

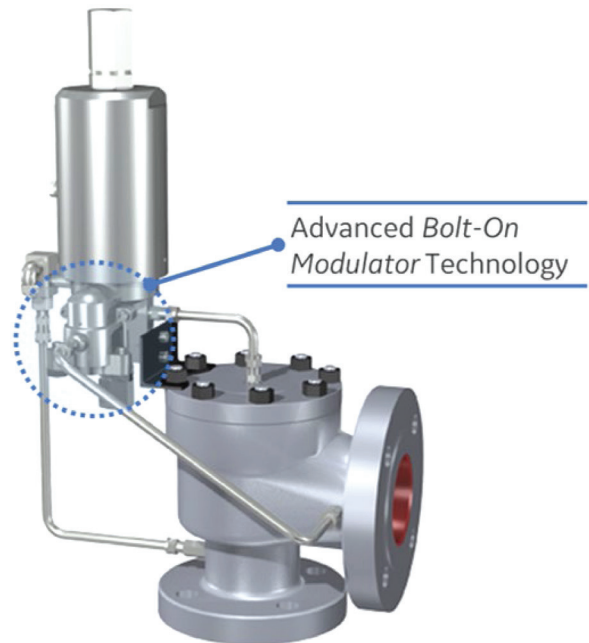
The “True Zero Leakage” Modulating Pilot:

Consolidated™ MV07 with Bolt-On Modulation



Consolidated™ MV07

The “True Zero Leakage”
Modulating Pilot Valve



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Introduction

PRDs and POPRVs

Pressure Relief Devices (PRDs) are designed first and foremost to ensure the safety of life, property, and equipment from the occurrence of unexpected overpressure events. However, this safety has historically come at the expense of unwanted environmental emissions and costly loss of process from leaking PRDs.

The single greatest advantage of a Pilot-Operated PRV (POPVR) is that it reduces emissions, improves operating efficiency, and increases profitability by allowing users to operate their system closer to set pressure while ensuring 'Zero Leakage' from the relief valve, even at operating pressures as high as 98% of set pressure.

This article will explore the importance of, and how to achieve, True Zero Leakage at high operating pressures which is made possible by advanced bolt-on modulator technology.



Zero Leakage? Who Cares?

Environmental Protection Agency

The Environmental Protection Agency (EPA) was established December of 1970 by United States President Richard Nixon with a stated mission to protect human and environmental health. Since the inception of the EPA and other similar agencies around the world, humans have developed a deeper understanding of the negative impact of emissions on human and environmental health, leading to a rapid expansion in EPA authority and exponential growth in environmental regulations around the world.

As it relates to equipment leaks, the EPA publishes the *"Leak Detection and Repair Compliance Assistance Guidance - A Best Practices Guide"* to offer guidance on why and how to reduce or eliminate these unwanted emissions. In Section 1.0 of this guide, the EPA lays out a compelling problem statement:

1.0 Purpose "In general, EPA has found significant widespread noncompliance with Leak Detection and Repair (LDAR) regulations and more specifically, noncompliance with Method 21 requirements. In 1999, EPA estimated that, as a result of this noncompliance, an additional **40,000 tons of Volatile Organic Compounds (VOCs) are emitted annually from valves at petroleum refineries alone.**

Raising the Bar for Reducing Emissions

Section 2.0 of “Leak Detection and Repair Compliance Assistance Guidance” speaks to why equipment leaks must be identified and regulated:

2.0 Why Regulate Equipment Leaks? “The Agency has estimated that approximately **70,367 tons per year of VOCs and 9,357 tons per year of Hazardous Air Pollutants (HAPs) have been emitted from equipment [including valves] leaks.** Emissions from equipment leaks exceed emissions from storage vessels, wastewater, transfer operations, or process vents.”

Historically, the primary industry focus for reducing emissions has been only on the biggest offenders within their equipment portfolio. However, the industry is quickly trending toward a more comprehensive and holistic approach to reducing emissions.

James Lowery, Global Product Line Leader for Masoneilan™ Control Valves at Baker Hughes, shares where he believes the valve industry needs to be thinking as it relates to reducing leakage and emissions for all valve types:







“Fugitive Emissions has been centered around on/off valves and pumps historically. However, the bar is being raised higher every day, and our engineers and product managers are **exploring new boundaries** to ensure our entire product portfolio meets **Zero Emissions.**”

With a clear and growing trend to reduce equipment leakage and emissions, what does this mean in the context of Pressure Relief Devices (PRDs)?

The “Perfect” Pressure Relief Device

If there were to exist a perfect PRD, what would its attributes be? Broken down into the three stages of operation, the perfect PRD would look something like the following:

- 1. Before Relief Event:** Closed with **Zero Leakage** up to **100% of set pressure.**
- 2. During Relief Event:** Opens exactly at set pressure, relieves only enough capacity to protect the system, and operates in a stable manner without chatter or flutter.
- 3. After Relief Event:** Re-closes on its own with a minimum blowdown and returns back to its original state of **Zero Leakage.**

Pressure Relief Devices			Relief Event Performance		
PRD Type	Technology	Application	Before	During	After
Rupture Disc 	Non-reclosing device that opens at set pressure and is destroyed upon actuation.	Used in applications which are not suitable for a reclosing pressure relief device.	+	-	-
Weight Loaded 	Stacked weights on a pallet open and close proportional to inlet pressure.	Typically covers applications below 15 PSIG and into vacuum protection for storage tanks.	-	→	-
Spring Loaded 	A spring opposes force of inlet pressure. As pressure approaches and arrives at set pressure, the spring contracts to relieve pressure.	Versatile pressure relief valve used in most applications including power, O&G, and chemical.	→	→	→
Pilot Operated 	The pilot valve loads operating pressure into the main valve dome keeping the main valve seat tight until set pressure is reached. At set pressure, the dome pressure exhausts which opens the main valve and relieves pressure.	Applications with space/weight restrictions, inlet line loss > 3%, or when operating pressure exceeds 90% of set pressure.	+	+	+

Pilot Valves Can Offer Significant Performance Advantages Over Traditional PRDs

When compared to other PRDs such as rupture discs, weight loaded PVRVs, and Direct Spring PRVs, modulating action **Pilot-Operated Pressure Relief Valve (POPRV) technology clearly comes the closest to achieving “Perfect PRD” status, particularly as it relates to ‘Zero Leakage’** before and after a relief event occurs.

Obviously ‘Zero Leakage’ is a critical factor in the performance of a PRV, but what exactly does it mean? The answer begins with a deeper examination of PRV seat leakage.

PRV Seat Leakage Defined

API 527 Fourth Edition “Seat Tightness of Pressure Relief Valves” is the globally accepted standard for establishing the methods of determining PRV seat leakage as well as defining acceptable seat leakage rates.

Methods of Determination

API 527 Section 1 prescribes a seat leakage test with air, steam, or water in accordance with the primary stamped media of the valve. For each of the test procedures on air, steam, or water, API 527 Sections 2 through 5 only require a leakage test to be performed on the seat of the main valve, making no mention of main valve dome media discharging from the pilot exhaust.

For example, API 527 Section 2.1 and 2.2.2 shows and describes the test apparatus and configuration for PRV seat leakage testing on air:

API 527-2.2.2 “The valve shall be vertically mounted on the test stand, and the test apparatus shall be attached to the **valve outlet**, as shown in Figure 1. All openings—including but not limited to caps, drain holes, vents, and outlets—shall be closed.”

From a scope perspective, API 527 focuses only on one aspect of PRV leakage, but fails to comprehensively address all forms of possible PRV media releases.

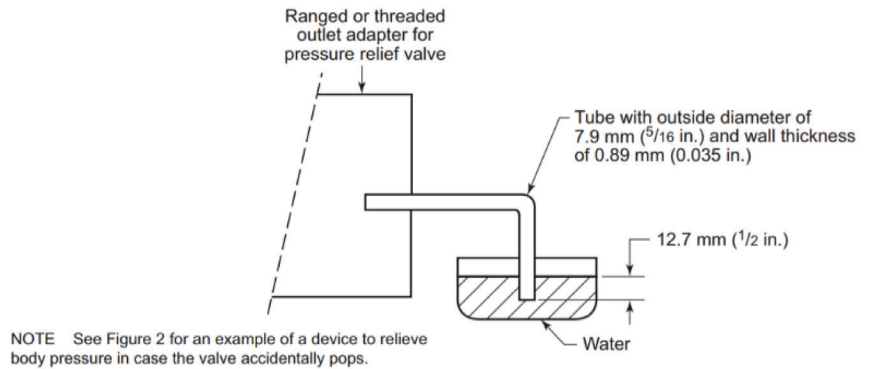


Figure 1—Apparatus to Test Seat Tightness with Air

Acceptable Leakage Rates

API 527 defines acceptable leakage rates by media type for the valve outlet, but again offers no guidance on acceptable leakage or allowable media discharge from the main valve dome through the pilot exhaust.

“Put more simply, metal-to-metal seated PRVs are designed and allowed to **constantly leak** even in standard and controlled operating conditions, resulting in **unwanted emissions and costly product loss.**”

For example, Section 2.3 Table 1 of API 527 defines an allowable leakage rate for metal-to-metal seated PRVs on air. Leakage rates as high as **100 bubbles/min at operating pressures as low as 90%** are deemed allowable according to the acceptance criteria. Put more simply, metal-to-metal seated PRVs are designed and allowed to **constantly leak** even in standard and controlled operating conditions, resulting in unwanted **emissions and costly product loss**. By contrast, soft seated valves, including POPRVs, are allowed no leakage (0 bubbles/min) for up to one minute.

It should also be noted that this standard and acceptance criterion only applies to the state of the valves in a **controlled production and testing environment**, but not in a true

operating environment full of service debris, vibration, and other undesirable operating conditions. Actual operating conditions along with wear of metal components will presumably only increase the actual leakage rate of a metal seated valve over time.

Table 1—Maximum Seat Leakage Rates for Metal-Seated Pressure Relief Valves

Set Pressure at 15.6 °C (60 °F) kPa (psig)	Orifice Diameter Less Than or Equal to 18 mm (0.700 in)		Orifice Diameter Greater Than 18 mm (0.700 in)	
	Leakage Rate (Bubbles/min)	Approximate Leakage/24 hr Standard m ³ (ft ³)	Leakage Rate (Bubbles/min)	Approximate Leakage/24 hr Standard m ³ (ft ³)
13 to 6896 (15 to 1000)	40	0.017 (0.60)	20	0.0085 (0.30)
10,300 (1500)	60	0.026 (0.90)	30	0.013 (0.45)
13,800 (2000)	80	0.034 (1.20)	40	0.017 (0.60)
17,200 (2500)	100	0.043 (1.50)	50	0.021 (0.75)
20,700 (3000)	100	0.043 (1.50)	60	0.026 (0.90)
27,600 (4000)	100	0.043 (1.50)	80	0.034 (1.20)
34,400 (5000)	100	0.043 (1.50)	100	0.043 (1.50)
41,400 (6000)	100	0.043 (1.50)	100	0.043 (1.50)

Are All Modulating Pilots Created Equal?

SPOILER ALERT

All modulating pilot valves are not created equal, specifically when it comes to pilot valve zero leakage at high operating pressures.

What is causing this difference and how big is the delta? All modulating POPRV designs can be boiled down to 2 different designs/approaches: internal modulation and bolt-on modulation.

Typical internal modulating pilots lock in main valve dome pressure at some unknown point before 95% operating pressure (commonly referred to as the "Null Zone"). In the range of 95% to 100% of set pressure, they then achieve main valve modulation by **continually venting main valve dome pressure (premature leakage)**, inversely proportional to inlet pressure down to 70% of set pressure, creating balance in the main valve. By contrast, bolt-on modulation technology enables the pilot to wait all the way up to 100% of set pressure before venting main valve dome pressure down to the same 70% of set pressure. At 100% of set pressure, both main valves will then modulate through the relief cycle.

Figure 2 – Typical Internal Vs. Bolt-On Modulation Technology

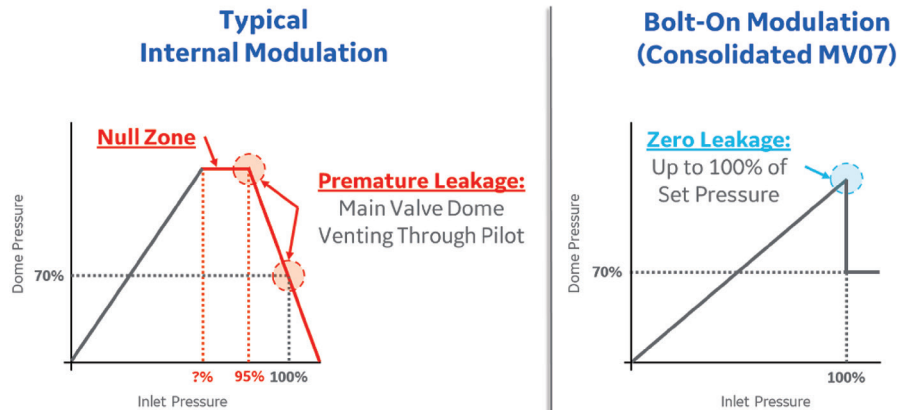


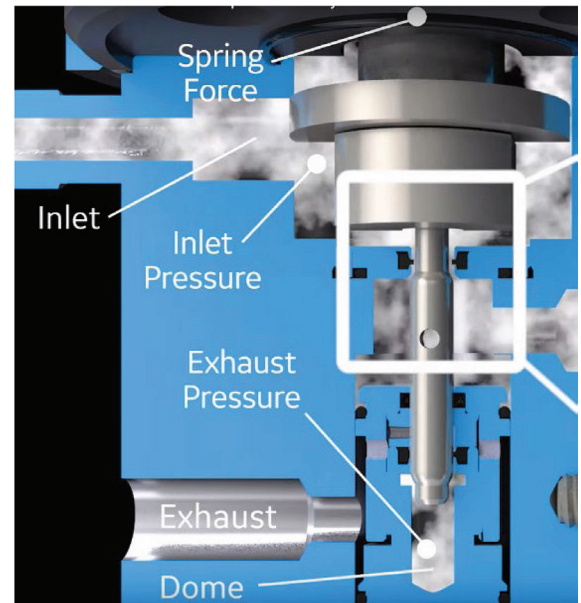
Figure 2 above offers a summary comparison of the performance of a typical internal modulating pilot vs. advanced bolt-on modulation technology. Here is a deeper dive into the differing approaches to modulation of a typical internal modulating pilot vs. advanced bolt-on modulation technology.

Internal Modulation

The industry standard for non-flowing internal modulating pilot designs operate on a force balance described by the following formula:

$$F_s = P_i(A_1) + P_d(A_2)$$

- **F_s** = The pilot loading spring, which allows pilot set pressure adjustment
- **P_i** = System inlet pressure
- **P_d** = Pressure in the main valve dome chamber sensed from the pilot dome area
- **A₁** = Area described by the pilot main sensing piston or diaphragm
- **A₂** = Area described by the pilot dome area



As the system pressure increases, the internal modulating pilot goes through 4 phases:

- 1. Unbalanced:** The pilot is typically in the unbalanced state during normal operating conditions, in which the pilot spring is applying a greater force (F_s) downward than the summation of forces generated by the system pressure acting on the pilot piston ($P_i \times A_1$) and dome pressure on the pilot dome area ($P_d \times A_2$). In the unbalanced state, both the pilot and the main valve are in a zero-leakage state.
- 2. Balanced:** When the summation of forces from system pressure and dome pressure equals the force of the pilot spring, the pilot enters into a balanced state. Balance is achieved at a pressure less than the desired set pressure (typically around 95%) of the valve. In addition, due to the delicate force balance, "stable inlet pressure" is required in order to ensure that the pilot does not leak further.
- 3. Pilot Discharge:** As system pressure continues to increase beyond balanced pressure, the pilot will control the main valve dome pressure inversely proportional to the change in system pressure in order to satisfy the force balance equation. As a result, the main valve dome pressure will discharge through the pilot discharge port at a system pressure of 95% and greater. As system pressure moves up and down between 95% and 100% of set pressure, the pilot would continue to vent and supply the main valve dome as it works to maintain a balanced state.
- 4. Modulation:** When main valve dome pressure is reduced to approximately 70% of the system pressure, balance will be achieved in the main valve piston, allowing opening of the main valve and relieving system pressure.

In summary, internal modulating pilots cannot claim 'True Zero Leakage' because they unrealistically require "stable inlet pressure" and will actually begin to leak at 95% of operating pressure.

Bolt-On Modulation

Advanced Bolt-On Modulation technology allows the pilot valve to achieve similar or better main valve modulation, while completely eliminating main valve dome discharge through the pilot discharge port all the way until 100% of set pressure, thus presenting the only True Zero Leakage Modulating Pilot Valve on the market. Here is how it works (Figure 3):

- 1. Below Set Pressure:** The dome exhaust seat in the pilot remains closed all the way until 100% of set pressure.
- 2. At Set Pressure:** The pilot closes the inlet supply seat and opens the dome exhaust seat, thereby opening the cavity between the modulator bottom and the main valve dome. System pressure and main valve dome pressure are equal at this point. Pressure in the main valve dome will then decrease until the modulator is balanced, typically a value of 65% of set pressure.
- 3. Above Set Pressure:** The main valve is now balanced with a slight upward net force acting upward on the main valve piston. The main valve piston will move upward proportional to an increase in system pressure. The modulator will always be in a balanced state, thus controlling the pressure in the main valve dome chamber to 65% of inlet conditions. When pressure reduces to closing pressure of the pilot (typically 3%-5%), the pilot will close the exhaust port and reopen the supply to pressurize the main valve dome again to system pressure.

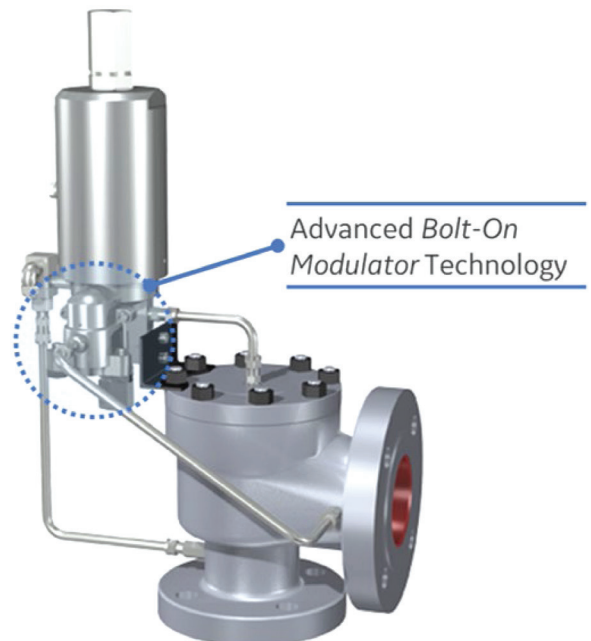
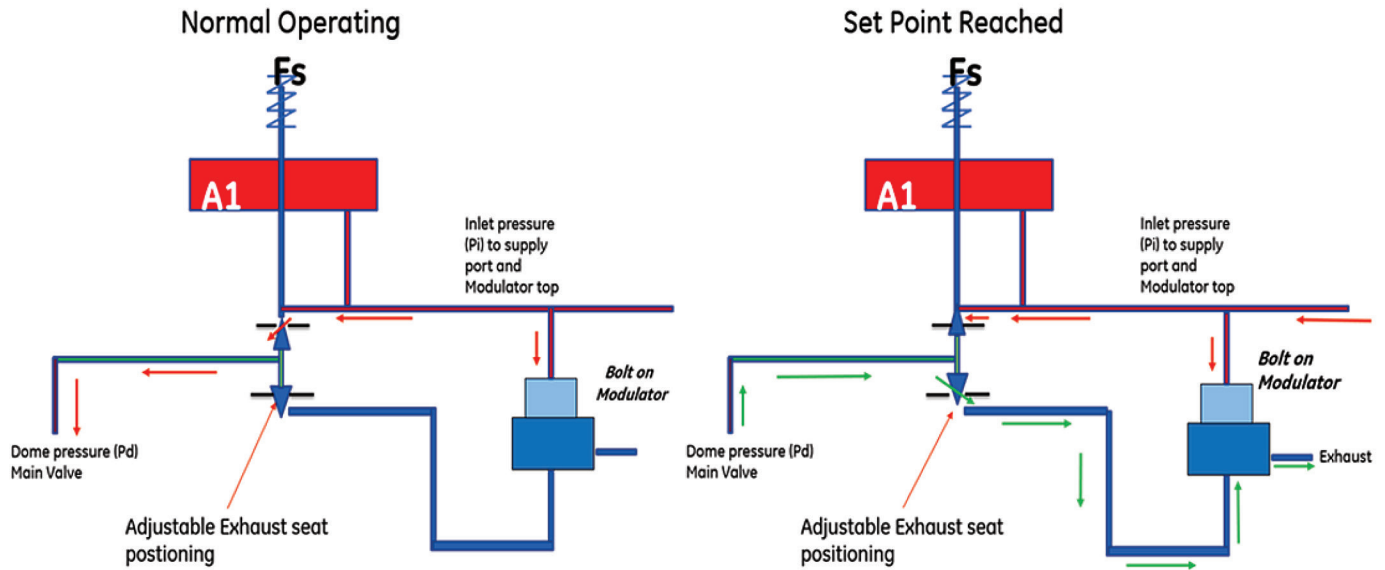


Figure 3 – Bolt On Modulator Diagram



Conclusion

While typical internal modulating pilot valves will begin to release dome pressure through the pilot beginning at 95% operating pressure, the **Consolidated™ MV07** bolt-on modulator pilot valve is the only modulating pilot valve on the market that can claim **'True Zero Leakage' for the complete valve up to 98% - 100%** (depending on set pressure tolerance) of set pressure. In addition, this robustly designed pilot does not rely on "stable inlet pressure" in order to achieve this superior performance.

Figure 4 – Modulation Type Performance Summary

Modulation Type	First Emission	Null Zone	Null Zone %	Requires Steady Conditions?
Internal	95%	YES	?? to 95%	YES
Bolt-On	100%	NO	N/A	NO

Note – % denotes % system pressure compared to set pressure

Contact your Green Tag Center (GTC) or licensed Consolidated representative today to upgrade your internally modulating API 526 pilot valve to a Consolidated 3900 Series or your API 526 direct spring valve to a Consolidated 2900 Series. They conform to the API 526 center-to-face global dimensional standard, so no need to worry about piping modifications.



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