ANALYTICAL INSTRUMENTS

Innovative TOC Fluidics Design Eliminates Unnoticed Downtime and Damage to Equipment

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Executive Summary

Accurate and precise determination of a continuous online Total Organic Carbon (TOC) measurement requires strict control of the measuring environment. The AMI-II LineTOC from Swan Analytical has a well-engineered fluidics design and additional components that will be discussed in depth on how control over the environment is achieved. The design of the analyzer flow path maintains a constant flow through the measurement system by pulling the sample through the measurement process at a constant rate utilizing a peristaltic pump. A sample inlet manifold allows for an aliquot to be pulled from the sample stream allowing the instrument to maintain the internal flow rate independently of the flow rate and pressure at the sample inlet.[1] The AMI-II LineTOC now includes a heat-resistant Hall sensor to quickly alert operators of process changes and loss of flow at the sample inlet manifold. The instrument utilizes a heat exchanger to strictly control the temperature of both conductivity cells within ±0.2°C temperature difference between each cell, minimizing temperature compensation between the two cells required for TOC determination. A thermal flow sensor after UV oxidation provides insight into the relative flow rate within the UV reaction chamber. With the addition of flow condition monitoring and protection features, the AMI-II LineTOC is better positioned to provide customers with accurate and precise online TOC determination through differential conductivity determination.

Table of Contents

1. Fluidics Design Principle

Peristaltic pumps are a well-established method for Flow Injection Analysis (FIA) systems where rapid and automated analyses are conducted.[1] Peristaltic pumps are widely used to deliver sterile or highly reactive fluids without exposing those fluids to contamination from exposed pump components.[2] Water for Injection (WFI), Pharmaceutical Water (PW), and Ultra-Pure Water (UPW) are all highly reactive fluids due to their high purity and will readily react with the atmosphere.[3] The Swan AMI-II LineTOC uses peristaltic pumps after the TOC determination has been calculated, further reducing the risk of contamination of the analysis stream.[Fig. 1. B] If the customer is operating a distillation water loop, which typically are designed to provide process water from 70-80°C, Swan has a sample cooler and a pressure reducing valve to allow samples to be taken up to 95°C and 5 psi, respectively.[Fig. 1. C and N] The Swan sample cooler is efficient and air cooled, which is accomplished by only cooling the 5 ml/min aliquot that is pulled from the sample stream (10 ml/min for UPW applications).[Fig. 1. C]

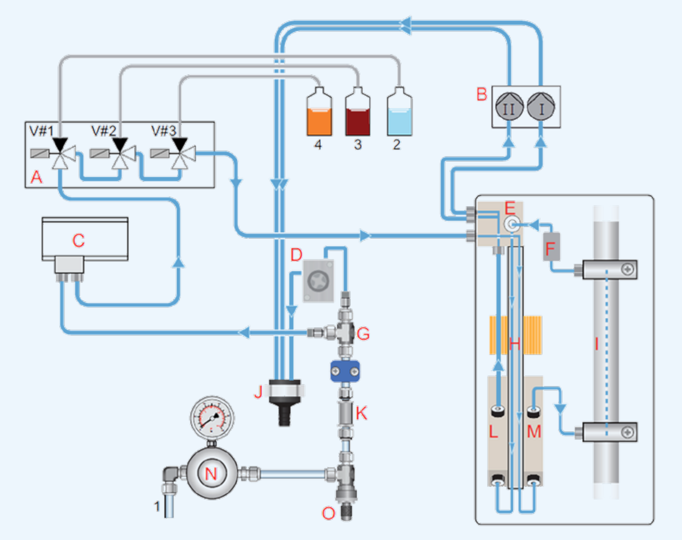

Figure 1: The robust fluidics design of the Swan AMI-II LineTOC.

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Sensor	Event	Response	Benefit
• Heat-resistant Hall sensor	• No external sample flow • Restored sample flow	• Shut-off of the UV reactor and pump • Normal operation of UV reactor and pump resumes automatically	• Dynamic response to process changes and protection of key components • Automatic recovery of normal operation without operator intervention
• Thermal flow sensor	• No internal sample flow • Reactor tube leak or air-locked sample	• Alert to operator	• Safety redundancy, slower response than Hall sensor • Directs operator to assess UV reactor tubing

Table 1: Whatever the root cause might be, Swan AMI-II LineTOC will detect and alert in case of low sample flow.

The Swan AMI-II LineTOC peristaltic pump rotates at predefined Revolutions Per Minute (RPM), allowing the pump to pull the sample through the measurement process at a consistent rate. This design implementation allows for accurate TOC determination by maintaining stable flow through the measuring conductivity cells and the UV reactor to allow for adequate contact time with the sample to ensure sufficient UV oxidation of any organic compounds present in the sample stream. The Swan AMI-II LineTOC also utilizes a heat exchanger to control the pre and post-oxidation temperatures of the sample to minimize bias introduced from conductivity temperature compensation calculations, as conductivity is temperature dependent.[4] Therefore, the instrument must be designed to provide consistent flow. Precise tube lengths and design construction are critical for the pump tubes and housing to deliver consistent flow, which is why all Swan pump tubes and housings are hand assembled and tested at Swan's headquarters in Switzerland. Swan has also added additional features to monitor the flow conditions of the process water supplied to quickly adapt to process changes and a thermal flow sensor after UV oxidation to ensure the UV reactor has sample flow.

2. Fluidics Monitoring

The latest feature added to the Swan AMI-II LineTOC is the addition of a Hall sensor after the sample inlet manifold. This integration allows the analyzer to respond dynamically to process changes and loss of flow at the point of measurement. If a loss of flow is detected, the instrument will institute protocols to protect instrument components, as well as alert operators to the process change if the alarm relay is utilized.[Tab. 1] This alarm is self-resolving and when flow is restored the analyzer will automatically resume normal running operation. The Hall sensor is also made from thermally resistant material and sensor integrity is guaranteed up to sample temperatures of 95°C, making this sensor suitable for most applications.

The AMI-II LineTOC also includes a thermal flow sensor, which is located after the UV reactor. The thermal flow sensor measures a temperature differential after the sample UV oxidation point. Due to the loss of thermal energy as a fluid is moving through a tube, measuring the temperature difference between the two points provides insight into the relative flow rate.[5] If these differentials align this indicates that flow is being lost after the UV reactor and the analyzer will generate a distinct alarm. This alerts operators to the loss of flow after the oxidation point and directs them to assess the analyzer reaction chamber, saving valuable diagnostic time.

3. Conclusion

The AMI-II LineTOC is equipped with a precision fluidics desgin, ensuring accurate and reliable TOC determinations. This is achieved by maintaining a highly controlled and stable internal system, considering the precise flow required to ensure for stable conductivity measurements, adequate UV oxidation contact time, and sufficient flow through the heat exchanger to homogenize the temperature between both conductivity cells. The addition of the heat-resistant Hall sensor enhances the instrument's ability to respond to change in flow dynamics, while simultaneously safeguarding vital system components. The thermal flow sensor measures relative flow rate after UV oxidation and if there is a loss of flow, it triggers an alarm, prompting the operator to check the UV chamber. Although these sensors serve two different functions, they are designed to be redundant, safeguarding the system and alerting operators promptly in the event of loss of flow at the sample point or within the reaction chamber. These considerations were crucial in the design and engineering of the AMI-II LineTOC fluidics to offer our customers a stable and accurate continuous online TOC analyzer.

References

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