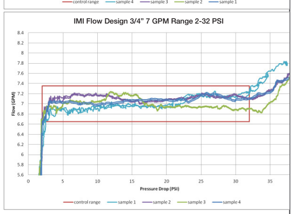
For all the 4 samples tested for 7 gpm, the flow regulation started at about 4 psi vs. 2 psi as published. Most of the cartridges showed decreasing flow with increasing pressure over much of the pressure operating range. This may result in issues like pulsing, water hammer etc. The underflow experienced in the operating pressure range was about 15% at 75% of pressure point on the curve. The flow also showed a significant overflow, very quickly at the end of the flow range. The samples had moderate to significant hysteresis which makes the automatic flow regulator cartridge unreliable at pressure changes in the system.

Performance Summary

IMI Flow Design







Flow at Start Up Pressure:

The graphs for all the samples show that the flow rises quickly to the design flow just before the start of the pressure control range as desired.

Flow within the Operating Range:

As seen from the graphs , the flow remains within the ± 5% of the design flow accuracy box (red colored box). As stated earlier, keeping the flow accuracy within ± 5% in the operating pressure range enables tremendous pump energy savings and thus reduced operating costs.

A Flow at the End of Pressure Range:

As seen from the graphs, the flow at the end of the pressure range is still in the ± 5% flow accuracy box and increases in a linear fashion outside the operating pressure range, which gives the valves a good flow profile.

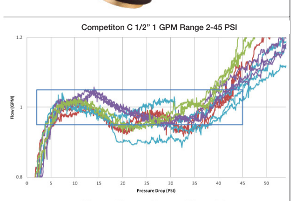
As can be seen from the graphs, the graphs for the rising and falling pressure look alike, so there is little or almost no hysteresis from the valve cartridge design, which enables great precision in flow accuracy and repeatability.

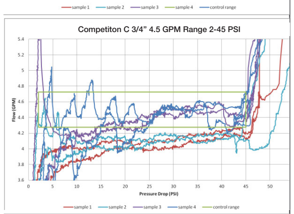
No. of Samples:

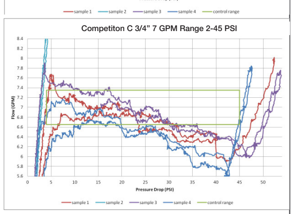
As noticed in the graphs, the flow curves for all the samples tested for the same flow, fall in the design flow accuracy box in the operating pressure range, thus giving the building stakeholder confidence, that any flow cartridge selected will flow at the stated flow. The flow profile is the same for samples for different flows.

For all the samples tested, the graphs do not show a characteristic of suddenly dropping the flow with rising pressure, which may lead to pulsing or water hammer, as can be seen in other manufacturers flow regulator cartridges tested.

Competition C







Flow at Start Up Pressure:

The graphs show that flow regulation for the automatic flow regulator cartridge does not take place at 2 psi for the samples tested. The average starting point for flow regulation was around 4 psi.

Flow within the Operating Range:

For one of the flows tested i.e. 7 gpm, the samples had decreasing flow at increasing pressure. This may cause pulsing, water hammer, etc. in the system. For another flow i.e. 4.5 gpm, there was a significant underflow in the operating pressure range.

A Flow at the End of Pressure Range:

The flow at the end of pressure range was high in most cases and extremely high for the 7 gpm samples.

Hysteresis:

Random samples in a particular flow range, showed huge hysteresis. This characteristic makes the valve unreliable because when installed in the system, the terminal units might experience overflows or underflows at a particular pressure without any reasonable explanation.

No. of Samples:

As can be seen from the graphs, the flow curves for all the samples tested for the same flow, did show variations. This variation was significant for some samples and acceptable for others, so it is an inconsistent behavior. There is also a significant variation seen in the flow profiles for samples for different flows.