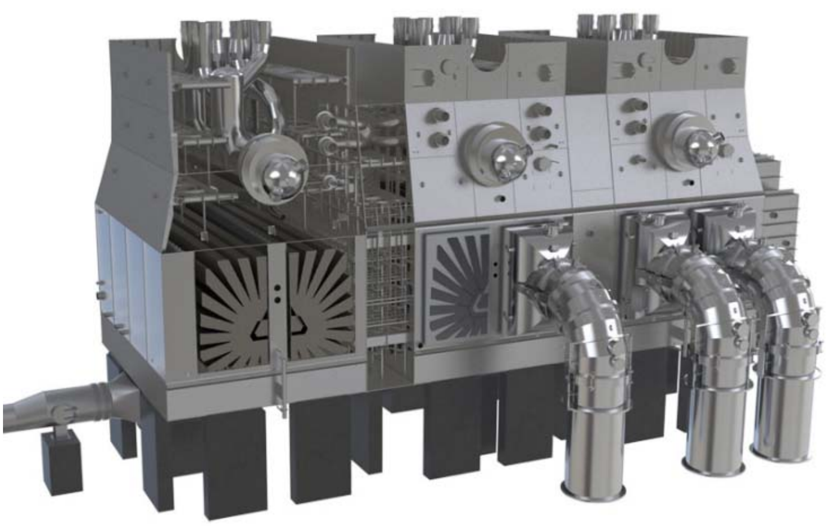
Sample conditioning and analyzer configurations for condenser monitoring in water steam cycles

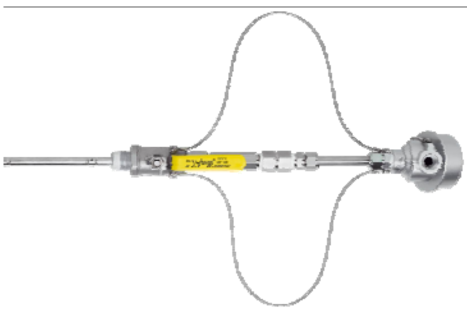
Author: M. Sigrist, Swan Systeme AG
Date: 09.05.2013
Revision: 1.3



NPP / Steam plant condenser *

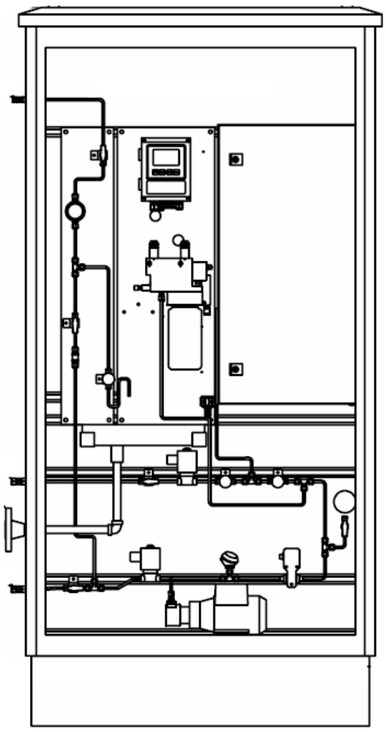
CCPP condenser *

* same relative scale



Retractable insertion probe for specific conductivity (In-line measurment)

Hotwell condensate sample pump skid



Hotwell condensate sample pump skid with integrated online acid conductivity analyser

Introduction
This paper addresses questions related to the monitoring of the condensate in water steam cycles with water cooled condensers. In a closed water steam cycle, the condenser has the function of evacuating the unusable heat energy of low pressure steam. The steam condenses to water which is fed back to the feedwater tank and into the water steam cycle.

On the steam side of the condenser a vacuum of 30-50mbar absolute pressure is maintained in order to bring down the steam condensation temperature in the range of the cooling water temperature (25-50°C). Through any leak in the part of the cycle that is kept under vacuum, contaminants are sucked in from the outside. These contaminants can be:

1) Cooling water leaking in through leaks at the interface water box – tube bundles or leaks in damaged tubes. This cooling water (from sea or river) contains levels of salts which are dangerous for the water steam cycle. An undetected cooling water leak in a condenser will result in severe corrosion, scaling damage in boiler and turbine and in extended plant downtime.

2) Air leaking in through LP turbine seals and outlet flange. This air will have two effects:

   a. oxygen will dissolve in the condensate and will need to be removed at later stage in the feedwater (steam required for deaerator and/or dosing of expensive and toxic oxygen scavenger).

   b. Carbon dioxide (CO_2) will dissolve in the condensate and will increase water conductivity.

   While the consequences of air leaks are not as severe as those of a cooling water leaks, this contamination still has a major cost impact during start-up phases. [1]

As the condenser is an important potential entry point for contaminants into the water steam cycle, it is essential to closely monitor the quality of the condensate downstream of the condenser.

Condenser monitoring concepts
The detailed definition of a condenser monitoring concept for a particular plant constellation requires consideration of the following aspects:

- Cooling water quality
- Condenser type and materials
- Number of condenser units
- Condensate extraction pump configuration
- Possible condenser operating modes on CW side (i.e. isolation of a single water box possible or not)
- Availability and capacity of condensate polishing plant
- Plant operating modes

The parameters usually monitored in condensate are:
- Acid conductivity and sometimes degassed acid conductivity (in plants with frequent start-ups)
- Sodium
- Oxygen
- pH

Sample monitoring downstream of main condensate extraction pump

As per VGB S-006-2012, the recommended sampling location for condensate is the main condensate downstream of the condensate extraction pump(s).
The decision whether it is safe or not to operate a water steam cycle or not in the event of a condenser cooling water leak is based on the quality of the main condensate only. The immediate operational questions to address are “how bad is the leak?”, “How does the main condensate quality evolve?”, “What temporary measures are possible to minimize the consequences?”

Using the main condensate sample for permanent monitoring has the following advantages:

- The sample is not under vacuum and sample conditioning is simple.
- The sample is still closely related to the sample in the condenser (minimal delay only)
- The main condensate sampling & analysis rack can be located in an accessible location where proper operation of the system can be guaranteed
- State-of-the-art sodium and silica analysers will detect condenser leaks even in the mixed condensate of several condensers long before such leaks become critical to the plant operation.

Sampling from the condenser hotwell

If the online analysers in main condensate indicate an early leak but the plant can nevertheless remain in operation for some time, the next question is “Is it possible to identity the location of the leak?”

Tracking a leak with grab samples from multiple tapping points

VGB-S-006-2012 recommends the installation of multiple tapping points below condensate level at various critical locations in the individual condensers and condensate pipes. With a portable membrane pump, grab samples can be extracted at various points and can be analyzed in the lab. Along with comprehensive online monitoring in the main condensate, this set-up provides great flexibility and efficient leak localization at reasonable cost: from the condensate pipe sample of each condenser, the concerned condenser can be quickly identified. Within the condenser the probable location of a leak can be estimated by comparing grab samples taken from different tapping points.

In-line conductivity probes

Unfortunately, several specification templates of technical consultants and owners engineers list by default a condenser hotwell sample and associated online measurements. If such requirements end up in an EPC contract, this will lead to discussions.
A frequent compromise between the EPC and operator in order to provide some form on hotwell condensate monitoring are specific conductivity probes installed directly in the condenser walls at various locations. The probe closest to the leak should indicate the highest conductivity values.

Hotwell sampling skids

The most expensive and complex sampling set-up is a dedicated sampling and instrumentation skid for hotwell condensate. This is technically feasible but it is complex, expensive. Therefore the need and expected benefit of such a system should carefully be checked and compared with the alternatives listed above. Refer to Annex 1 for details.

Conclusions

Condensate and condenser hotwell monitoring is a very specific topic in water steam sampling systems. Operators and EPCs are well advised to consider the new guidelines [2] [3], to take the overall perspective of BOP and of condensate contamination detection / mitigation. This will avoid expensive misunderstandings and subsystems with limited added value to chemistry monitoring. Please consult Swan Systeme if you require further assistance on a particular project.
For quick reference, the 3 approaches for condenser hotwell monitoring described above are compared in the following table:

Hotwell monitoring concept	**Comment**	**Advantages**	**Disadvantages**	**Cost**
Multiple tapping points for leak tracking using grab samples	As per VGB-S006-2012. Used only for secondary diagnostics, to locate leak origin within condenser	High flexibility, better leak localisation performance (more sampling points)	Requires manual grab sample extraction and lab analysis.	Only cost of tapping points in condenser.
In-line conductivity probes	Compromise solution: specific conductivity is the only measurement where the sensor can be installed directly into the hotwell	Medium invest cost Provides a permanent measurement	Specific conductivity not sensitive enough for detection of small leak.	~3000 EUR per retractable in-line SC measurement
On-line hotwell sampling skid	Required only for very large condensers which can be partially isolated on the cooling water side during operation	Permanent online measurement, usually acid conductivity.	High cost compared to regular online sampling systems Requires detailed hydraulic planning of complete sample loop	18 – 25'000 EUR per condenser block.

Lit. references

[1] Cation conductivity monitoring during start-up, Power Plant Chemistry, Special print 2007, 9(11), M. Rzhia, Dr. P. Wuhrmann

[2] VGB S-006-2012, 2012, www.vgb.org

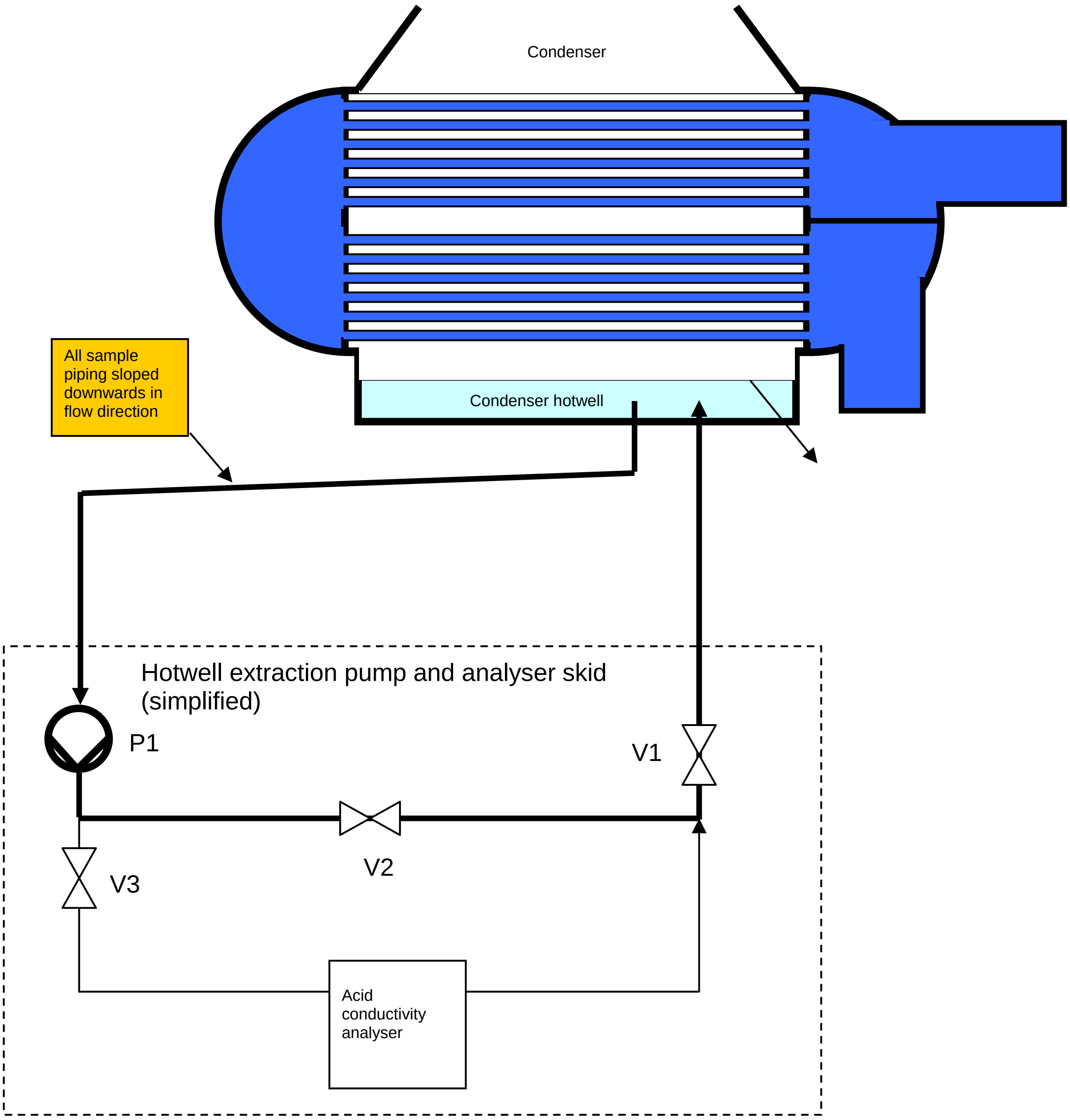
[3] VGB S-010-2011, 2011, www.vgb.org

ANNEX1:
Design considerations for hotwell sampling skids

In the rare cases where a sample extraction and monitoring skid is required for condenser hotwell(s), this Annex provides further guidance and illustrates the particularities of these sampling systems:
Condenser hotwell monitoring stations with sample extraction and dedicated online analyzers are in also only secondary diagnostic systems and in most designs, they provide only information as to which condenser is affected, not where the leak is located in the particular condenser. They are typically only found in the following plant types:

- Large coal fired units or nuclear power plants with multiple condensers
- Condensers with multiple condenser lungs with provisions to fully isolate one condenser lung on the cooling water box side while the plant is in operation

Hotwell condensate at 30-50mbar pressure is always water at boiling point. The slightest pressure drop will immediately generate steam bubbles in the water. If such a sample is to be extracted from the hotwell, the extraction pump must be located far enough below the condenser water level to allow for a sufficient water head on the pump suction side. It is also crucial to minimize pressure losses and avoid air traps from extraction point to pump. The arrangement in the sketch below shows a simplified P&ID of a condenser hotwell monitoring station.



Sample is extracted from the hotwell by a sample pump P1. This pump builds up some pressure against throttle valve V1 from which the sample returns to the condenser. The circulating flow is typically 60-80l/h.

Most of the sample (80-90% of total pump flow) will simply circulate through the bypass valve V2. The remainder of the sample flows through valve V3 to the instrument.

The measurement of choice for this application is acid conductivity, for the following reasons

- Acid conductivity measurement is not affected by alkalizing agents and is much more sensitive to contaminating salts than specific conductivity
- Reliable and low maintenance instrument. This is important as the pump and analyzer rack needs to be installed below condenser water level, a location that is not convenient to access.
- Affordable instrument allowing installation of multiple monitoring stations at reasonable cost
- Instrument can be operated in closed loop (i.e. with sample returning to condenser) and under slight vacuum conditions. This reduces power requirement for the sample pump and allows system operation with minimal water head.

The design of a hotwell sampling station must consider the following key aspects:

- Detailed local arrangement planning is required to guarantee proper hydraulic conditions for system operation
- Extraction point must always be located below water level and must consider water flow patterns inside condenser
- The extraction point should not be a butt-welded pipe flush with the condenser wall. A probe inserted 5-10 cm into the condenser will collect less particles which could damage the sampling equipment.
- Sample pipe characteristics (length, diameter, surface roughness and material) must be carefully matched to pump and regulating valve characteristics.
- Sample must always be extracted in downwards direction (at least 10° downward angle with respect to horizontal direction)
- Pump must be self-priming in vacuum conditions. Positive displacement pumps are not recommended due to potential wear and clogging problems.
- Cation column must have a de-aerating element evacuating air into the sample return line to the condenser
- When the pump is stopped, all sample pipe segments shown are under vacuum. Therefore all components must be absolutely vacuum-tight.

The above are only basic design considerations. Detail design must consider functions such as pump and instrument flow monitoring, automatic start-stop capability, pressure and temperature safety, valves for deaeration and priming etc.