Iron Monitoring with Non-Contact Nephelometry

Rev 2.3
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Overview of topics

- Iron monitoring
  - Chemistry guidelines
  - Forms of iron in the water-steam cycle
  - Challenge of grab sampling for iron determination
- Iron monitoring during start-up
  - Additional challenges
  - Definition of a suitable detection method
- Example
  - Iron monitoring during start-up of a modern CCPP
- Conclusions

Limits for Iron in Water-Steam Cycle

According to VGB-S010-2011 (in base load conditions):

Parameter		µg/l (ppb)
Iron (Fe)	Normal	<<AL1 (site specific range)
	AL 1	20
	AL 2	-
	AL 3	-

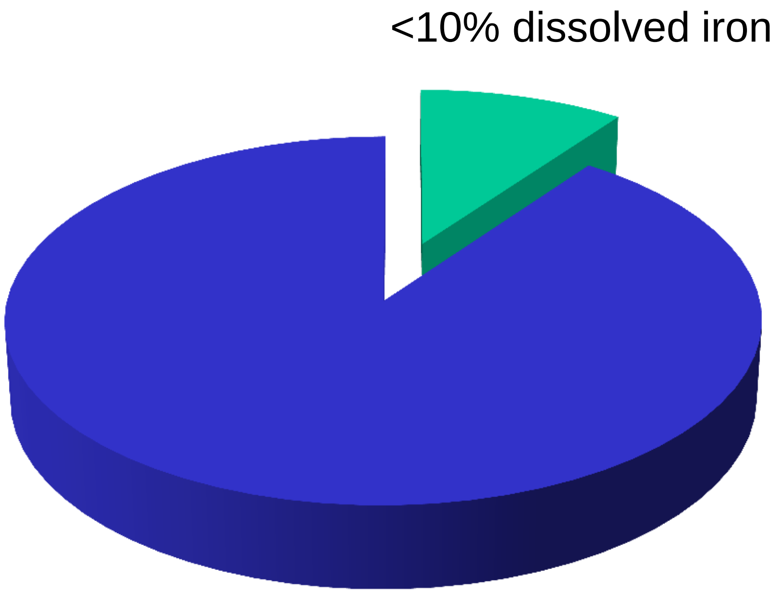
According to EPRI / IAPWS
(lab analysis, in base load conditions):

- Feedwater / condensate: <2µg/l !!
- Drum water: <5 µg/l !!

OPEN POINTS:

- Dissolved/ undissolved/ total iron?
- During normal operation / start-ups?
- How often?

Iron Distribution in Condensed Water-Steam Samples

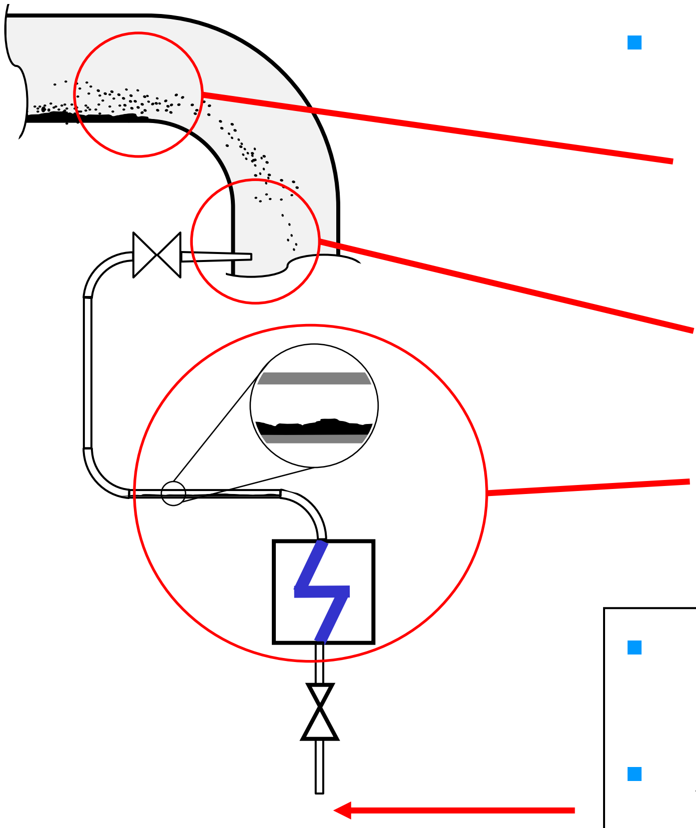


90% of the iron in the water-steam cycle is undissolved

- Mixed oxides
- Various particle sized (mostly <5µm)

Typical WSC iron particles collected on magnetic filter rods

Representative Sampling for Iron is Challenging



- Sources of iron content bias in sample:
  - Uneven distribution in process line, changing plant load
  - Extraction probe hydraulics
  - Sample line & conditionning

- Sample for iron taken at the normal grab sample point is always biased
- Any measurement in such sample will only indicate a trend, never an absolute value!

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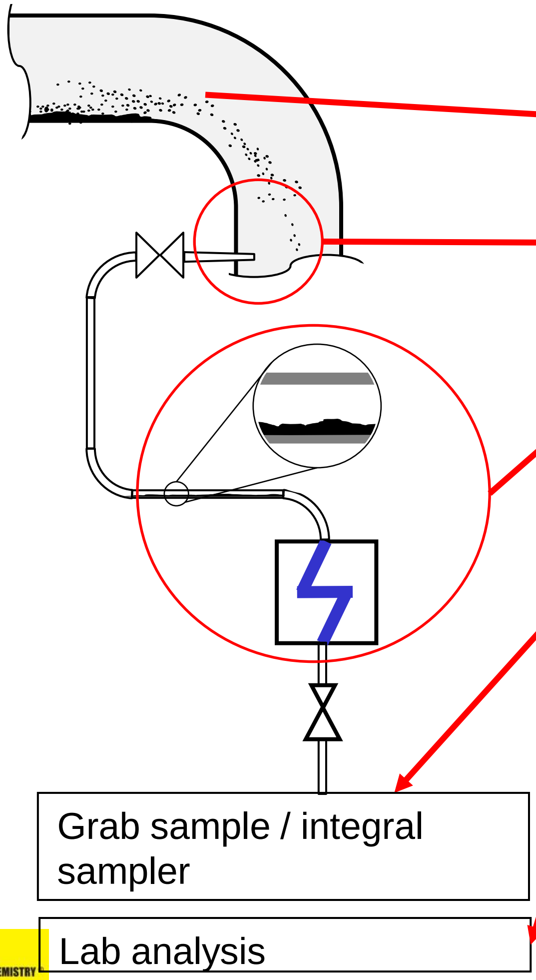

Contents of the guideline

- Definitions & background to dissolved and total corrosion products
- Corrosion product sampling and sample locations
- Sample line and sample conditionning
- Grab sampling methodology
- Integral corrosion product sampling
- Analytical methods

Reference:
IAPWS Technical guidance document - Corrosion Product Sampling and Analysis for Fossil and Combined Cycle Plants – September 2013

Iron Monitoring during Plant Start-Up

THE EXTRA CHALLENGE:

- During start-up...
  - ...iron levels exceed values in guidelines
  - ...iron levels change rapidly

- Representative grab sampling and analysis is not feasible
  - too much fluctuations & bias in particle load
  - too frequent sampling required

- Iron levels unknown → Operator is blind!

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Iron Monitoring during Plant Start-Up

THE QUESTIONS:

- What is the **benefit from trend monitoring** for undissoved iron in normal SWAS?
- What could be an efficient and reliable **detection method?**

THE ASSUMPTIONS:

- Most particles in cycle water are iron
- Turbidity could be well correlated with ppb undissolved iron

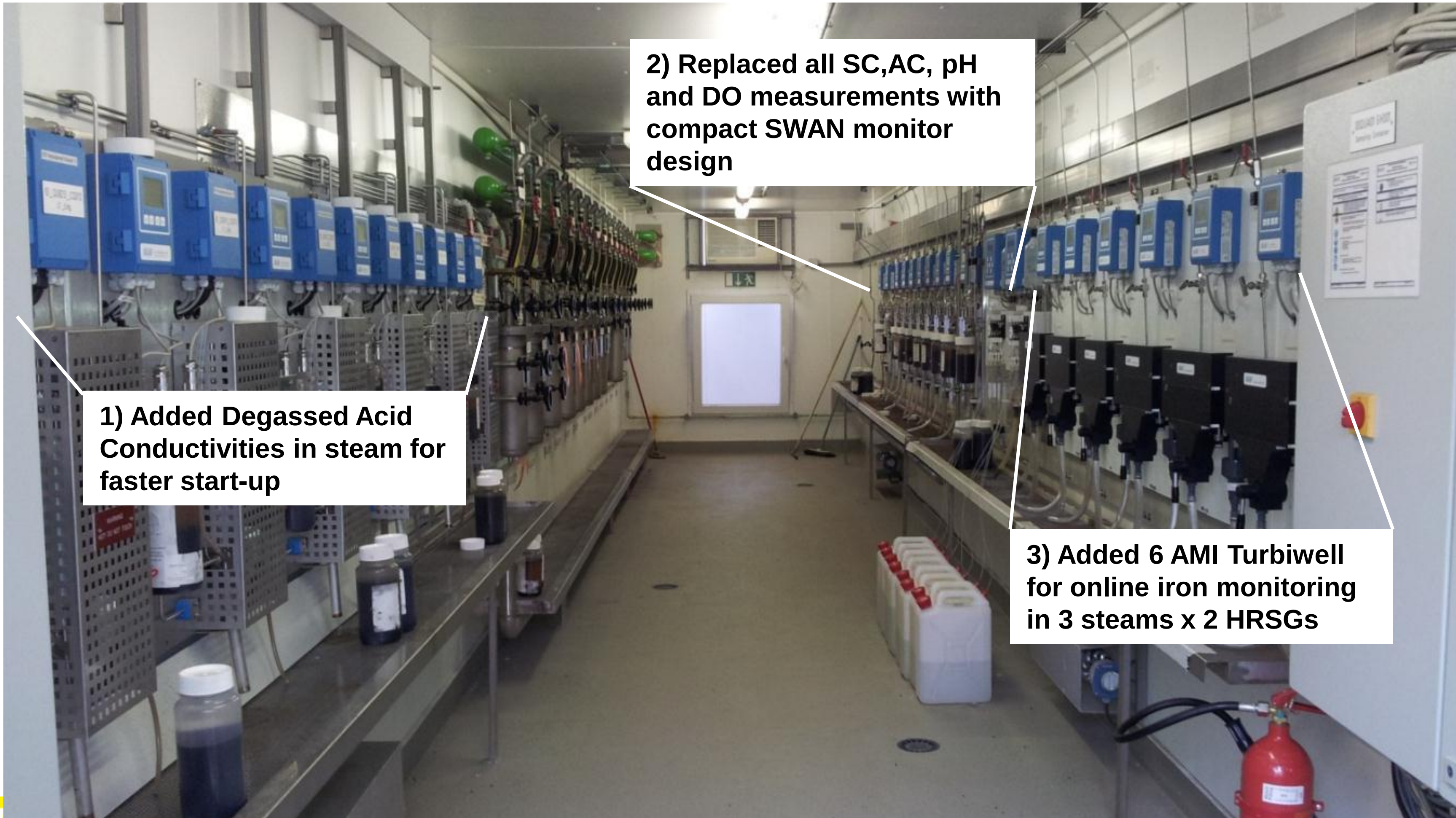
The Test Site: CC Power Plant Köln-Hürth

- Operator: Statkraft (Norway),
  operating 3 power plants in Germany
- Site Köln-Hürth CCPP
  - 800 MW multi-shaft CCPP with 2 HRSGs, 1 ST (EPC Siemens)
  - Commissioned 2007
  - Plant with frequent start-stop duty

Original SWAS equipment (status 2007)

- **Minimum scope** for instrumentation and sample conditioning, suitable for base load plant only
- **Investment cost optimized** system (mixed instrument brands, flow cells / cation exchangers by panel shop)
- **High operation and maintenance cost**

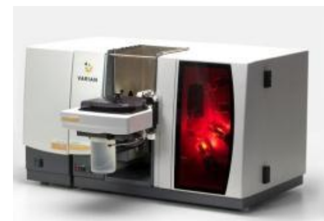
Improved SWAS (2012)



Offline vs Nnline Iron Monitoring

Offline Iron detection

Steam bypass → Wait for pressure → Grab Sample → Lab Analysis (+10min) → <40µg/l? → Further Analysis (+10min)

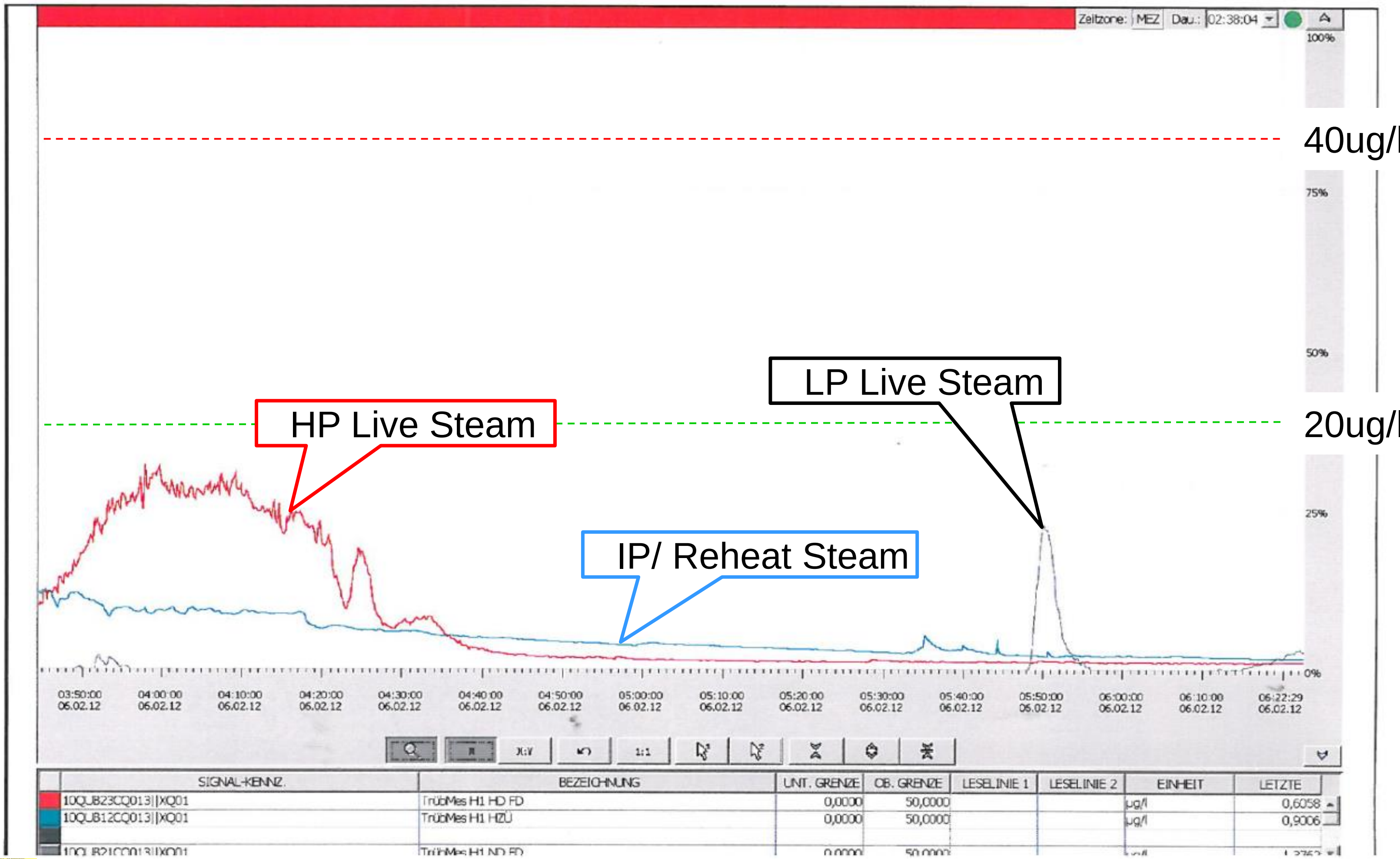


Online Iron detection

Steam bypass → Wait for pressure → Wait for AL*

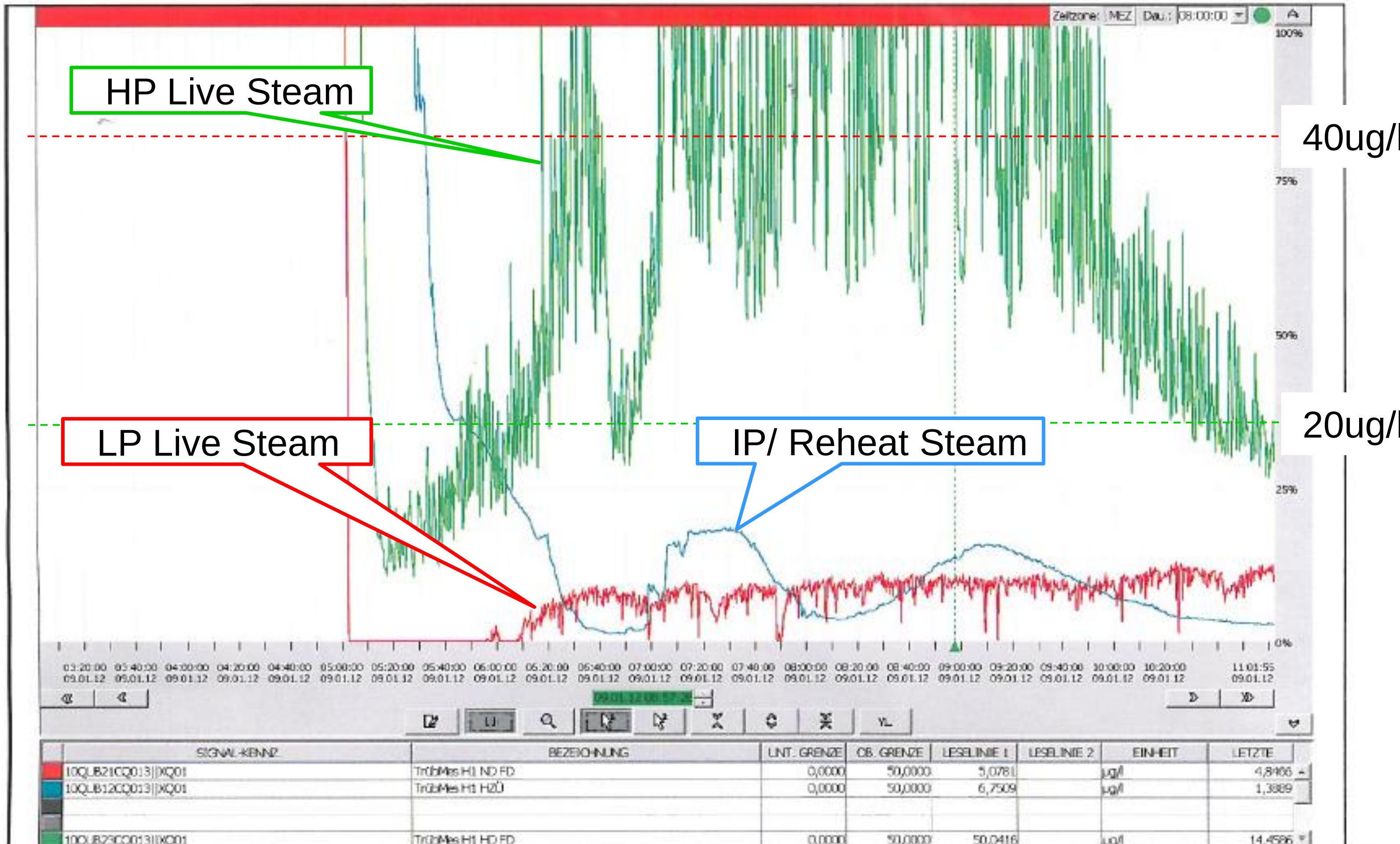
*Action Level

Iron monitoring with AMI Turbiwell
Case 1: a well Managed Warm Start



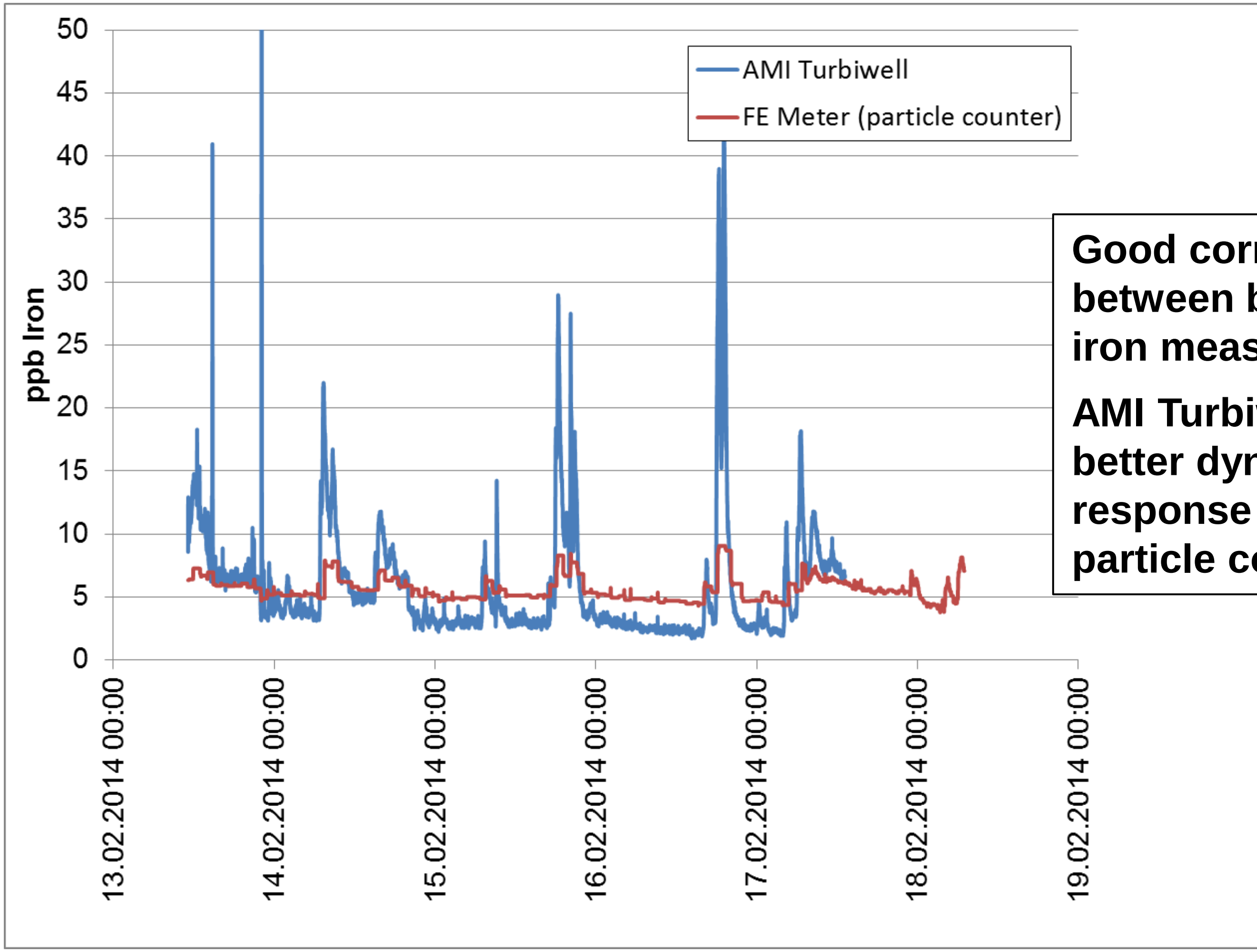
Iron concentration in start up procedure
Measuring range: 0.0ug/l upto 50ug/l

Iron monitoring with AMI Turbiwell
Case 2: a Cold Start with a lot of Surprises



Iron concentration in start up procedure
Measuring range: 0.0ug/l upto 50ug/l

The test site B: CC Power Plant in Germany
Comparison of AMI Turbiwell with Particle Counter in Boiler Water



Good correlation between both online iron measurements

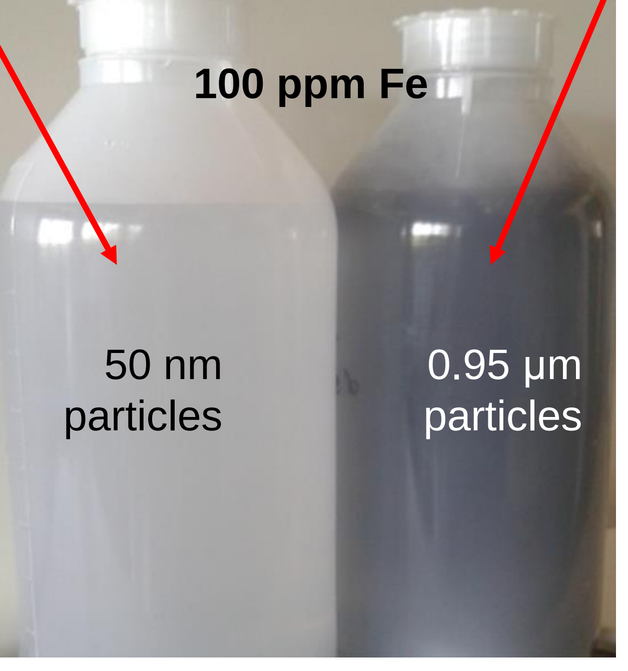
AMI Turbiwell has a better dynamic response than the particle counter

- What is the influence of particle size distribution on turbidity?

- What is the most suitable turbidity measurement principle?

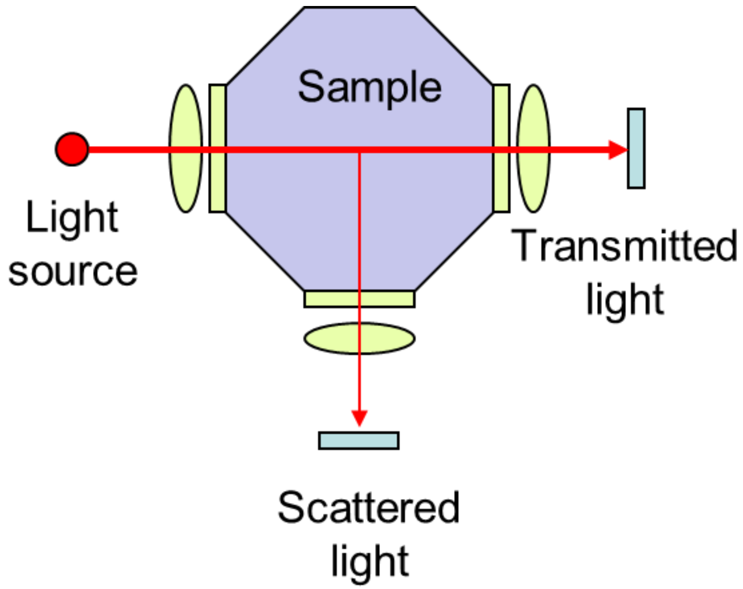
Conclusion number 1: Particle Size has an Influence on Optical Characteristics of the Sample

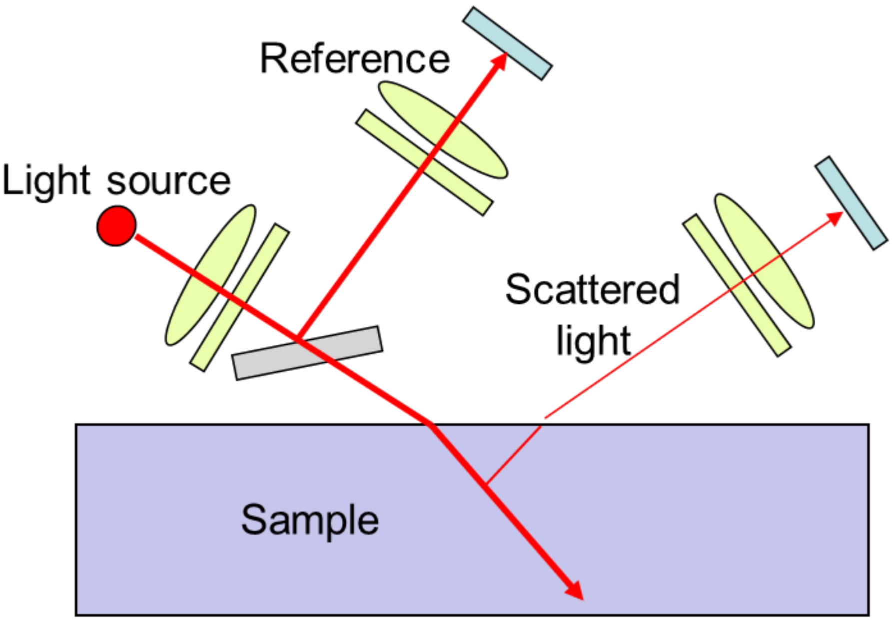
- Iron(II,III) oxide nanopowder Average particle size: < 50 nm, 68.0 % Fe (Sigma-Aldrich Certificate)
- Iron(II,III) oxide powder <5 µm Average particle size: 0.95 µm, 70.7 % Fe (Sigma-Aldrich Certificate)



- Very small particles will generate a smaller optical response than larger ones
- The correlation turbidity with ppb iron is specific to the particle size distribution

2 Nephelometric Measurement Principles (Examples)





Ratio design

- Scattered light detected at 90°
- Transmitted light detected at 0° to light source
- Non-regulatory applications only
- E.g. Swan AMI Turbitrack

Non Ratio design (scattering only)

- Scattered light detected at 90°
- Complies with ISO and USEPA (for potable water applications)
- E.g. Swan AMI Turbiwell

PotableWater Regulations for Non-Ratio Turbidity Measurement Principle

	USEPA 180.1	ISO 7027
Units	NTU	FNU
Wavelength	400 – 600 nm	860 nm
Primary Standard	Formazin	Formazin
Advantage	Sensitivity (for Formazin)	No bias due to color of particles and solution

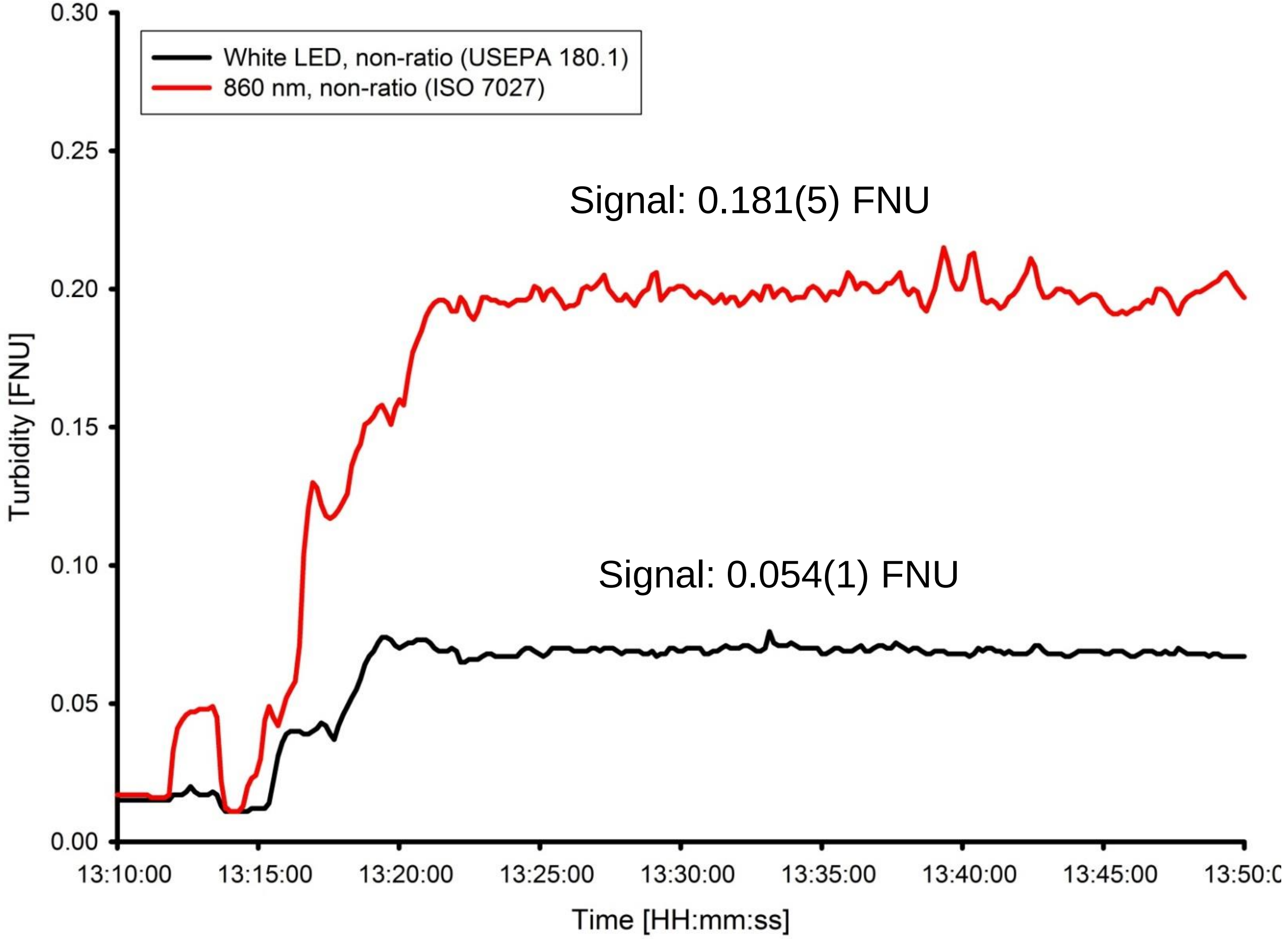
1 NTU = 1 FNU

FNU: Formazin Nephelometric Unit

NTU: Nephelometric Turbidity Unit

ISO 7027 vs. USEPA 180.1

50ppb total particulate Fe (1µm)



Conclusion No. 2

- Turbidity measurement of black particles requires a special wavelength (860 nm)

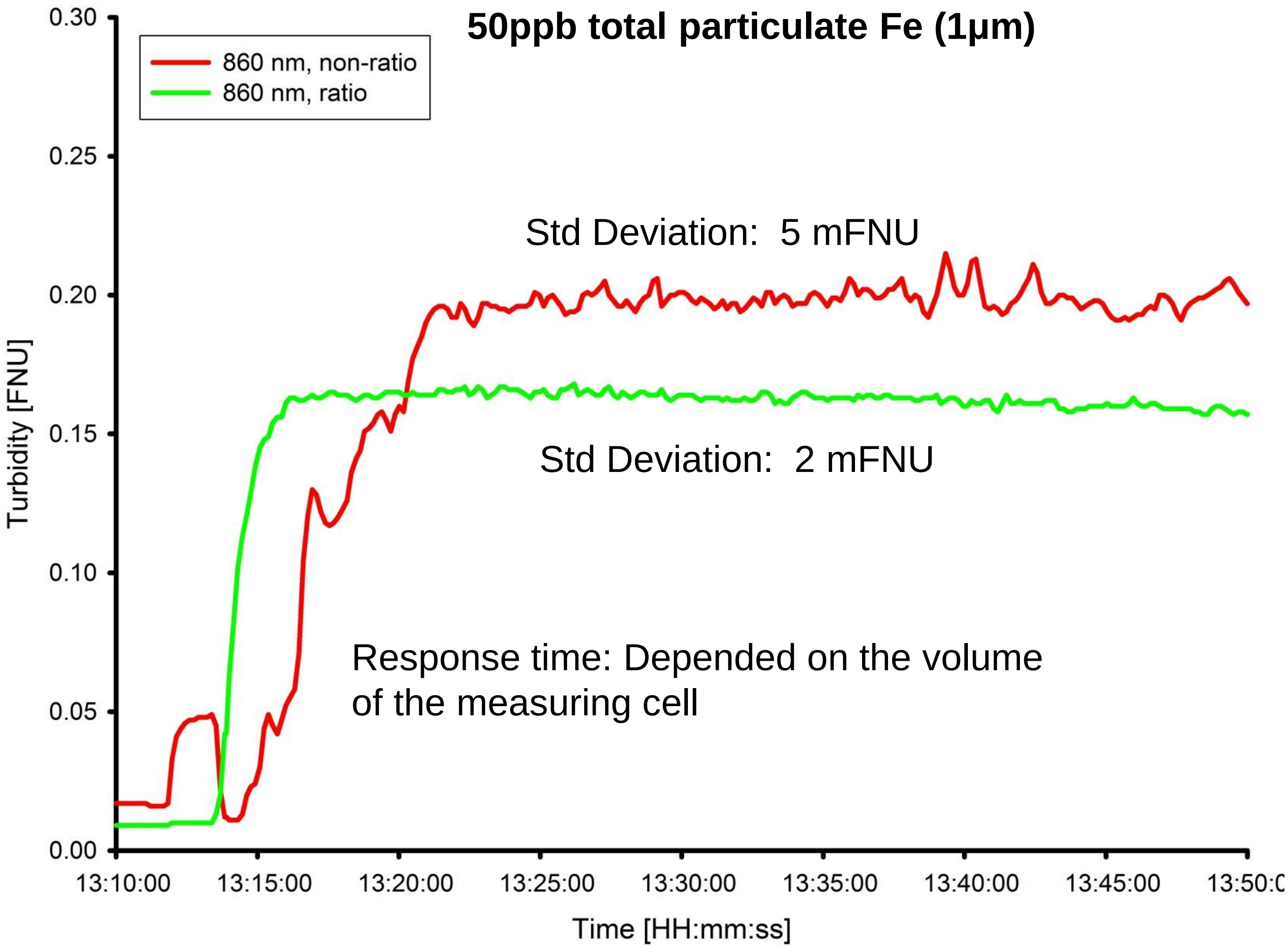
- Extract from EPRI [1]

[…] Since metal oxide particles are usually dark they absorb rather than reflect light so nephelometry is not a preferred method for this application […]

- Correct for analyzers using an USEPA wavelength
- Wrong for analyzer that comply with ISO 7027

[1]: Fossil Plant Cycle Chemistry Instrumentation and Control—State-of-Knowledge Assessment. EPRI, Palo Alto, CA: 2007. 1012209

Ratio vs. Non-ratio Design



Conclusions…

- Determining **absolute values for iron is challenging** (bias of sampling, time lag and limitations of lab measurement methods)
- **Trend of undissolved iron** is an important **diagnostic parameter during transient phases** and to quickly **detect upset conditions**
- **Nephelometry using 860nm** light is a **sturdy and affordable detection method** for particulate corrosion products -> allows trend comparisons in a given plant
- **Ongoing site tests** to evaluate stability, detection limits and reliability different turbidity measurement principles
- **Economic benefits:**
  - Faster start-ups
  - Extension of plant operating life