ASME Meeting of the Research Committee on Power Plant & Environmental Chemistry

Detroit October 13th – 15th

Introducing VGB Standard S006-2012

Sampling and Physico-Chemical Monitoring of Water and Steam Cycles

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Date: September 2014

Rev: 1.2

- **What is the right water chemistry?**
- **What are key and diagnostic parameters?**
- **What are the operating limits?**

VGB S010-T-00 2011 (former VGB R450 L)
Feed Water, Boiler Water and Steam Quality in Power Plants

- Describes water steam cycle components and water chemistry effects
- Describes water treatment methods for WSC
- Defines water chemistry parameters and action levels

- **Where should samples be taken?**
- **How should sample be extracted, transported and conditioned?**
- **Requirements for systems and online analysers?**

VGB S006-00 2012 (NEW GUIDELINE)
Sampling and Physico-Chemical monitoring of Water and Steam Cycles

- Describes how to select sample points
- Describes how to realize sample transport and conditioning
- Defines minimum requirements for online analysers
- Provides recommendations for operation, maintenance and quality assurance

S006 Workgroup participants and background

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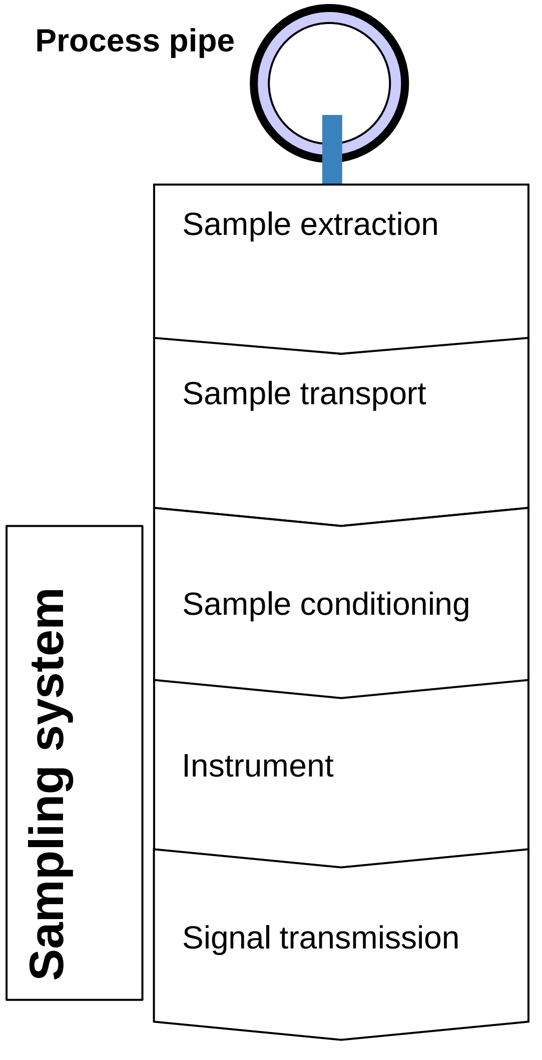
24 people involved in water chemistry as...

- Operators and plant chemists,
- EPC engineers in charge of water-chemistry systems
- water-chemistry consultants
- sampling system manufacturers
- online and laboratory instrument manufacturers

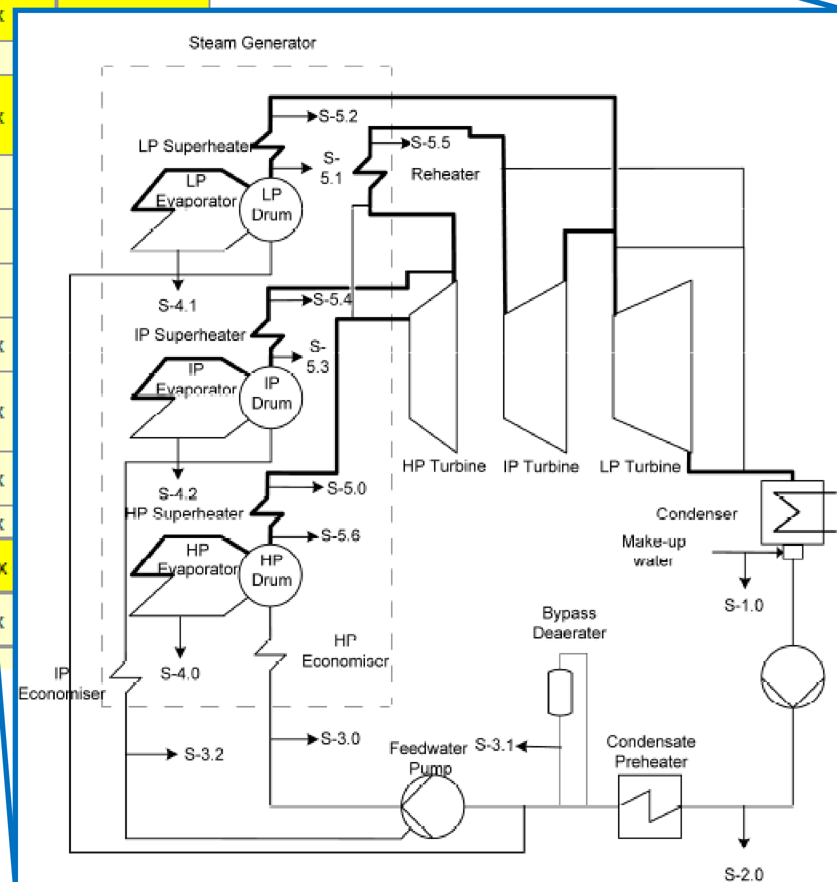
VGB Guideline S006-2012 released September 2012
Contents and structure

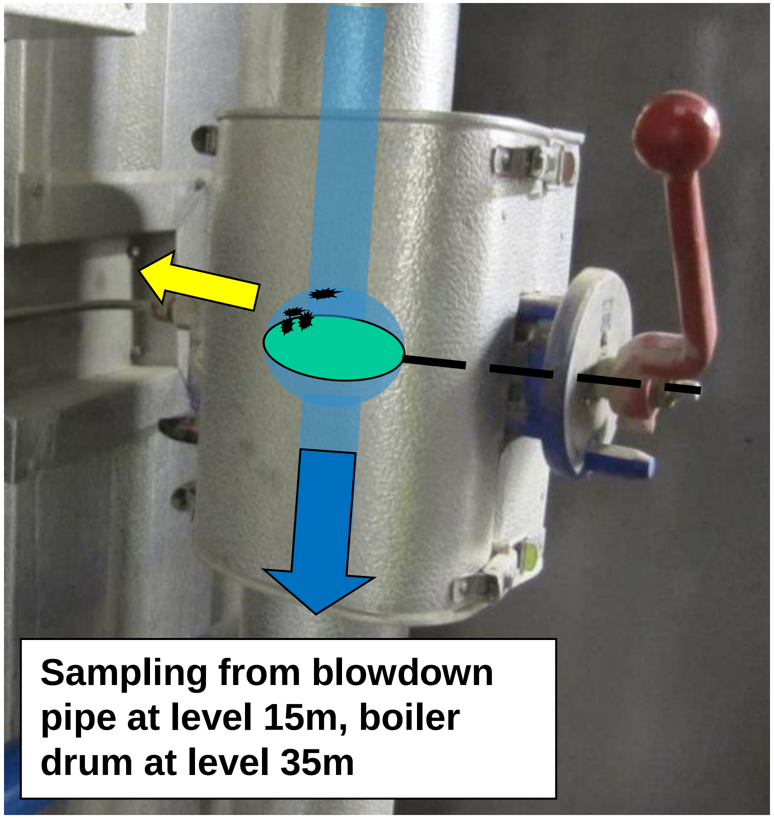


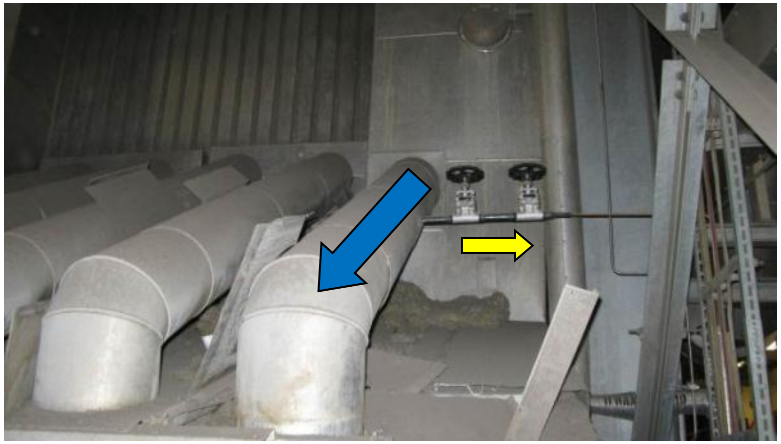
5 examples of typical water-steam cycles

Indi-cated Text	Location of sampling point	SPP with once-through boiler	Triple pressure CCPP with Benson type HP section	SPP with drum-boiler, using demin-eralised water	Triple pres-sure CCPP, drum-type HRSG	SPP with drum-boiler, using salt-containing water
S-1.0	Make-up water downstream of DI water pumps	x	x	x	x	
S-1.1	Treated make-up water					
S-2.0	Main condensate (down-stream of condensate polish-ing plant)	x	x	x	x	
S-2.1	Raw condensate upstream of condensate polishing plant	x	x	x		
S-2.2	Condensate drains LP heater	x		x		
S-2.3	Main condensate upstream of feed water tank	x		x		
S-2.4	Returned process conden-sate	x	x	x	x	
S-2.5	Process steam condensate downstream of condensate polishing plant	x	x	x	x	
S-2.6	Condensate from district heating grid	x	x	x	x	
S-2.7	Condensate storage tank	x	x	x	x	
S-[illegible]	[illegible]	x	x	x	x	
[illegible]	[illegible]				x	

Applicable sample lines





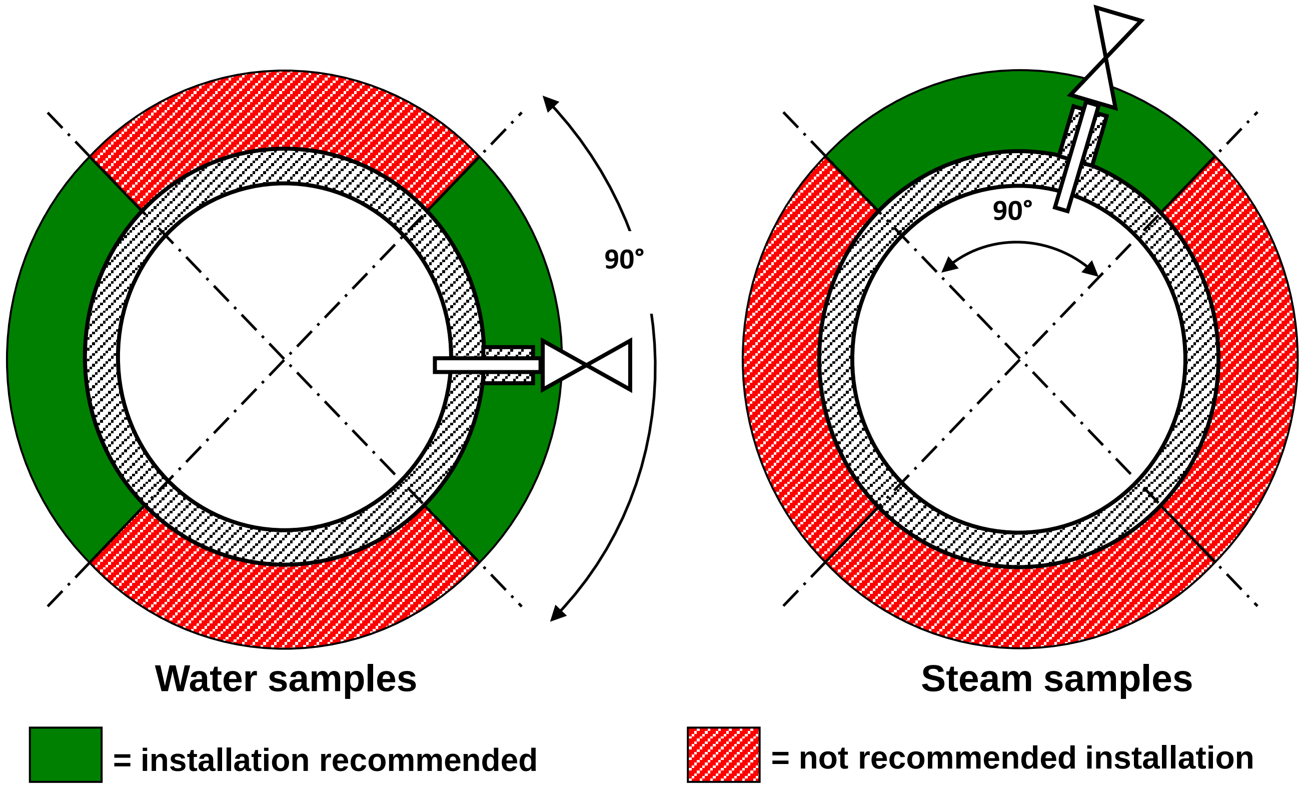


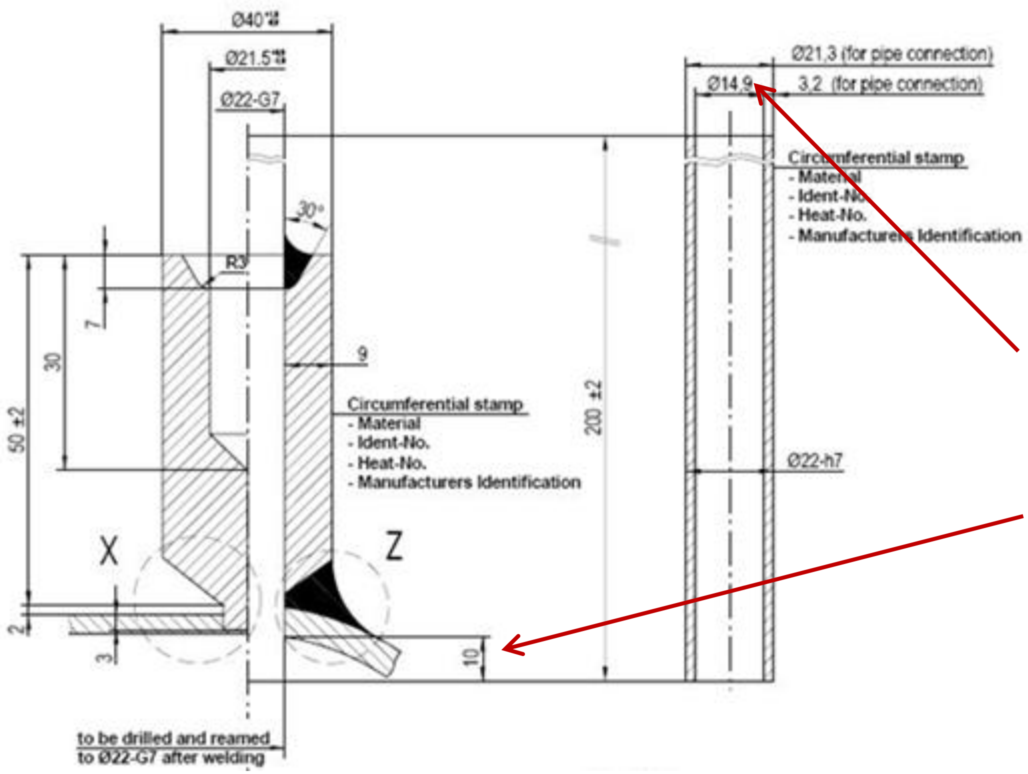
- No representative sample
- High accumulation of solid particles

- Correct extraction point for boiler water from downcomer pipe

Samples are to be taken...

1. **...from vertical process pipes with downwards flow**
2. **If not possible, sample from horizontal process pipe at following positions:**





- **Isokinetic sampling is whishful thinking for the purpose of online monitoring**
- **Simpler probe designs have similar performance**

- Recommended inner diameter of probe ca. DN15mm up to system shut-off valve
- Sampling from within the stream: penetration depth ca. 10mm from wall

Dimensions

- Recommended inner diameter DN 6mm for water and steam
  (Sized for 40-60l/h condensate flow)

	Ø Inner diameter of sample line		
Flow speed condensate [m/s]	4mm	6mm	8mm
0,5	22,6 l/h	50,9 l/h	90,5 l/h
1,0	45,2 l/h	101,8 l/h	181,0 l/h
1,5	67,9 l/h	152,7 l/h	271,4 l/h
2,0	90,5 l/h	203,6 l/h	361,9 l/h

- The magic 6ft/s (1.8m/s) rule is obsolete!
- Steam lines <50bar require larger tubes (DN 15 oder more)

Materials:

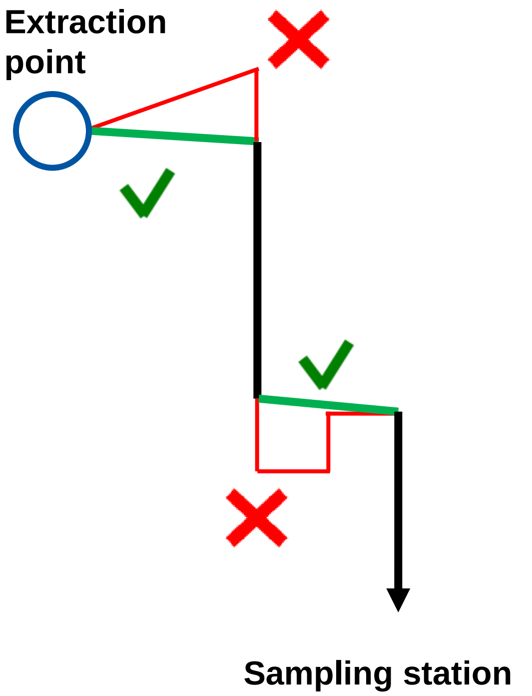
- Inert stainless steel to minimize sample bias. Up to 575°C z.B. 1.4571, 1.4404 gem. EN 10297-2 bzw. EN 10216-5.

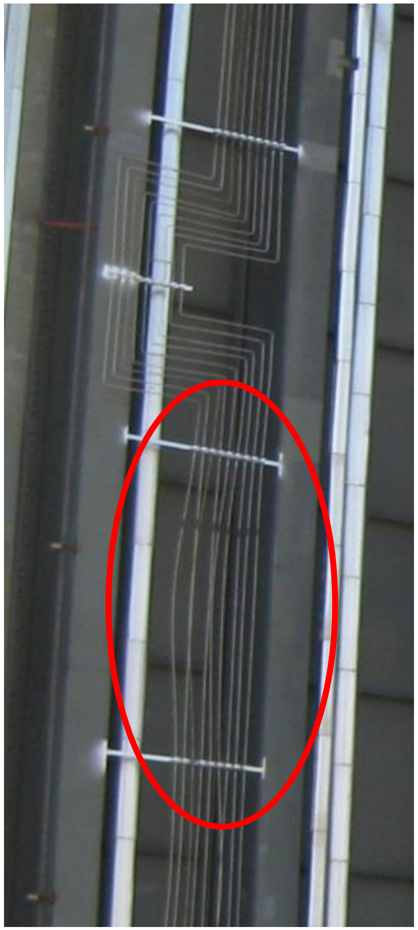
Sample line routing

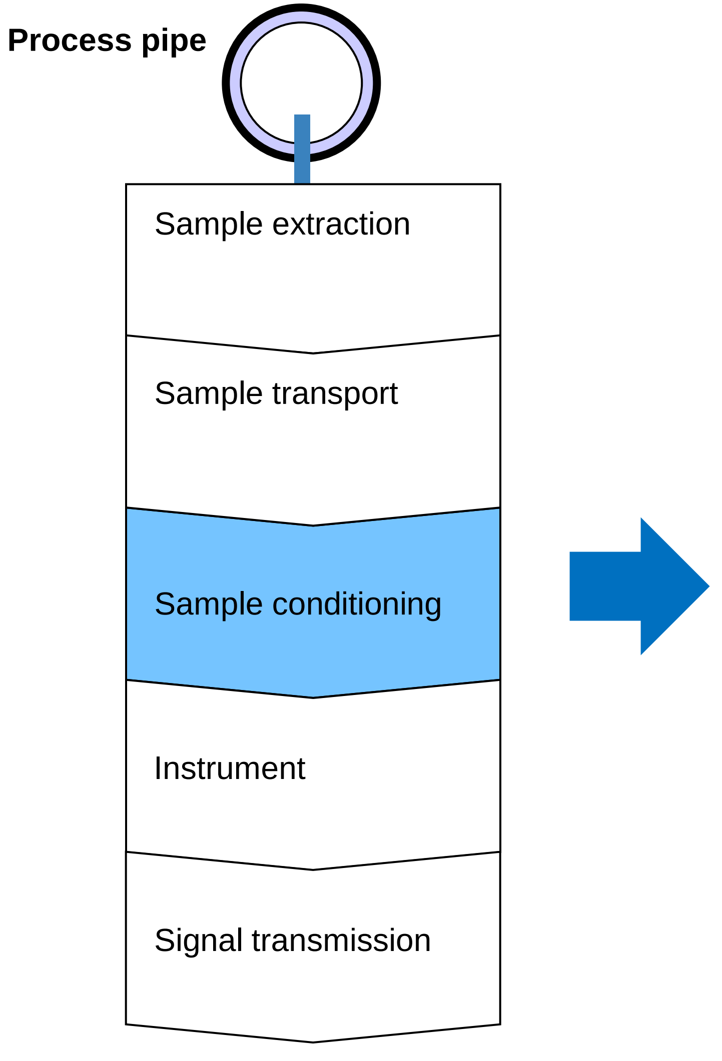
- Always sloped downwards in flow direction (Minimal sedimentation)
- Supports: take into account thermal expansion
- Avoid excessive length.

Insulation

- Contact protection in critical zones only
- Insulation only if freezing protection is required







Process side conditions

- High temperatures /pressures
- Fluctuating plant load, Starts/stops

Sample conditioning

- Functional requirements
- Safety requirements
- Operation & maintenance requirements
- Cost of ownership

Downstream requirement

- Reliable sample flow for instruments & grab
- Pressure and temperature safety

Sample line isolation

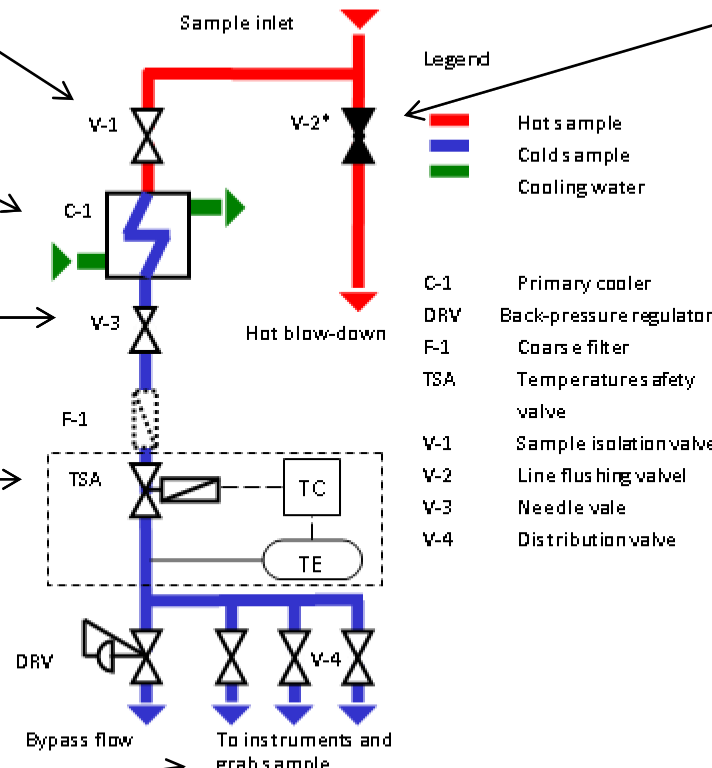
Sample cooling

Flow throttle
Pressure reduction

Temperature shut-off (safety)

Sample pressure regulation

Sample distributon to instruments



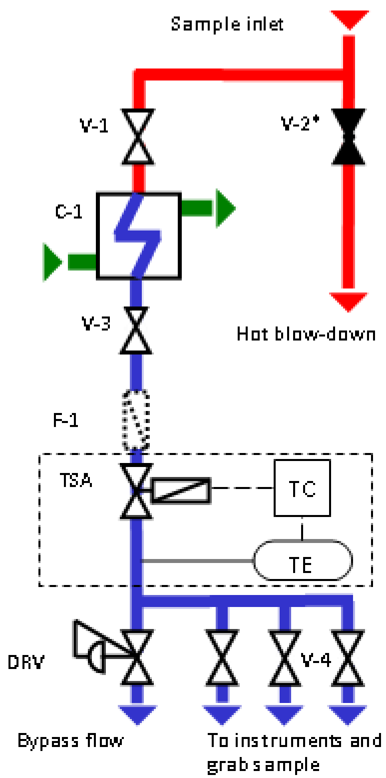
Sample line flushing

Secondary cooling

Filtration

Mandatory

Optional



Upstream conditions

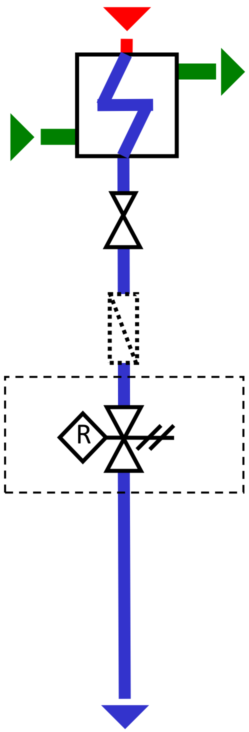
- Most samples have temperatures >50°C, up to 600°C
- Sample P 1-250 bar

Temperature shut-off is a mandatory safety function.
What are the design requirements?

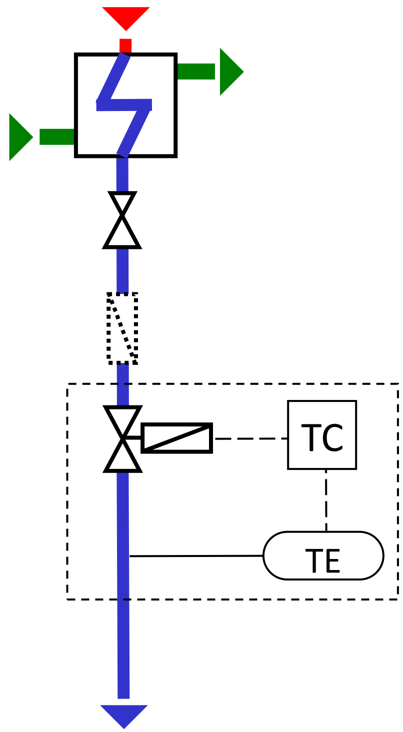
Downstream

- SWAS instrumentation in shelter or room
- Instruments and other components not rated for high temperatures
- Operators taking grab smaples
- Open drains

Chapter 4.5.2.7 Temperature protection
Design requirements



Spring loaded mechanical T-protection valve



Solenoid valve with T-controller

- Stop sample flow completely
  - No bypass flow allowed: hot sample must be stopped
- Full line pressure rating for all components up to temperature shut-off valve
- Fast reaction (<3seconds)
  - Temperature sensor time lag?
  - Valve actuator switching time?
- Fail-safe in case of loss of power

Sample line isolation

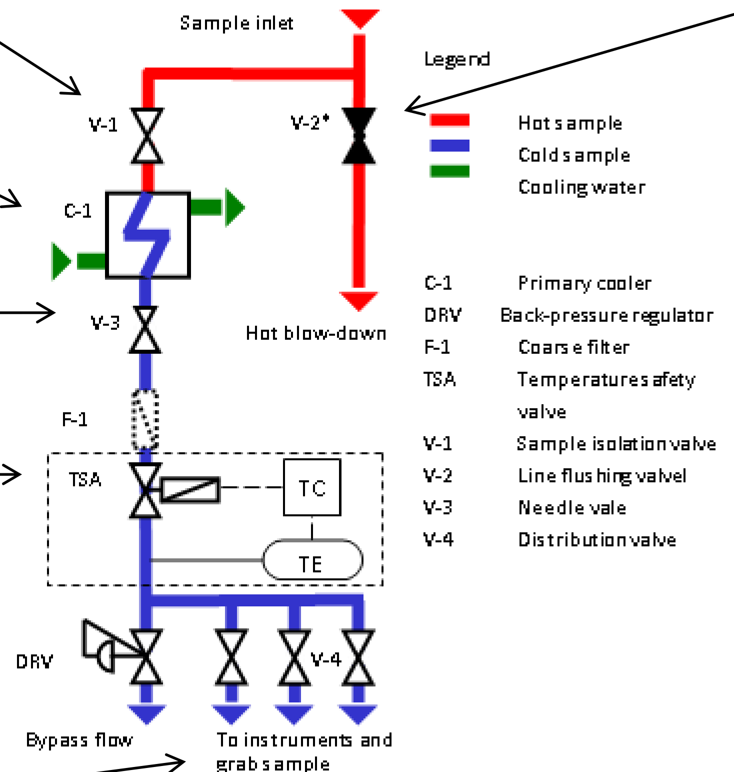
Sample cooling

Flow throttle
Pressure reduction

Temperature shut-off (safety)

Sample pressure regulation

Sample distributon to instruments



Sample line flushing

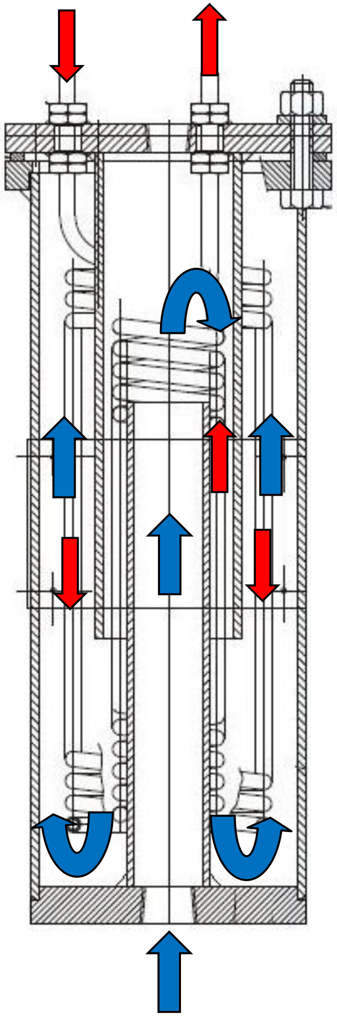
Secondary cooling

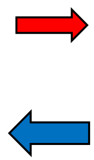
Filtration

Mandatory

Optional

Primary cooling - helical tube sample cooler design basics





Characteristics

- Sample flows in cooler coil /double coil (typically 40 – 60l/h). Coil sized for high pressure and high temperature
- Cooling water flows on shell side (counterflow guided by baffles). Shell sized for lower pressure, highly turbulent cooling water flow

Key thermodynamic and hydraulic data

- Typical heat exchange area 0.2 - 0.35 m2
- Cooling power 20 – 40kW
- CW mass flow required: ~20x sample flow for water, ~40x sample flow for steam
- Pressure drop accross cooler on CW side 0.4 – 0.7bar
- Sample outlet T 2-3°C above CW inlet T

Features for maintainability

- Flanged shell to allow coil inspection / cleaning
- Port at lower end for purging and/or CW supply

Primary sample cooling

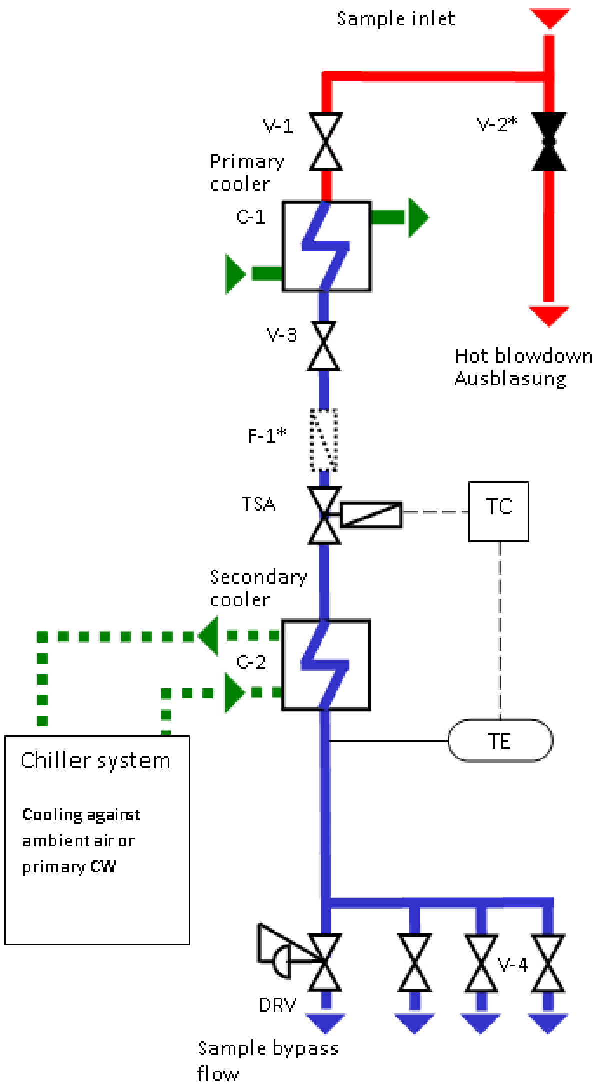
- Reduces sample temperature to primary cooling water inlet T plus 2-3°C
- Sample temperature changes with primary CW temperature

Secondary sample cooling (acc. VGB S006 2012)

- Should be used **ONLY if primary cooling water is too warm** to reduce sample temperatures below 45°C
- Should **simply reduce sample temperature below 45°**, where online instruments can handle the sample and compensate measurements to ISO conditions.

- Secondary cooling **SHOULD NOT BE USED FOR THERMOSTATIC CONTROL OF SAMPLE T AT 25°C!**
  - It does not work reliably in all load conditions
  - T-changes downstream of the chiller occur
  - It is expensive (invest and maintenance)

WHY NOT?



Sample line isolation

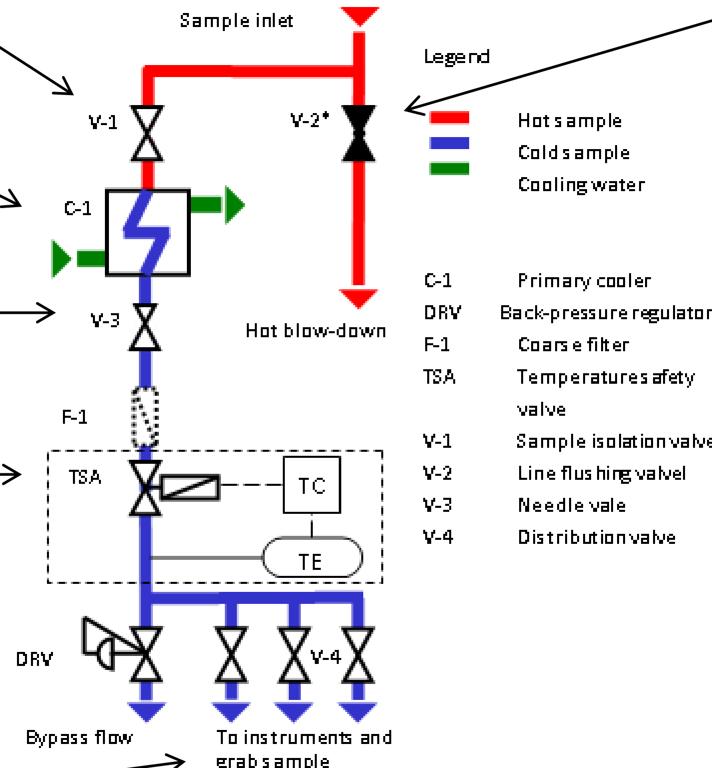
Sample cooling

Flow throttle
Pressure reduction

Temperature shut-off (safety)

Sample pressure regulation

Sample distributon to instruments



Sample line flushing

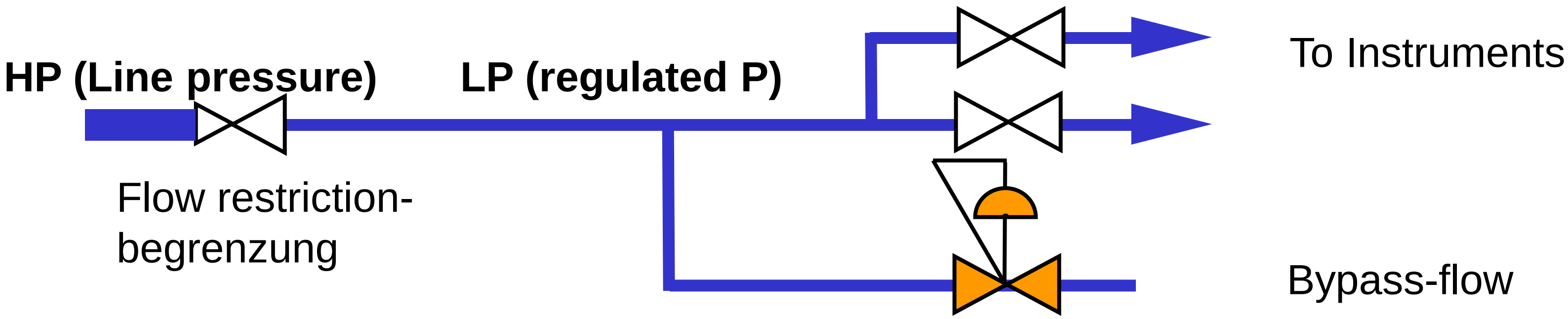
Secondary cooling

Filtration

Mandatory

Optional

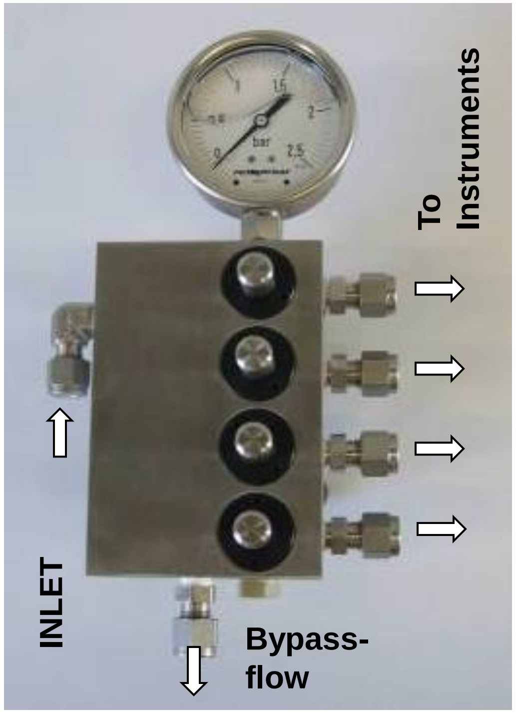
Sample pressure regulation using back-pressure regulator

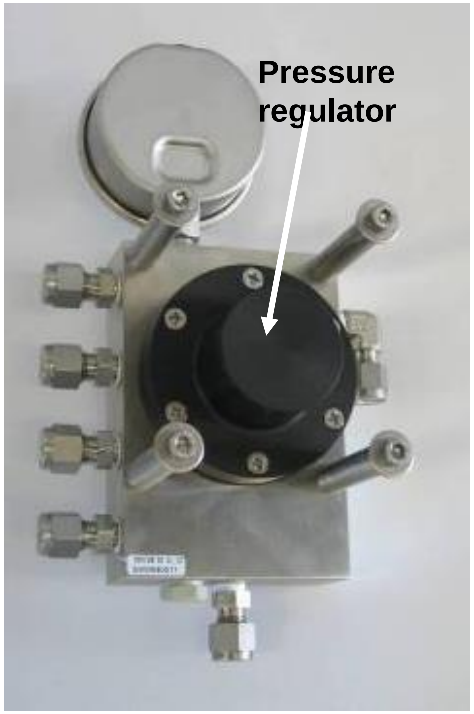


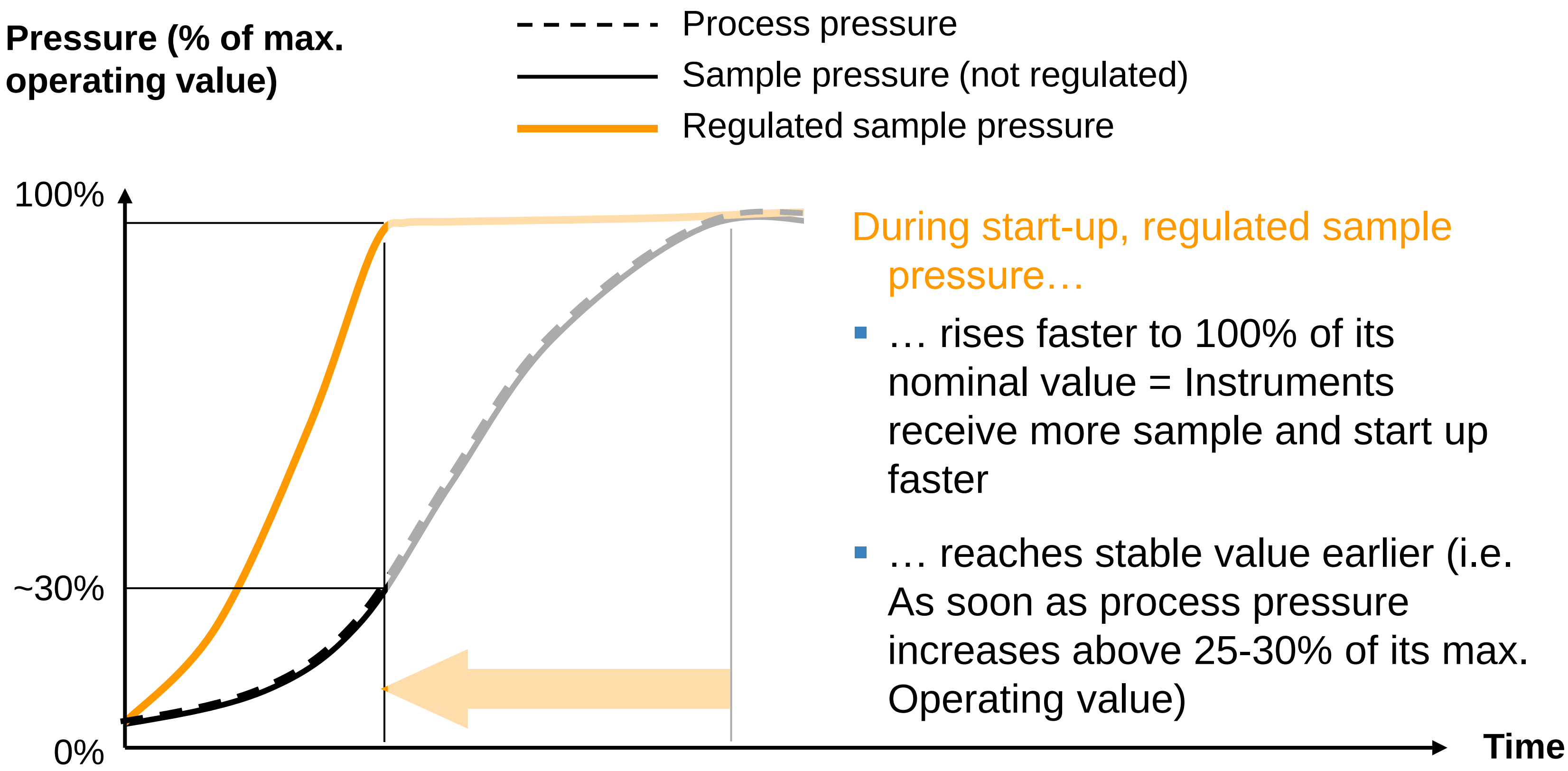
Example

Back-pressure regulator

- Integrated manometer and distribution channels to instruments
- Fixed regulating pressure of 0.5bar
- 5-150 l/h normal operating range







During start-up, regulated sample pressure…

- … rises faster to 100% of its nominal value = Instruments receive more sample and start up faster
- … reaches stable value earlier (i.e. As soon as process pressure increases above 25-30% of its max. Operating value)

Stable regulated sample pressure =

- Less disturbances, less operator interventions
- Reliable operation

4.6.1 General instrument transmitter requirements

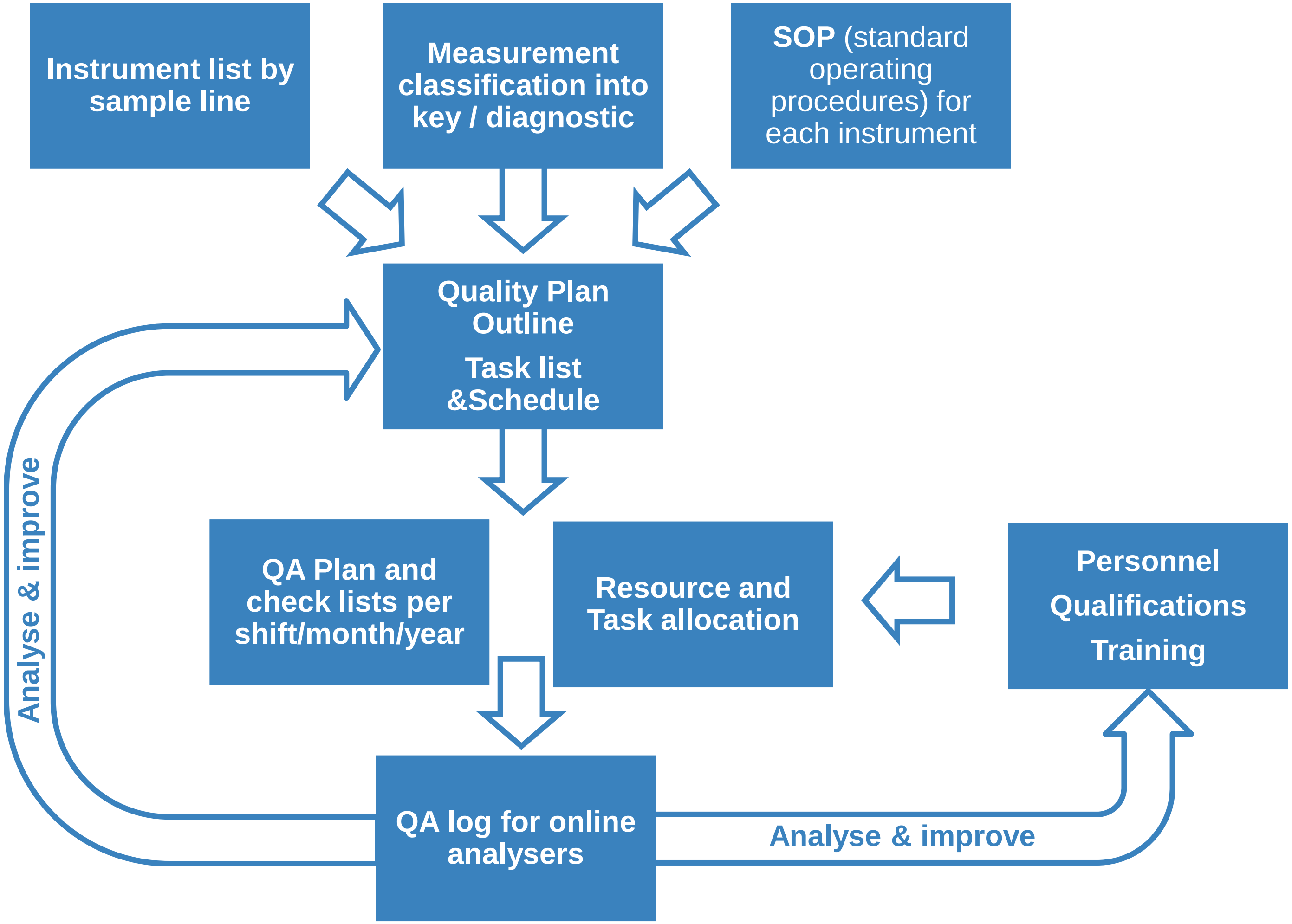
- Min IP54 protection level or higher
- Parametrizable on site. Lockable settings.
- Summary alarm required
- Simulation of analog outputs shall be possible
- Sensor and transmitter close to each other (easier handling) and use of short cables for passive analo sensors

4.6.2: Flow rate monitoring:

- Mandatory remote sample flow monitoring (for key parameters)

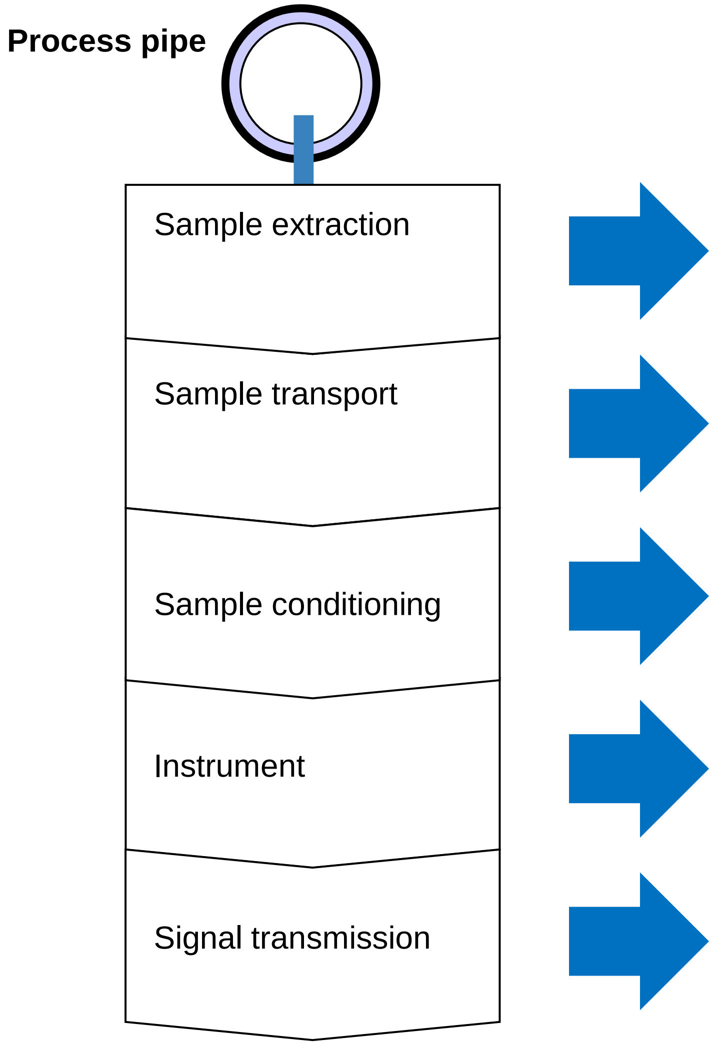
Chapter 4.6: Specific requirements for most frequent online analysers (extract only)

Parameter	Main requirements
Specific conductivity (SC)	Adequate and high precision cell constant Temperature compensation for neutral salts, strong acids, strong bases, ammonia and linear coefficient
Acid conductivity (AC)	Deaeration of cation exchanger Non linear temperature compensation for strong acids
Degassed acid conductivity (DAC)	Same as fro AC Reproducible degassing method
pH	pH electrode adapted to low conductivity waters Atmospheric outflow of flow cell Temperatue compensation according to Nernst and to solution temperature Calculated pH from conductivities as alternative for AVT in alcalic samples
Oxygen **O2**	Leak tightness Sample switching not recommended Automatic sensor verification recommended in case of oxygenated treatment
Silica **SiO2**	Temperature effects on reaction time must be considered Cross-sensitivity to phosphate must be considered
Sodium **Na**	DIPA as prefered alkalasing agent (ammonia as alternative) Permanent monitoring of pH recommended Auto-calibration with standard addition recommended for critical applications


Instrument list by sample line
Measurement classification into key / diagnostic
SOP (standard operating procedures) for each instrument
Quality Plan Outline
Task list &Schedule
Analyse & improve
QA Plan and check lists per shift/month/year
Resource and Task allocation
Personnel
Qualifications
Training
QA log for online analysers
Analyse & improve

Sample TAG / Name	**Instrument** **Manufacturer / Model / Ser. Nr.**	**Parameter / TAG**	**Cat.**	**QA measures**	**Frequency**	**Responsible**
HP Feedwater 10QUA20	Swan / AMI Deltacon Power SN 1034, 2009	SC CQ010 AC CQ020 Ph CQ030	KEY	Check sample flow	1/Shift	Shift
				Check resin	1/Week	Lab techician
				Check cond. with reference instrument	1/Year	Chemist
Sample line B ##QUx##	*Manuf. Instrument XY Type, serial number*	*Measurement CQ### CQ### ...*	*KEY or DIAG*	*Check sample flow*	*1/Shift*	*...*

Conclusions



Essential items from process to online measurement

- Correct extraction point
- Adequate extraction probe

- Sample pipe size / material
- Sample pipe length – subsystem arrangement
- Pipe routing

- Key functions (temperature protection, cooling & pressure regulation)
- Functional arrangement by sample line

- Temperature compensation
- Self-diagnosis capability
- Functional instrument arrangement

- Digital bus vs. analog signal exchange
- Remote diagnostic information to DCS

Links and references

VGB Homepage
http://www.vgb.org/en/startpage.html

Guideline VGB-S006-2012
„Sampling and Physico-Chemical Monitoring of Water and Steam Cycles“
http://www.vgb.org/shop/s-006-2012-en.html

Guideline VGB-S010-2011 (Former VGB R450L)
„Feed Water, Boiler Water and Steam Quality for Power Plants / Industrial Plants“
http://www.vgb.org/shop/s-010-2011-en.html

Thank you for your attention!

ANNEXES

- Illustration of chiller myth

25°C = reference temperature for all online measurements

Temperature compensation by the online instruments

Condition sample at 25°C

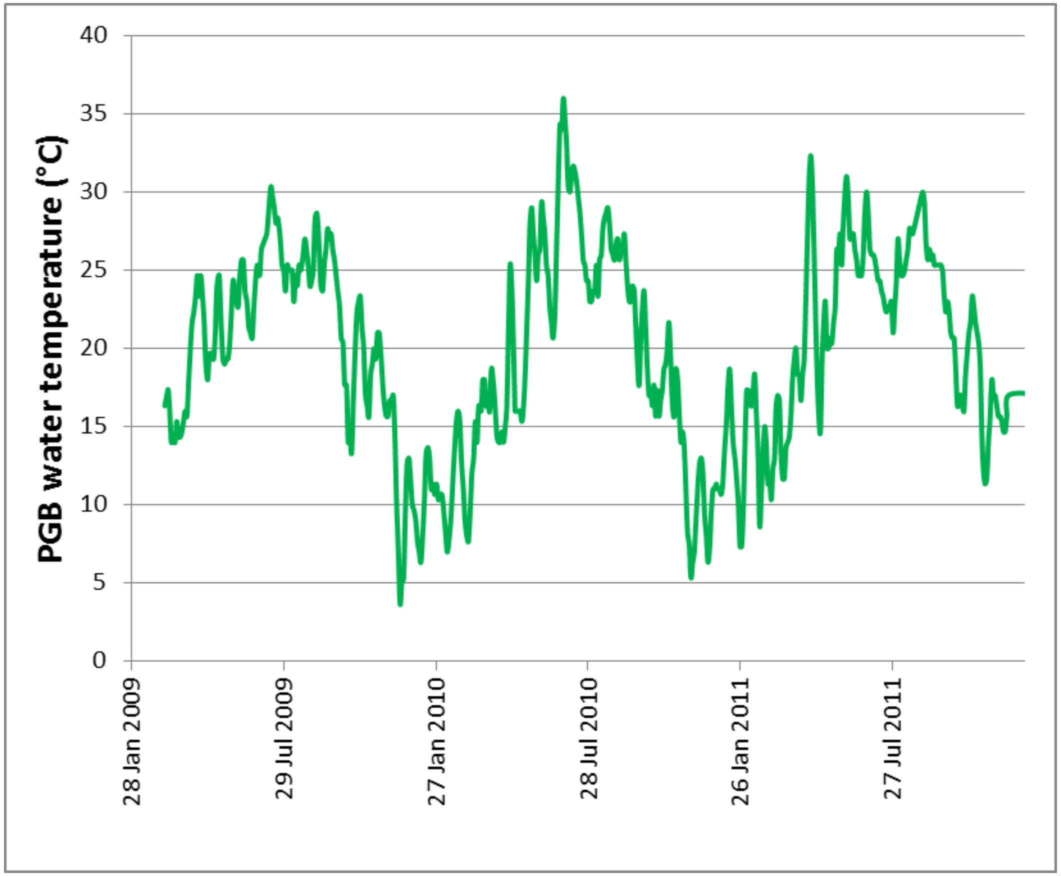
Can I trust this?

Sounds like the easier way...

Is it REALLY?

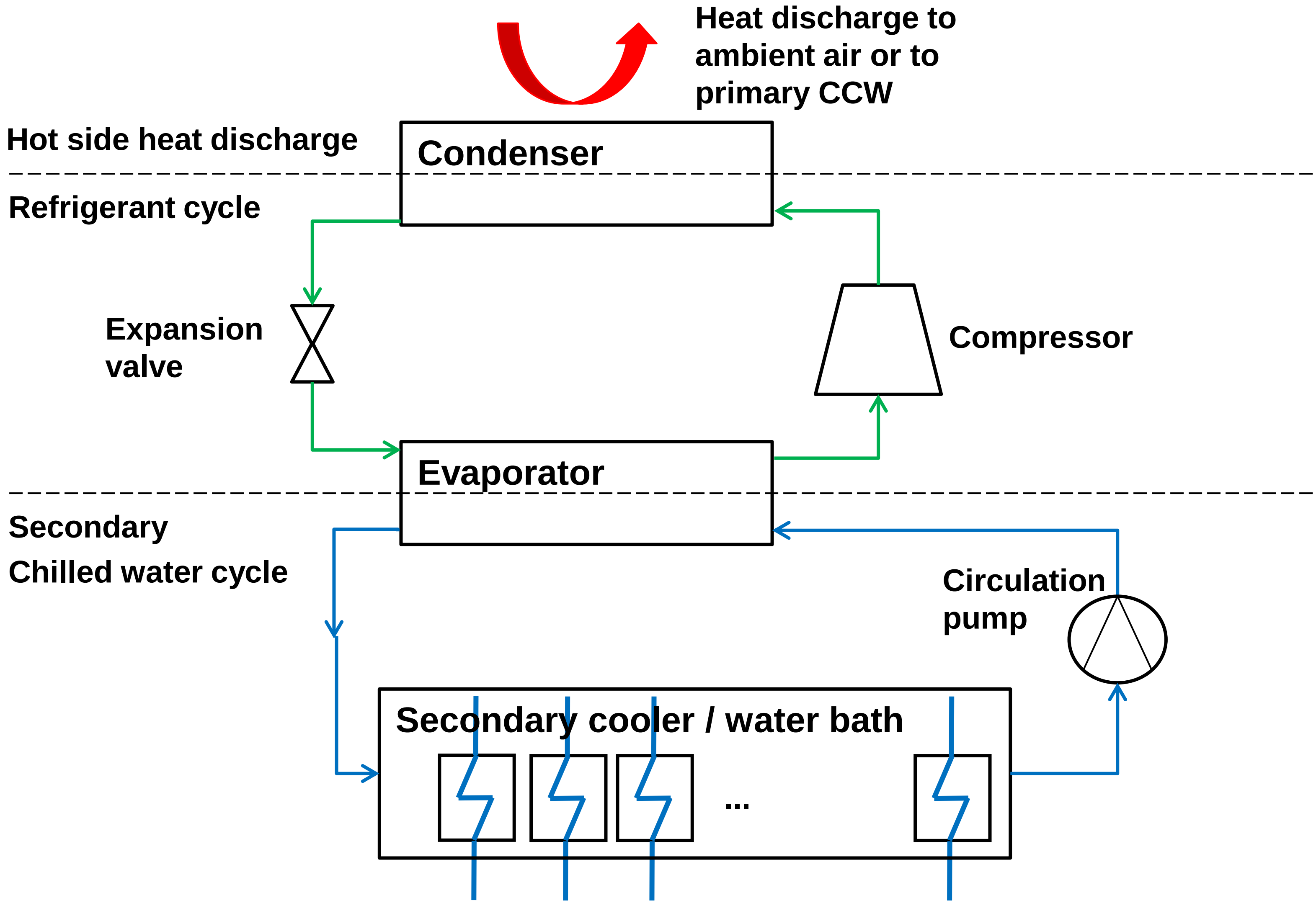
CCW temperature changes with ambient T

Typical average daily CCW temperature for CCPP in Northern Europe



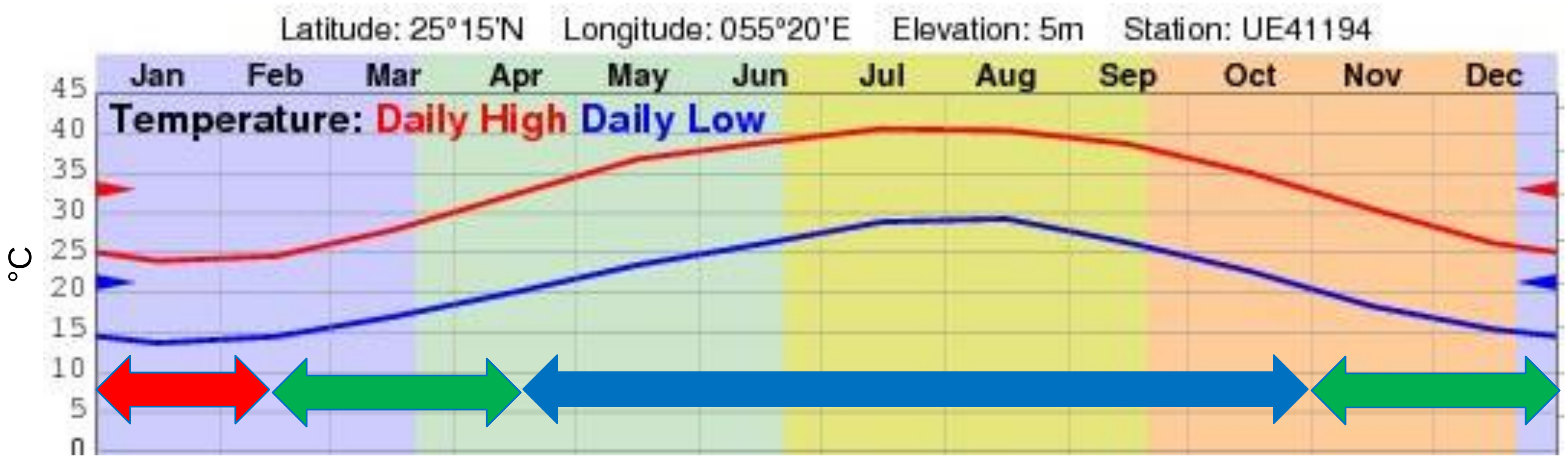
- 30° MIN – MAX span (seasonal)
- Day-night variations af several °C
- Sample temperatures vary in the same span
- Vast majority of new sampling and analysis systems run WITHOUT secondary cooling and chilelr system

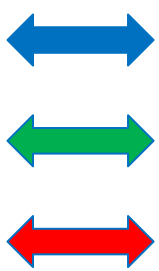
Typical secondary cooling and chiller set-up



Example of chiller requirements – bad practice
Chiller attempting precise sample T control at 25°C

Daily high / low T-chart for Dubai, UAE





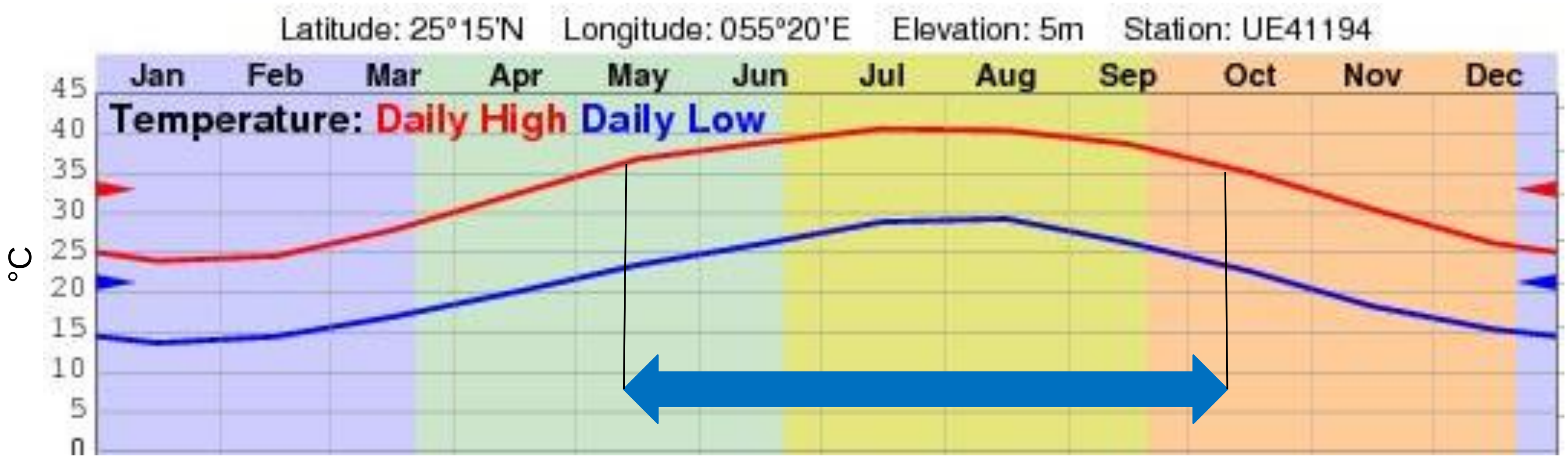
Chiller must operate all year round with changing load cases:

- in cooling duty during extended hot period, when PGB-cooling water is >25°C (typically ambient >20°C)
- in mixed duty (part load cooling daytime, heating nighttime, 2 no-load-transitions every day) during intermediate periods
- mainly in heating duty during cold period where PGB-coling water is below 23°C

CHILLER IS A SINGLE POINT OF FAILURE

Example of chiller requirement – good practice
Chiller used only for temperature reduction during hot period

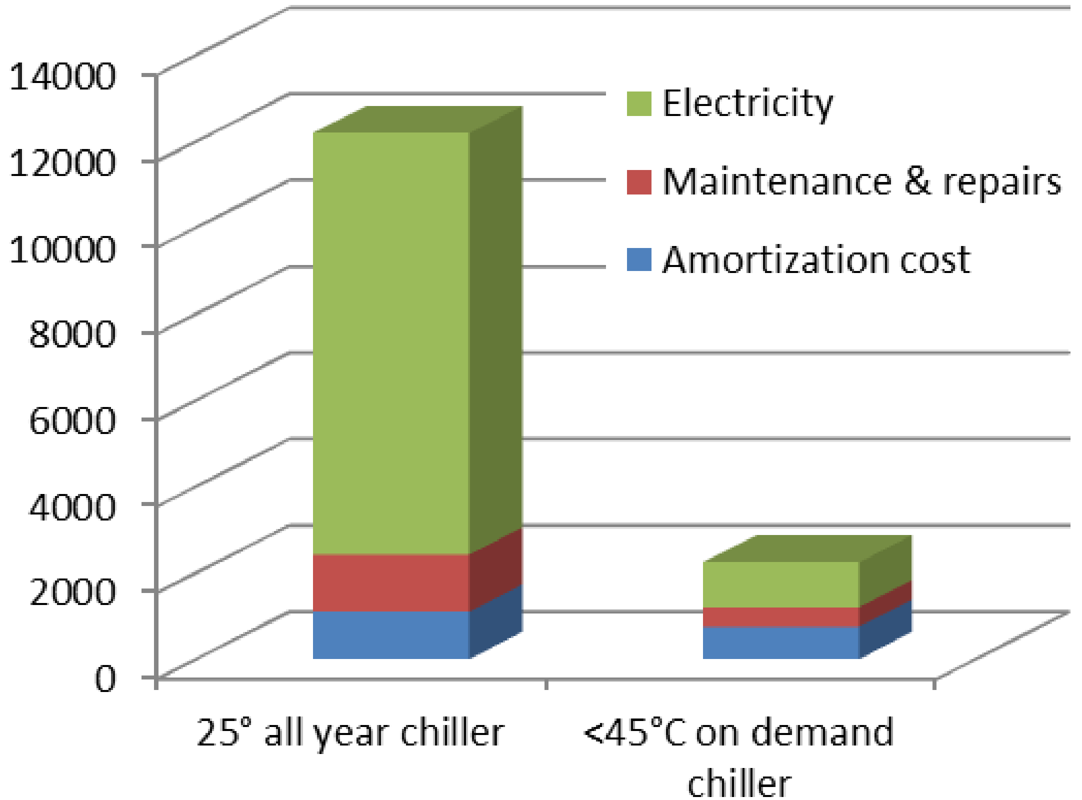
Daily high / low T-chart for Dubai, UAE



- Chiller operatoes in cooling duty, only during hot period, when PGB-cooling water is >40°C (typically ambient >35°C)
- Even in during hot period, the chiller is not required during night time
- Chiller is sized only to bring down sample temperature in a range of 35 - 45°C (reduces chiller size, facilitates T-control in all load conditions)
- **REQUIRES ONLINE INSTRUMENTATION WITH CORRECT TEMPERATURE COMPENSATION**

Unnecessary secondary cooling is expensive…
…too expensive to do it just to be on the safe side!

Chiller operating cost (US$/year)

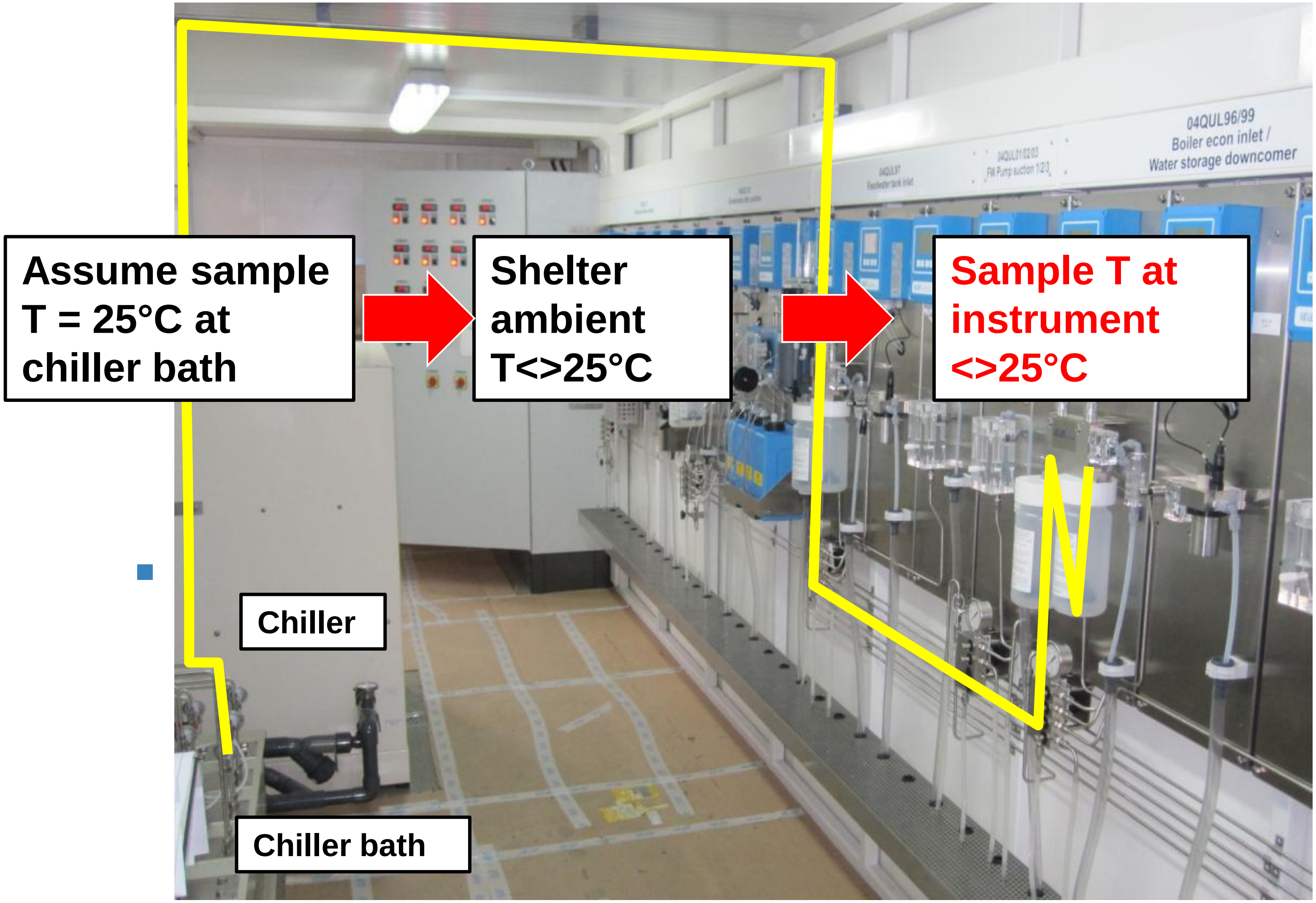


Sampling system with 15 sample lines, electricity cost 20ct/kWh, amortization over 20 years,
25°C all year chiller: invest 22k, 7000 h/y, 20kW cooling power, average η0.4
-45°C chiller: invest 15k, 2000 h/y, 10kW cooling power, average η0.3

Further arguments against all year chiller to 25°C:

- Chiller failure more likely in all year duty
- Sample temperature may still change downstream of chiller (e.g.room temperature influence**)**

Sample temperature – quo vadis?



ANNEXES

- 4-20 mA limitations

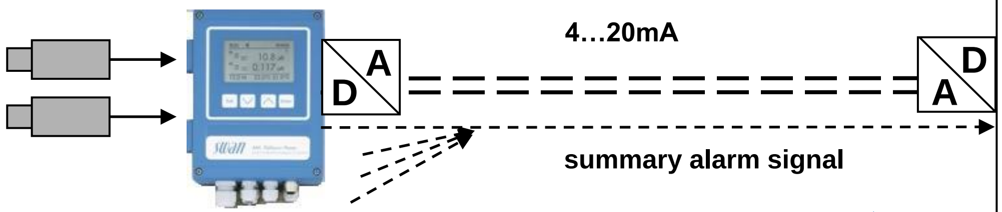
Hardwired signal exchange - the traditional bottleneck in signal exchange for online water analysers

Instrument level

Sensors **Transmitters**

Hardwired signal exchange

Plant operator level (remote)



Available information

- **Process values**
- **QC values**
- **Calibration history**
- **Diagnostic values**

Reasons for hardwired information exchange

- **Tradition**
- **Perceived cost saving on SWAS invest by EPC**
- **Focus on contractual process values only**

Remaining information at DCS level

Process values:

- Are current values valid?
- Is the process log real or junk data?

Summary alarm(s):

- Is it displayed?
- Is this information still worth anything?

Online quality assurance :
Defining the STATUS of a process value

STATUS BAD

- Instrument in operation with error message (e.g. lack of reagents)
- Maintenance required.

- **Measurement must not be used.**
- **Instrument requires immediate maintenance**

STATUS UNCERTAIN

- Some conditions (e.g. sample flow) not in desired range or unknown
- Measured values on hold due to instrument maintenance

- **Measurement can no be trusted. Risk of “false truths”**
- **Instrument will require maintenance shortly**

STATUS GOOD

- Instrument in operation, no device error
- All conditions required to ensure a valid measurement are fulfilled

- **Measurement can be trusted. No risk of “false truths”**
- **Any related process alarm is really related to the process**

Status information allows

- Fast identification of real versus false alarms
- Detection of blind spots in monitoring (false truths)
- Enhanced quality of data logs used as inputs for further data analysis