The Actual most frequent Reasons for Chemistry Related Damages in Thermal Power Plants

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Power & Plant Chemistry

……Once Upon a Time……How the Power Plant Chemistry Journey began….

Let me take you on a little, quick ride through the historical development of Power Plant Chemistry, with the goal to travel further….

Power Plant Chemistry – A Historic Review (Europe)

- <u>March 9th, **1920:**</u>
  Heavy explosion of a vertical tube boiler (year of manufacture in 1917; 660 m² heating surface, 10 atü – atmospheric excess pressure ≈ 10 bar). Beside the high material damage 28 fatalities and 30 injured persons fall victim to the explosion
- <u>November 29, **1920**:</u>
  Formation of a working group, the so called Association of Large Boiler Operators/Owners e.V. (VGB).
  Goal of the association: Safer, more reliable and economic operation through an exchange of experience and technical-scientific questions.
- **1924** Special fund for feed water (Guideline for building type, acceptance and operation).
- **1925** Manual for the care of feed water
- **1950** Promotion of the “Long term program” to gain breaking limits and strain values of special materials according to an operation time of 100,000 h for 500°C to 650°C.

Power Plant Chemistry – A Historic Review (Europe)

Mitteilungen der VGB, Heft 10, Jahrgang 1950

INHALT

- Principles of physical deaeration
- The behavior of salts in boiler water
- Influence of ammonia and CO2 to the determination of the salt content in feedwater by means of conductivity

Power Plant Chemistry – A Historic Review (Europe) – The 60`s – 80`s (just a Mini Selection of a few Highlights)

- Once Through Boiler`s penetrated more and more the power market
- Nuclear Plants appeared on the Scene
  - Power Industry spends lot of money for R&D in the field of Chemistry, as a resulting reaction to fight numerous damages
  - Chemical experts became standard in each Power Station, incl. with a well equipped Laboratory
  - Development and Definition of different Treatment Programs established (Caustic, Phosphate and AVT), incl. Recommended Values
  - OT (oxygenated treatment) developed and established
  - TRD 611, VdTUEV and VGB guidelines for Water and Steam established for the first time.
  - Conferences exclusively for Power Plant Chemistry established (e.g. VGB-Speisewassertagung started in 1964)
  - Intensive Research on FAC (Flow Accelerated Corrosion) initiated and all fundamental basics discovered and explained!
  - Online Monitoring and Development of Instrumentation Techniques strongly enforced
- ✓ Chemistry became a well accepted and fully integrated part in each organization and plant.
- ✓ Chemistry was clearly seen as important and indispensable part for a safe, reliable and economic operation!!
- ✓ Also Statistics delivered clear evidence that by following chemistry standards, combined with on site expertise + monitoring, the number of plant failures had been drastically reduced! So, all the hard work, R&D, etc. paid off and **Power Plant Chemistry was a real success story**!

Some Examples of this Success

- Achieving and Keeping in all Recommendation for Steam Purity resulted in <u>annual cost savings of 650`000 €</u>
  [Ökonomische Bedeutung der Kraftwerkschemie A. Bursik, H.G. Seipp,VGB Kraftwerkstechnik 76 (1996) Heft 4, S. 340-344]

- **<u>USA</u>**: Duke Power Company reported in 1992 for their Fleet (7500 MW) savings of <u>12.4 Million US$ in 20 Years</u> by following the Chemistry Guidelines

Some Related Literature References (only a small number of Examples!)

[1] **I/S Vestkraft, Block 3, Esbjerg**
S. Linhardt, A. Lind-Hansen
VGB Kraftwerkstechnik 74 (1994) Heft 1, S. 15-24

[2] **Technik als Anstoß zum Strukturwandel in der Kraftwirtschaft der USA**
K.E. Yeager
VGB Kraftwerkstechnik 74 (1994) Heft 3, S. 187-192

[3] **Erste Erfolge mit innovativer Technik im Kraftwerk Staudinger 5**
B. Stellbrink
VGB Kraftwerkstechnik 74 (1994) Heft 4, S. 322-326

[4] **Ökonomische Bedeutung der Kraftwerkschemie**
A. Bursik, H.G. Seipp
VGB Kraftwerkstechnik 76 (1996) Heft 4, S. 340-344

[5] **Umgestaltung einer gewachsenen Kraftwerksstruktur**
in eine effiziente marktfähige Struktur
K.O. Abt, U. Wawrzik
VGB Kraftwerkstechnik 77 (1997) Heft 4, S. 4-8

[6] **Kraftwerkschemie heute - notwendig oder überflüssig?**
H. Maier, H. Pflug, H.G. Seipp
VGB Kraftwerkstechnik 77 (1997) Heft 4, S. 326-328

[7] **Maßnahmen in den USA zur Senkung der Investitions- und Betriebskosten**
bei der Stromerzeugung
K. Ullmann, D. Gowdy
VGB KraftwerksTechnik 3/98, S. 36-42

[8] **Optimierte Fahrweise von Wärmekraftwerken mit SR4**
J. Kern, W.A. Benesch, P. Cmejrek
VGB KraftwerksTechnik 5/98, S. 85-89

Power Plant Chemistry – A Historic Review (IAPWS)

- International collaboration on the properties of steam (and water) commenced in 1929 with International Steam Tables Conference in London
(Just 8 years until its 100 anniversary)
- 1972 **IAPS** was formed and included the first group on cycle chemistry
- **1979 Establishment of PCC** (Power Cycle Chemistry Working Group)
- 1984 IAPS Formulation for Thermodynamic Properties of Ordinary Water Substance
- 1989 renamed to IAPWS to include Water
- 1990 PCC reorganized to address plant chemistry and to elaborate Technical Guidance Documents
- 1996 IAPWS IF-97 – Basis of all current Steam Tables
- 2008 **PCC**: Release of 1st TGD ➔ TGD1-08
"Procedures for the Measurement of Carryover of Boiler Water into Steam"
- **2021 ➔ PCC:** 11 Technical Guidance Documents, all related to cycle chemistry, freely available!

So…..Power Plant Chemistry was clearly a Succes Story……!?!?
The Wind of Change in the Mid of 1990`s

- The Wind of Change started in the Mid of the 1990`s, when the Power Market became more and more privatized and harsh Cost Reduction Programs had been initiated everywhere!
- Chemistry became a Victim of its own Success, as the Number of Chemistry related Issues and Damages reached such a low Level at that Time, that Financial Consultants (completely new in this branch) started to question the need for further R&D and the need for Chemical Experts on Site.
- As a Consequence on site Chemistry was more and more reduced, concentrated eventually in the Headoffice solely, where care should be taken for xx Plants remotely.
- Some organizations also sourced out Plant Chemistry and contracted a 3rd party for Chemistry Service (1 or 2 x per week a site visit for quick "check")

➢ **This resulted in a steady "*Evaporation* of Knowledge and Experience"**

➢ **Experienced Experts retired without any Chance or Possibility to hand over Precious Knowledge to Successors, simply as there was not any Successor**

The "Wind of Change" turns slowly into a Thunderstorm!

"Corrosion is one of the largest costs associated with the power industry. In 2013, the cost of corrosion was estimated to exceed $2.5 trillion annually."

Source: EPRI Corrosion in Fossil Power Plants—State of Knowledge Report: 2017 Update

Cycle Chemistry Order of Priority for Failures

1. Balance of Plant = a problem
2. Cooling System = a big problem
3. Feedwater System = a major problem
4. Boiler/HRSG = a extreme problem
5. **Steam Turbine = super ultra bad news problem**

Typical Cycle Chemistry Repeat Situations

Situations		Evaluation Criteria
1	High levels of corrosion products.	Metal transport above treatment limits, failure to periodic check corrosion product transport (for example, every 6 months), or improper metals monitoring techniques.
2	High boiler deposition.	Not taking periodic boiler tube samples to assess boiler deposition, collecting samples from improper location, not using tube samples to determine time to clean or excessive deposit weight density.
3	Non-optimum chemical cleaning.	Not cleaning when tube deposits indicate the unit should be clean, improper cleaning procedures, or inadequate clean due to issues with cleaning process.
4	Drum carryover.	Failure to periodically check drum carryover (for example, every 6 months), improper sampling techniques applied when checking carryover.
5	Contaminant ingress with no reaction by operators.	Continued operation in action levels with no response by operators, failure to take correct actions when problems discovered.
6	High level of air in- leakage.	Failure to address air in-leakage resulting in > 10 ppb dissolved oxygen in the condensate system or not monitoring for air in-leakage.
7	Lack of shutdown protection.	Failure to have processes in place to protect the boiler, turbine, and feedwater / condensate during shutdown periods, or inadequate processes for protection.
8	Inadequate online alarmed instrumentation.	Instrumentation not meeting the core level of instrumentation or in instrumentation out of order for pro-longed periods.
9	Not challenging the status quo.	No process for reviewing current chemistry practices and evaluating these practices versus the state of the art.
10	No action plans for any of these repeat situations.	Failure to adopt management endorsed plans to address any one of these repeat situations once they have been identified.

Source: David Addison, Thermal Chemistry

Most typical Finding received very recently!!

- Scale built-up on the blade surfaces
- Corrosion of the blade material
- Particle impact

Heavy Salt Deposits after 3 months only!

No Joke – This Damage was worth 1 billion Euro!

1. Heavy ingress of highly aggressive impurities during operation
2. Unit was not stopped in time, **due to ignorance**!
3. Impurities had been distributed all over the **entire cycle**
4. Once the unit finally was turned down, no measures for standstill protection had put in place
5. Consequently the overall damage became incredibly high
6. Complete Unit (Boiler, BoP, Turbine) was effected extremely by Corrosion

- 1 Year later the entire station had to be demolished!!
- So the investment of nearly **1 billion €** was gone for ever!

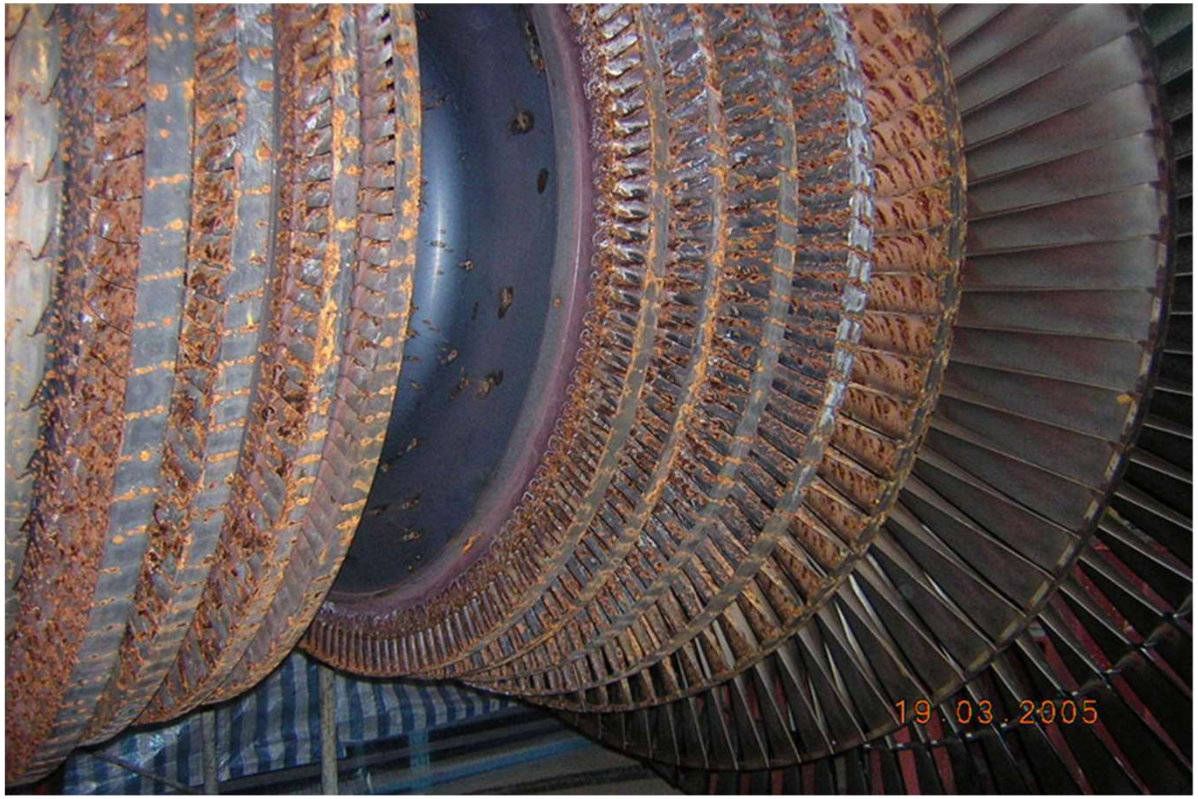
Commissioning in a rush, combined with ignorance to cleanness and start up chemistry

Lightning and Thunder…… **FAC**

FAC (Flow Accelerated Corrosion) due to

- "Sub-Optimal" Choice of Chemical Op. Regime
- Simply Zero Knwoledge about FAC mechanism, even all know how is accesible and available since the the early 1980`s
- Insufficient Control of the pH-Value
- *Just* Routine Chemistry and **no** Checks for Total-Fe
- Simply "believing" on Recommendations from 3rd parties, without questioning or checking!

A Tornado due to lack of understanding!

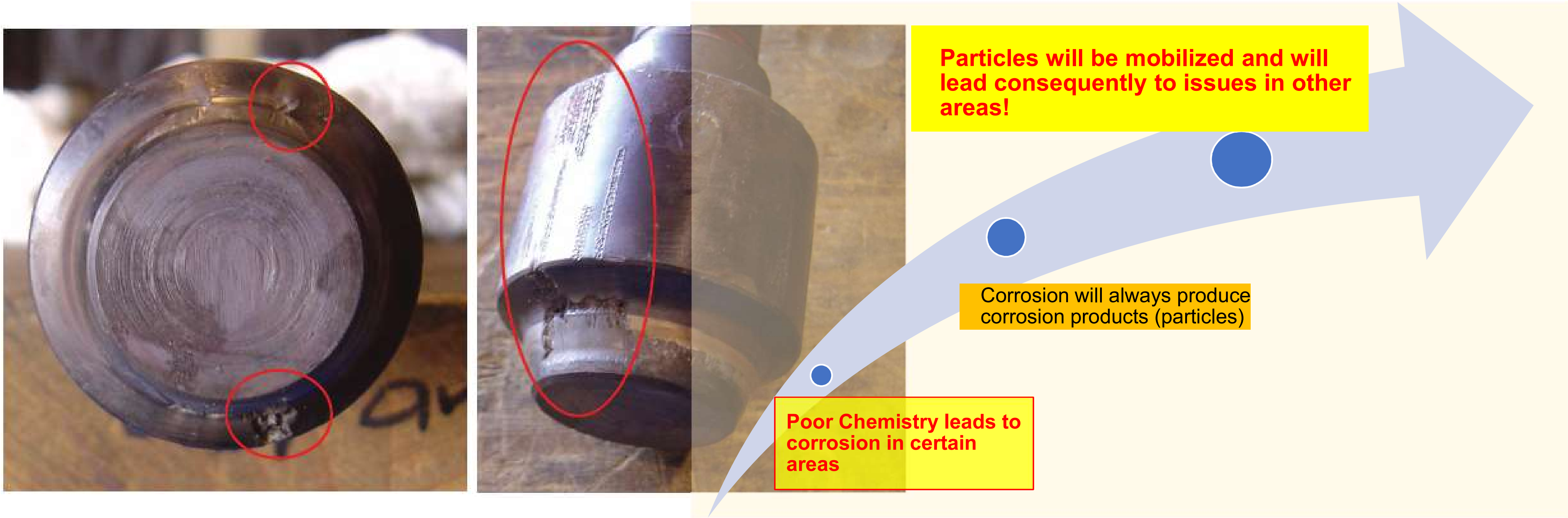


1. Poor steam purity
2. Corrosive deposits built up during operation
3. Standstill without any conservation!
4. Corrosive deposits became very agressive during standstill
5. Entire turbine (blades and rotor) totally damaged
6. **No repair anymore possible!!!**
7. **Complete Turbine, incl. Rotor became valuable scrap**

Effects by Cycling are underestimated

Damaged Valves – Erosion at Valve Seat

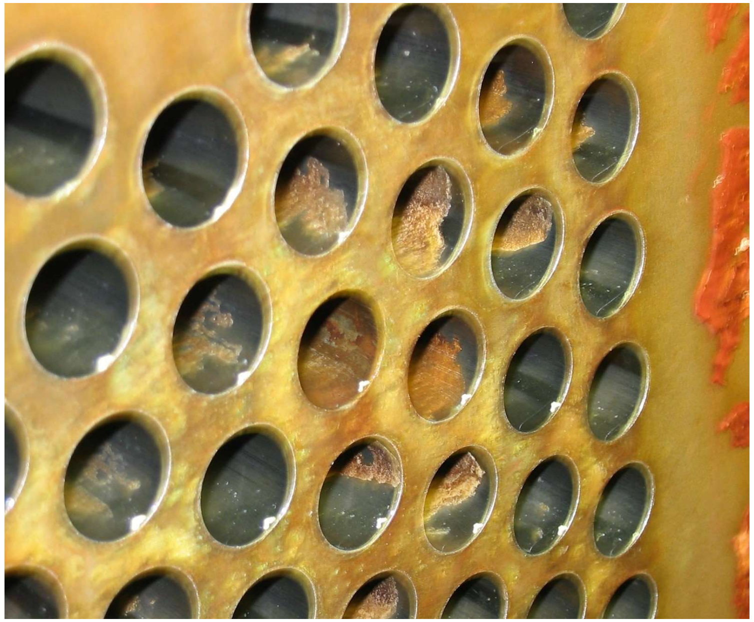
Reason: Elevated Level of Particles due to Corrosion caused by Impaired Chemistry



Cooling Water Chemistry??? Totally Forgotten!

- Insufficient control of the chemistry of main cooling water
- Due to this deposits formation of an enamel surface and loss of heat transfer and so efficiency.
- **Cost only for cleaning 1 Mio. US $!**

➢ **Outage time 4 weeks !**



Interim Summary

- The shown pictures and examples are NOT extraordinary!
- This is meanwhile **again** "*daily routine*" worldwide!
- Keep in mind, **1 day** unplanned standstill easily costs 100 k$ or more (simply loss of production)
- **Plus** the costs for repair
- **Plus** evtl. Penalities (grid)

➔ **1 Damage caused by chemistry easily can reach 1 Mio or >>>**

➔ **Don't forget the possible risks of fatal accidents (e.g. Turbine blade rupture, FAC in pre-heaters, etc.)!!**

What are the Reasons for this Unfavorable, Worldwide Situation?

➢ Under Resourcing of Chemists

- In simplest sense –too much work for the number of people at site
- Divided resource needs –environmental demands, health and safety, outage management etc.
- Reluctance to bring in outside help –contractors/consultants or outsourcing services (like analytical testing)
- Inability to differentiate “busy work” from truly critical cycle chemistry tasks
- Poor understanding of what role of chemist at a plant actually is –routine vs. strategic vs. trouble shooting chemistry
- Development and training eliminated due to cost saving measures..

What are the Reasons for this Unfavorable, Worldwide Situation?

➢ Poor or Zero Knowledge Transfer

- Often combined with under resourcing + lack of technical training/courses/conferences/journals etc,
- Lack of basic and advanced cycle chemistry technical understanding
- What is important and what is not important?
- Short term vs long term issues? Acute and chronic chemistry issues
- Assuming observations are “normal” –low experience base
- Assuming alarms are nuisance alarms – e.g. high steam CACE being CO_2, when its actually chlorides
- Less experience in utilities, lack of corporate chemists etc. to share knowledge.
- Use of inexperienced chemical vendors, incorrect technical advice given “confidently”, lacking confidence to robustly question.

What are the Reasons for this Unfavorable, Worldwide Situation?

➢ Lost Knowledge @ OEM`s (e. g. boiler manufacturers)

- Brand new plants, all ferrous, still commissioned on AVT(R)
- Ongoing AVT(R) in all ferrous units
- Incorrect dissolved oxygen levels for all ferrous units
- Insufficient feedwater pH –not controlled to conductivity
- Incorrect phosphate treatment –phosphate blends, pressures, no amine correction, no CACE correction for phosphate. Phosphate hideout not managed
- Film forming products being incorrectly applied
- Incorrect dosing locations –phosphate and hydroxide being dosed to the feedwater and not to the steam drum
- Products with unknown compositions being dosed
- Products dosed that the site is unclear of the function

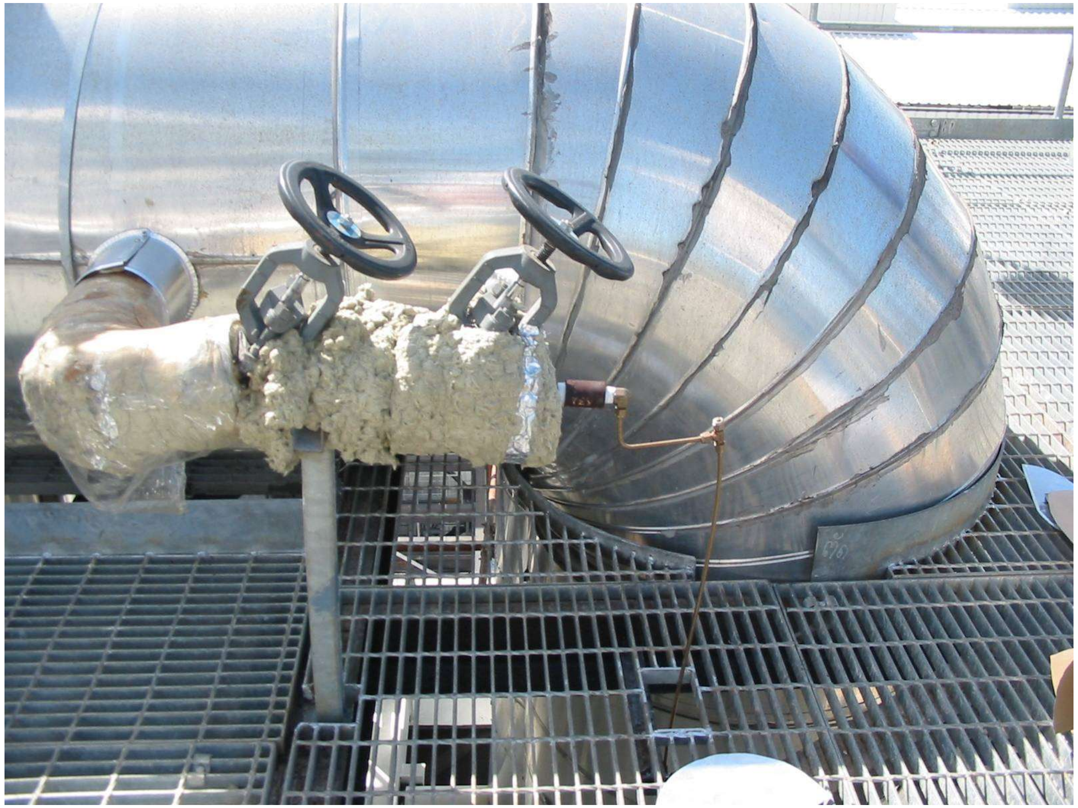
What are the Reasons for this Unfavorable, Worldwide Situation?

➢ Sampling (SWAS) and Instruments

- Instrumentation levels ≠ IAPWS minimum acceptable levels
- Missing or decommissioned sample points
- Instruments with no output signals
- Insufficient or incorrect alarming
- Instruments not calibrated or serviced
- Instruments set up incorrectly

Reliable Instrumentation ?????

Poor Sampling



Calibration ????? Maintenance??

No further comments

Courtesy: David Addison

Data *Management*

	Speisewasser ND (A1LAL20CQ0 [3]												
Datum	Bemerkung	Leitf. n. Kat. Betrieb µS/cm	Leitf. Betrieb µS/cm	Leitf. Labor µS/cm	O2 Betrieb µg/l	O2 Labor µg/l	pH-Wert Betrieb	pH-Wert Labor	Na Labor µg/l	SiO2 Labor µg/l	NH4 mg/l	Fe µg/l	Kupfer µg/l
14.08.2018													
21.08.2018		0.95	14.1				9.6		< 5	50	3.90	380	
22.08.2018		0.30	7.1	6.9		5.0	9.4	9.3	< 5	19	1.40	29	< 0,8
23.08.2018		0.19	7.2	6.2	1.4	2.5	9.3	9.2	< 5	11	1.13	27	
24.08.2018		0.26	3.9		1.4	2.4	8.8	8.8		11	0.47	80	
28.08.2018													
29.08.2018		0.25	9.8		1.0		9.5		< 5				
30.08.2018		0.10	6.0	5.9	1.0	6.0	9.3	9.3	< 5	< 5	0.94	12	< 0,8
05.09.2018													
06.09.2018		0.23	10.3		1.3	4.0	9.6	9.5	< 5	15	2.34	85	< 0,8
10.09.2018													
11.09.2018		0.15	7.1		7.5		9.5		< 5	< 5	0.99	24	< 0,8
19.09.2018					0.7	7.0							
28.09.2018		0.18	5.9		2.4		9.3		< 5	7	0.92	10	< 0,8
11.10.2018													
17.10.2018													
24.10.2018		0.08	3.7		18.5	28.0	9.2		< 5	< 5	0.18	49	< 0,8
31.10.2018		0.09	5.9		30.0	40.0	9.5	9.3	< 5	< 5	0.79	10	< 0,8
07.11.2018		0.09	5.8		2.3	4.5	9.4	9.3	< 5	< 5	0.75	5	< 0,8
28.11.2018													
05.12.2018		0.12	7.5		17.0	15.0	9.5	9.6	< 5	< 5	1.35	24	< 0,8
12.12.2018		0.08	3.2		88.0	96.0	9.1	9.1	< 5	< 5	0.35	< 3	< 0,8
19.12.2018		0.08	7.6		93.0	87.0	9.4	9.6	< 5	7	1.21	5	< 0,8
27.12.2018													
27.12.2018													
03.01.2019		0.06	2.6		16.8		9.0	9.0	< 5	< 5	0.28	< 3	< 0,8
16.01.2019													
23.01.2019													
29.01.2019													
29.01.2019													
06.02.2019		0.08	3.1		43.0	45.0	9.1	9.1	< 5	< 5	0.33	< 3	< 0,8
13.02.2019													
20.02.2019													
25.02.2019													
05.03.2019		0.06	3.4		95.0	93.0	9.1	9.0	< 5	< 5	0.35	7	< 0,8
12.03.2019		0.09	8.6		0.6		9.6		< 5	< 5	1.68	6	< 0,8
13.03.2019													
19.03.2019		0.10	6.9		1.0	4.0	9.3	9.2	< 5	< 5	1.07	6	< 0,8

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Data Management

- ✓ Look on trends instead on single data
- ✓ Correlate the chemical data always with the situation in the plant (load, start up, load change, etc.)
- ✓ Any Grab sample is a snapshot only and cannot replace an online monitor at all!
- ✓ Grab samples and lab analysis are important as well! But as supplementary information!
- ✓ Check always all data in correlation and combination for plausibility
- ✓ Chemical data should be contained in the longtime storage!
- ✓ Make statistical evaluation routinely in order to detect early signs of impairment!
- ✓ Determine your plant specific N-values

Repeat Failures

- Most of the Failures are "classical"!
- Failure Mechanism are well known since xx years!
- Most typical failures are (own / private observations and experiences):
  - FAC
  - UDC
  - Stand still corrosion
  - Hydrogen damage
  - Stress Corrosion Cracking

This is just a simple list without ranking

What are the Reasons for these Failures TODAY?

1. Loss of Knowledge (no transfer of know how)
2. Unreasonable Cost Saving Measures (no budget for training, no budget for conferences, collaboration in specialized organizations etc.) hampers built up of know how.
3. Twitter and Whatsapp Cultur ➔ No time to read details! Essential information is lost by that!
4. Missing or incomplete operating instructions on chemistry for operational staff!
5. Copy & Paste of operating procedures from other plants without deeper investigation and examination!
6. Too often there is no proper and correct **RCA** been made. ➔ No lessons learned!
7. Sampling and Monitoring outdated and not as per latest recommendation (IAPWS, VGB). Still too often grab samples instead of online monitoring!
8. Either wrong or none control of corrosion product release and transportation rates!
9. Too many plant chemists don't know their plant and its process! Simply comparing measured values with limit values, without any trend and without any relation to the process and the process data.
10. Too high workload by other additional tasks (e. g. environmental protection officer) preventing proper care of chemistry!

Certainly I could continue this further on, as this list does not claim to be complete, but it is a little collection of my personal observations.

And now??????

- We have to approach the top management and demonstrate the economic risks and possible losses, if no countermeasures are taken! **Speak the management language**!!
- Training, Education & Training, Education!!
- Review operating procedures and operating instructions
- Educate non chemical staff and give them proper instructions, what to do in case of a chemical alarm appears!
- Review of SWAS and Monitoring Instruments
- When a failure occurred make a complete and correct RCA and extract lessons learned from it!
- Read all Guidelines complete and carefully! Do not just select the page(s) with the tables without reading and understanding the rest of the guideline!!
- Try to stay updated with all ongoing developments ➔ Participation in intl. working groups such as IAPWS or also VGB.


BACK
TO THE FUTURE