PPCHEM
POWERPLANT CHEMISTRY

SPECIAL PRINT

Seven Sins of Steam Sampling

Manuel Sigrist
CTO
SWAN Systeme AG, CH-8340 Hinwil

PowerPlant Chemistry SPECIAL PRINT (2011) PowerPlant Chemistry 2010, 12(7)

PPCHEM
POWERPLANT CHEMISTRY

PowerPlant Chemistry® Journal (ISSN 1438-5325)

Publisher:
Waesseri GmbH
P.O. Box 433
8340 Hinwil
Switzerland
Phone: +41-44-9402300
E-mail: info@waesseri.com

Editor-in-Chief:
Albert Bursik, Germany (editor@ppchem.net)

Copyediting and Proofreading:
Kirsten Brock, USA/Germany

Graphics and Layout:
te.gra – Büro für Technische Grafik, Germany

Production:
Appenzeller Druckerei, Switzerland

Frequency:
PowerPlant Chemistry® is published monthly

Seven Sins of Steam Sampling

Manuel Sigrist

ABSTRACT

Over the past 20 years the main components of power plants such as gas turbines, steam turbines, boilers, and plant control systems have been continuously improved. Strangely, during the same period an auxiliary system with interfaces to several of these main components has hardly seen any changes: the steam/water sampling and analysis system (SWAS).

For engineering, procurement, and construction contractors and boiler manufacturers, it is still common practice to specify designs which are out of date. Neither the changed requirements of modern power plants nor the possibilities offered by state-of-the-art online instrumentation are taken into account.

With a broad palette of sampling system examples from around the world, the most common SWAS design "sins" are illustrated. Alternatives presented illustrate that a water/steam sampling system does not have to be a purgatory for the plant chemist and that reliable measurements, ease of maintenance and low cost of ownership can be achieved.

INTRODUCTION

Over the past 30 years the main components of power plants such as gas turbines, steam turbines, boilers, and plant control systems have been continuously improved. Strangely, during the same period an auxiliary system with interfaces to several of these main components has hardly seen any changes: the steam/water sampling and analysis system (SWAS).

The focus of this paper is on sampling and analysis stations alone, as they are commonly purchased by original equipment manufacturers (OEMs) as turn-key subsystems. The topics of sample extraction and on-site sample piping are not considered.

In any SWAS, one will generally find the functional elements illustrated in Figure 1. There are many ways to realize these functional elements, but in the end the proper arrangement and interaction of these elements is essential to obtain valid online measurements and a user friendly system. Unfortunately, many SWAS designs do not take this into account.

The article illustrates a selection of common design flaws found in SWASs and shows alternatives with improved designs. It concludes with an analysis of the root causes for these design flaws and an overview of how to change things.

Tragic Sampling Skid Design

In many parts of the world, it is still common practice to specify a SWAS architecture consisting of a so-called wet rack and a dry rack. The wet rack contains sample conditioning equipment and a grab sampling sink as well as flow cells and sensors. The dry rack is reserved for transmitter electronics (usually panel mount transmitters). The wet rack is placed next to the dry rack, or they are sometimes also located in different rooms (Figure 2).

These designs date from a time when transmitters were bulky, sensitive to ambient temperature and had limited control logic and display capabilities. In the typical arrangements of such racks, only flow indicators, valve handles and transmitters are visible from the outside. Sensors, flow cells and sample tubing remain hidden and difficult to access. Even the most routine calibration, problem diagnostic or maintenance task quickly turns into a nightmare (Figure 3).

Today, such concepts are outdated:

- Modern transmitters are compact, are not sensitive to ambient temperature changes, have sufficient protection grade to operate in wet environments and have large displays to display measured values and alarms;
- Wet analyzers for parameters such as silica and sodium (routinely measured online in power plants) do not allow

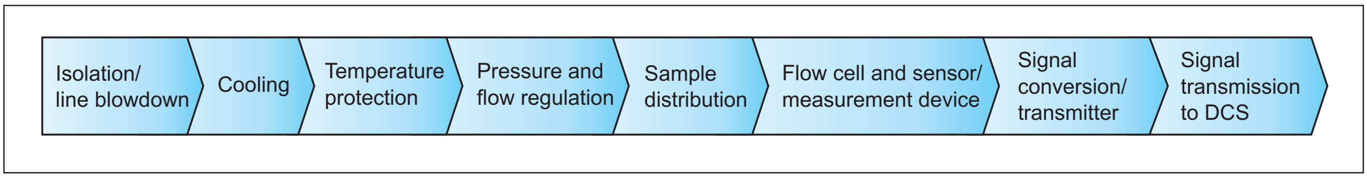


Figure 1:
Functional elements of a SWAS, from sample conditioning to distributed control system (DCS) signal exchange.

Figure 2:
Front view of a sampling system with wet and dry rack sections.

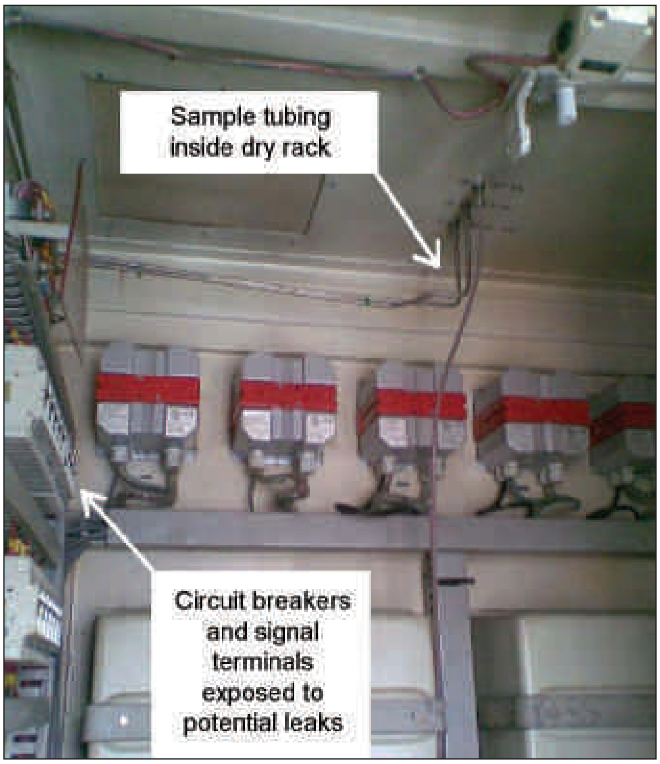


Figure 3:
Rear view "dry" rack. view).

a separation between a wet "sensor part" and a dry transmitter. In practice sodium and silica analyzers are often integrated in the so-called dry rack. This is dangerous as it means routing sample tubing (sometimes flexible tubing!) and an extra drain inside an electric cabinet. See Figure 4.

Despite the obvious disadvantages and regardless of the available alternatives, the specifications for SWASs still frequently require separate wet and dry racks, grouped transmitters, and a central grab sampling sink. Many traditional panel shops do not object to these arrangements as they allow extremely compact arrangements if one is willing to sacrifice maintainability, upgradability, reliability and ease of operation of a SWAS system.

Figure 4:
Rear view wet rack with sensors.

Temperature Protection: Guideline to Minimizing Operator Safety

Example 1 Most samples analyzed in a SWAS will require cooling (typically 20–40 kW cooling power per sample line). In case of failure of the cooling, it is essential to stop the sample flow before it reaches instrumentation or a grab sample where a hot sample could damage equipment or injure operators. One would think that temperature protection is considered an important safety feature. The reality shows many design concepts with severe compromises to operator safety.

The OEM responsible for the design shown in Figure 5 argues that the cooling water supply is fail-safe. However, it is still possible to stop the cooling water of a single cooler by closing valve 4) or to increase sample flow above cooler rating by opening the pressure reduction valve 3) – both actions will result in hot sample in the instrumentation and a potentially dangerous situation for the operator.

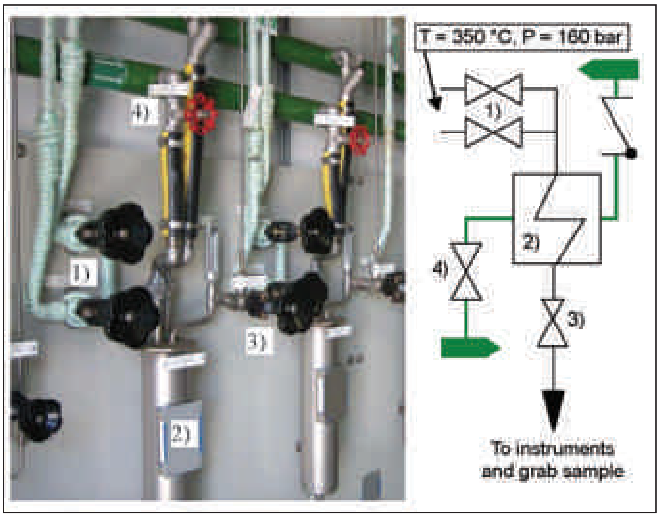


Figure 5:
Sample conditioning line for drum water without thermal safety shut-off valve (TSV).

Example 2 Solenoid valves rated for pressures above 120 bar and with sufficient cross section are hard to find and expensive. A cheap alternative is to use solenoid valves rated to lower pressures than sample line pressure and to add a pressure relief element between the pressure reducing element upstream and the thermal safety shut-off valve (TSV) solenoid (Figure 6). The TSV stops the flow to the instruments, but there is a bypass flow through the pressure relief element. If this bypass is simply evacuated into an open drain, there is still an unacceptable risk of injury to operators.

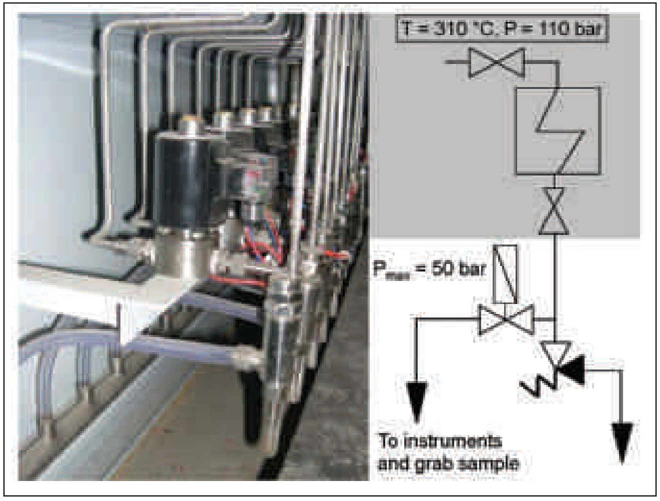


Figure 6:
TSV not rated to full line pressure.

The alternative: the following basic design rules will ensure safe TSV design:

- All sample lines above 50 °C must be equipped with a TSV.
- The TSV must stop the sample flow completely. Therefore TSVs and all elements upstream must be sized to full line pressure.
- TSVs must be protected by a coarse filter to ensure proper function when triggered.
- Between sample extraction point and TSV, no pipe segments branching off to open drains are allowed.
- The TSV should be placed close to the primary cooler to minimize pipe length and the number of components potentially exposed to full line pressure.

Bleeding Edge Concepts for Line and Instrument Sharing: Ways to Maximize Confusion

Certain samples do not require permanent monitoring. Therefore it is common to have two samples sharing a common sample conditioning line and instrumentation, typically for a saturated and superheated steam of the same pressure. Sometimes, however, line sharing is used for unrelated lines (e.g., steam lines of two different boilers or make-up/feedwater/main condensate as shown in Figure 7).

Another frequently seen arrangement is a set of manual valves upstream of an instrument allowing different samples to be sent to this instrument. Such configurations aim at reducing instrument cost or are included only to provide additional diagnostic possibilities during the commissioning phase.

The downsides of exaggerated line and instrument sharing solutions are often overlooked:

- There is a major risk of incorrect allocation of measurement to sample line, as the manual valves' positions cannot be remotely checked.
- The corresponding pipe routings are often difficult to follow and confusing, thus increasing the risk of error, especially if the system is no longer run by experienced commissioning technicians.
- The quality of certain measurements can be severely impaired: for example, an oxygen measurement at the $\mu g \cdot kg^{-1}$ level will be disturbed by air diffusion through any unnecessary ball valves placed upstream.

Solution:

1. For measurements used during commissioning or for periodic diagnostics only, we recommend the use of portable analyzers. Such analyzers are available off the rack for pH, conductivity, and dissolved oxygen.
2. If a sample line includes measurements used for control purposes, this line should not be shared with unrelated sample lines.
3. If sharing of a fixed instrument is still required on a periodic basis, do not use hard piping; equip sample lines with connection ports and use flexible tubing to establish temporary connections. On multichannel analyzers, dedicate one channel to flexible sample line allocation.

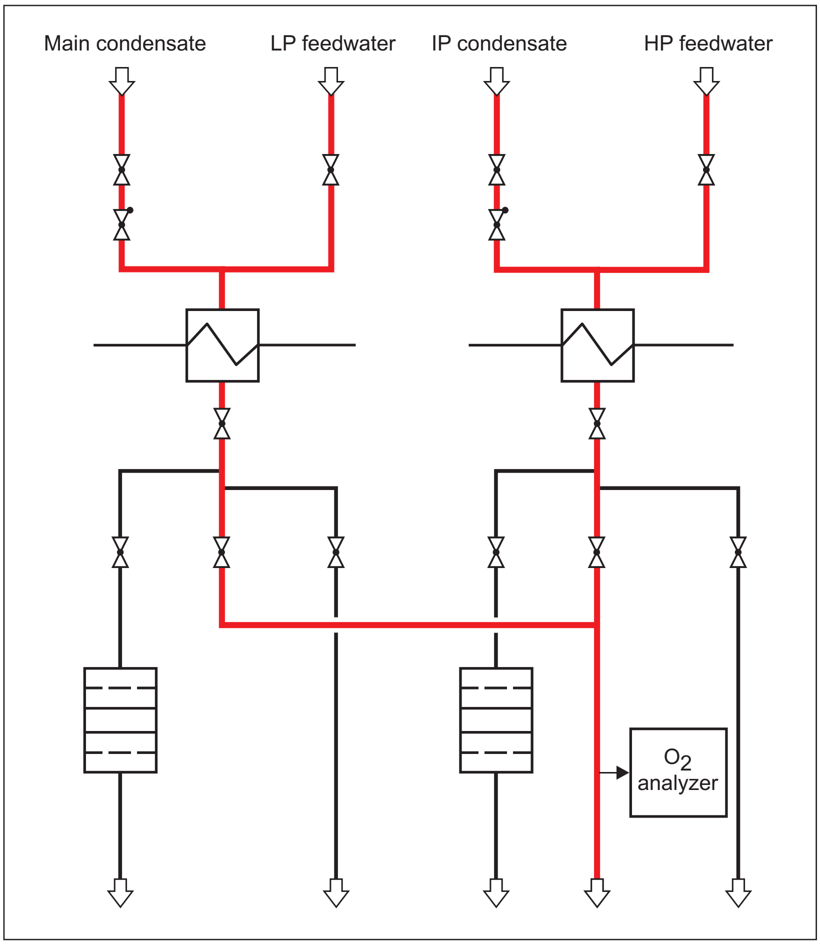


Figure 7:
Example of 4 sample lines sharing 2 coolers and 1 instrument.

Impractical Pressure and Flow Regulation for Instruments

Online analyzers require stable sample flow conditions in order to work reliably. Stable sample flow through an analyzer can only be ensured by maintaining a stable inlet pressure upstream of the analyzer. This pressure needs to be actively regulated as it is constantly influenced by process pressure fluctuations and variations in sample flow rate (e.g., grab sampling operations, switching on/off of analyzers sharing the same line).

- It is still common practice to find sampling systems without active sample pressure regulation. Such systems will require frequent valve adjustments by the operators.
- There are two main design philosophies for pressure regulation in water sampling applications (Table 1).

Backpressure regulation is the method of choice recommended by ASME [1]. It has several advantages compared to arrangements with forward pressure regulators:

- Splitting flow restriction and pressure regulation follows the design principle of separating functions for simpler and safer system design.
- Back pressure regulators (BPRs) have no small moving parts exposed to sample flow – this means low maintenance and high reliability.
- BPRs with low pre-set pressures of 0.5–1 bar have a large valve section, allowing evacuation of particles in flow. Stable low pressure is maintained even in high flow conditions.
- A BPR is a reliable safety device against high pressure: it opens further in case of a pressure rise; unlike with a forward pressure regulator (FPR), tight sealing is not required.

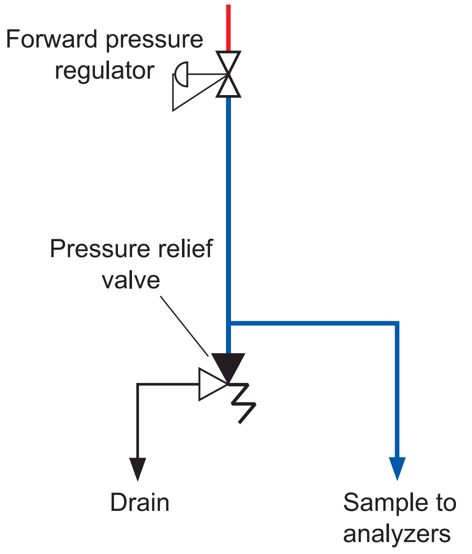
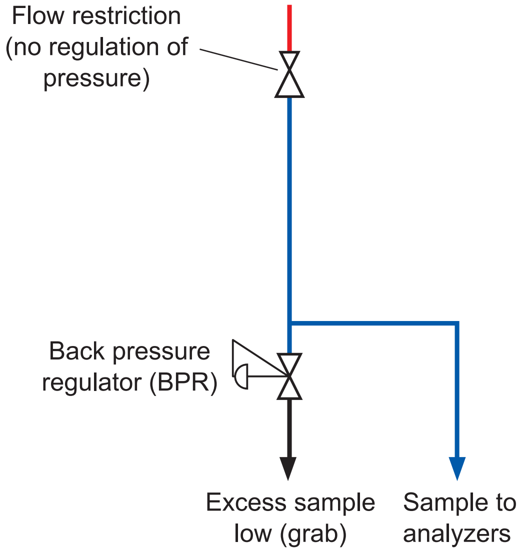
	Forward Pressure Regulation	Flow Restriction Combined with Backward Pressure Regulation
Description	Pressure and flow are controlled with a single device placed upstream of the distribution point to the analyzers. A pressure relief valve is required in case of failure of the pressure regulation.	Flow and pressure control are split: flow is restricted with a needle valve (usually not an actively regulating element) and pressure is regulated with a back pressure regulator (BPR) placed downstream of the distribution point to analyzers. Pressure is regulated by discharging excess sample flow through the BPR.
Typical set-up (simplified) Full line pressure Regulated pressure		
	Forward pressure regulator	Flow restriction (no regulation of pressure)
Working principle of the pressure regulating element	Forward pressure regulators regulate pressure at the outlet. The pressure at the outlet acts on the flow as follows: – flow is increased if outlet pressure is below set-point; – flow is decreased if outlet pressure is above set-point.	The back pressure regulates the pressure on the inlet side by allowing some excess flow. Higher pressure causes valve to open further, allowing more excess sample flow, which causes pressure to drop again.

Table 1:
Design philosophies for pressure regulation in water sampling applications.

When Calibration Rhymes with Desperation

Most water analyzers require periodic calibration or verification. For this purpose, the operator needs simultaneous access to the sensors and to the related transmitter. A pH measurement, for example, is calibrated by putting the sensor into two standard solutions with defined pH and executing a calibration routine on the transmitter. This simple procedure becomes a nightmare as soon as the operator has to walk back and forth looking for the isolation valve, the flow cell holding the sensor and the transmitter. Examples of such arrangements are shown in Figures 8–10.

In sampling systems with the traditional wet and dry rack arrangement, where flow cells and cation columns are barely accessible inside a cabinet, the problem is even more acute.

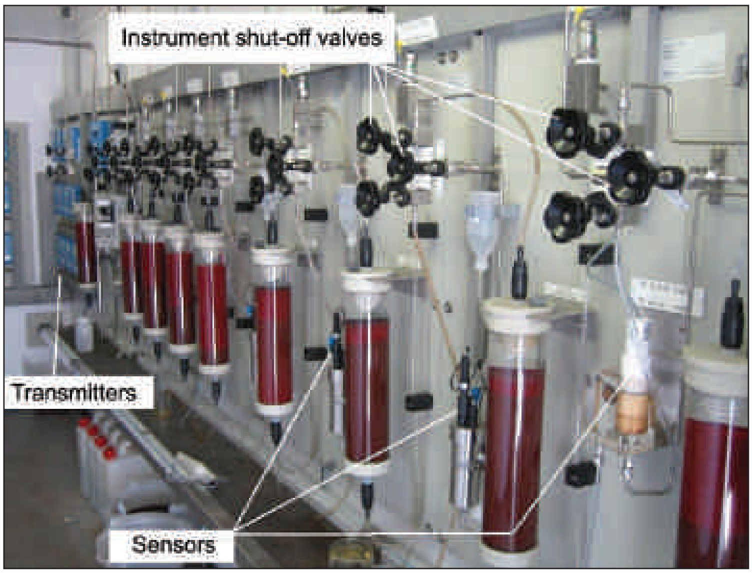


Figure 8:
Flow cells and transmitters in separate locations.

Figure 9:
Random arrangement of flow cells and transmitters.

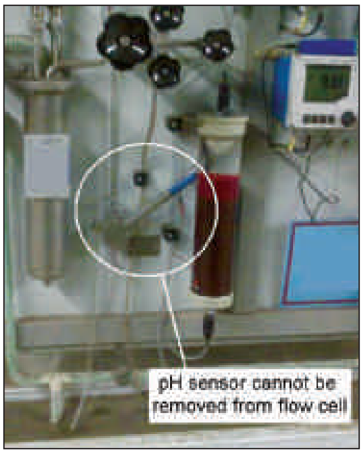


Figure 10:
pH sensor blocked by cation column.

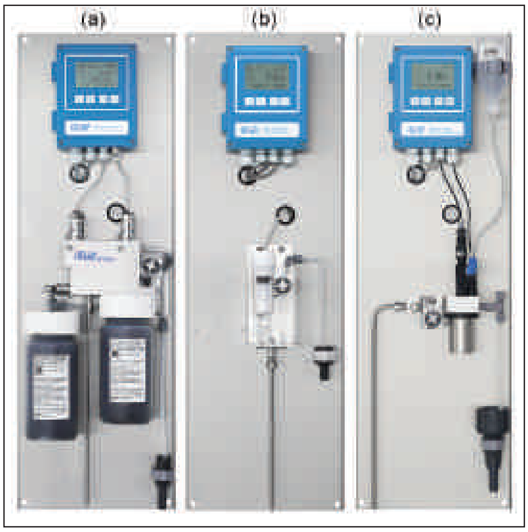


Figure 11:
Dual-channel monitor for specific and acid conductivity (a), oxygen monitor (b), and pH monitor (c).

The alternative: the transmitter, instrument flow regulating valve, flow cell and sensor of a given measurement must be grouped and arranged consistently. This calls for a modular instrument design (Figure 11). The SWAN Monitor concept is one way to realize this requirement and it offers the following advantages:

- Ease of operation and maintenance friendly design
- Consistent instrument documentation and systematic operator training
- Easy instrument upgrades/changes at any time

Cation Exchanger Frenzy

The very common measurement of acid conductivity requires cation exchangers to neutralize the effect of the alkalizing chemicals before sample conductivity is measured. There is a great variety of designs for cation exchangers. A few examples are shown in Figure 12:

1 No deaeration, stiff tube connection on outlet side, cation column under suction when the system is at rest

2 Stainless steel columns (resin not visible), without deaeration, stiff tube connections

3 Inaccessible glass bottles without deaeration

4 Redundant columns, without deaeration. Stiff connections, columns under suction when the system is at rest

5 Bulky column, with manual deaeration, plastic quick disconnect fittings and gas permeable flexible tubing

The most common problems experienced with cation exchange columns are listed below:

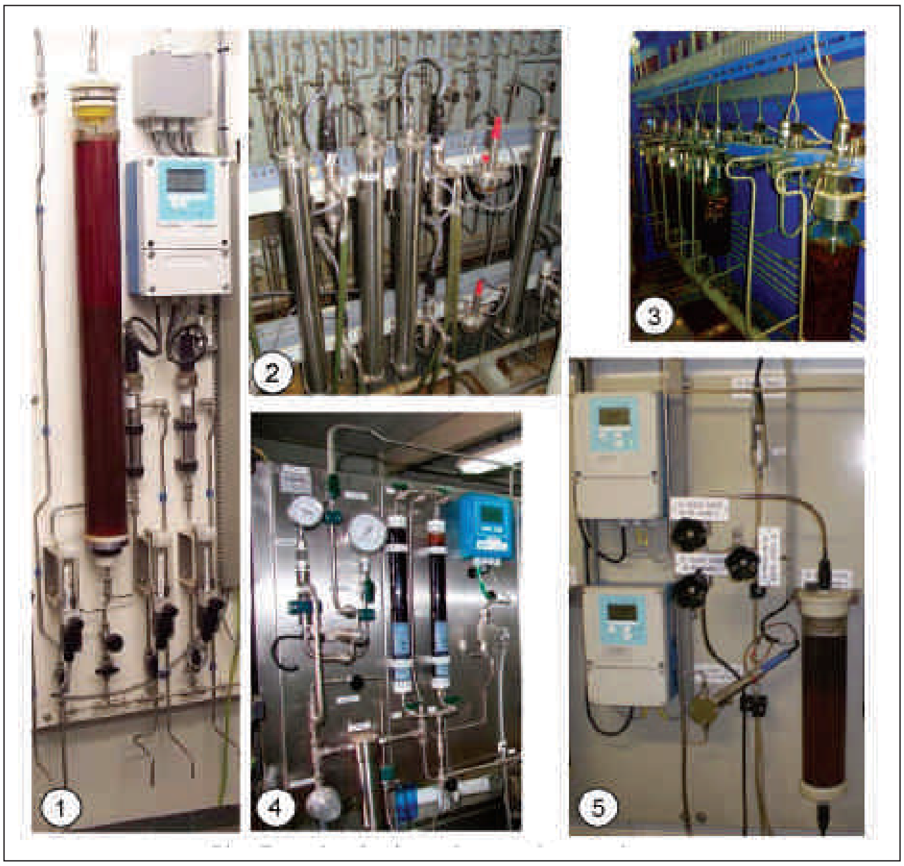


Figure 12:
Examples of cation exchanger columns and arrangements.

- Resin monitoring
  It is important to monitor resin exhaustion (indicated by resin color change). Designs with opaque resin columns or with columns placed in inaccessible locations do not allow any monitoring of resin consumption.

- Deaeration
  A proper deaeration of the column is essential. Air in the column will not evacuate by itself as the water flow through the columns is from top to bottom to keep the resin stratified. Residual air will cause CO_2 contamination of the sample (the conductivity value will be biased) and will limit the available active resin surface. The source of air in columns is often incorrect hydraulic arrangements of columns, piping and sensors causing columns to drain when the system is at rest.

- Redundant cation columns or replacing a problem with a bigger one
  When an exchange of the resin is required (every 8–12 weeks), the handling of resin columns with traditional top-in bottom-out flow configuration is cumbersome and time consuming. For this reason, some SWAS panel shops have come up with designs featuring parallel two resin columns with three-way valves to switch between columns.
  The water in the stand-by column is very different from the sample, as it has been at rest in the column for an extended time. Once the resin column is switched on, it will take a long time (up to several hours) until the column is properly flushed to allow proper acid conductivity measurements.

Such problems can be avoided with the following **design rules for cation exchangers**:

- Resin columns must be transparent.
- Cation columns must have at least a deaeration valve or auto-deaeration features.
- To prevent ingress of air, the hydraulic arrangement must be such that in a wet system at rest, the resin column is not exposed to negative water head (i.e., the sample exhaust to the atmosphere must be above the top of column).
- Columns must be easily accessible for maintenance.
- Column sample connections and supports must allow easy resin replacement.
- Parallel resin columns with manual switch over should not be used.

State-of-the-art integrated instrument designs meet all the above requirements in a standardized compact and user friendly arrangement. An extensive analysis of cation exchanger columns used in water analytics can be found in [2].

Ways to Hide the Truth from the Distributed Control System

Forget about Instrument Flow Monitoring In most SWASs there is no possibility to verify remotely that the sensor is receiving sample flow. Lack of sample flow is the number one cause of wrong measurements, but still most SWASs are built without flow monitoring at the instrument level. Local flow indicators are often installed for adjusting flow on individual instruments, however these do not provide a remote flow alarm in case of loss of flow. Sometimes a flow switch will be installed to monitor total sample flow, yet some instruments might still be without flow even if the sample line has flow (see Figure 13). At the distributed control system (DCS) level, no validation of the measurement is possible: a measured value is displayed but it could be measured in standing water.

The alternative: the requirements for proper measurement validation with respect to sample flow are the following:

- Instruments must be fitted with a flow monitoring device at the instrument level, located close to the sensor.
- Local flow indicators are not sufficient: the DCS needs a remote alarm in case of loss of flow. To limit the number of alarms, this alarm should be combined with the instrument summary alarm.
- Monitoring total flow in a sample line with a single flow switch is not sufficient: a single instrument could still be off line while there is flow on the line.

For an example of proper instrument flow monitoring at the instrument level, see Figure 14.

Build Summary Alarms without Information Content Each instrument will generate at least two signals: 1) the signal for the measured parameter, and 2) a summary alarm for the instrument (e.g., combining sensor failure, lack of reagents, sometimes sample flow alarm (see *Forget about Instrument Flow Monitoring*), etc.). When it comes to forwarding this information to the DCS, a frequent request in SWAS specification is to combine all summary alarms of instruments into a single alarm. However at the DCS level it will no longer be possible to validate a single measurement. The alarm will simply be disregarded, as it will permanently go off with the smallest problem on any instrument. As some measured parameters are used for dosing or process control, the lack of validation is a severe risk, a risk taken to save a bit of cabling work and some interface cards.

See Figure 15 for a sketch illustrating the above point.

Stick to Hardwiring in the Digital Age When it comes to signal exchange between the SWAS and the DCS, the SWAS is frequently considered to be field instrumentation or a group of field devices. In reality, the SWAS is a subsystem exchanging a rather large number of signals with the DCS:

- At least two signals per instrument (measurement value + summary alarm)
- Alarms for sample line high temperature (one per line)
- Alarms for power supply failure/cooling water failure
- Signals for sample line/pump ON/OFF switching (if applicable)

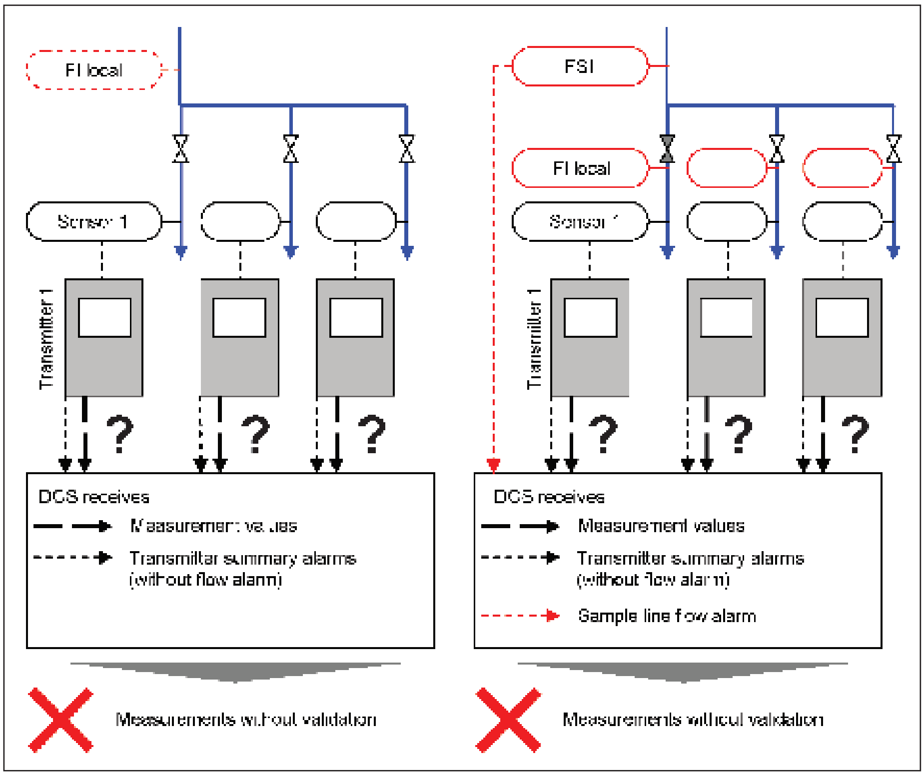


Figure 13:
Arrangements with and without insufficient flow monitoring for remote validation.

A SWAS with 10 lines, 20 instruments and some auxiliaries will typically have ~50–70 signals exchanged with the DCS (25–30 analog signals, 30–40 digital signals), more than most auxiliaries in a power plant. Traditionally, OEMs will ask for hardwired signals for the SWAS despite the following disadvantages:

- Lack of flexibility for system upgrades
- Bulky electrical cabinets with large terminal blocks (see the example in Figure 16)
- Additional costs on site for individual signal cabling, DCS interface cards, electric tests

The alternative: use bus-based communication for signal exchange between the SWAS and the users of SWAS data (DCS, instrumentation and control (I&C) or chemical department). State-of-the-art instruments offer bus com-

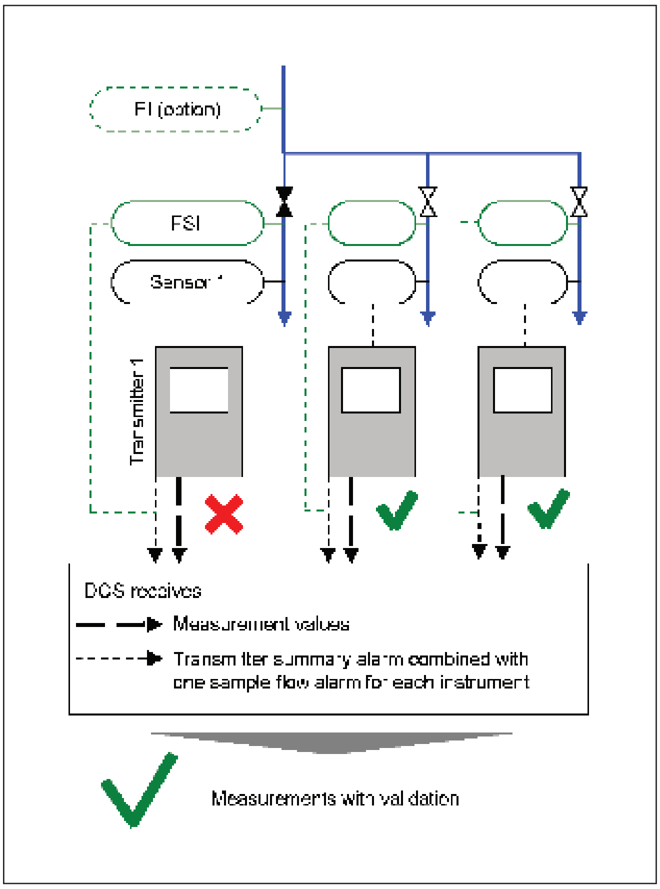


Figure 14:
Instrument flow monitoring at the instrument level.

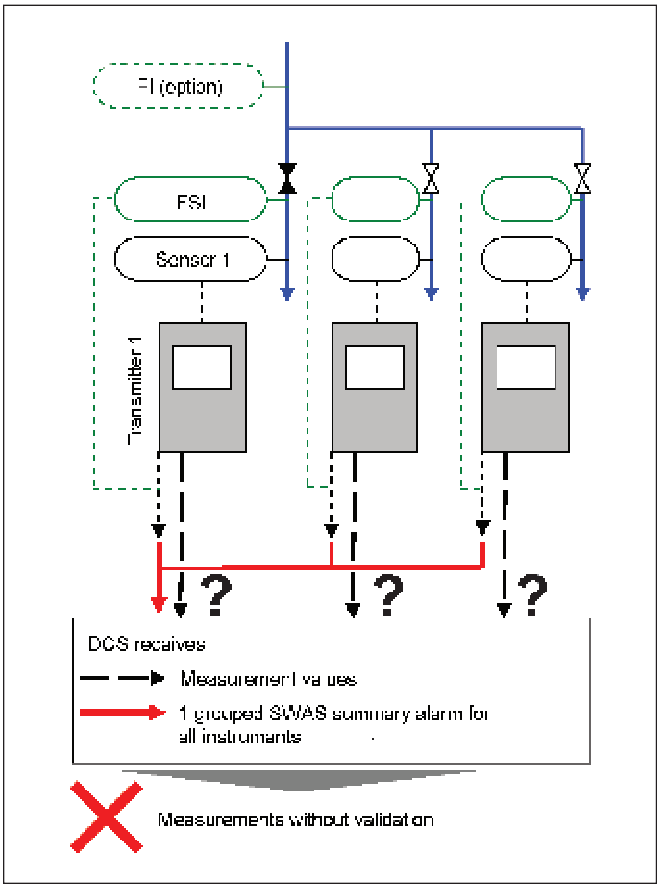


Figure 15:
Example of excessively grouped summary alarms.

munication options (e.g., Profibus/Modbus). The advantages of fieldbus-based signal exchange are:

- Lower cost for on-site cabling, electrical hardware and installation (30–40 % savings).
- More information from the instruments is available (sample flow, temperature, instrument status, error messages, etc).
- This information is not only available to the DCS, which only needs a few of the measurements and a general validation per measurement, but also to other parties (e.g., chemical or I&C department).
- System upgrades/extensions are easy to integrate.

One concern brought up against bus-based systems is that in case of a bus failure, all instrument data is inaccessible and the DCS can no longer control the cycle water chemistry. There are two solutions to bring redundancy into the signal exchange and address this concern:

- In addition to the bus communication, install hardwired signals for the critical measurements only (as stated above, the critical measurements are only a fraction of the parameters being monitored).
- Use redundant bus systems on the critical bus section between SWAS and DCS.

An overview of the history and development of DCS architecture and signal exchange can be found in [3].

WHY DOES THIS HAPPEN?

Why is it so common to find SWASs with major design flaws?

Water Analysis in Power Plants is a Niche Topic

- SWAS performance is not directly related to plant performance.
- The investment for the SWAS is proportionally very small (~0.2–0.3 % of the total plant cost).
- System design for water analysis in power plants is complex, mainly because it is linked to many engineering fields (water chemistry, mechanical engineering, process engineering, I&C engineering, civil engineering).

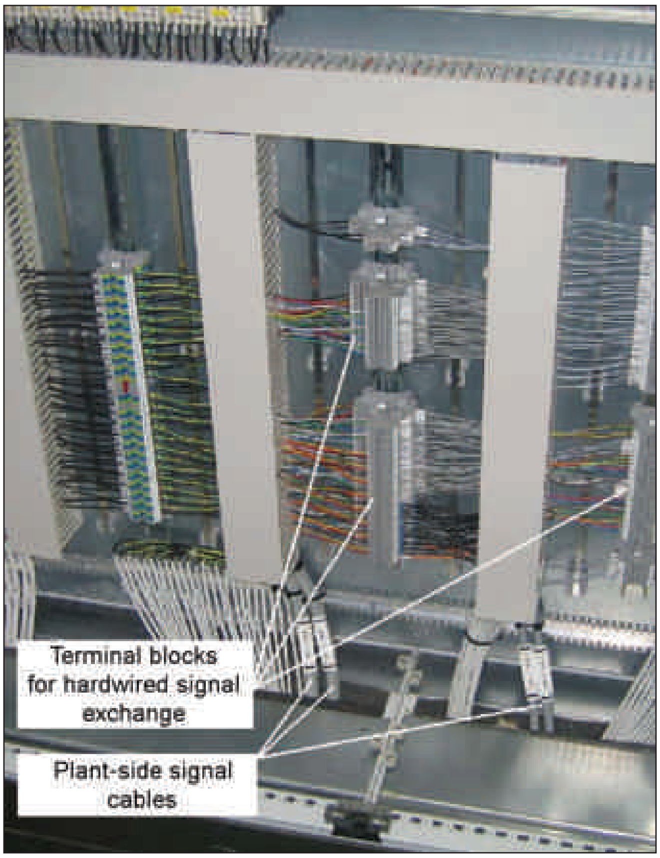


Figure 16:
Hardwired signal exchange to DCS – view inside a SWAS electrical cabinet.

Many Parties Are Involved in the SWAS Design and Manufacturing Process Requirements affecting SWAS design are defined in several stages and by different parties: the process starts with the definition of the chemical regime and online measurement requirements at the plant operator or owner's engineer's level. These requirements are embedded in the overall specification for the OEM. The OEM completes the general requirements and writes the specification for the SWAS. The system is built by a panel shop, commissioned by the OEM and handed over to the plant owner chemical and I&C staff. Figure 17 illustrates the usual parties involved in SWAS design for new power plant projects. It also shows the cascade of specifications between these parties.

Plant operator/owner, end customer:

- People with SWAS operating experience are not involved during the planning phase of a new plant.
- Some operators still rely on generously staffed chemical departments. SWAS deficiencies can easily be compensated with laboratory analysis of grab samples (typical in markets with low labor costs).
- Opinion about SWAS specifications: "Leave this detail to our owner's engineer" or "This is a detail point – just copy the requirements from plant XYZ" (built 20 years ago).

Owner's engineer:

- Involved in overall planning and general specifications.
- Opinion about SWAS specifications: "We also need to write some technical requirements for the SWAS. Let's see if we can recycle some specification from a previous project. The OEM will take care of detail design."

OEM:

- If the OEM discovers flaws in the SWAS specifications, it will be after signing the contract. At this point, it is difficult to negotiate changes with the end customer.
- Some OEMs will transfer the risk of SWAS supply to one of their subcontractors (e.g., the boiler manufacturer).
- Many OEMs have had water chemistry experts retire without successors.
- Responsibility for SWAS design and sourcing is often delegated to junior engineers or to third parties.
- Without technical assessment of SWAS quotes, OEM purchasing focuses on investment cost optimization.
- There is a lack of interaction between the concerned departments within the OEM (e.g., commissioning, purchasing, SWAS engineering, I&C engineering). Feedback from the field is rare due to the long time lag between purchasing and commissioning of a SWAS (often >1 year).
- Some OEMs hire technical consultants without up-to-date know-how and field experience about SWAS.

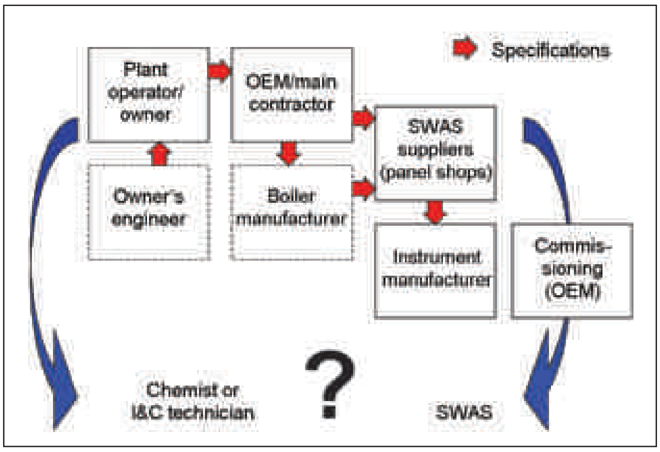


Figure 17:
Parties involved in SWAS specification and manufacturing.

- Opinion about SWAS specifications:
  "Let's see how we can combine customer requirements with what we are used to doing." At this stage the detailed SWAS specification is created. It often turns out to be unstructured (as a result of copying pervious projects and making adjustments), rich in inconsistencies and overloaded with general requirements about any topic that could be related to SWASs.

SWAS Supplier:

- The SWAS supplier market is fragmented: it consists mainly of small- to medium-size companies.
- Many of the SWAS suppliers simply purchase instrumentation and lack in-depth instrumentation know-how.
- Opinion about SWAS specifications:
  "We do not question the requirements. We strictly follow specification. We use any degree of freedom left to minimize our manufacturing costs (compact but impractical arrangements of components, instruments from short-listed vendor with lowest price)."

Instrument Manufacturer:

- Large instrumentation companies see SWAS applications as one small market segment among others. They are happy to provide panel shops with products from their standard portfolio and are not interested in the specifics of SWAS instrumentation.
- Specialist companies with a focus on a single measurement technique/limited parameter set (e.g., photometry, total organic carbon, oil-in-water, etc.) do not get involved in SWAS design topics either.

This constellation as a niche topic requiring specialist know-how on the one hand and an extreme fragmentation of responsibilities on the other is in essence what allows design sins as illustrated above to continue to be committed.

WHERE CAN WE START TO CHANGE THINGS?

Plant operators starting new power plant projects:

- Pay attention to the SWAS topic early. Visit plants with state-of-the-art SWASs.
- Make sure SWAS requirements are up to date and binding for OEM.
- Involve your chemical department.

At the **OEM** level:

- Keep technical know-how up to date.
- Gain feedback about SWAS operation from the field.
- Consider the total cost of ownership for a SWAS, including commissioning and after sales.
- Choose SWAS suppliers that provide on-site service in your regional markets and that have system design AND instrumentation expertise.

All **parties involved in defining SWAS specifications** can evaluate their current SWAS specification with the following questionnaire:

- How good is the structure of the SWAS specification?
  - Does the specification include sufficient context information (e.g., plant type and configuration, operating modes, general plant layout, site conditions)?
  - If the specification is for several subsystems (e.g., several racks located in different locations), are these subsystems defined concisely in a part describing the scope of supply? Does the specification consistently refer to these subsystem definitions?
  - Does the specification include a structured overview of all applicable documents?
  - Is the specification file package organized consistently with this structured overview?
  - Does the SWAS specification package include fewer than 30 files?
- What is the quality of the SWAS specification?
  - Does the specification include background information about plant type, operating mode, chemical regime, climatic conditions, plant overall layout?
  - Is the scope of supply listed concisely (1–2 pages max.), including all subsystems, spares and consumables, services and documentation required?
  - Are the sample lines clearly identified, grouped by subsystem and characterized with temperature, pressure, measured parameters, measuring ranges?
  - Are there separate specifications for sampling and analysis subsystems in the water/steam cycle and in the main cooling water/discharge water?
  - Does the specification include requirements that will avoid the typical design sins?

If more than three answers are NO, we recommend that you contact an expert in the field to rework your SWAS specification.

waesseri

Publisher of the PowerPlant Chemistry® Journal

Subscription Form

To subscribe to the PowerPlant Chemistry® Journal, please fill in this form and tick the appropriate boxes.

Start date:		End date:	
Subscribers address	Printed Version	e-paper*	Printed Version + e-paper*
Europe	200 € ☐	172 € ☐	210 € ☐
Outside Europe	220 € ☐		230 € ☐

* A subscription to our e-paper requires accepting and signing of a license agreement.

First name:	....	Name:	....
Company:	....		
Company address:	....		
City:	....	Postal/ZIP code:	....
Country:	....	State:	....
E-mail address:	....	Phone:	....

Charge my credit card: .... (MasterCard/Eurocard, VISA or Amex)

Card Holder's Address (City): ....

Name of Cardholder as Printed on the Card: ....

Credit Card Number:	....	Expiration Date:	.....................(MM) ....(YY)
CVV/C ....(You can find your card verification value/code on the front of your American Express credit card (a four-digit number) above the credit card number on either the right or the left side of your credit card. This number is printed on your MasterCard and Visa cards in the signature area on the back of the card (it is the last 3 digits after the credit card number in the signature area of the card).			
Signature:		Date:	..................................(DD/MM/YYYY)
Email or fax this form to: +41 44 940 23 40 subscription@waesseri.com			
Remarks:			

www.swansystems.ch

PPCHEM
POWERPLANT CHEMISTRY

SPECIAL PRINT

Seven Sins of Steam Sampling

Manuel Sigrist
CTO
SWAN Systeme AG, CH-8340 Hinwil

REFERENCES

[1] *Steam and Water Sampling, Conditioning, and Analysis in the Power Cycle*, **2008**. ASME International, New York, NY, U.S.A., ASME PTC 19.11-2008.
[2] Maurer, H., *PowerPlant Chemistry* **2006**, 8(11), 658.
[3] *Instrument Engineers' Handbook: Process Control and Optimization (Ed.: B. G. Liptak),* **2006**. CRC Press, Boca Raton, FL, U.S.A.

THE AUTHOR

Manuel P. Sigrist (M.S., Mechanical Engineering, École Polytechnique Fédérale de Lausanne, Switzerland) has worked for ABB (now ALSTOM Power AG) in the gas turbine design group, for McKinsey & Company Inc. as a consultant, and for MTS AG (now AAT AG) as a project engineer for balance of plant optimization and gas turbine refurbishments of power plants. In 2006, he joined the Swan Group, a manufacturer of water/steam instrumentation and sampling systems, as the technical director of SWAN Systeme AG.

CONTACT

Manuel P. Sigrist
SWAN Systeme AG
Studbachstrasse 13
CH-8340 Hinwil
Switzerland

E-mail: manuel.sigrist@swansystems.ch