How VPInstruments tackles toughest compressed air flow challenges

Compressed air discharge flow measurement presents extreme challenges including heat, saturation, oil and limited installation space. Different technologies behave differently under these conditions, with trade-offs in reliability and accuracy. Here, VPINSTRUMENTS CEO and founder Pascal van Putten discusses the solutions his company has developed to address such harsh environments while maintaining consistent, dependable flow measurement performance.

Let's talk about compressed air discharge flow measurement. (You can apply most of this to blower discharge as well; it's similar in a lot of ways.) Measuring compressor discharge can feel like uncharted territory in flow measurement. It's probably one of the harshest, ugliest environments you can put a flow meter in. You're really putting the instrument to the test. And why is that?

WHY COMPRESSOR DISCHARGE IS SUCH A TOUGH MEASUREMENT

Compressed air coming straight out of a compressor is warm, sometimes very warm, especially if there's no aftercooler. It's humid. Actually, it's essentially 100 percent saturated. Think of it like a sauna: as soon as that air hits a surface that's even a bit cooler, it will condense. And it can be oily. Sometimes the condensate is aggressive, sometimes even acidic, depending on what's in the system and the nature of the condensate. It's not exactly the environment you'd choose to 'live in' if you were a flow meter. But we build instruments, so we try to make the impossible possible, and we try to make it easy. That's also why we offer flow meters intended specifically for discharge applications. And we were the first to introduce them about 15 years ago, when introducing our VPFlowScope DP, an insertion-style differential pressure flow meter. One more very practical problem: installer companies and contractors often have a lack of space. The compressed air room is rarely the nicest room in the building; it's often downstairs or in a corner of the factory. Space is limited, compressors have grown over time (more air consumption), and as a result, you often don't have enough straight pipe length to get accurate measurements. Pipes go up, pipes go down, left and right, like a bunch of spaghetti. Sometimes you must install the flow meter in a really ugly spot where the flow goes every way except straight. That's another major challenge.

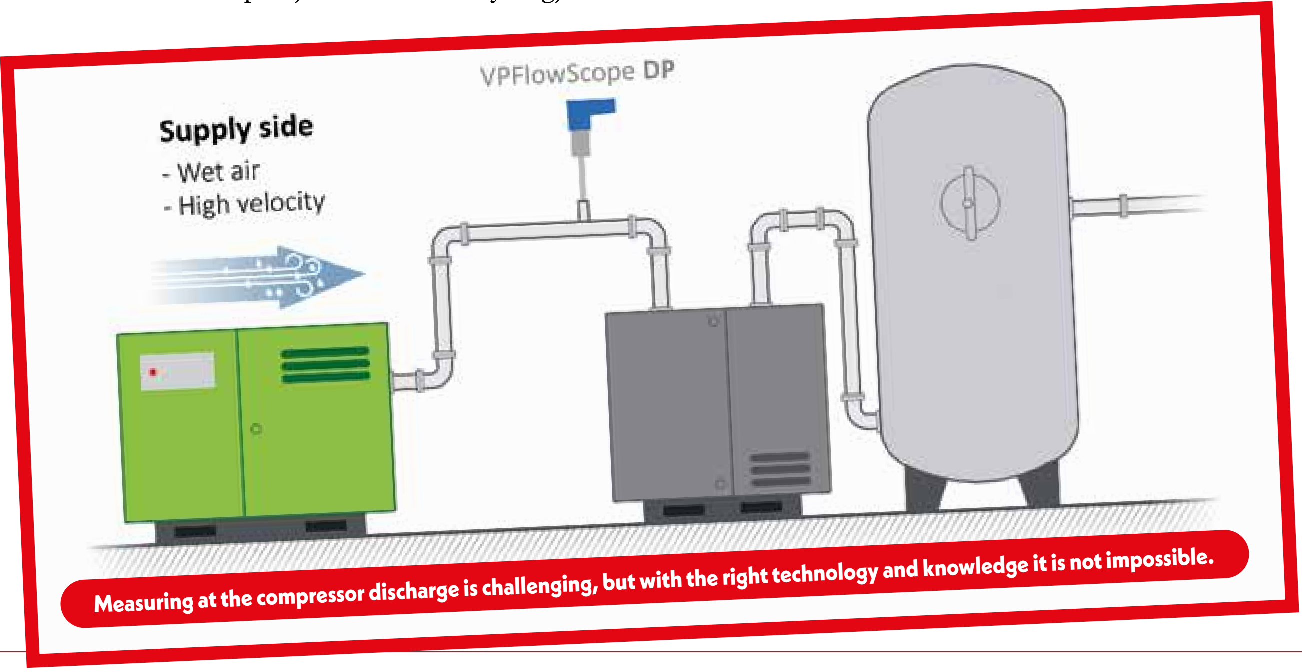
WHAT A DISCHARGE FLOW METER NEEDS TO HANDLE

So, what technologies are out there to measure discharge flow? First, let's define the basics. A discharge flow meter should:

- Be relatively insensitive to high temperature and temperature sweeps;
- Work with short metre runs (limited straight lengths);
- Deal with wet air flow (condensation and water droplets).

THERMAL MASS FLOW METERS (SOMETIMES, BUT OFTEN PAINFUL)

If you put a thermal mass flow meter in these applications, the problem is that it works on heat transfer. Water has much higher thermal conductivity than air, so you can get big spikes in your signal, or even completely flat-lined readings when water sits on the sensor. Add oil to the mix, and the sensor can foul, meaning the sensitivity changes over time. So thermal mass is typically not the technology of choice for discharge. That said, there are tricks to mitigate some of these issues. In the past (and some manufacturers still do this), you can use an 'umbrella' structure to shield the sensor or heat the sensor above a certain temperature so water boils off. We also tried these methods when we introduced the VPFlowMate probe for a large OEM to perform audits back in 2003. In some cases, it can work, especially when the water content isn't too high (for example, when there's a good separator), or when inlet air humidity is lower due to weather conditions. So yes, sometimes a thermal mass metre can work on the discharge of a compressor. Just don't assume it will always work. Differential pressure flow meters (old school, reliable … until they clog) The other common technology for compressor discharge flow is differential pressure (DP). It's been used for a long time. If you look at compressor test benches, many are based on critical nozzles or orifice metres, also DP-based methods. The good thing about DP is that, as long as the metre doesn't clog (those pressure holes can be quite small), it's measuring differential pressure over a geometry. The actual sensor isn't really sitting in the process, so it's not exposed to the full temperature, and it doesn't 'see' the water-again, as long as those impulse/pressure ports stay open. Water content changes the density of air a bit, but you can compensate for that quite easily. Use the ISO 1217 directive to find out how you do this. So, it's a straightforward, very reliable measurement method, with some limitations. If you're using an insertion probe, people sometimes (incorrectly) call it a Pitot tube. A Pitot tube (invented



Measuring at the compressor discharge is challenging, but with the right technology and knowledge it is not impossible.

by Henri Pitot back in 1732) was originally used to measure the speed of the River Seine in Paris, and the basic concept is still what you see on airplanes and boats. Those devices can have their own real-world issues (for example, icing). In compressed air, condensate can create a similar 'instrument gets confused by the environment' problem, just in a different way. The probes sold for compressed air flow metering, like the VPFlowScope DP, are fundamentally not the same thing, which is why we call them insertion-style differential pressure metres. You'll also find variations like multi-hole designs that do a kind of averaging over the flow profile. But anyway, back to the story.

WATER: THE HIDDEN TROUBLEMAKER (FOR PROBES AND ORIFICES)

So even with insertion-style DP metres, water can still be a problem. Water can build up on or around the probe and cause misreadings, especially when the compressor is off or during start-up. That's when you can get a lot of water coming out of the separator (and it gets even worse when drains are broken-which, honestly, happens). This is why orientation matters. You want water to drip off the probe instead of staying on it. I often compare it to water on your car windshield: gravity helps, and airflow can help, but some droplets still 'stick' in certain spots. Also, the actual installation point matters. In old, brownfield plants, the compressed air installation may be so badly designed and maintained that it is recommended to fix these issues before installing any sensor. Talking about condensate in the pipes: you can see the same effect on a car in the rain. Even at speed, there are places where the airflow force is basically zero, and a droplet just doesn't move. That can happen on probes too-certain shapes and orientations encourage droplets to stay put, even when there's flow trying to blow them off. So orientation (and even probe shape) has a real influence on how well the probe drains. We have put inlet filters in VPFlowScope DP flow meters on both DP channels. This is not always seen as positive in the market. But let me tell you this: without those filters, excess water can enter the sensor chamber (also true for competitor flow meters) and cause serious issues. So we put in these filters to keep your DP metres measuring even when there is an accidental sludge of water entering the probe. If you use orifice-type metres, you can run into similar issues. The pressure holes can clog with water droplets, and suddenly your signal is gone or distorted. Remember: many of these metres use something like 100-500 mbar of pressure differential full scale to measure flow. A single water droplet can represent a surprisingly large 'equivalent pressure' in that world, so it doesn't take much to excite (or mess up) the DP sensor.

RANGEABILITY: THE CLASSIC DP LIMITATION

Another big point is rangeability. With differential pressure flow measurement, the typical usable range is about 1:10, sometimes 1:20. Anything beyond that is often a bit of a marketing claim, because it usually comes with a catch, like having to re-zero/reset the transmitter regularly due to offset drift. Are you having fun climbing the ladder again to take the sensor out to do this offset calibration? Offset drift is, to some extent, in the nature of a DP sensor. And there's another fundamental reason rangeability isn't great: differential pressure is proportional to velocity squared. That means high velocity gives you a strong signal, but low velocity gives you almost nothing, except for the offset. (And yes, this is different from thermal mass, where the relationship behaves more like a square root: high sensitivity at low velocities, and relatively lower sensitivity at high velocities. Keep that in mind when comparing those technologies in other applications.) Back to DP: at low velocities, you can have no signal (or a very small signal). That's why, if you put a DP insertion probe or orifice in a common header where three compressors discharge into the same line, and only one compressor is running, you might see almost nothing: the metre simply can't 'see' less than about one third of the total design flow. This is one of the reasons discharge flow can be so challenging with DP in real installations. There are newer developments that aim to measure DP over a larger range without the offset effects over time, but the classic limitations are still important to understand.

VORTEX, ULTRASONIC, CORIOLIS, ROTARY – AND WHAT TO WATCH OUT FOR

Vortex metres are sometimes used for wet air and can work, but again, rangeability is also limited. What you often see is that people undersize the pipe (or install a metre


Optimise your compressor efficiency by measuring compressor discharge output. Combine this with other signals and combine data into a centralized monitoring system as VPVision. Get data driven optimizations.

with a reduced bore) to squeeze more signal out of it. That can be a bad idea because you create a permanent pressure loss across the metre, which costs money every hour of every day. Always ask for the pressure loss curve before buying a metre. It's one of the simplest ways to avoid unpleasant surprises in operating cost. Ultrasonic metres are also used for wet air. It sounds great, especially clamp-on, because it's outside the pipe. But water buildup on the transducers (or inside the pipe affecting acoustics) can kill the signal. You can get gaps in your data: the signal disappears, then comes back when the water clears. It can be a viable technology; just be aware of how sensitive it can be to wet conditions. Coriolis metres are the Rolls-Royce of flow metres. You'll find them from vendors like Micro Motion, Emerson, Siemens, and Endress+Hauser. They're very accurate because they measure mass flow directly (first principle). In a way, it's like having a weighing scale for your air. So, you might ask: why doesn't everyone use Coriolis on compressor discharge? Pressure loss is the big issue. You can see a very significant pressure drop, sometimes up to around 1 bar, especially because these metres are often undersized to get enough velocity and a stronger Coriolis effect. And last, but not least, with Coriolis, water buildup can completely mess up the measurement. Orientation matters a lot: you typically want gravity to help water drain naturally. Also consider weight and installation effort. A 4-inch Coriolis metre is a big piece of hardware that needs proper support. It's flanged, so installation is doable, but it's not the same as installing an insertion probe in a hot tap. For standard monitoring applications, Coriolis is relatively rare. But for test benches, it can be a nice choice. Rotary gas metres are sometimes used for discharge flow too, but you need dry air; otherwise, they can fail. In some test applications, we have seen large dryers to keep them safe. Pressure pulsations can also be devastating. Bearings can wear out due to mechanical stress from pulsation. Pressurization has to be very gentle: think on the order of 100 mbar per second or slower. Otherwise, you can create serious issues. A quick note on compressor test benches When we talk about compressor test benches, you'll often see critical nozzles used because they're very accurate (first principle). There are companies that make all-in-one compressor test benches with a high level of automation: data collection, automated test runs, and a clean report that can be compliant with CAGI and/or ISO standards. If you're into compressor testing and you don't want to build your own software and measurement setup, a complete solution can be worth looking at.

PRACTICAL LIMITS

And then there are the practical limits that are easy to forget but important in the real world:

- Temperature rating: How hot can the meter actually handle? And how fast can it follow those temperature swings?
- Pressure rating: What is the maximum rating of the built-in absolute pressure sensor (10 bar, 16 bar, 50 bar…)?
- Usability features: Do you need a display, a data logger, Ethernet connectivity, wireless, etc.?
- Selection complexity: engineered DP vs. 'one size fits all'

With some traditional DP setups, you'll discover you're not buying 'a flow meter.' You're buying a primary element (orifice, venturi, etc.) from vendor A, a differential pressure transmitter from vendor B, and a manifold block from vendor C. And then you engineer the whole thing together. Add to that: complicated selection codes, long delivery times, and a lot of room for ordering mistakes unless you're a subject matter expert (or you work with one). That's why many people prefer solutions that are easier to select and deploy, with less chance of mistakes and faster projects.

WRAPPING UP

Discharge flow measurement is not an easy application. High temperatures, saturated air, condensate, oil contamination, and limited straight pipe length quickly expose the weaknesses of generic flow technologies. Getting reliable data requires instrumentation specifically designed for these harsh conditions, combined with practical application knowledge. ■