

DESIGNING SCALABLE AND RELIABLE LOW LIQUID FLOW PROCESSES

E-BOOK

Designing scalable and
reliable low liquid flow
processes

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SUMMARY

Why have we written this e-book?

How to design scalable and reliable low liquid flow processes from day one? That's what this e-book is about. It shows how low-flow (< 1000 kg/h) technologies enable faster, more reliable and more scalable process development.

TIP!

*Read this e-book
alongside our more
practical guide on*

**'How to handle
liquid flows'**

Scalability and reliability are key in this journey. Successful scaling by increasing throughput is no longer self-evident. Instead, it is more about the replication of proven process performance reliability across different scales from day one. Scaling-out rather than scaling-up.

Low-flow technologies enable organizations to transfer laboratory knowledge into production environments with lower risk, faster validation and greater reproducibility. Bronkhorst High-Tech as a low liquid flow specialist is at the forefront in this field. The Bronkhorst Coriolis-based low liquid flow handling instruments (meters and controllers) play a central role in this scaling journey.

INTRODUCTION

The new reality of scaling

Many companies are looking for ways to provide added value. For example, dairy manufacturers used to produce regular milk and regular yogurt. Something you see more and more these days: all kinds of flavors and a higher protein content. Products are more customized, and individual batches are getting smaller.

Another trend is that there is a great deal of pressure, to shorten time-to-market. That's because the large-scale, efficient processes they normally focus on are now being handled in parts of the world that bring a product to the market at a lower price. And if you, want to compete with that, you must distinguish yourself. That often comes down to speed of market entry and innovation. So, you simply have to be the first to enter the market.

The time between a successful laboratory experiment and large-scale production is getting shorter and shorter. Traditionally, processes used to be redesigned for industrial upscaling (vertical scaling) by increasing the capacity of the relevant manufacturing machine. However, many organizations now opt for a parallel operation of several small production units. This scaling-out or horizontal scaling approach allows proven laboratory processes to be implemented more quickly, while limiting development risks and validation processes. Reliability therefore becomes a design requirement from the earliest development phase.

As a result, accurate flow measurement at low flow rates is no longer solely a laboratory issue but is becoming an essential prerequisite for commercial production.

Insights from the specialists

Compact low-flow instruments enable small scale processes.

Thanks to the existence of Bronkhorst's accurate low liquid flow instruments, as a customer you are able to realize processes on a small scale. Conducting experiments on a small scale allows you to keep the conditions well-controlled and to closely examine the results. After all, you have the instruments to do so. And if we, as Bronkhorst didn't offer them, then that option simply wouldn't be available.

PART ONE

Why are low flow processes reshaping modern manufacturing?

Low liquid flows play an increasingly important role. By supplying chemical additives, valuable raw materials and other process fluids in small amounts, companies can minimize their material consumption, limit product loss and reduce their environmental impact.

Just for the sake of completeness: low liquid flows are mass flows up to 1000 kilograms per hour (< 1000 kg/h). Very low flows are up to 100 grams per hour, and ultra-low flows are defined as 5 grams per hour and lower.

With **continuous manufacturing** in the pharmaceutical industry, there are no longer any large batches, so you don't need very high flow rates. Instead, smaller flow rates are combined to enable continuous production. To make continuous manufacturing parallelized, more flexibility is needed. With this type of 'parallel production', you can also easily make small changes to the recipe. It's much easier to personalize. And what's more: it can be made traceable, because you can track everything you dispense.

In the field of **semiconductors**, it is also becoming increasingly important to generate very accurate low liquid flows. In atomic layer deposition (ALD), liquid precursors that need to be vaporized are being used more and more. The quantities involved are very small - just a tiny puff of vaporized liquid - and this is where low liquid flow technology is of great benefit.

Low liquid flow handling is suitable for processes in which you want to be flexible, so with lots of variations. There is a trend in customization: **personalized** medicine, personalized perfumes or personalized water - today with an orange flavor, tomorrow with a banana flavor. That does not involve large quantities, and scaling-out is more relevant than scaling-up.

Handling these low liquid flows offers another advantage compared to large batches: less effort is required to rinse between batches to avoid cross contamination. You only need to flush a short section of pipe, rather than a huge tank and pumps. Less water is used, and it is **environmentally friendly**.

In many of these industries, small quantities of liquid are being used, while the demands for quality, reproducibility and efficiency continue to rise. Accurate measurement of these low liquid flows is particularly important when the liquid used is expensive, when the final product is of high value, or when a consistent process outcome is crucial. Consistent color, composition or efficacy of the final product begins with accurate control of every liquid flow in the process.

"The economic value of every microliter has increased dramatically"

- Ferdinand Luimes, Product Manager Liquid portfolio at Bronkhorst -

Insights from the specialists

The bottom of the barrel

Typically, oil companies operate with very high flow rates, well above the low-flow range. But what we are seeing more often is that oil companies are exploring the 'bottom of the barrel'. That is a very thick sludge with extremely high viscosity that can only be processed by heating it.

The new Bronkhorst CORI-FLOW flow meter family includes a model suitable for higher temperatures. Which means we can help make that research possible. Such exploration can therefore only be carried out if instruments are available that can handle low flow rates, are highly accurate, and can measure at high temperatures.



PART TWO

The scale-up myth: bigger does not always mean better

For many processes, the traditional 'economies of scale' still apply: the larger the scale, the cheaper the cost, and therefore the greater the returns. However, a trend emerging from the market is individualization: we no longer all want to be treated the same way. So, for example, we no longer all want to drink the same milk in the morning. Consequently, the need for large-scale batches is decreasing.

This trend is reflected in the production process, with the size of batches continuing to decrease in some sectors. If you want to scale there - either scale-up or scale-out - the key is to focus primarily on the smaller-scale operations, because that is where you can save a lot. If you measure flows accurately on that small scale, you can ultimately optimize your process much better with fewer chemical additives. This produces less waste. In case of scaling-up, you have better control over the process at higher throughput because you've thoroughly analyzed it already at a low level. Focus primarily on getting it right at the lab level.

The added value is that you can achieve better quality and charge a higher price for your products. If something goes wrong, your waste is reduced as there are fewer quality rejections, in absolute terms. You can also adjust more quickly on a small scale:

stop the process and resume once the issue has been rectified.

Accuracy makes it easier to scale. The more accurately you can carry out the process on a small scale, the better you'll be able to scale it up to a large-scale process later. This also makes it possible to tweak a recipe slightly if necessary. So, you can make small changes and quickly adapt by using different recipes.

'Faster' is linked to accuracy. If you have a very inaccurate flow meter in your process, you must run long tests to filter out the noise, so to speak. Whereas if you can measure very accurately, you have less noise and can test faster. You can then achieve better results in less time, and after that, you can indeed scale up faster. And what's very important to our customers: a shorter time-to-market. We offer the solutions to make that happen.

In a practical sense, modular skids are used for continuous manufacturing in pharma. Production occurs continuously, but in addition these skids can be re-used to manufacture another type of medicine. Thanks to its modular design, the setup can be adapted within a short period of time, which offers a further economic benefit.

Insights from the specialists

Bronkhorst as a laboratory brand

Something you see more and more these days: small businesses are popping up that take a small-scale approach. They start out in a lab where they are familiar with the 'lab brand' Bronkhorst. Next, they move on to the pilot plant stage, and that's when they ask: can Bronkhorst handle that, too?

Since we now have a slightly larger Coriolis-based flow meter in our portfolio - capable of handling up to 1000 kilograms per hour - we're able to capture more of that pilot plant phase. includes a model suitable for higher temperatures. Which means we can help make that research possible. Such exploration can therefore only be carried out if instruments are available that can handle low flow rates, are highly accurate, and can measure at high temperatures.



PART THREE

Understanding the physics of low-flow systems

Reliability becomes difficult at the very low liquid flow range, especially at $\mu\text{l}/\text{min}$ and ml/min flows. At these low flows, seemingly insignificant physical effects are decisive process variables. Some of them are discussed here:

Gas in your instrument often causes problems. For low liquid flow rates, you really mustn't have any gas bubbles. Even a single bubble can block the entire liquid flow. If there is gas present, our flow meter will simply detect it. As a customer, you might think our flow meter isn't working properly, but it is simply a physical phenomenon that the flow meter renders visible. For the user, this is a sign that action needs to be taken. What often helps is thorough flushing. The better you flush, the less gas you usually will have. Related to this, **dead volumes** are almost always detrimental. Try to avoid them.

Bubble formation often occurs during a pressure drop. Gas is dissolved in the liquid, and when the pressure drops, the gas is released. Typically, you suddenly see a string of air bubbles. When using certain pumps, you experience **pulsation effects** reflected in the flow meter

reading. Is that a problem for you or not? We can resolve this by, for example, fitting filters. Alternatively, use a different type of pump, or no pump at all.

Be aware of any **leaks** in your system. At high liquid flow rates, this results in dripping, which isn't a major issue. But at low flow rates it can make a significant difference.

The key message is: be aware that when you are working on a very small scale, 'normal minor details' become more important. Our Bronkhorst specialists can help you with this. You are not just buying a liquid flow meter - you also get specialist knowledge as part of the package. In our practical guide on 'How to handle low liquid flows' you will find more solutions to these physical effects.



PART FOUR

Microfluidics, dosing and precision process control

Low-flow technologies are strongly connected to modern process development. Microfluidic applications are rising fast. Technologies such as lab-on-a-chip and organ-on-a-chip use extremely small fluid flows to simulate or analyze complex biological, chemical and medical processes.

In such applications, even the slightest deviation in flow can have a direct impact on the reliability of research results or product quality. In those cases, there is a need of instruments capable of handling flow rates of around 100 grams per hour.

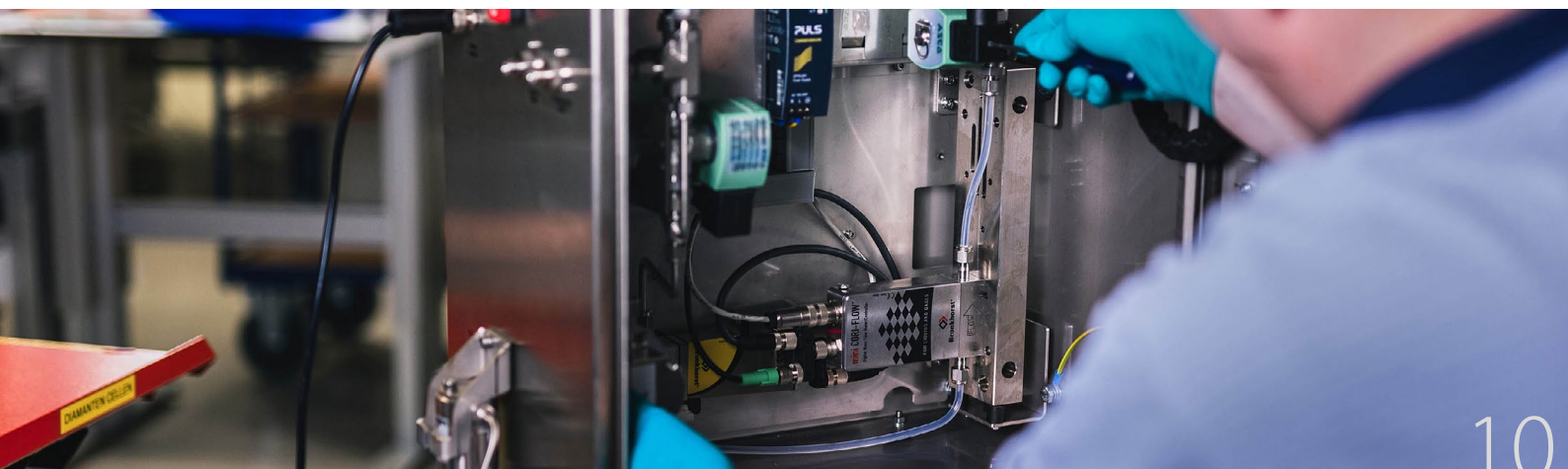
Microfluidic and low-flow platforms are increasingly becoming the preferred environment for rapid process development, as they deliver high-quality measurement data while minimizing material consumption.

Dosing with FLUIFILL®

A customer doesn't want one gram per hour; (s)he just wants one gram in a bottle. And that's where Bronkhorst's FLUIFILL® comes in. This is a batch dosing technology, meaning that you dose a specific amount within a specific time frame into a vessel - whether it's a bottle, a can, or a vial. You can use it in the pharmaceutical industry, for filling

of vials or vaccines into syringes. You can use it for flavorings in beer and soft drinks and bottled water. What makes FLUIFILL® unique? It's a fast and user-friendly technology. Just attach a pump to the instrument, run a self-test, and then it takes care of itself. Enter a quantity and a time, and the instrument handles the rest. After running an auto-setup, it recognizes what type of valve or pump is connected, and it can operate accordingly. In normal mode, FLUIFILL® operates in a range from half a second to ten hours. And fast batch dosing takes less than half a second, which is unique. We can even dose in as little as tens of milliseconds. And all of this with an accuracy of 0.2 percent for flow and 1 millisecond for time. FLUIFILL® makes the job very simple. The added value is that it saves customers a lot of programming time. And because of the small flow rates, you can also handle small dosages.

Is FLUIFILL® easy to scale up? Two grams in twenty seconds is pretty much the holy grail in the world of lemonades and water-based flavorings. If you want to dose more, you can scale up by putting multiple skids side by side - in other words, by operating in parallel.



PART FIVE

Reliability starts with system design

Ultimately, it's all about the reliability of the result - the measured mass flow rate. What the flow meter says must be correct.

To this end, you simply need a high-quality flow meter that is properly calibrated. However, you also need to have knowledge of the conditions around the flow meter, in order to do a proper measurement. If you connect a leaking hose, or a porous hose that slowly draws air into the system, or use the wrong fittings, this will affect the low liquid flow. The product is so much more than just the flow meter itself - it's the system.

If you want to know how good a flow meter is on its own, check its zero stability. Do not connect anything to the flow meter, and check whether it reads zero. Even under these conditions, a very small flow may be measured because of environmental influences or the instrument itself. Although this deviation is very small in absolute terms, it can still be relevant in low liquid flow applications. To correct any such deviation, the meter is subjected to a 'zeroing' process at zero flow.

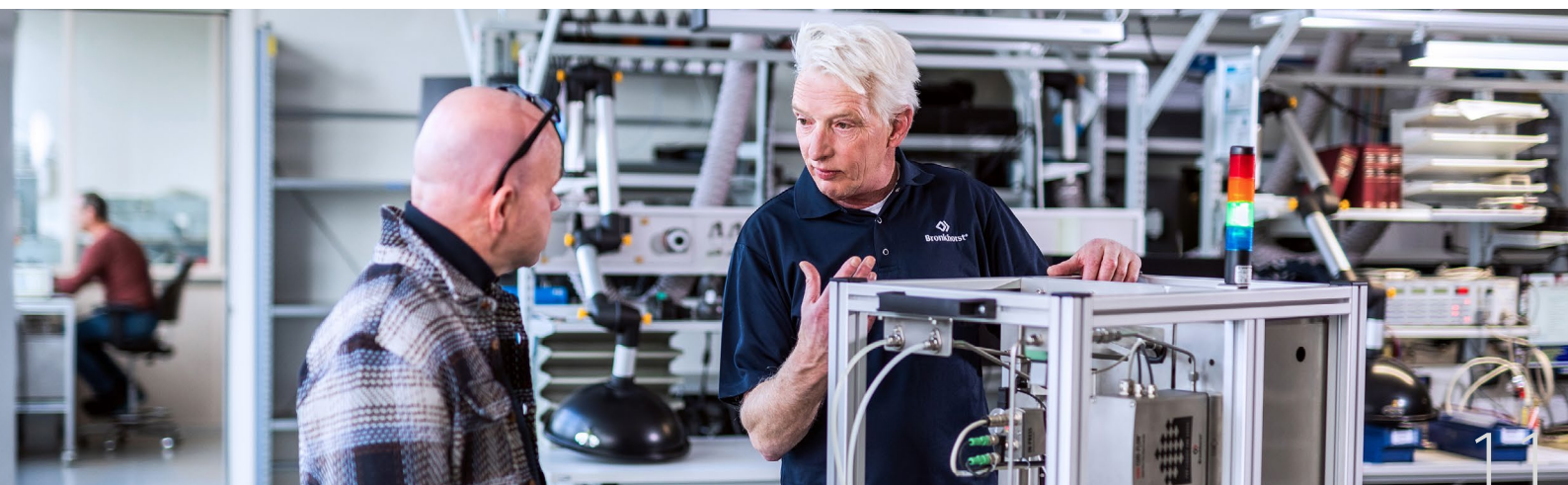
Essentially, you simply need a good flow meter, but there is more to it than that. At Bronkhorst, we believe - and this is confirmed by our customers - that we supply high-quality equipment that really does make a difference. The take-home message is here: reliability is not a property of a flow meter - it's an outcome of system design.

Insights from the specialists

Closed-loop control

At Bronkhorst, we also supply flow meters that feature a controller output. This means that our instruments can control a valve or pump, enabling you to set up a closed-loop control system. For example: dosing pumps depend on factors such as the inlet pressure in the system, the viscosity of the medium being dosed or the temperature. If you set the dosing pump to a specific value and connect a flow meter downstream of it, this flow meter will occasionally measure a flow rate value that differs from the setpoint on the dosing pump.

However, if you set up a closed-loop control system between the dosing pump and the flow meter, this flow meter will continuously correct the pump's output. Each Bronkhorst flow meter has an on-board circuit board with, for example, a 0–10 volt or 4–20 mA output. This can provide feedback to the pump. Pumps with an analogue input can process that signal. So, if the flow meter measures a flow rate that is too high, it outputs a lower voltage, thereby controlling the pump to deliver at a lower flow rate.





Insights from the specialists

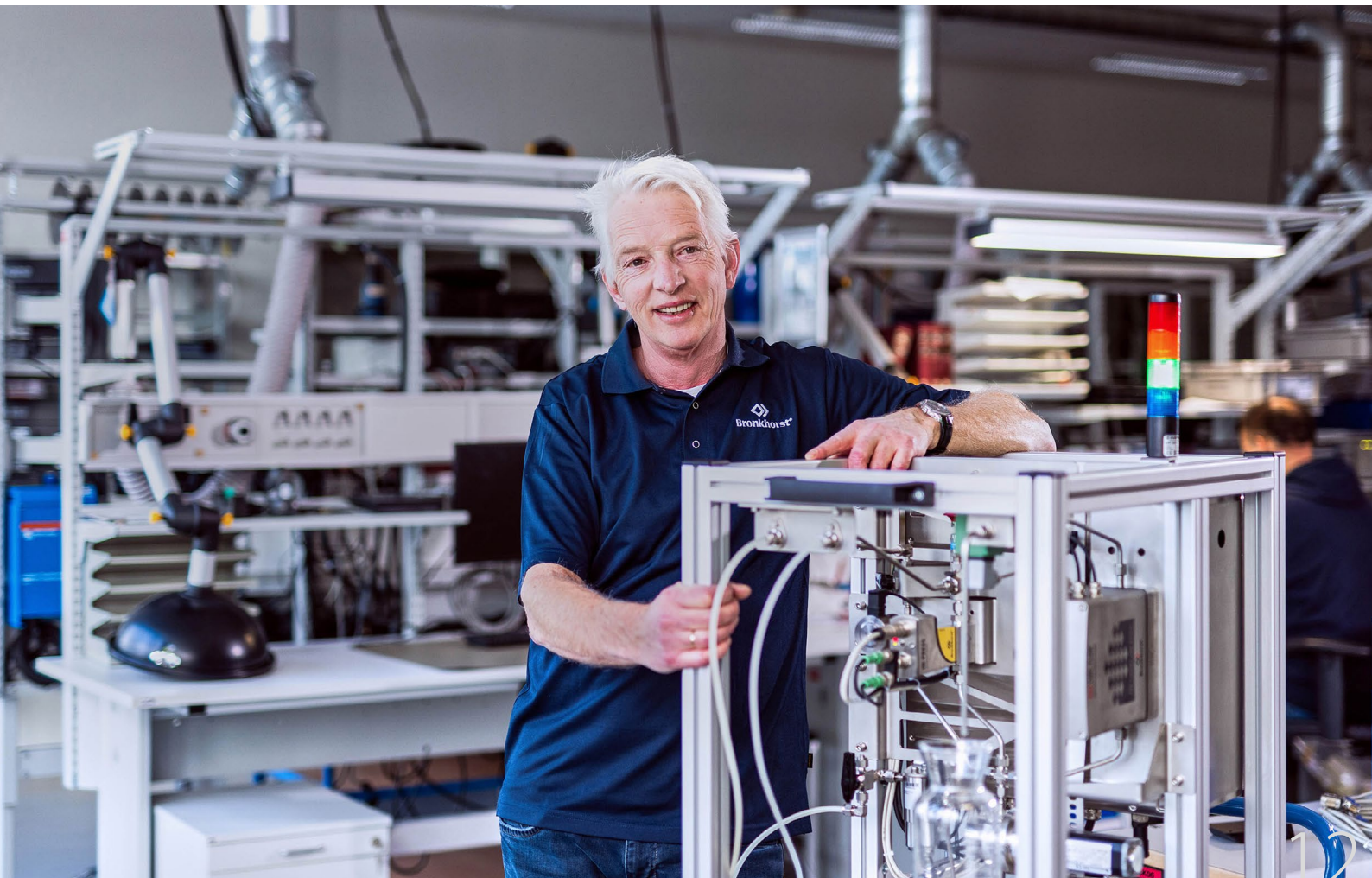
Reliability and quality control

With low liquid flow measurement, we at Bronkhorst provide some degree of reliability to our customers' processes. At a detailed level, we can monitor the quality of the process and determine whether its output is acceptable or not.

If a manufacturer has to discard an entire day's production because, based on a random sample, too much of a particular additive has been dispensed, there's a solution: add a flow meter to the existing machine to significantly reduce waste. It's a small quality control measure that can be implemented at a very basic level. You go from 'we don't know if it's good, and we have to discard the entire day's production' to 'we know which specific ones are defective, and we remove those.'

By using flow meters, you can be more certain about the quality of a batch, and you only need to discard the (few) defective products. Otherwise, you'd have to take a sample, and if that sample isn't good, you'd have to reject the entire batch.

The bottom line: you prevent waste, thereby saving a significant amount of money. In addition, you identify where things are going wrong in the process, and by addressing those issues, you improve the process output. You simply have better control over the process - at a very low level - which wasn't possible without low liquid flow measurement. And we make it transparent, too.



PART SIX

Choosing the right flow measurement technology

In this chapter, we outline technologies to be used for measuring low liquid flow rates. Along with their working principle, you can see that each technology represents a trade-off between accuracy, robustness, fluid compatibility, response time and operational complexity. Use this information to choose the flow measurement technology that fits your requirements best.

Principle of low liquid flow measurement technologies

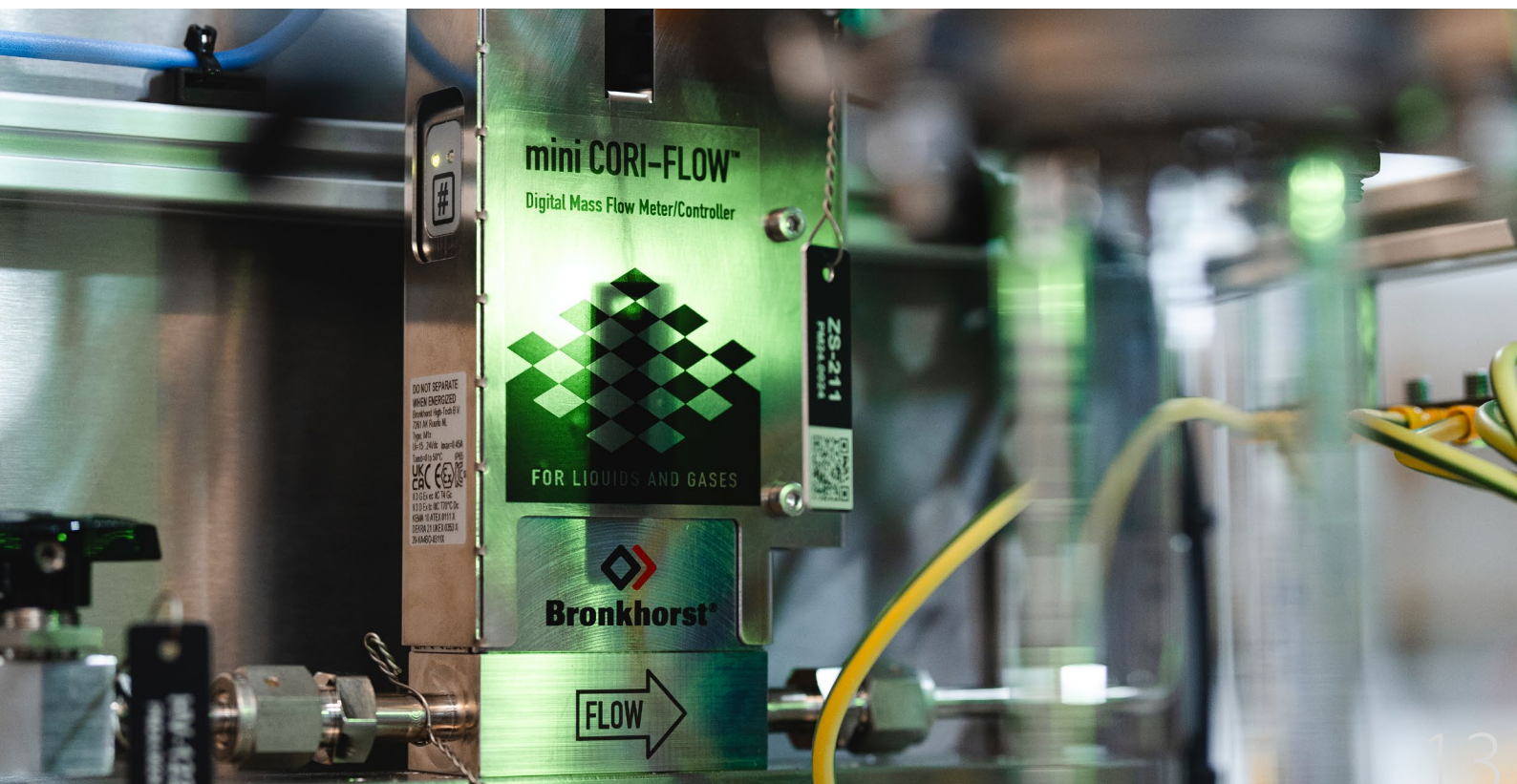
Thermal flow - The mass flow rate relates to the heat transfer between heated sensor and fluid, relying on the fluid's density and specific heat capacity. Calibration for a specific fluid is needed.

Positive displacement - The volume flow rate relates to (a gear's) rotational speed and fixed displacement volume per revolution. Mechanical type of measurement.

Ultrasonic - The volume flow rate relates to the transit time differences of ultrasound waves propagation through the fluid.

Electromagnetic - The volume flow rate relates to the voltage that is induced when a conducting fluid flows through a magnetic field. Is indeed limited to electrically conducting fluids.

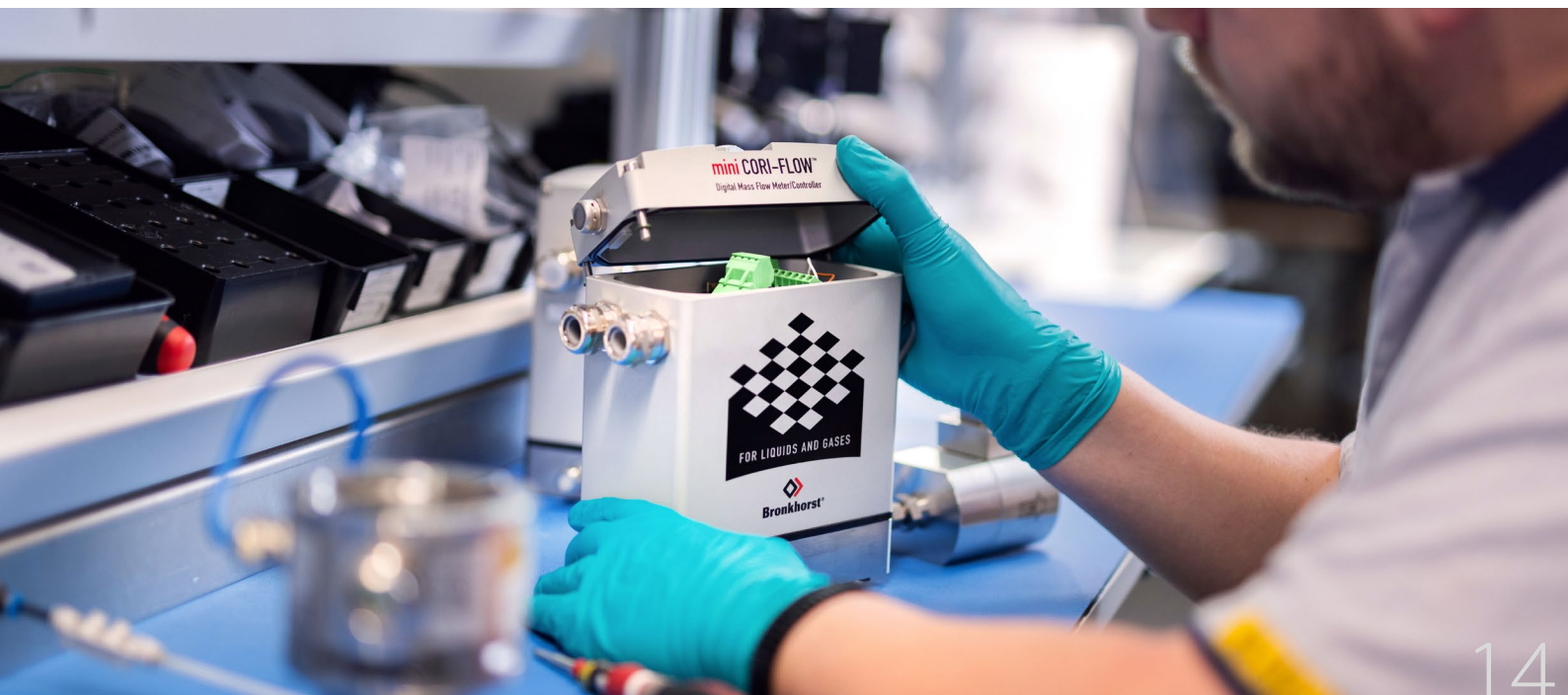
Coriolis - The mass flow rate relates to the phase shift of the measuring tubes' vibration caused by an inertial force acting on the flowing mass.





ASSESSMENT OF RELEVANT TECHNOLOGIES PROPERTIES

	Accuracy	Robustness	Fluid compatibility	Response time	Operational Complexity
Thermal flow	Average	High: temperature sensitive	Calibration for specific fluid needed	Average	Easy
Positive Displacement	Average	Prone to wear in course of time	Fluid independent	Pulse-based readout	Easy after installed filter and good process control
Ultrasonic	High	Very high	Fluid independent	Very fast	Very easy
Electro magnetic	Very high	Very high	Limited to conducting fluids	Fast	Precautions such as insulating flange
Coriolis	Excellent	High; vibration sensitive	Excellent	Fast	Easy; mount firmly



PART SEVEN

Why Coriolis technology changed the game

As the table in the previous chapter shows, Coriolis stands out when it comes to measuring low liquid flow rates. As such, it is a game changer, with excellent measurement accuracy and fluid independence. Let's dive deeper into the technology behind Coriolis.

The Coriolis effect explains the deflection of fluid flowing in a rotating or vibrating system. Gaspard-Gustave de Coriolis discovered the effect that flowing air experiences a lateral force due to earth rotation, which was named after this French scientist.

This effect is put to practical use in low liquid flow measurement. To this end, the to-be-measured fluid is forced to flow through a vibrating tube. This works as follows. In the Coriolis flow meter, an actuator causes a small, curved metal tube to vibrate continuously at its natural frequency. Two sensors positioned along the tube measure the deflection of this vibrating tube in time. When no liquid flows through the tube, both sensors measure the same deflection at the same time. However, when a liquid flows through the tube, the mass of this liquid exerts an additional twisting force on the tube due to the fluid's inertia. Now, each sensor measures a different deflection in time. The difference between the two, known as the 'phase shift', is a direct measure of the **mass flow** through the tube. This phase shift is proportional to the mass flow rate: a larger phase shift results from a higher mass flow rate.

Since the Coriolis principle measures mass flow independent of what is inside the tube, it can be directly used for any fluid flowing through it - liquid, gas or vapor. This demonstrates the technology's **fluid independence**. This is useful when dealing with unknown fluid mixtures, i.e. mixtures whose composition is unknown. 'Coriolis' is suitable for measuring the flow rate of

supercritical CO₂, which can exist in both liquid and gaseous phases.

These instruments are also able to measure fluid **density**. Where phase shift is a measure for mass flow rate, the vibration frequency is a measure for fluid density. The density of a fluid affects the vibration frequency of the tube: a denser fluid vibrates with a lower frequency than a less dense fluid. So this vibration frequency is a direct measure of the density of the fluid. Mass flow rate and density are measured independently of each other using the same device, illustrating the versatility of Coriolis flow meters

By additionally measuring the temperature of the fluid by a separate sensor, Coriolis-based instruments are able to supply **multi-parameter data** – mass flow rate, density and temperature.

These instruments typically have long sensor tubes, resulting in a relatively high pressure drop across the instrument. This can be considered as a disadvantage.

Coriolis flow meters are available with a single measuring tube and with two parallel tubes. With a single measuring tube, you measure the phase shift relative to the rigid flow meter base, and with a double-tube design relative to each other. As the Coriolis measuring principle is based on vibrations, you must isolate Coriolis flow meters as much as possible from ambient vibrations. The advantage of a double-tube meter is that this instrument is less sensitive to ambient vibrations. With a single measuring tube, this problem is more pronounced. So, you need to take additional measures, for example by attaching a mass block to the instrument, or by mounting dampers or springs to the flow meter.

BRONKHORST CORI-FLOW™

CORIOLIS TECHNOLOGY

*In the newest generation **Bronkhorst CORI-FLOW** series, the sensor and the control electronics are in separated enclosures. This way, any heat generated in the electronics has less influence on the sensor. The density measurement has improved, and a 0.2% of reading is obtained. Each in-house manufactured Coriolis sensor tube has from beginning to end of the instrument one continuous fluidic flow path, eliminating dead zones and obstructions. This reduces*

the risk of clogging, bacteria and air bubbles - ideal for pharma. The modular system allows Bronkhorst to respond more quickly to customer-specific requests. With the CORI-FLOW MN series, Bronkhorst is expanding its presence at the higher end of the low-flow range. Officially up to 1,000 kg/hour, but we can measure up to 2,000 kg/hour. So, if customers want to scale up, we can take it one step further.



PART EIGHT

Designing for reproducibility

Designing for reproducibility is about practice. You may well have a highly accurate flow meter and have set up your system as good as possible, but you still want consistent measurement results. That requires due attention, and here are a few practical tips:

- Avoid focusing on **sensor accuracy only**. That means: don't ignore all other factors. If you buy a flow meter with excellent accuracy but pay absolutely no attention to the system design, be sure that you won't achieve that flow accuracy.
- Avoid **dead spaces**. If there are dead spaces, there may occasionally be an air bubble present, and sometimes there won't be. This will affect the flow measurement, and that's not what you want. For example, ensure there is no sudden transition from a very large diameter to a small diameter of tubing. So not directly from DN100 to DN10, but a gradual transition.
- Make sure you have selected the correct **pump**. Pumps with pistons or gears have different effects on the flow meter. If you have a pump where you can see every stroke reflected on the flow meter - and you don't want that - then you need to choose a different pump measurement principle.

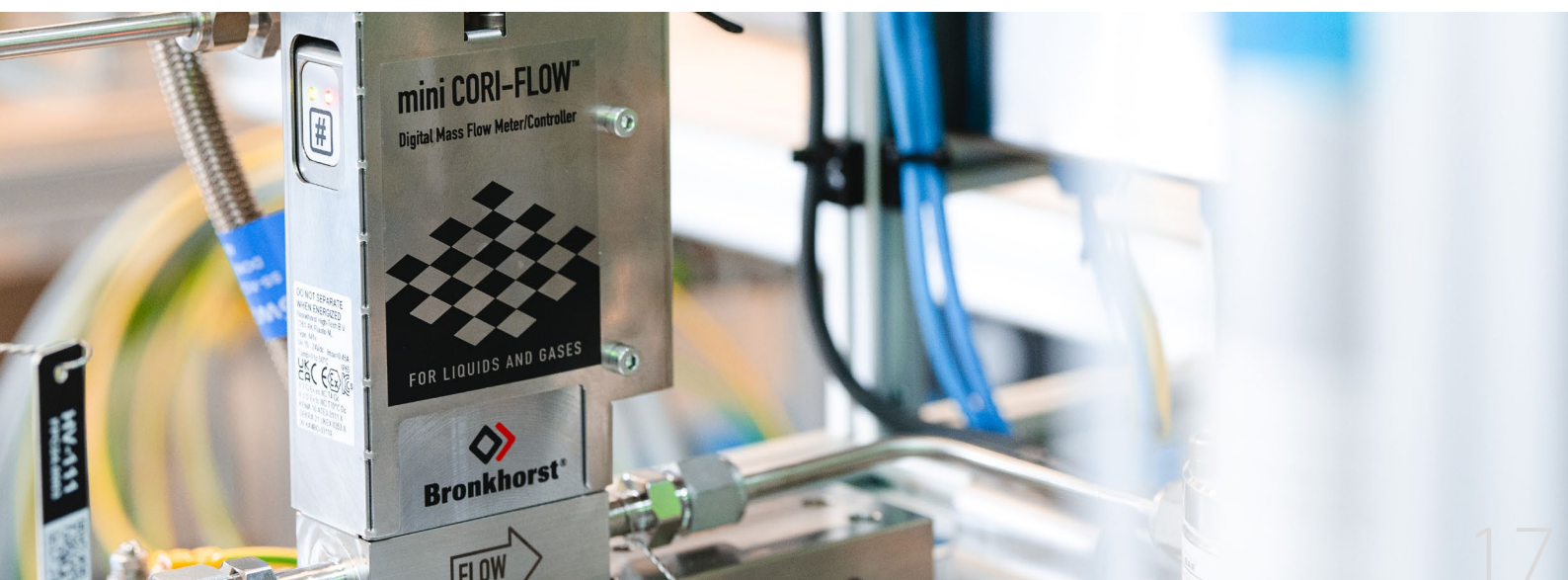
- Ensure good air management. If you know that your process involves **air or dissolved gases** in your liquid, you should not install the flow meter at the top of the system, but at a lower point.

- When calibrating or **zeroing**: ensure there is absolutely no flow, so close the valves on both sides of the flow meter.

The key message is: "reproducibility is engineered, not measured"

Insights from the specialists Bronkhorst: products, service and support

Bronkhorst supplies worldwide products as well as local service and support, enabling the accurate instruments to perform better in the real world. This is what sets us apart from other suppliers. We think along with you as our customer. You are specialist in your application, and we are measurement and control specialists.



PART NINE

Building a scaling strategy from day one

Keep in mind right from the start that you want to move from a low flow rate to 'the' ultimate desired flow rate, however high that may be. Take the whole process design into account to get there, from day one. Do you need to scale-up or scale-out? Why would you need such a large factory? It could just as easily be done on a smaller scale.

Look at the big picture. Make sure that you're using the right expertise and the right flow meters for what you want to achieve. In this respect, bear the following points in mind:

Design for transferability - When you scale up from small to large, make sure that you've given it careful thought.

Maintain process knowledge - As you scale up, ensure you know what you're doing. So, if you only have knowledge of large-scale processes, you are less likely to take degassing into account, for example.

Validation considerations - How can you be sure that you are validating something properly if you lack the necessary knowledge? So, if needed, bring that expertise in-house. As Bronkhorst we can provide this service.

Batch and continuous manufacturing - If you switch to continuous manufacturing, smaller flow meters will suffice. For batch production, you will need to choose larger flow meters. Make sure you have given this careful consideration.

Create digital process twins - For modelling the actual process, be sure to do this properly and with the right tools. We can advise for low flows.

The key message is: "if you get it right at lab level, you will face fewer risks at a higher capacity level.

The decisions made during laboratory development determine much of the risk encountered during commercialization."



PART TEN

Real-world applications

Here are some relevant practical applications in which Bronkhorst has been involved.

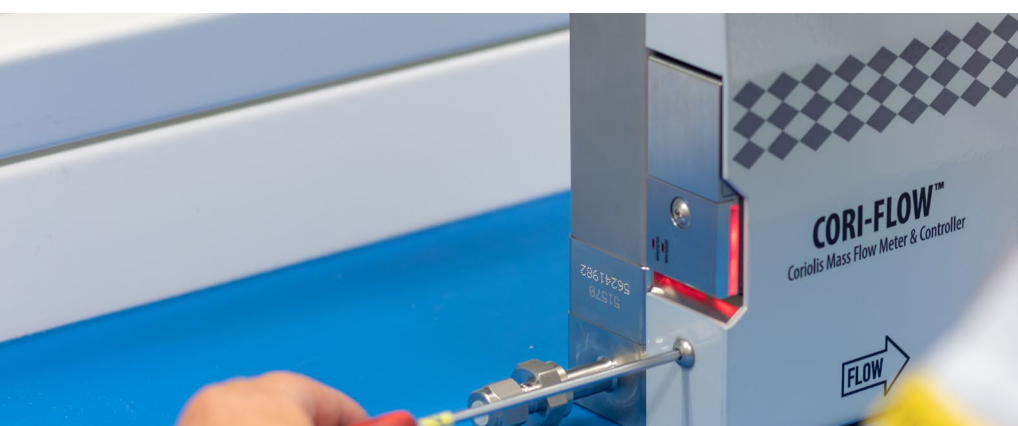
Continuous manufacturing for pharmaceuticals

- **Use case:** Liquid additive dosing.
- **Challenge:** All flow rates must be synchronized. This means you really need to keep a close eye on whether the process is running smoothly at certain points; otherwise, you will have to make constant adjustments.
- **Reliability requirement:** Measurement accuracy, response speed and low flow rates are important. The slower you react, the more you waste and the greater the production loss will be.
- **Low-flow solution:** A compact skid has been built incorporating Coriolis flowmeters, a pressure sensor, a pump and several filters. If a filter becomes blocked, you can quickly switch to another one so that the process continues. The pressure sensor controls the pump to ensure better flow control.
- **Scale-up benefits:** The skids are modular in design and can easily be extended with additional skids. This means they can simply build a second line alongside the existing one. Should the need arise, this can be done very quickly.

[Read more about this application](#)

Additive injection

- **Use case:** Odorization of natural gas/biogas.
- **Challenge:** Accurately dosing the correct quantity within a specified time. This involves adding THT odorant to give natural gas its characteristic smell.
- **Reliability requirement:** Speed and accuracy are crucial. In the gas industry, this typically involves the main flow line, where 18 milligrams of odorant must be dosed per cubic meter of gas. If too little odorant is added to the gas, it will not acquire a sufficiently strong warning smell.
- **Low-flow solution:** A skid featuring a mini CORI-FLOW M12 Coriolis-based flow meter and an HNP pump. The customer incorporated this into their setup, using a fixed bypass to achieve a lower flow range. An interesting aspect regarding reliability is that the Coriolis flow meter's density measurement function was used to verify that the correct fluid was being dosed.
- **Scale-up benefits:** For small-scale injection points, the mini CORI-FLOW M12 worked perfectly. For larger injection points, a smooth transition to the mini CORI-FLOW M13 Coriolis-based flow meter is possible. It is easy to scale up by using slightly larger flow meters. The pump can still cope. Since we can demonstrate that our flow meters are electronically identical, the customer can make this changeover quickly. This means there is no need to repeat a time-consuming validation process.



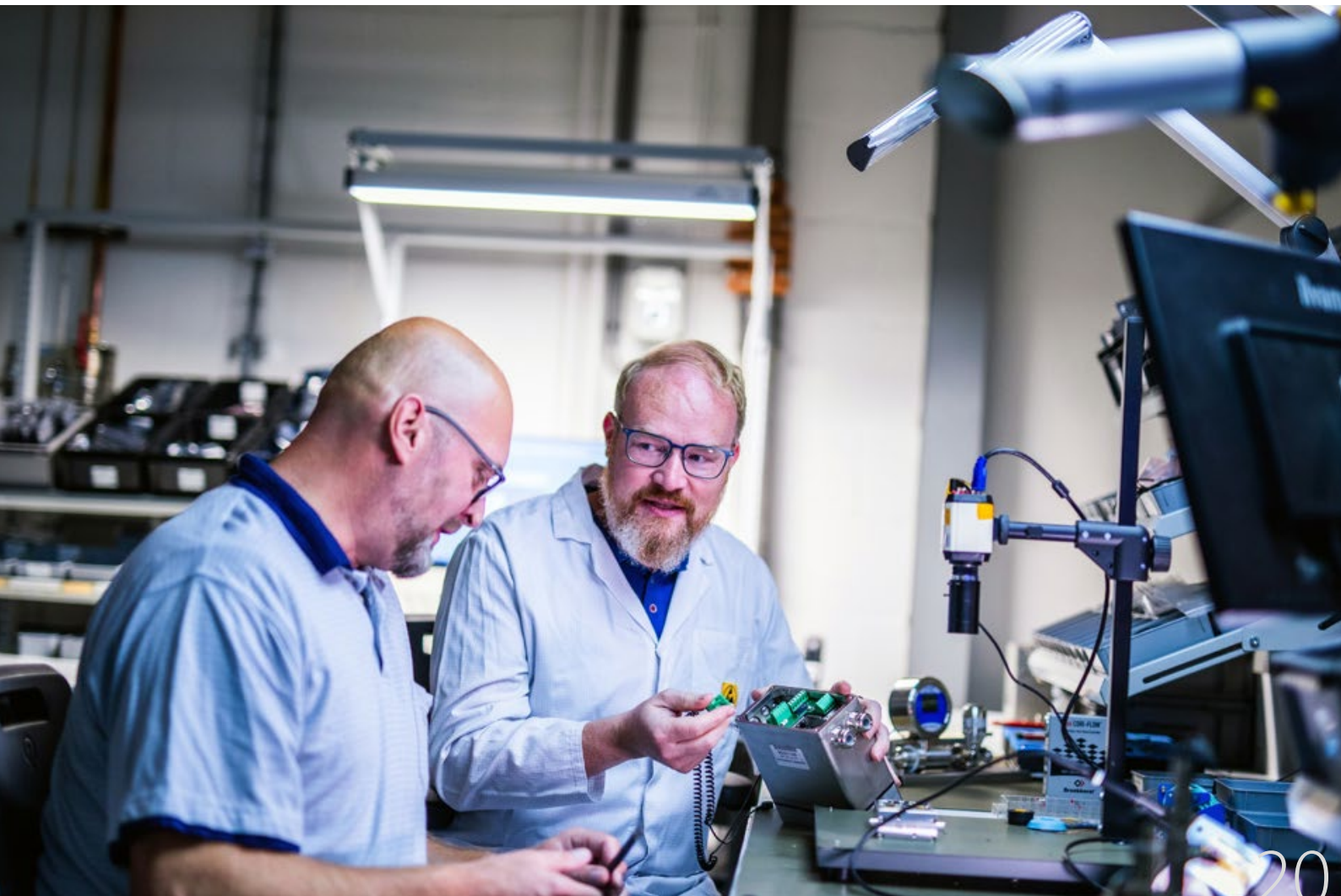
Insights from the specialists

Scaling-out example in pharmaceuticals

During the COVID-19 pandemic, there was immense pressure to develop a vaccine very quickly. The manufacturer didn't have time to scale up, a process that normally takes 5 to 10 years. So they took the setup out of the lab, installed 100 of these setups in a large factory hall, and ran them all in parallel. It was essentially a laboratory setup that was scaled-out, all using low-flow technology. And in a very short time: they were able to skip the step from pilot plant to

production in one go, simply taking a lab instrument and using it for production. All these parallel instruments operated with the same parameters to achieve the desired production output.

[Read more about this application](#)



PART ELEVEN

The future of reliable process design

Data and artificial intelligence (AI) have a major role to play in the future of reliable process design. To further optimize production processes, more and better measurement data is required. Each addition to a process must be closely monitored in order to gain an understanding of the relationship between process parameters and product quality. As a result, the role of flow measurement will shift from passive monitoring to active process control.

This goes along with another trend: the need for traceability. Legislation specifies that companies must provide increasingly clear and verifiable information about which compounds - and in what quantities - are present in products. Processes must be better controlled.

Continuous diagnostics, remote monitoring and predictive maintenance are becoming increasingly important in industrial processes. Modern flow meters will evolve from simple measuring devices into intelligent sensors that provide a flow reading and also provide insight into the condition of the process and of the sensor itself. This will help operators to identify problems at an early stage and prevent unplanned downtime.

The future of low-flow liquid measurement is about achieving higher measurement accuracy. However, the greatest progress will come from smarter, better-integrated measurement systems that provide data for automated process optimization. This way, also incorporating AI, flow meters will evolve from simple measuring instruments into self-diagnostic process components that actively contribute to quality, efficiency and sustainability. As a result, the reliable measurement of low liquid flows will become a fundamental building block for the manufacturing processes of the future.

In the end, future low-flow systems will still measure and control processes accurately. But in addition, they will actively help optimize and protect these processes.



CONCLUSION

Reliability across the scaling journey

Please find the summary of this e-book in five takeaways.

1. Reliability begins during process development

Reliability naturally applies to the flow meter itself, but also to everything surrounding it. And that is precisely where our specialists and advisers come in to help.

2. Scale-up is increasingly becoming scale-out

Think very carefully about your approach to scaling. Don't just follow the usual path that everyone always takes, from lab to pilot plant to large-scale production. Choose your own strategy: whether you want to do it in parallel (scale-out) or whether you really want to move to larger instruments (scale-up).

3. Low-flow applications require a deep understanding of process physics

If you are working with low flows, bear in mind that there are different factors at play compared to when you are working with high flows. And we know what those are, so please don't hesitate to ask us for help.

4. System design is more important than individual components

Of course, the components must be of high quality. But just because you have a good flow meter doesn't mean that you are measuring the flow correctly. There is actually much more to it. You simply need to look at the entire process, the whole installation, the skid.

5. The right flow technology reduces risk and accelerates commercialization

If you apply the right measurement technique - namely the Coriolis method - correctly, you will have the best data to make sound decisions. And that makes it much easier to scale-up or scale-out afterwards.

Thank you for reading

If you need any advice
feel free to contact us



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