TOWARDS SMART WATER ANALYSIS

The road to predictive preventative maintenance in online TOC monitoring

Introduction

Since last year, "new normal" is a buzzword re. digitalization in working environments. It covers not only industrial processes, but also new communication channels and digital access to information from virtually anywhere, often facilitating increased productivity while saving costs. Complex knowledge and the experience of experts are accessible from the comfort of the own home. In process automation, this trend has been gaining ground for years, a development that is gradually finding its way into process analytics as well.

Process analyzer technology

Today, many industrial processes are at least partially, if not fully, automated. There is little need remaining for human intervention in defined and unchanging environments. However, especially in processes where large quantities of water are treated, used, or transported, monitoring of analytical parameters is typically conducted.

While relatively simple sensors are used to determine physical parameters such as pressure, temperature and flow rate, the group of comparatively complex "process analyzers" is utilized for analytical measurement tasks. Examples are gas chromatographs, photometers, or probes. Such analyzers require some human interaction, mostly in form of maintenance, in order to ensure undisturbed operation and valid measurement results.

The increased effort and required knowledge are outweighed by the high benefit of process analyzer technology (PAT), for it is classically used to determine the concentrations and compositions of substances. This in turn allows monitoring of both intentional and unintentional changes in substances and the flow of materials, making it an essential tool to continuously uphold process integrity – for the protection of equipment and the environment.

Many of the substances monitored in this way are organic compounds which occur both as natural ingredients as well as contaminants in water. For a thorough monitoring, careful analysis is necessary. This requires parameters that can be analyzed quickly, reliably, and can be automated to cover as many substances as possible.

While the determination of individual organic components is generally possible using various techniques, it simply would take too much time to provide a quick response to critical process changes. And although laboratory analysis can also deliver extremely accurate and even more flexible measurement results, sample transport, evaluation, and reporting increase time expenditure. In many cases, only the sum of all organics is the parameter of interest for the process – and only when measured online.

Total Organic Carbon

One of the most meaningful parameters is TOC (Total Organic Carbon), which measures the sum of all organic carbon-containing molecules. The known quantity of distinct organic compounds is estimated to be about 40 million. This means that the largest group of chemical substances is captured in a single measured value.

Originally, TOC is a parameter determined by laboratories. However, since it is relatively easy to automate and provides results within minutes, it is also being determined "on-line" with the help of TOC process analyzers.

Shimadzu's TOC-4200 is an example for a TOC analyzer specializing in online monitoring. Equipped with an automatic sampling station, it can automatically withdraw process water for analysis. It is important to adjust the sampling method to the respective water quality – e.g., if it contains particles, it has to be treated differently than saline, particle-free water.

Shimadzu offers various sampling modules allowing adaptation to various types of samples. Often, a single analyzer needs to monitor several measuring points at the same time. For that purpose, up to six different sample streams can be connected and measured by a single analyzer – automatically or on demand.

Important for TOC determination is the differentiation between organic and inorganic carbon. After all, carbonates and bicarbonates can be found in every natural water. The most used method for TOC determination is therefore the so-called NPOC (Non-Purgeable Organic Carbon) method. Utilizing its automated integrated sample pretreatment unit (ISP-Module), TOC-4200 acidifies the sample to convert the carbonates and bicarbonates contained to CO2. Subsequently, the resulting carbon dioxide is expelled by gas purging.

Once the inorganic carbon is removed, an aliquot is injected automatically onto a 680 °C platinum catalyst where all existing organic compounds are oxidized to carbon dioxide. Water vapor is condensed, and combustion products that may be harmful to analyzer components, are removed from the gas flow by means of halogen scrubbers and filters. CO2 resulting from the combustion of organics is transported by a carrier gas flow to a highly sensitive CO2-selective NDIR detector and subsequently quantified.

Based on an external calibration, the TOC concentration is then calculated. Meanwhile, the flow line is rinsed with clean water in order to prevent carry-over between individual analyses. Once rinsed, the next sample is already taken and prepared. Depending on the parameterization of the analyzer, a TOC value can be determined every three to four minutes. Utilizing an automatic dilution function, the measurement range can be extended in relation to the external calibration. This not only increases the wide measuring range, if necessary it can even be dynamically, but also enables the creation of calibrations from higher concentrated, longer shelf life standard solutions.

Maintenance requirements to online-TOC analyzers

TOC process analyzers could be roughly summarized as CO2 gas analyzers with automated liquid handling and oxidation module. They must be able to largely operate autonomously and unattended. Maintenance requirements should be as low as possible and service life as long as possible.

However, with all that in mind and even with constant improvement and advances in technology, every online-TOC analyzer ultimately requires maintenance. Filters for gas treatment and scrubbers for the protection of the detector have a maximum service life. The gas flow line has to be kept leak tight, combustion tubes for oxidation need to be cleaned or exchanged and chemicals require refills. In case of highly polluted samples, it is advised to clean the sampling line every now and then.

Ultimately, the nature of the sample, especially its matrix, can have a corresponding influence on how maintenance-intensively a device performs. Best practice is executing required actions on time; a distinction can be made here between "run-to-failure" and "preventative maintenance" – the latter is expressly recommended.

In case of processes that run in a very regular and defined manner, it is usually easy to set up maintenance schedules that, if followed, will result in little unscheduled maintenance. However, this is not always possible, as the composition of samples can change quickly and, in the worst case, unexpectedly due to accidents, environmental influences or simply the seasons. This can lead to the need for unplanned maintenance.

Unfortunately, such actions are often much more cost-intensive than planned activities, may require a higher level of experience and on-site support. Hence, one important goal in process analyzer technology is to identify a need for maintenance before it is required.

Remote diagnosis possibilities

In failure situations where trained personnel is not present on site, appropriate data transmission and diagnostic capabilities are crucial. Conventional data transfer in process analytics is realized for example, using the 4-20mA interface for the output of measured values, in combination with digital contacts for signaling errors and warnings. However, the information provided either does not allow any further conclusions to be drawn about the validity of the transmitted result, or signals error messages only as collective alarm.

Somewhat more efficient is the connection of analyzers via fieldbus systems. This enables both measured values and metadata to be read out in plain text. In addition, error messages can be specifically assigned so that the service personnel can prepare for the action accordingly.

Modern systems, such as the TOC-4200, can be connected to the company network allowing relevant information to be viewed via the web browser. With the appropriate IT infrastructure, this can also be done on the office PC, smartphone or even from the home office.

Next generation maintenance

In order to facilitate predictive preventative maintenance, more than just measurement results and alarms are required. Trained staff can identify problems before they arise, especially on site. Technicians analyze the sum of information provided by the direct assessment of a device and inspect, assess, initiate appropriate measures based on their trained expertise and experience.

To enable such diagnoses and interventions remotely, analyzers need to output additional information – nowadays often referred to as "vital data". It is recorded internally by the instruments and may trigger an alarm when pre-programmed thresholds are reached, which then signals disturbed measurement operation and declares the measurement result as invalid by alarm output. The trick is to extract this data in a way that identifies long-term trends indicative of a possible problem occurring in the near future.

Towards smart water analysis

The availability of continuous diagnostic data, such as baseline signal, pressures, temperatures or mechanical parameters, is the foundation for a next generation digitalization of maintenance and diagnostics in process analytics. The requirement itself is not new at all – but what did not existed until now was a manufacturer-independent interface. Only with standardization will the implementation effort of this type of data connection be reduced to such an extent that the transmission of large amount of diagnostic data is worthwhile in the first place.

Figure 1: TOC-4200 from Shimadzu.

To make this possible, towards the end of the last decade, the main users from the industry and equipment manufacturers agreed on such independent protocols, the "language of online TOC analyzers", based on common and modern transmission standard. The next step was the start of the projects in which the new data interfaces are tested in practical experiments and running large-scale plants.

After all, data is worth nothing if it is not possible to draw appropriate conclusions from it. Together with maintenance personnel, technicians and developers, gigabytes of data are being analyzed. They must be brought into relation with real incidents and peripheral process data in order to create data models on the basis of which diagnoses, and interventions are only possible in a meaningful way.

As soon as this is completed, it will become clear whether the dream of the intelligent process analyzer for smart water analysis, which for the most part can be serviced and parameterized remotely requiring only scheduled on-site maintenance, will become reality. In any case, the prospects for this are quite promising.

Biographies

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Markus Janssen is Product Manager for laboratory and online TOC systems. Started as an automation engineer in the chemical industry, where PAT quickly became his main area of expertise, he has since dedicated his expertise to "everything Total Organic Carbon" at Shimadzu, one of the leading manufacturers of TOC analyzers.

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