VPAC Technology
Through Valve Leakage Monitoring for Safety and Control of Loss to Flare
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Valves are an essential part of operating process plant, and represent a significant capital investment, statistically ten percent of valves leak when they should be closed, however only one percent of valves cause seventy percent of total through-valve leakage \(^{[1]}\).

This leakage causes a significant loss of product where valves are normally closed and leading to flare, and represents a significant safety risk for normally open valves that are only closed in an emergency.

VPAC™ technology provides a means to estimate the leakage rate, using either a portable unit, or an on-line system, as appropriate for the application.

VPAC™ technology was originally developed for use on refineries and offshore platforms by British Petroleum (BP) working together with Physical Acoustics, following which Physical Acoustics was granted exclusive rights to commercial exploitation. The first commercial implementation was the “VPAC-5131” system, a portable device used for surveying valves manually and primarily aimed at the control of losses to flare in process plant. Unlike other ultrasonic systems, VPAC™ operates successfully in the high-noise environments encountered in oil and gas operations, including process plant, a result of a sensor which is not affected by plant vibration and airborne noise. More than a thousand VPAC portable systems are in use worldwide, and operating experience has shown that most sites have losses to flare \(^{[2]}\) exceeding $1m per annum, one site even exceeding $15m per annum. Use of VPAC™ technology over the years has resulted in a reduction in flare losses of countless millions of tons, not only from refineries, but also from offshore platforms, gas plant, and chemical plants.

The estimation of leakage rate is made using “best fit” formulae which were developed by measurement of the leakage signal levels using the VPAC™ instrumentation, and comparing these with physical mass flow after removing and re-testing leaking valves in a workshop. More than 800 correlation measurement sets were made over a period of six years, following which BP statisticians developed “correlation equations” for gas and liquid leakage, for a range of valves and conditions.

A second program between Physical Acoustics, Shell Exploration & Production, and BP, extended the application experience to large ball valves with both hard and soft seats, in gas and liquid service, intended for upstream use primarily on safety critical shutdown valves. This involved both field and workshop testing of valves from 10” up to 36” in size. Following agreement with the authorities the technology was used at many locations to replace the statutory annual SI 1028 ESDV leakage test, which was both costly and time consuming.
Online Monitoring

For many situations "on-line remote" measurement of valve leakage is more appropriate. This is particularly true for remote or difficult to access sites, such as the top of columns, unmanned facilities, and controlled valves that can cause large and rapid losses if they do not fully shut off when required, such as blowdown valves.

On-line monitoring is also preferable for situations where an emergency shutdown involves closing many valves simultaneously. In this scenario there is not the time for operators to walk around the site using a portable unit to check the leakage rates from multiple valves. On-line monitoring provides leak rate information instantaneously to the operations desk, providing an essential safety function and minimizing impact of leakage on operations.

The solution to the on-line monitoring need is provided by the VPAC-1278 system, which has an industry standard 2-wire 4-20mA current loop connection that can go into any DCS, remote I/O or Wireless (e.g. HART or ISA-100) plant data acquisition system. Noise and dynamic range cover the full requirement for VPAC™ measurements. Many thousands of VPAC-1278 systems are now installed, providing operators with an instantaneous estimation of leakage rate through valves that are “closed”, but not necessarily “tight”.

![VPAC-1278 System](image-url)
ON-LINE MONITORING

In the case of the VPAC™ 1278 on-line system, an intrinsically safe piezoelectric sensor is permanently mounted to the valve body. For large valves, several sensors are required due to the attenuation effects on the signal amplitude around the body of the valve.

The schematic illustrations identify three phases of valve operation. In (a), the valve is open and as such, laminar flow results. In this case, little or no noise would be produced from the valve due to the absence of turbulent flow. In (b), the valve is correctly seated and therefore, no laminar or turbulent flow is present. In (c), the valve is passing, i.e. the seal around the valve is not sufficient to fully restrict the flow of product, and turbulent flow with its associated high frequency noise occurs, which is detected by the sensor.

Turbulent flow occurs when the inertial effects of the fluid flow overcome viscous drag; it is this turbulent flow that generates the source of sound or acoustic emission (AE). AE results from a fluctuation in the pressure field associated with turbulent flow of the product at the leak site. Owing to the frequency range that the sensors operate the system is virtually immune to environmental and process noise.

The signal produced by the sensor is processed by the VPAC™ subsystem (VPAC-1278). The unit works as a loop-powered 4-20mA system, so no additional power supply is needed.

The 4-20mA signal is connected either directly to the DCS via galvanic or Zener barrier, to remote field I/O, or via Wireless HART or ISA-100, into the plant data acquisition system.

Noncomplex processing is required using an algorithm appropriate for the valve to determine leak presence and estimate the leak rate. When valves do not fully close, or leak for other reasons, the operator knows immediately.
Monitoring setup

QUANTITY REQUIREMENTS

Valves leading to flare, low criticality, valves <18” NB, loss control application: One sensor mounted on the main valve casting is sufficient. For valves less than 6” NB (nominal bore), mounting anywhere on the casting, including the inside of a flange, is a good position.

For valves >6” a position nearer the seat will improve the sensitivity of measurement.

If the valve is on a small manifold with many other valves there is a risk of some “crosstalk” should an adjacent valve leak significantly. In this case either monitoring of all the valves on the manifold, or adding “upstream” and “downstream” sensors to the monitored valve will allow clear identification of which valve is responsible for the leak.

The additional sensors may be mounted on the pipe flanges or pipe itself each side of the valve.

For liquids, a location >5 pipe diameters from the flange is recommended, where possible, for the upstream and downstream sensors, because of sound propagation through the liquid.

When 100% confidence is required that the monitored valve is the leaking valve, and the valve is on the same pipe as a throttling control valve or other source of very high turbulence, then the addition of “upstream” and “downstream” sensors is always recommended.

When “upstream” and “downstream” sensors are used, the signal level on both “upstream” and “downstream” sensors should always be less than the signal level on the valve sensor if the valve is the source, if either are higher, then a source away from the valve should be suspected.
Monitoring setup

Emergency shutdown valves, high criticality, safety applications: Where 100% confidence is required that the monitored valve is the leaking valve, for the reasons outlined above, three sensors per valve are recommended, one on the main casting, and one each upstream and downstream.

Large diameter valves: Valves of large diameter, typically 18” plus, exhibit some attenuation around the casting instead of “ringing” like a bell. If the highest sensitivity is required, then several sensors mounted at the appropriate locations relative to the seat are recommended:

- 18” Two sensors on the casting.
- 24”-30” Three sensors on the casting.
- 36” Four sensors on the casting.

Note: sensors must be mounted on a flat or convex surface to maximize the surface area over which they are in contact. The sensors are usually installed in a protective stainless steel [316] housing; the housings are often installed at the valve manufacturer by welding to the valve prior to painting.
**Technical details**

**CONFIGURATIONS**

- Twisted pair cable → Safe area Barrier 4-20mA to DCS
- Remote ID – Field bus → Network
- Wireless → Wireless Gateway
- Wireless with local display → Wireless Gateway
- Local display only
- EXD Armoured Cable → Network or 4-20mA

**SPECIFICATION**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
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<tbody>
<tr>
<td>Maximum surface temperature:</td>
<td>125 °C (no waveguide), 650 °C (waveguide)</td>
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<tr>
<td>Minimum surface temperature:</td>
<td>-40 °C (no waveguide), -220 °C (waveguide)</td>
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<tr>
<td>Ambient temperature range:</td>
<td>-40 °C to +70 °C max. (see appropriate certification for detail)</td>
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<tr>
<td>Sensor cable length:</td>
<td>2 metres or 5 metres supplied, cut to length</td>
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<tr>
<td>Protection:</td>
<td>IP66</td>
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<tr>
<td>Output:</td>
<td>4-20 mA = 0-100 dB_AE Quiescent: 13 dB_AE</td>
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<tr>
<td>Operating voltage:</td>
<td>12-28 volts</td>
</tr>
<tr>
<td>Start-up time:</td>
<td>3 seconds (VPAC configuration)</td>
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<tr>
<td>Measurement Range (gas STP):</td>
<td>1” ball: ~0.1 – 2742 l/min. 48” ball: ~3.2 – 44,825 l/min.</td>
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<tr>
<td>Electrical data:</td>
<td>Ui = 30V, li = 100mA, Pi = 0.9W, Li = 100 µH, Ci = 0.05µF</td>
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<tr>
<td>Certification:</td>
<td>II 1 G  Ex ia IIIC T4 Ga -40 °C &lt; Ta &lt; +70 °C</td>
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<td>Ex ia IIIC T6 Ga -40 °C &lt; Ta &lt; +40 °C</td>
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<td>II 1 D  Ex ia IIIIC T135°C Da -40 °C &lt; Ta &lt; +70 °C</td>
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*Note: VPAC configuration refers to a specific configuration that may differ from other configurations.*