The Major Cycle Chemistry Aspects for HRSGs

Part 1. Introduction to the Key Cycle Chemistry Features for HRSG Reliability.
Barry Dooley, Structural Integrity Associates.

Part 2. Monitoring Iron in HRSGs. Ken Kuruc, Hach.

Part 3. Online Instrumentation Overview for the Healthy Operation of HRSG Plants.
Kirk Buecher, Mettler-Toledo Thornton.

HRSG Forum HF2021
Virtual Conference
19th August 2021

Introduction to the Key Cycle Chemistry Features for HRSG Reliability

Includes the main features of optimum cycle chemistry control and the latest international statistics which were previously presented at the European HRSG Forum, May 2021

Barry Dooley

HRSG Forum HF2021
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Optimum Cycle Chemistry for HRSGs

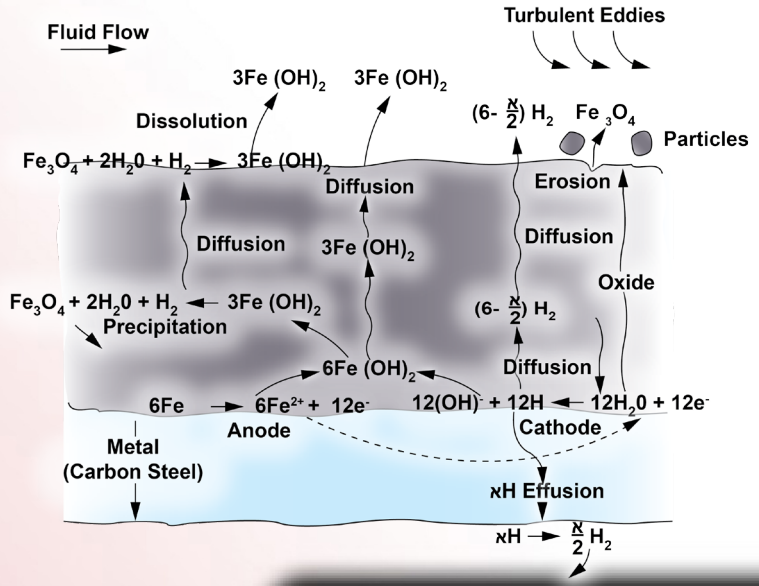
- Chemistry must be “designed” to address all possible cycle chemistry influenced damage/failure
- Condensate and feedwater
  - Optimum is oxidizing, AVT(O) (No reducing agents)
  - Ammonia/Amine and oxygen controlled by minimum air in-leakage
  - Careful application of FFS
- LP Evaporator
  - AVT or TSP and/or NaOH
- Optimize pH (up to 9.8) to minimize iron in the cycle
- HP drums should be red
- HP evaporator tubing should be red with minimum internal deposits
- Guidance level of continuous instrumentation
  - Should include steam. Grab sample control is not adequate

But -- Continuing Cycle Chemistry Damage in Combined Cycle / HRSG Plants

- **Chemistry influenced Tube Failure (HTF) damage / failure mechanisms**
  - **Flow-accelerated Corrosion (FAC) (Leading HTF)**
  - **Under-deposit Corrosion (UDC) (mainly HD)**
- **Corrosion Product Transport due to Inadequate FW and Lower Pressure Circuit Chemistries**
  - **Deposition in HRSG HP Evaporators**
  - **Importance of an ACC in the Cycle**
  - **More difficult for Frequent / Fast Start Plants**
- **Steam Turbine Deposits / Damage / Failure**
  - **PTZ (Pitting, SCC and CF cracking) (All leading ST problems)**
  - **Deposition in LP (Mainly chloride in PTZ)**

Flow-Accelerated Corrosion in Fossil and Combined Cycle/HRSG Plants

- Continues to occur in >70% of fossil plants, and represents >40% of all tube failures in HRSGs despite R&D since the 1960s, and
- Many 100s of plant assessments worldwide, and
- Numerous fatalities and serious failures, and
- Major source of corrosion products.



Source: Dooley & Lister, *PPChem* 2018, 20(4), 184.

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Hydrogen Damage in HP Evaporators

Ingress of chloride when evaporator has deposits. How and why are they allowed?

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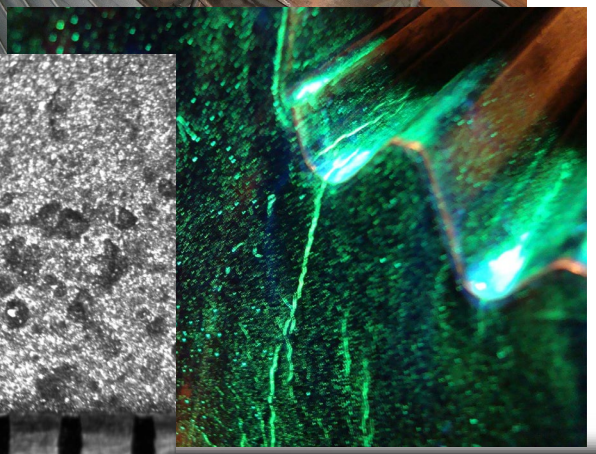
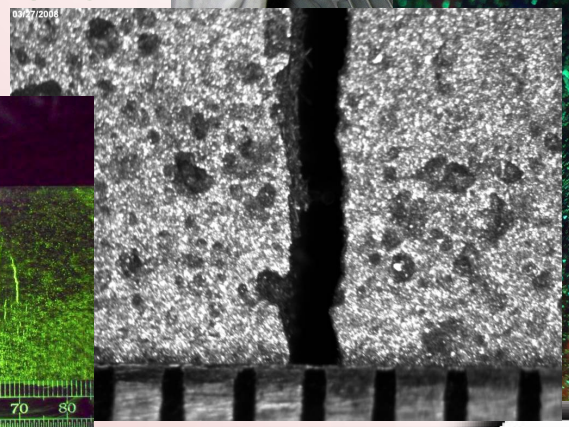
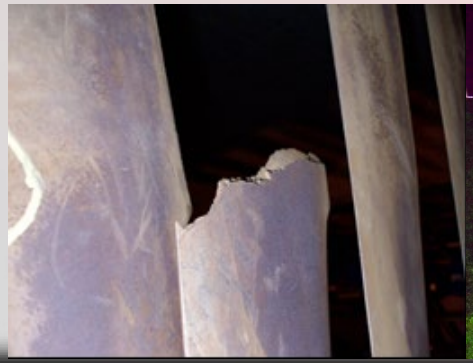
Leading Steam Turbine Damage Mechanisms

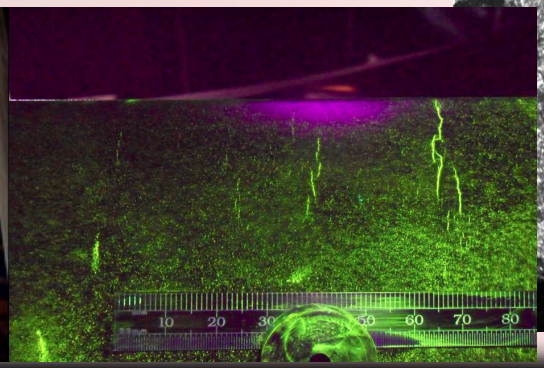
(Most are cycle chemistry influenced and appear to be increasing in combined cycles worldwide)

- Corrosion Fatigue of blades and discs in PTZ of LP
- Stress corrosion cracking of discs in PTZ of LP
- Pitting (is initiator of this damage)
- Liquid Droplet Erosion
- Flow-accelerated Corrosion
- Deposition









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Repeat Cycle Chemistry Situations (RCCS)

Since the original RCCS paper in 2008 the 2021 detailed data accumulated from assessments at over 250 plants worldwide continues to confirm that all this failure and damage can be directly related to plants operating with multiples (two or more) of RCCS.

* Corrosion products (total iron)
* HRSG evaporator deposition
* Contaminant ingress (with no reaction)
* Drum carryover
* Lack of shutdown protection
* Inadequate on-line alarmed instrumentation
* Not challenging the status quo
* Non-optimum chemical cleaning
* High level of air in-leakage

See: Dooley et al, PPChem., 2008 & Dooley/Anderson, PPChem,. 2019

The Data has been Collected from Detailed Plant Assessments using RCCS Analysis

* 145 Fossil Plants

BTF Mechanism and Root Cause Assessments
FAC Assessments. ACC Assessments
Cycle Chemistry Assessments and Conversions to OT and PT
PTZ Blade and Disk Failure / Damage Assessments
Copper Deposition on HP Turbine and in Superheater
Development of Shutdown / Layup and Preservation Procedures

* 107 HRSG/Combined Cycle Plants
(19 HRSG manufacturers)

HRSG Assessment (Cycle chemistry, FAC and Thermal Transients)
Cycle Chemistry Assessments and Optimization
HRSG FAC Assessments. ACC Assessments
HRSG Tube Failures
CC / Desalination / LNG / Alumina Refinery Interface Problems
Development of Shutdown / Layup and Preservation Procedures

Let's Look in Detail about RCCS in HRSG Plants

What are features which contribute to recording or recognizing a RCCS in a plant?

Categories within RCCS

Corrosion Products (total iron)

Not Known or Too High

- above local Guidance achievable values

Techniques used – No digestion - Incorrect detection limit – Results in Soluble CPs only

Inadequate extent and not sufficient or too many locations

Samples not representative

- Taken at same time / shift each day

Sampling systems not adequate

S&W / Wet Rack sampling troughs need frequent cleaning

Black S&W sampling troughs on AVT(O), or red ones on AVT(R)

Will be covered in Detail in Part Two

Achievable Total Fe & Cu Levels – Different Plant Types/Optimized Chemistry

Feedwater		
OT:	Total Fe =	< 1 µg/kg
AVT:	Total Fe =	< 2 µg/kg
AVT (Mixed):	Total Fe & Cu =	< 2 µg/kg
HP/LP Heater Drains:	Total Fe & Cu =	< 10 µg/kg
HRSG Evaporators/Drums		
AVT/PT/CT:	Total Fe =	< 5 µg/kg
Air-Cooled Condenser (ACC)		
ACC Outlet:	Total Fe =	< 10 µg/kg
Post Condensate Filter:	Total Fe =	< 5 µg/kg
Cogeneration Plants		
Condensate Return:	Total Fe =	< 10 µg/kg

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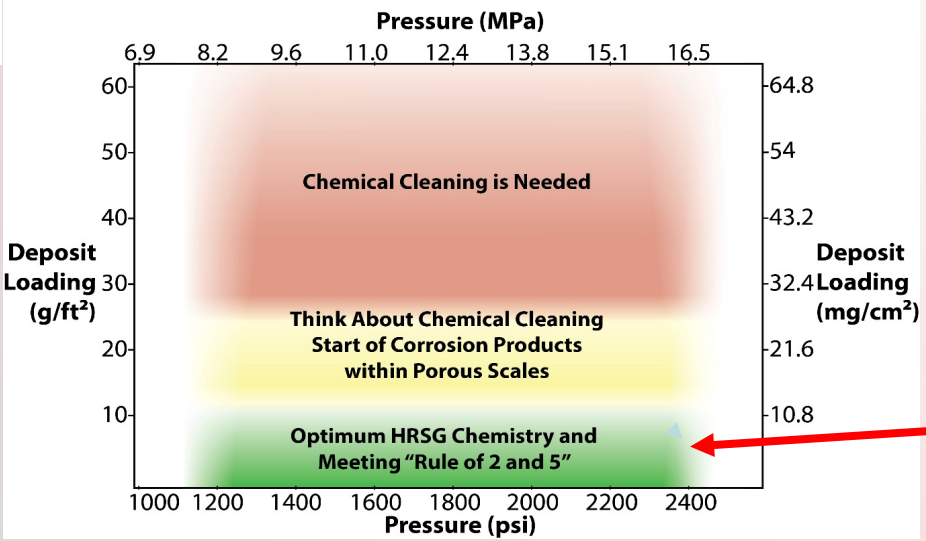
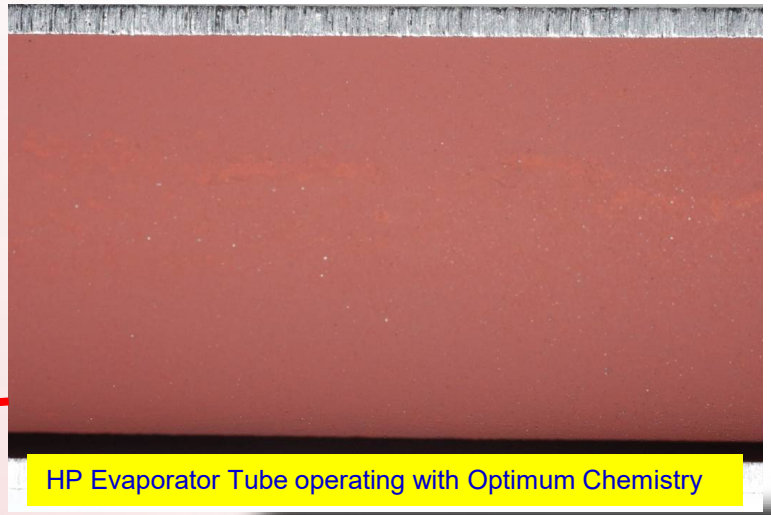
Categories within RCCS

HRSG HP Evaporator Deposits

Samples not taken (For HRSGs this is improving since the IAPWS TGD)
No knowledge of deposit and deposition rate
Samples taken but not analyzed comprehensively
Deposits excessive. Not linked with chemistry and FAC in fossil feedwater or HRSG lower pressure circuits
Unit needs cleaning but management delayed or cancelled





HP Evaporator Tube operating with Optimum Chemistry

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Categories within RCCS

Continuous On-Line Instrumentation

Low % compared to International Standard

CACE (cation conductivity) and Na on Steam
and Conductivity on MU line most often missing

Not alarmed. Many shared and not / never switched

Plant relies on grab samples to control plant (1 - 2 times per day)

Too many out of service, not maintained or calibrated

Plant	Range	Average
CC/HRSG	0 - 100%	58%
(107 plants)	(3 @ 100%)	
	(10 over 85%)	
	(10 at 0%)	
Fossil	0-100%	65%
(145 plants)	(9 @100%)	
	(24 over 85%)	

Will be covered in Detail in Part Three

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Categories within RCCS

Drum carryover

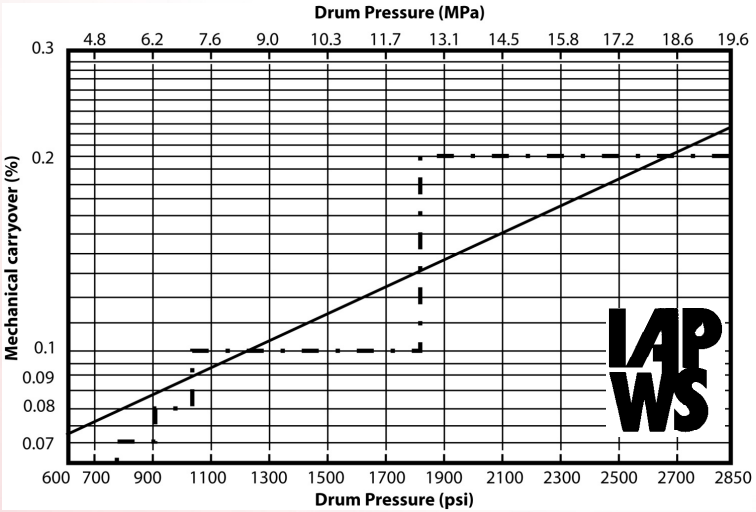
Not conducted since commissioning

Even on units with PTZ problems !

Not aware of simple process

Saturated steam samples not working or non-existent

Samples often not isokinetic



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Categories within RCCS

Not Challenging the Status Quo

Same chemistry since commissioning

No chemistry manual for plant, OR assembled by chemical supplier as compared to company guidance

Continue to use wrong phosphate treatment

Continue to use reducing agents in combined cycle/HRSGs and in all-ferrous fossil plants

No questioning of proprietary chemical additions

Using incorrect or outdated guidelines

No changes for frequent / fast start plants

Incorrect addition point for chemicals (most often reducing agent)

AVT(O) vs AVT(R) or incorrectly used for either

Lower end of pH ranges is often bad

Repeat Situations in Cycle Chemistry Control

(252 Plants Worldwide)

RCCS Categories	In 145 Fossil Plants %	In 107 Combined Cycle / HRSG Plants %
Corrosion Products	93 =	90 ↘
Fossil Waterwall / HRSG Evaporator Deposition	55 ↗	60 ↘
Chemical Cleaning	15 =	10 =
Contaminant Ingress	15 =	10 =
Drum Carryover	77 ↘	80 ↘
Air In-leakage	36 =	10 =
Shutdown Protection	74 = (& 92*)	50 ↘ (& 92*)
On-line Alarmed Instrumentation	80 =	85 ↘
Not Challenging the Status Quo	84 =	75 ↘

Increasing in last 5 years ↗

Decreasing in last 5 years ↘

Based on 252 Comprehensive Plant Assessments 2008 – April 2021

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A few concluding remarks:

- Well established and understood chemistries for > 30 ys
  - AVT(O), AVT(R), OT, PT and CT + PTZ Failure/Damage in ST
- Simple rules for optimum chemistry control
- But RCCS exist as shown, relate to the very basics of these chemistries and can lead directly to plant reliability and performance issues. Need to be eliminated.
- Ensure simple rules are applicable to my plant and
- Conduct a comprehensive monitoring review using total iron to ensure rules are applied and RCCS are not allowed to continue
- Most important for new chemistries such as FFS and operational changes (frequent / fast start)