



Good practical engineering of on-line process analyzer systems for condensate water and steam condensate

How to design an on-line process analyzer system for condensate, steam or boiler feed water

ODS Sampling & Analytical Systems installed many on-line process TOC-analyser systems to monitor TOC-contamination of pure water such as condensate return water, boiler feed water, purity water and steam condensate. The TOC limits, as mentioned in official regulations, are very low nowadays. An alarm setting of 0,1 or 0,2 mg/litre C. is common practice. Most TOC-analysers on the market are just not stable enough or suffer with memory problems. Only a few on-line TOC analysers on the market are good enough for this job. ODS has the experience of designing the complete analyser system and selecting the most suitable TOC-analyser to meet all these requirements. We also have the know-how to engineer and install the correct sample extraction-, sample transport- and sample conditioning system. In this article we will do some recommendations.

It is of great importance to transport the sample from take of point to the analyser in such a way that the sample composition keeps unchanged. Furthermore the total response time of the system should be optimised. Nevertheless, loss of expensive pure and hot water should be minimized.

Response time

Response time of the total system adds up:

- Ad- and absorption effects and memory effects
- Sample transport delay time
- Analyser cycle time

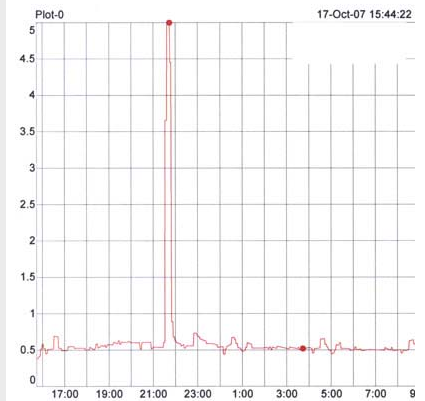
Response time due to ad- and absorption effects:

In general low concentrations of hydrocarbons are very hard to transport via sample lines to the process analyzer. The components will be absorbed and adsorbed to and desorbed from all wetted parts. Some components/hydrocarbons are more "sticky" than others. Examples of hard to transport components are oil, phenols, formaldehydes etc. This phenomena results in a very long response time from real spill event up to analyser TOC-limit alarm. The lower the TOC-concentration ... the longer the response time. There is a risk that contaminated return water is pumped back into the boiler drum, before being detected.

Adsorption effects will result in memory effects. After a spill, due to sticky components absorbed on all wetted parts, it can take hours before the concentration is back to normal level (due to desorption). During that period the analyser will report a too high TOC-reading. Expensive, uncontaminated steam condensate or boiler feed water will be flushed to the drain. During that time the condensate buffer tank (normally used) may be emptied and the boiler installation will run out of boiler feed water. Either more make-up water from the polishing installation (demin water) needs to be used or the installation needs to be shut down. After a severe contamination it could be necessary to strongly flush sample lines with steam to clean them from hydrocarbons.

Tricks to get rid of the described effects:

- Create sufficient sample velocity in sample lines; at least 0,3 m/s .. preferably 1 m/s. As the customer does not want to spill his expensive condensate water, steam or boiler feed water a water flow of about 1 litre per minute is recommended.
- Use small sample line diameters because the wetted surface will be less. In general we recommend OD = 6 mm or ¼ inch lines; The ID is about 4 mm. In the industry this is seen as a tiny non-robust sample line size. The customer would prefer to use ¾" or ½" lines. Do not use these sizes, instead protect the sample lines via cable ducts and or protection piping. By the way; high pressure can be easily, and without risk, transported through small diameter pipes.



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- Use seamless sample pipes in Stainless Steel quality 316. In special cases use special steel, inside coated with quartz oxide.
- Every meter of sample line is one meter too much. From practice: 40 meter of SS sample line, 100 ppb in steam, 1 litre per minute, easily results in an absorption response loss time of over 15 minutes.
- Keep lines warm/hot. If necessary, trace them.
- Use the correct materials for filters, valves, pressure reducers and other sample conditional components; SS 316, SS 304, glass fibre, Teflon, viton and quartz glass.
- Always flush sample lines and wetted parts constantly without any interruption. Especially when using sample sequencers etc. do not interrupt the sample flow by shutting of sample lines.

Sample transport delay time:

At a 1 m/s sample velocity it is easy to calculate the line flushing response time. 50 metres of sample line adds up to about 50 seconds. This delay time adds up to the total response time.

Analyser response time:

ODS has a lot of experience and prefers to use TOC analysers with the high 1200 degrees Celsius oxidation method in combination with multi-loop injection. These analyser have the following advantages:

- Low range, accurate and stable TOC or TC analyser. The lowest detectable limit is about 2 ppb (ug/l C.)
- Contamination of the sample due to CO₂ entering from the ambient air is impossible.
- The injection loop has a constant volume, the injected sample volume is constant and normally 400 microgram of sample per injection.
- If the sample concentration is very low, a multi-loop injection is used. Example 50 ppb at 4 times 400 micro litre.
- No pump is used in the sample stream. Peristaltic pumps use flexible tubes causing absorption effects. The pump in a Quick TOC-loop is situated downstream in the circuit where absorption effects are of no interest any more.
- With thermal oxidation all hydrocarbons are 100% oxidised to CO₂ resulting in the analyses of all hydrocarbons. The TOC-analyser commonly measures an organic hydrocarbon base-line due to the content of polishing amines, corrosion inhibitors, anti-foam and oxygen scavenger components. The response of the analyser using thermal oxidation is the fastest you can get.
- In general and at levels of about 0,5 to 5 ppm / mg/litre a response time of 3 to 4 minutes T-99 is normal. Sticky components at low concentrations, and using multi loop injection, result in a response time T-99 of about 5 to 6 minutes.

TOC-levels and TOC-ranges:

TOC-levels to be monitored in general depend on the pressure of the boiler:

Boilers that operate at high pressure (100 – 120 bar and higher) will not allow water contamination at concentrations higher then 0,1 to 0,2 mg/l C. Boilers at lower operation pressure (60 - 80 bar) allow a water contamination at a slight higher level of about 0,5 mg/ litre C.

In many boiler installations chemicals are injected to avoid corrosion or/and foam and as a surface protection component. These brand name components are often complex hydrocarbons mainly consisting of amines. These components will be taken into account in the TOC/TC reading as a constant background. The analyser/operator thereby is capable of determining a change in dosing injection settings of these expensive chemicals. It can save a lot of money.



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pH and Oxygen:

Normally some ammonia or a caustic solution is used to bring the pH to about 8. A scavenger and chemicals are used to knock out oxygen.

TOC or TC:

A boiler needs pure water, called boiler feed water. This water is being produced via the make up water installation. Cat-Ion, An-Ion, Mixed bed filter and Polishing installations are used to clean ground water, river water or tap water. Every litre of this water costs money! All impurities are removed as far as possible. No inorganic carbon should be in the water. Carbonates are removed because in the boiler they will be transformed to carbon acid. Carbon acid attacks the metal boiler wall, process pipes and heat exchangers, resulting in pit corrosion.

A TOC-Analyser analyses only organic carbons. A TC-analyser responds to organic hydrocarbons as well as in-organic carbon (carbonates). For that reason we strongly recommend to install a TC-only analyser.

An extra advantage of a TC-analyser:

It does not consume acid and does not need time to remove the carbonate. So, a TC-analyser is faster than a TOC-analyser. Furthermore, it is almost impossible to prepare an acid solution without any hydrocarbon contamination. Acid contamination also effects the TOC analyser. So finally the TC-method is preferable for more than one reason!

Sample Take of point:

Normally the sample needs to be extracted from a big process pipe. The customer will point out a sample point, normally where already a process connection with shut off valve is situated. Be aware not to take a sample point at the lowest point especially at horizontal pipes. This point will act as a buffer collector for fine particles like metal oxides etc.. From practice; a pharmacy company informed us that there could be no particles in the steam because all pipes where of SS and the steam was extremely clean. Via the hard way we found out that this was not true. The complete sample conditioning system was polluted with black particles within hours and several components such as pressure reducer etc. where destroyed. Particles are present! Use either a sample take of point at the side of the pipe (90 or 270 degrees) or on top (0 degrees). If there is no other solution then 180 degrees, then use an additional on-off valve with a 1/2" connector and a 1/2" retractable probe sticking into the centre of the pipe. Use at this point, down stream of the extra shut-of valve, Y-strainers with 50 or 100 um SS sintered in-line filter elements. The strainers should be safely accessible by personnel for maintenance and replacement of filter elements.

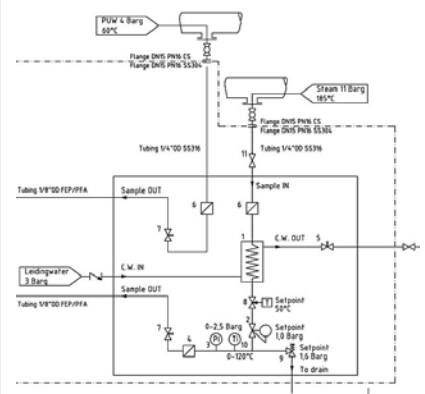
Pressure and temperature:

Steam: Be aware of flashing effects from steam conditions! Normally the steam flushes at high speed through the sample line, losing heat and pressure and ending up as condensate in the sample conditioning panel. After transportation of the sample to the analyser, sample conditioning needs to be taken place. In principle the panel consists of:

- Pressure reduction to about 1 bar; pressure reducer
- Overpressure bleed
- Temperature reduction to about < 40 degrees C.; heat exchanger via water or via air
- High temperature shut-off valve
- Fine sample filter; Teflon or paper; 2 um
- P and T-monitoring

Contaminated particles:

Small particles need to be filtered out. Not that the analyser is not capable of handling these particles but they are normally of a sort of spongy state and contaminated by hydrocarbons. One particle results in a freak-TOC-peak, upsetting the operation of the boiler installation. Filter them out. When changing the filter, use clean plastic hand gloves and be not surprised when the analyser is reading higher values during the first hour!



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Heat and temperature reduction:

There are several methods to reduce the temperature of the sample. Normally the analyser can handle a temperature of more than 50 degrees (optionally up to 95 °C.) but it is safer to reduce the temperature to a lower value such as between 30 and 40 degrees C.. Maintenance personal can work on the analyser without any risk.

ODS uses standard heat exchangers operating via a cross flow system and cooling via a (tap)water flow. It is easy to drop the temperature of about 1 litre per minute sample from 100 °C. back to 40 °C. but realize that this costs a lot of (tap) water. At a flow of ~ 1 litre per minute the heat/energy of several thousand Watts should be exchanged from the sample to the cooling water. Finally the analyser will use only several millilitres of that cooled sample.

As an alternative, ODS has designed a method using an air cooled heat exchanger with a very low internal volume. In fact we transport the sample continuously as close as possible to the analyser. The flow in the sample pipe (4 mm I.D.) is about 1 litre per minute. Then we split up the flow to a sample flow of about 50 ml/minute and a drain flow of 950 ml/minute. We only cool down the sample flow of 50 millilitres per minute using an aluminium cooling rib element with an internal 6 meter long 1/4" SS loop sample pipe. About 200 to 400 Watts of heat/energy should be cooled now only. No tap water is used. The rest of the HOT water is drained via SS piping into a SS header. All hot parts are covered via protection screens to avoid direct skin contact of personnel.

Calibration:

How to calibrate a sensitive TOC-analyser with a 0,5 mg/litre C. range or even less? How to prepare the standard using what kind of pure water? How to store the standard? That is a very important problem!!!

From practice: An operator told us :

"my problem is not to maintain the analyser. That is easy. My problem is that when the analyser suddenly measures high TOC-values the operator runs in and tells me my analyser is not analysing correctly and that he is losing expensive steam for no reason. How can I prove him fast and accurate that it is not the analyser but the contaminated steam causing the high reading?"

For that reason ODS advised, for any application with ranges lower than 2 mg/litre., a TOC-analyser with an input for calibration gas. Via CO₂ calibration gas, a very stable and inexpensive gas, the analyser is checked. This routine is completely automatically generated and gives 99% assurance that the analyser is reading correctly. It is always available to be used by anyone at any moment.

2-stream or multi-stream via sequencers:

High temperature oxidation TOC-analysers are suitable for 2-stream or multi-stream applications. The analyser is built and designed in such a way that cross over effects are minimized. Cross over = concentration stream 1 effecting concentration stream 2. Sample lines should be connected directly as a closed system. Do not use external overflow cups! If the analyser takes 4 minutes to measure, then of course a 2-stream analyser will use a total cycle time of 8 minutes. We can design, build and offer 3 to 8-stream sequence systems. However, sample lines should not be too long (for described reasons).

Atex zone 1 or 2:

Analysers can be delivered in a special housing or cabinet for the ATEX zone 1 or 2 area. Special attention should be taken for conditioning and cooling the environment of the system and/or the analyser itself.



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