Cycle Chemistry Control in part load and cyclic operation

Issues, impacts and their mitigation

Gopi Kanta Nayak-AGM (OS-Chemistry I/C)-NTPC

Academic & Professional Profile: MSc (Chem-IIT-KGP), MBA-HR,

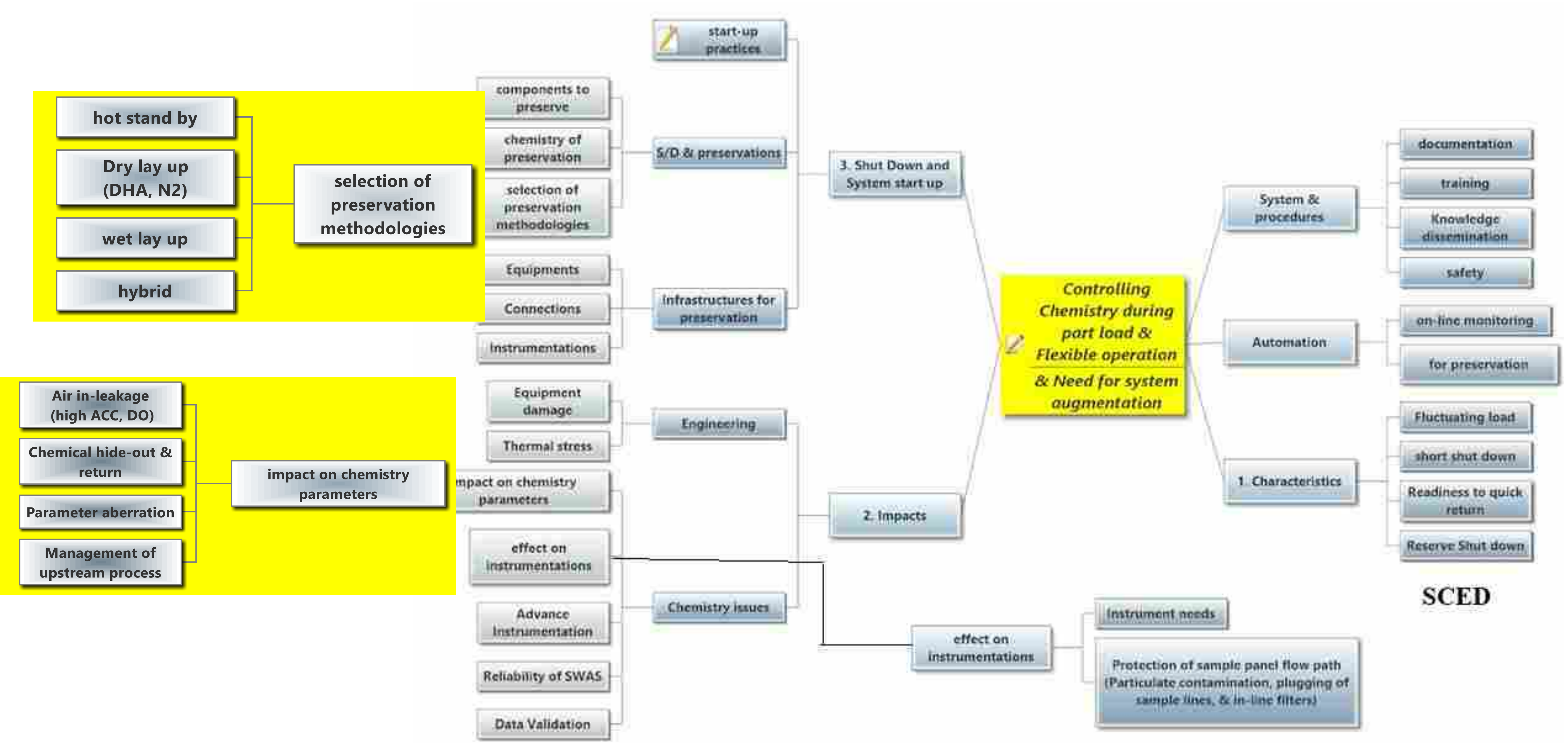
Six Sigma BB, BE Assessor, ISO LA

27 yrs at Singrauli Super thermal power station (including 7 years in Business Excellence dept), 7 years in NTPC-R&D (NETRA), at present in OS-Chemistry I/c

One book on water technology, one copyright on coating & painting, four patents at application stage

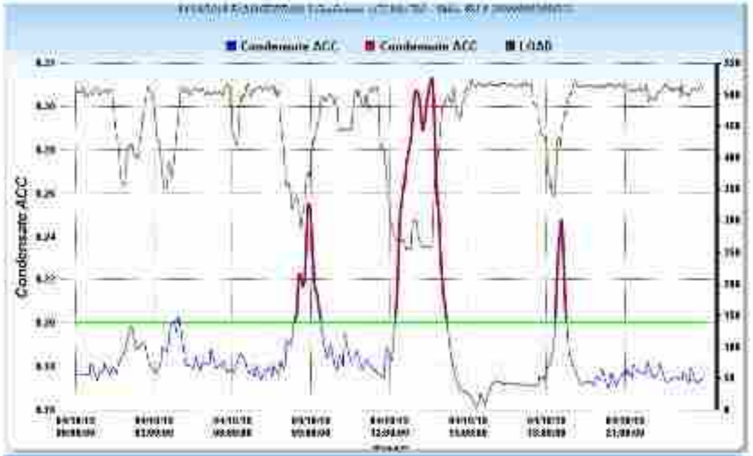
Key messages

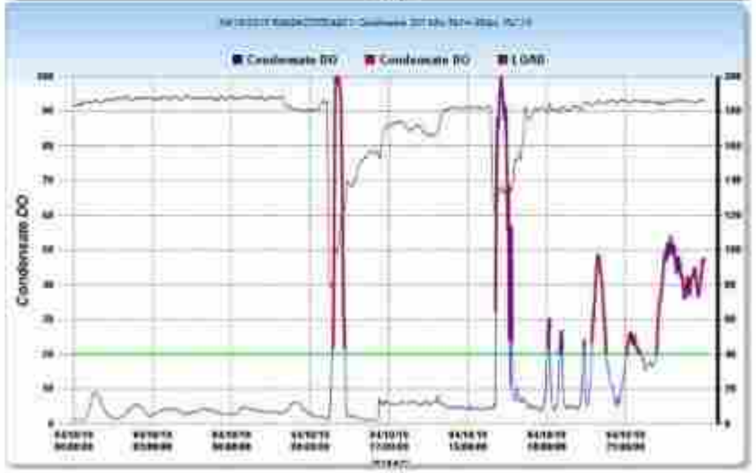
- For a power plant, Chemistry is a strategic necessity
- Professionals and Management should pay unequivocal attention to matters related to power plant chemistry. This is even more relevant in the era of flexible generation.
- Taking care of some basic requirements of chemistry could make a difference between problem-ridden units and efficient operation of units.

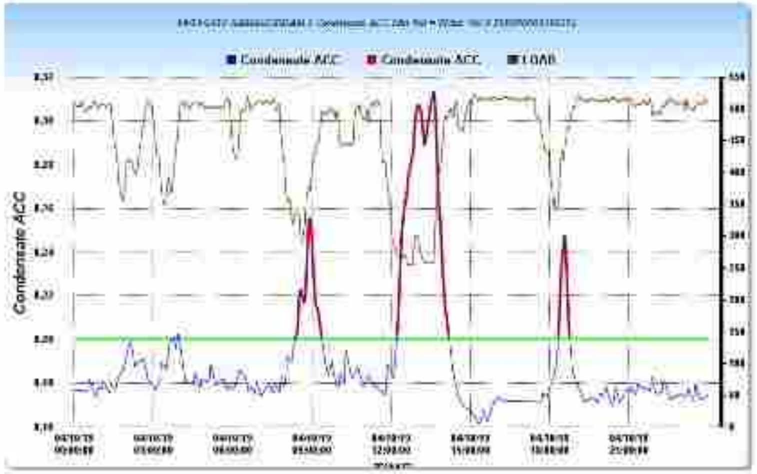


Flexible operation and Power plant chemistry

Chemical Parameter Aberrations								16
Sl. No	**Unit**	**Parameter**	**Deviation (High/Low)**	**Aberration**	**Duration in Hours**	**Max/Min Value**	**Avg Value**	**Consistancy of Aberratio**
1	1	Condensate ACC	High	Above 0.20	24	0.32	0.30	Repeat
2	5	Condensate ACC	High	Above 0.30	24	1.20	0.66	Repeat
3	2	Condensate ACC	High	Above 0.20	24	0.39	0.31	Repeat
4	1	Condensate ACC	High	Above 0.20	24	0.21	0.20	Repeat
5	2	Condensate ACC	High	Above 0.30	24	0.80	0.70	
6	2	Condensate ACC	High	Above 0.20	24	0.28	0.22	
7	7	Condensate ACC	High	Above 0.20	22	0.31	0.27	Repeat
8	8	Condensate ACC	High	Above 0.20	9	0.247	0.19	
9	6	Condensate ACC	High	Above 0.20	8	0.22	0.18	
10	6	Condensate ACC	High	Above 0.20	6	0.26	0.20	Repeat
11	3	Condensate DO	High	Above 20	24	196	147	Repeat
12	5	Condensate DO	High	Above 20	24	48	24	Repeat
13	6	Condensate DO	High	Above 20	24	61	53	Repeat
14	7	Condensate DO	High	Above 20	24	39	29	Repeat
15	1	Condensate DO	High	Above 20	24	47	43	Repeat
16	5	Condensate DO	High	Above 20	24	46	41	Repeat
17	1	Condensate DO	High	Above 20	24	108	92	
18	5	Condensate DO	High	Above 20	24	49	49	
19	4	Condensate DO	High	Above 20	24	50	46	Repeat
20	4	Condensate DO	High	Above 20	24	78	62	Repeat
21	3	Condensate DO	High	Above 20	24	96	58	Repeat
22	3	Condensate DO	High	Above 20	24	200	66	Repeat
23	2	Condensate DO	High	Above 20	24	200	94	Repeat
24	2	Condensate DO	High	Above 20	24	34	22	Repeat
25	2	Condensate DO	High	Above 20	24	49	30	Repeat
26	5	Condensate DO	High	Above 20	24	303	54	Repeat
41	1	Feed Water DO	High	Above 10	24	56	42	Repeat
42	6	Feed Water DO	High	Above 10	11	53	15	
43	3	MS ACC	High	Above 0.30	24	0.44	0.378	Repeat
44	7	MS ACC	High	Above 0.20	11	0.31	0.194	
45	1	MS ACC	High	Above 0.30	7	0.53	0.33	Repeat
46	2	MS ACC	High	Above 0.30	5	7.8	0.75	Repeat
47	9	MS Sodium	High	Above 2	18	4.6	2.5	Repeat
48	6	MS Sodium	High	Above 2	17	14	2.8	
49	5	MS Sodium	High	Above 2	16	4	2.2	







Variation of CEP ACC
& DO with load

Figure 3-9
FAC Failure and Damage on an Economizer Inlet Header Tube. All HP and LP Heater Tubing in This Unit Was Stainless Steel. The Feedwater Was AVT(R).

FAC failures

Figure 3-2 shows an example of severe ongoing FAC damage in a header and a header that is now protected (red hematite surfaces) but with similar FAC damage from earlier operation.

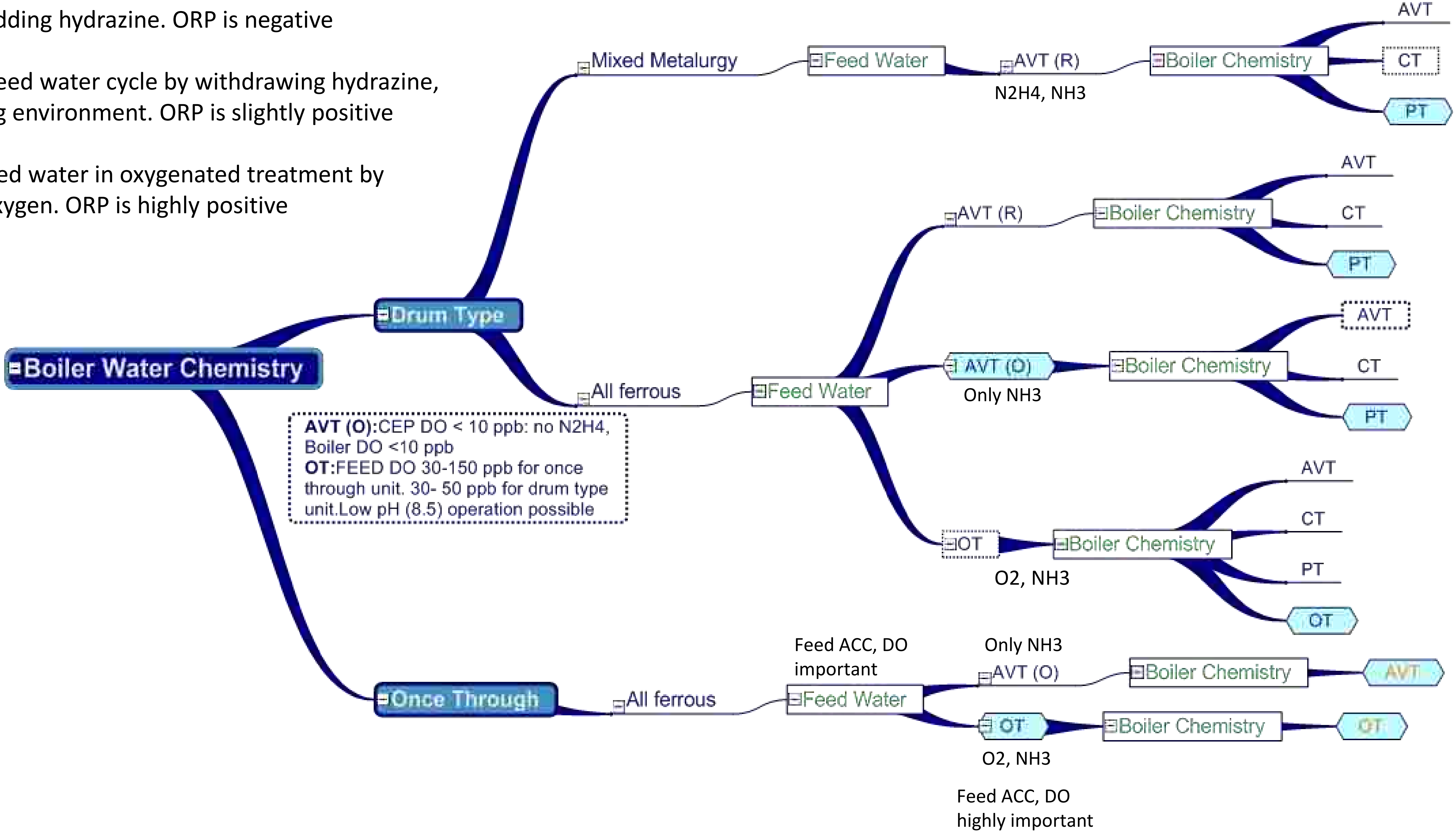
Figure 3-2
Example of Severe Ongoing FAC Damage (Above) – Black Magnetite Covered Surfaces, Example of Previous FAC Damage Now Protected (Below) – Red Hematite Covered Surfaces

Excuse me! Some Jargon please!!

AVT (R) – It is to run feed water cycle in reducing environment by adding hydrazine. ORP is negative

AVT (O) – To run feed water cycle by withdrawing hydrazine, in slightly oxidising environment. ORP is slightly positive

OT – it is to run feed water in oxygenated treatment by adding external oxygen. ORP is highly positive



SCHEMATIC COMPARISION AVT Vs OT I ONCE -THROUGH SYSYTEM

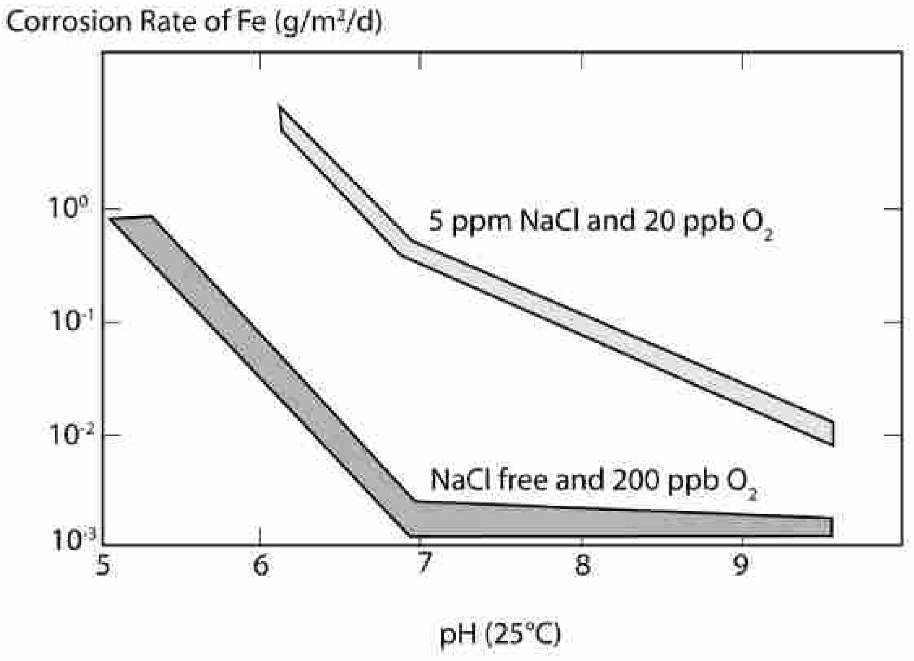
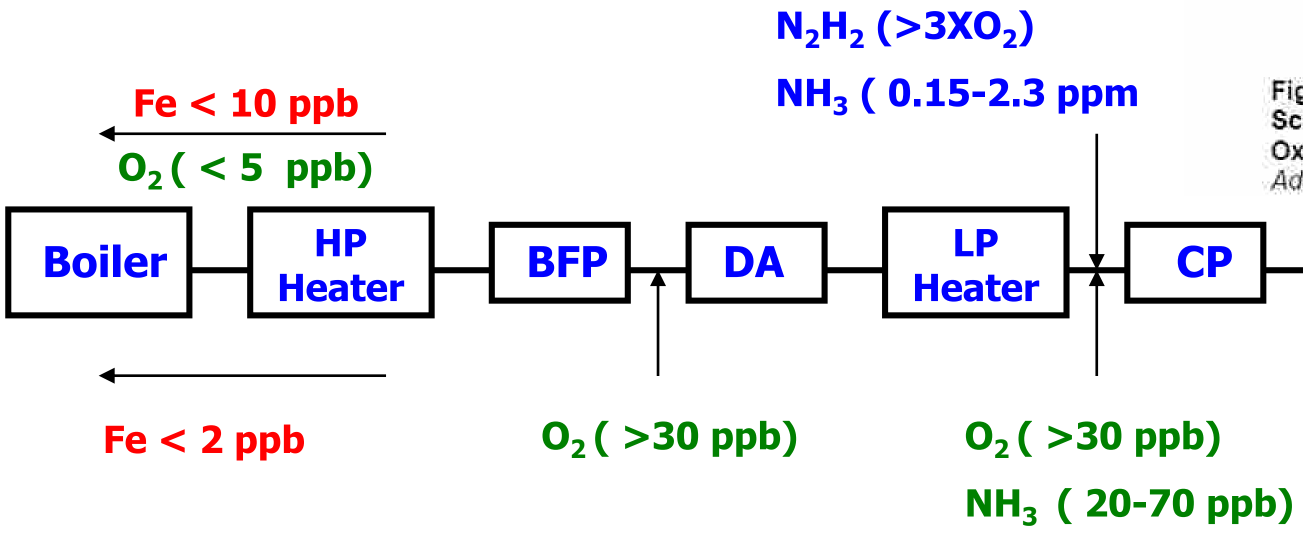


Figure 2-22
Schematic of Corrosion Rate of Carbon Steel in Flowing Water as a Function of pH and Oxygen at Around 65°C (150°F)
Adapted from data in Reference [39]

All Volatile Treatment (AVT)

- Ferrous or mixed feedwater train
- Cation conductivity 0.2-0.4 µS/cm
- pH 8.8-9.6 (Dependent on feedwater metallurgy



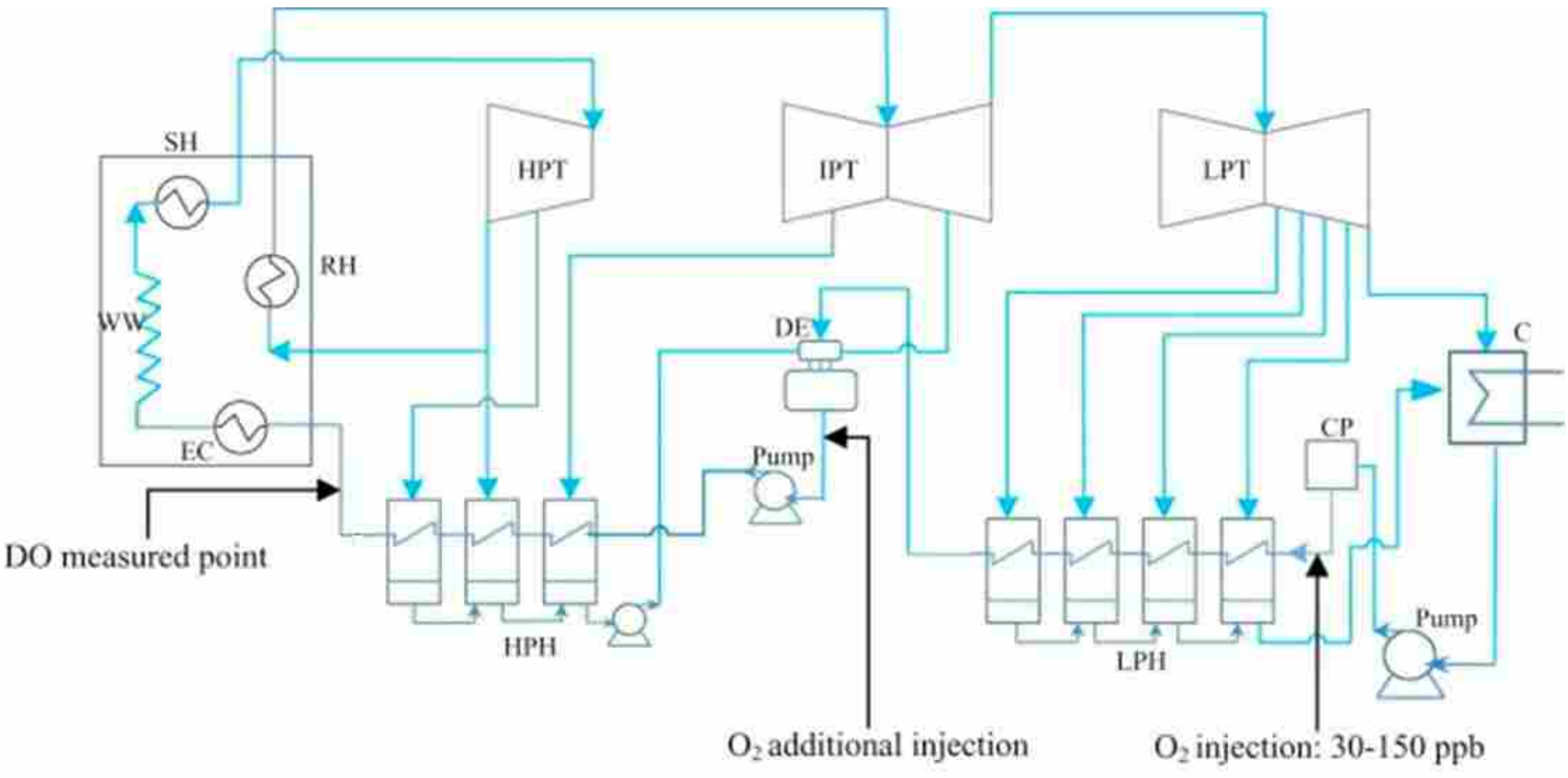
Oxygenated Treatment (OT)

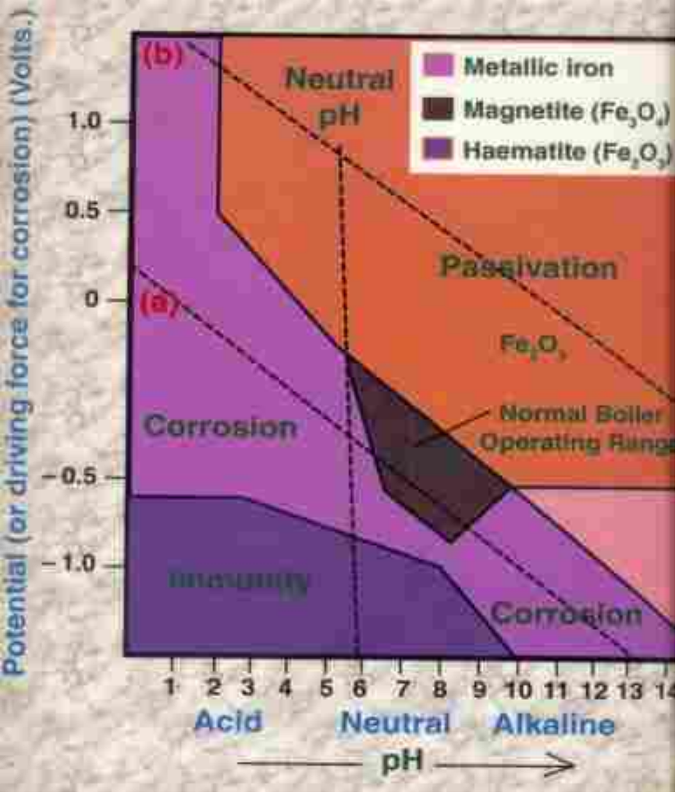
- All ferrous feedwater train
- Cation conductivity <0.15 µS/cm
- pH 8.0-8.5

OT Target Relationship of pH and Oxygen

pH_{25C}	Oxygen, ppb
7.0	≥200
8.0	≥150
8.5	≥100
9.0	≥50
9.5	≥30

OT in once through unit





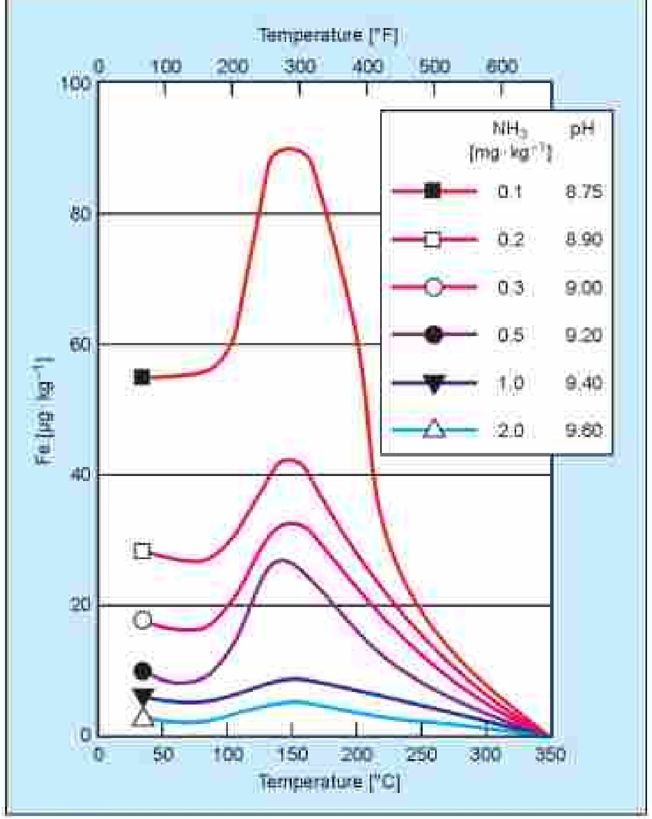


Figure 8:

Solubility of magnetite as a function of temperature at various ammonia concentrations (Source: Sturla [45]).

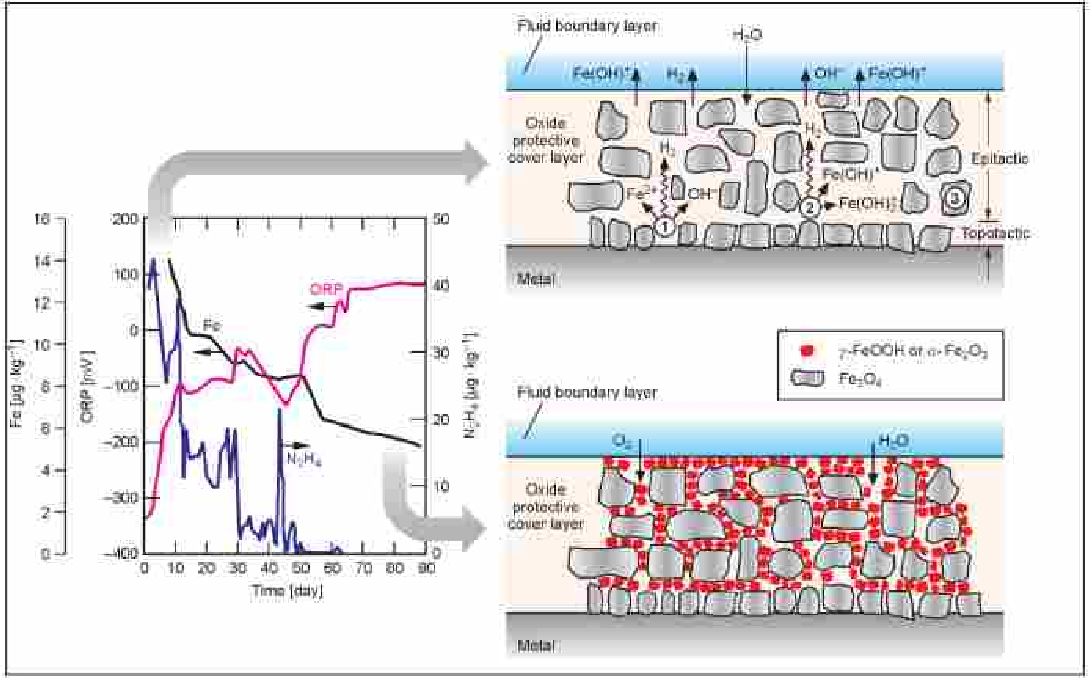
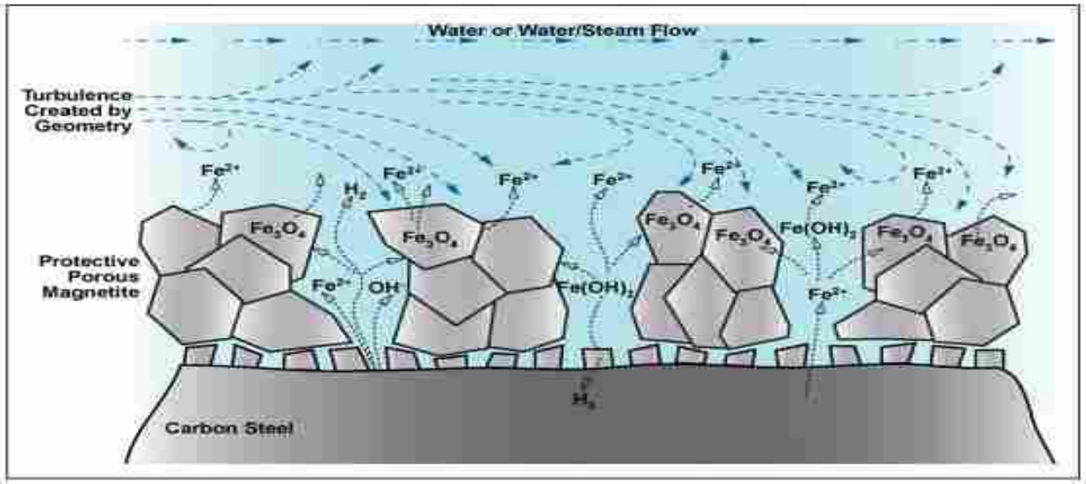
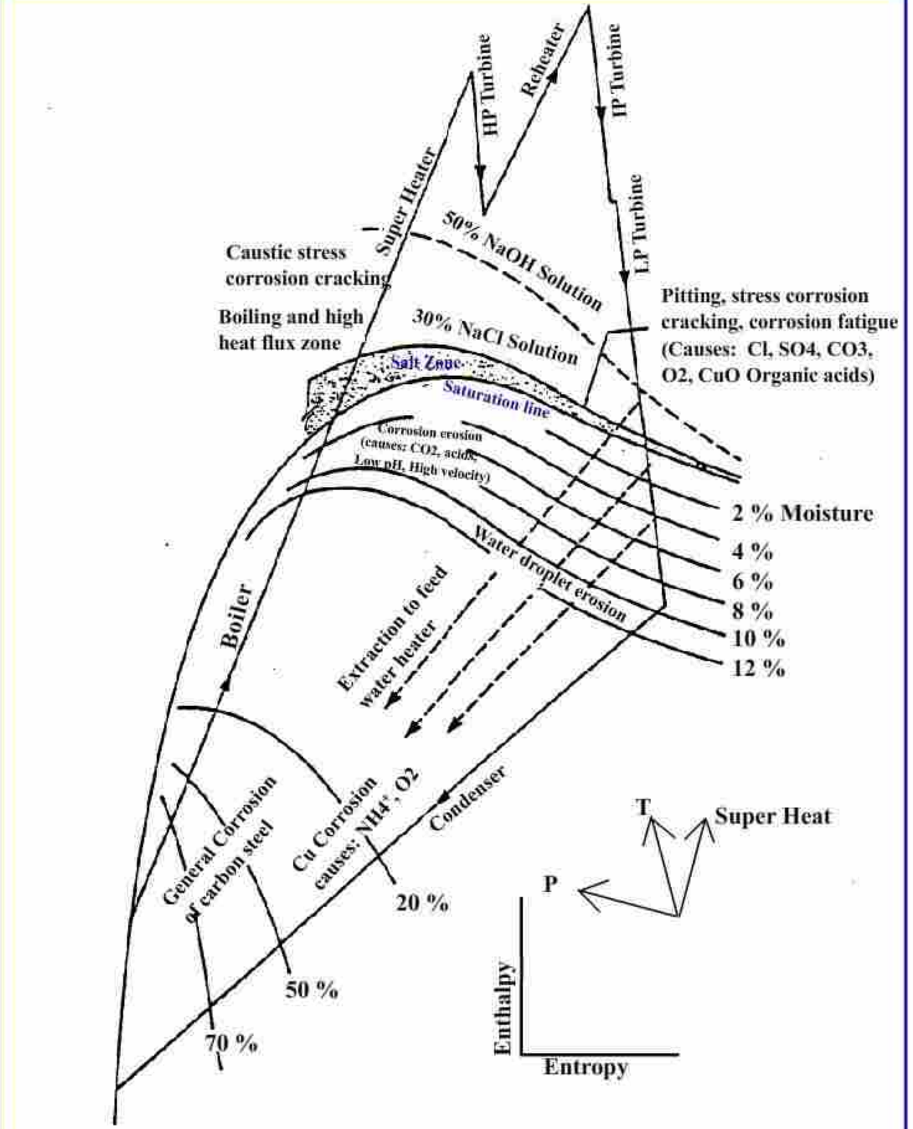


Figure 7:

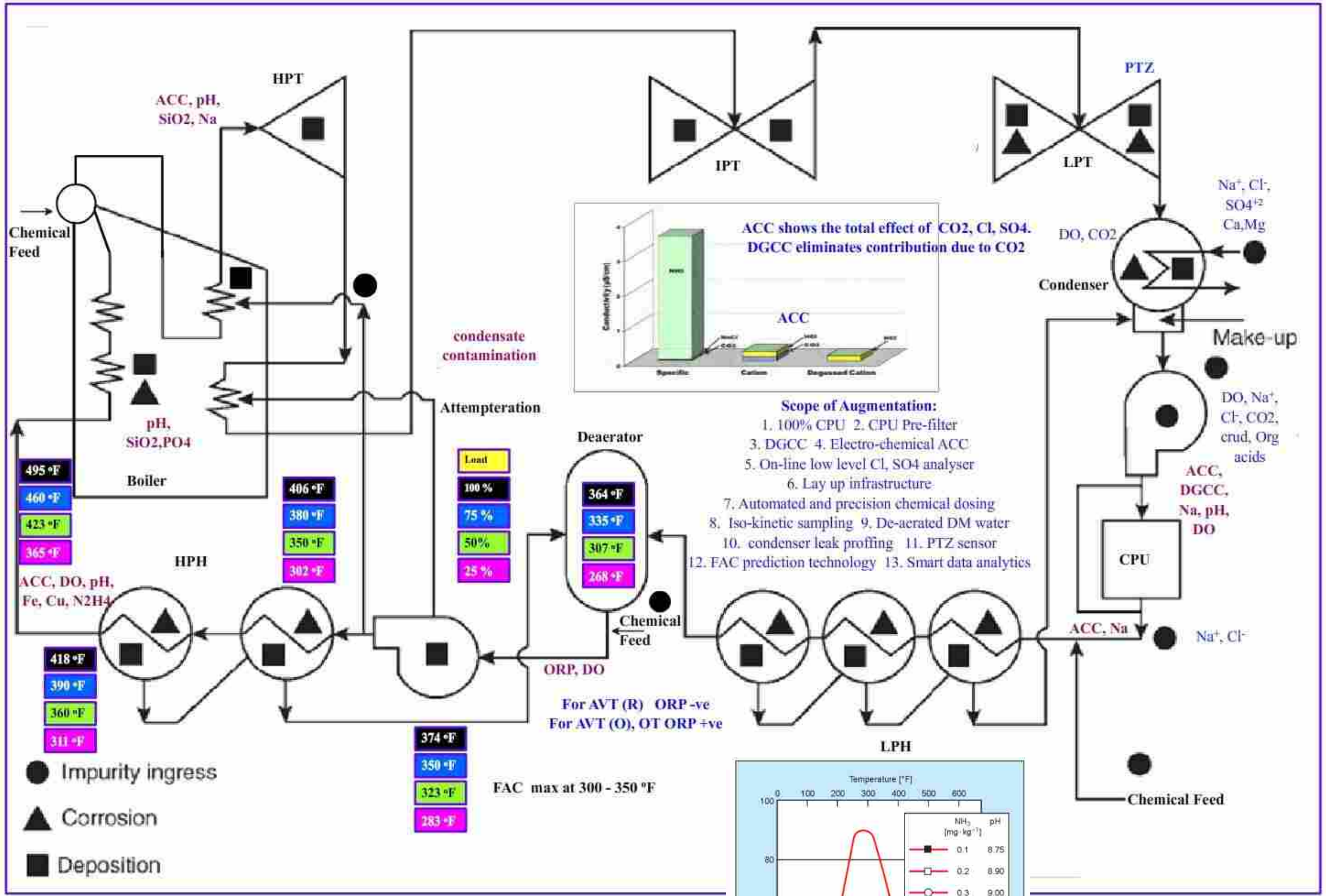
Illustrating how the growth of oxides on carbon steel surfaces is controlled by the potential (ORP). The figure on the left shows how the amount of iron at the economizer inlet changes as a function of the ORP when the reducing agent is gradually eliminated to zero (Source: Platt, Vinnicombe [43]). The two drawings on the right illustrate schematically under laminar flow conditions (with a slow moving boundary layer or liquid) the growth of magnetite (top) under reducing conditions and the growth of a cover layer of FeOOH (bottom) on the magnetite under oxidizing conditions of AVT(O) or OT (Source: Dooley [36,44]).



Schematics of the mechanism FAC



Note: This diagram illustrates regions where impurities will concentrate and promote corrosion. points in the diagram should relate to actual conditions at component surfaces, not to the theoretical average flow path conditions. Heat transfer, surface cleanliness, crevices, and surface-flow stagnation conditions determines theactual surface temperature and pressure.



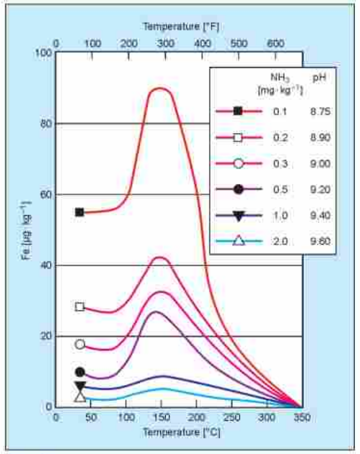


Figure 8:
Solubility of magnetite as a function of temperature at various ammonia concentrations (Source: Sturla [45]).

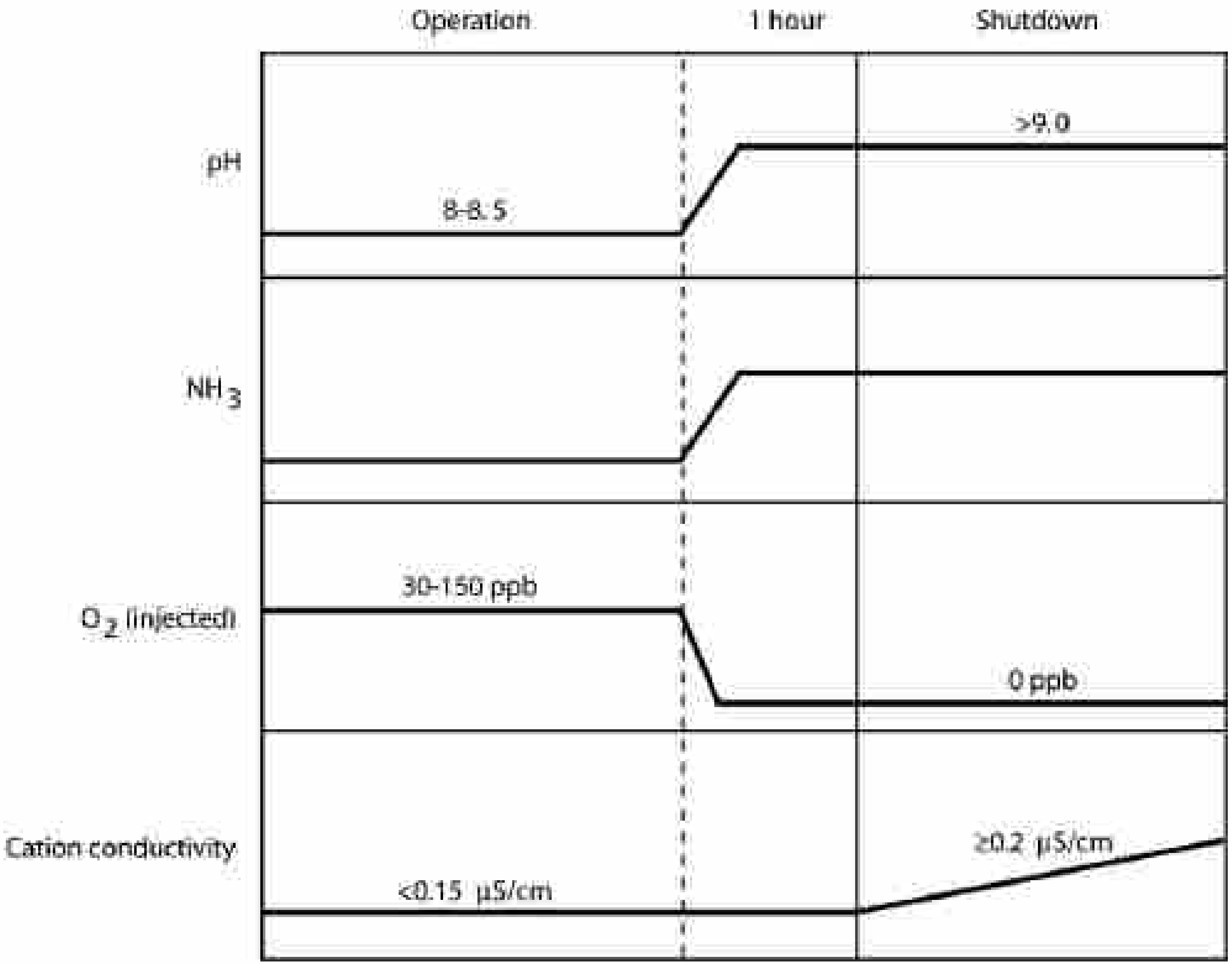


Figure 5-6
Shutdown and operation guidance on ot chemistry for wet layup (once-through units) [16]

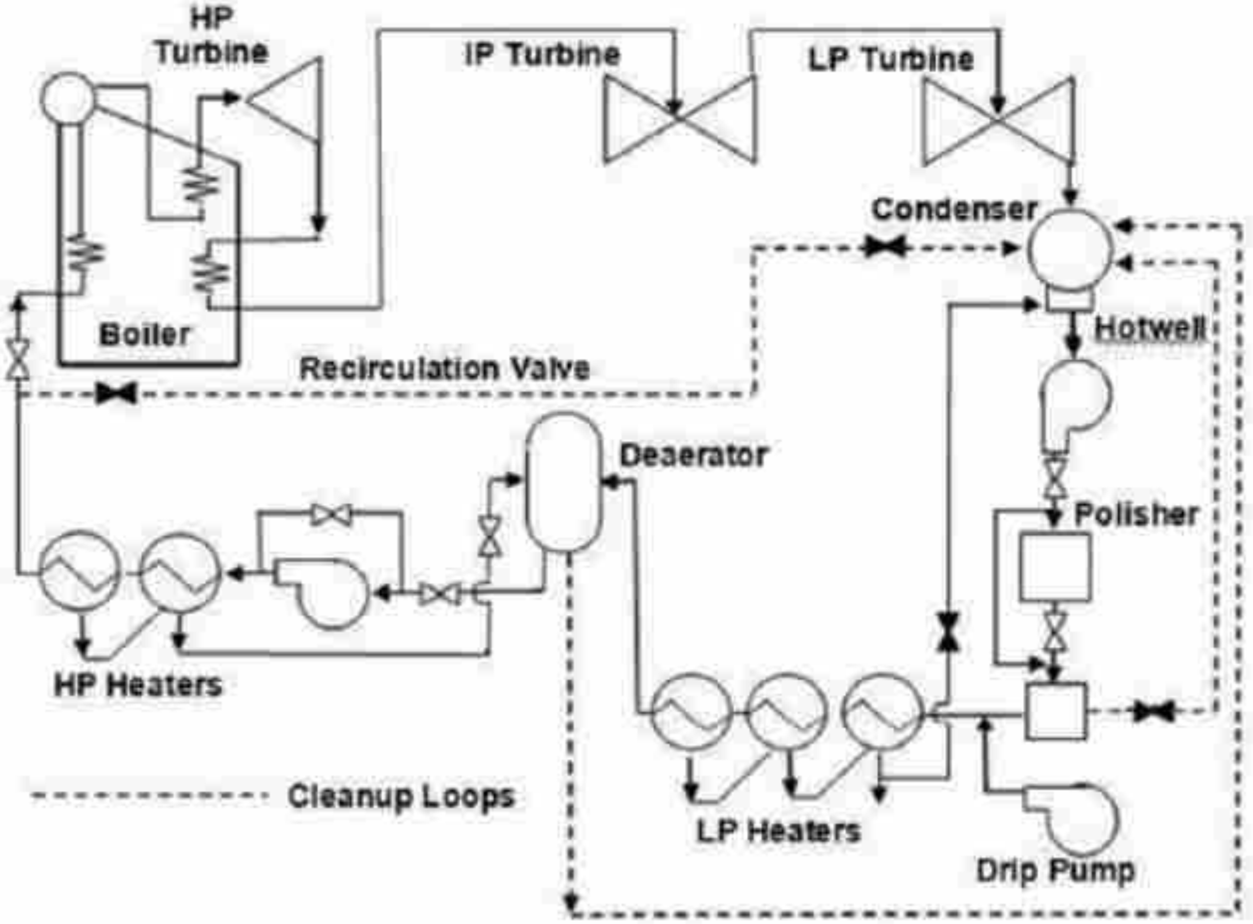
Sampling Point Location	Analysis	A Charge Condensate	B Fill Boiler	C Fire Boiler	D Roll Turbine/ On-Line	E Ready to Ramp	F Full Load Capable
Condensate Pump Discharge Units with Polisher	pH, S.U.	9.2 - 9.6	9.2 - 9.6	9.2 - 9.6	9.2 - 9.6	9.2 - 9.6	9.2 - 9.6
	Oxygen, ppb	< 200	< 200	< 100	< 100	≤ 20	≤ 20
	Cat. Cond., µS/cm	-----	-----	≤ 0.80	≤ 0.40	≤ 0.30	≤ 0.30
	Sp. Cond., µS/cm	4.0 - 10	4.0 - 10	4.0 - 10	4.0 - 10	4.0 - 10	4.0 - 10
	Sodium, ppb	-----	< 24	< 24	< 12	≤ 6	≤ 6
	Silica, ppb	≤ 200	≤ 100	≤ 50	≤ 50	≤ 20	≤ 20
Condensate Pump Discharge Units without Polisher	pH, S.U.	9.2 - 9.6	9.2 - 9.6	9.2 - 9.6	9.2 - 9.6	9.2 - 9.6	9.2 - 9.6
	Oxygen, ppb	< 200	< 200	< 100	< 100	≤ 20	≤ 20
	Cat. Cond., µS/cm	-----	-----	≤ 0.80	≤ 0.3	≤ 0.2	≤ 0.2
	Sp. Cond., µS/cm	4.0 - 10	4.0 - 10	4.0 - 10	4.0 - 10	4.0 - 10	4.0 - 10
	Sodium, ppb	-----	≤ 12	≤ 12	≤ 6	≤ 3	≤ 3
Condensate Polisher Effluent (If Applicable)	Cat. Cond., µS/cm	-----	-----	≤ 0.80	≤ 0.3	≤ 0.2	≤ 0.2
	Sodium, ppb	-----	< 12	≤ 6	≤ 6	≤ 3	≤ 3
	Silica, ppb	≤ 100	≤ 50	≤ 20	≤ 20	≤ 10	≤ 10

Sampling Point Location	Analysis	A Charge Condensate	B Fill Boiler	C Fire Boiler	D Roll Turbine/ On-Line	E Ready to Ramp	F Full Load Capable
Economizer Inlet	pH, S.U.	-----	9.2 - 9.6	9.2 - 9.6	9.2 - 9.6	9.2 - 9.6	9.2 - 9.6
	Oxygen, ppb	-----	$<$ 200	$<$ 100	$<$ 100	$\leq$20	$\leq$20
	Cat. Cond., µS/cm	-----	-----	$\leq$ 0.80	$\leq$ 0.3	$\leq$ 0.2	$\leq$ 0.2
	Sp. Cond., µS/cm	-----	4.0 - 10	4.0 - 10	4.0 - 10	4.0 - 10	4.0 - 10
Boiler Water	pH, S.U.	-----	9.0 - 9.6	9.0 - 9.6	9.0 - 9.6	9.0 - 9.6	9.0 - 9.6
	Phosphate, ppm	-----	0.2 - 2	0.2 - 2	0.2 - 2	0.2 - 2	0.2 - 2
	Cat. Cond., µS/cm	-----	-----	Use Cat. Conductivity versus Drum Pressure Curve			
	Sodium, ppb	-----	-----	Use Sodium versus Drum Pressure Curve			
	Silica, ppb	-----	-----	Use Silica versus Drum Pressure Curve			
Superheat or Reheat Steam	Cat. Cond., µS/cm	-----	-----	-----	$\leq$ 0.40	$\leq$ 0.2	$\leq$ 0.2
	Sodium, ppb	-----	-----	-----	$\leq$ 8	$\leq$ 4	$\leq$ 2

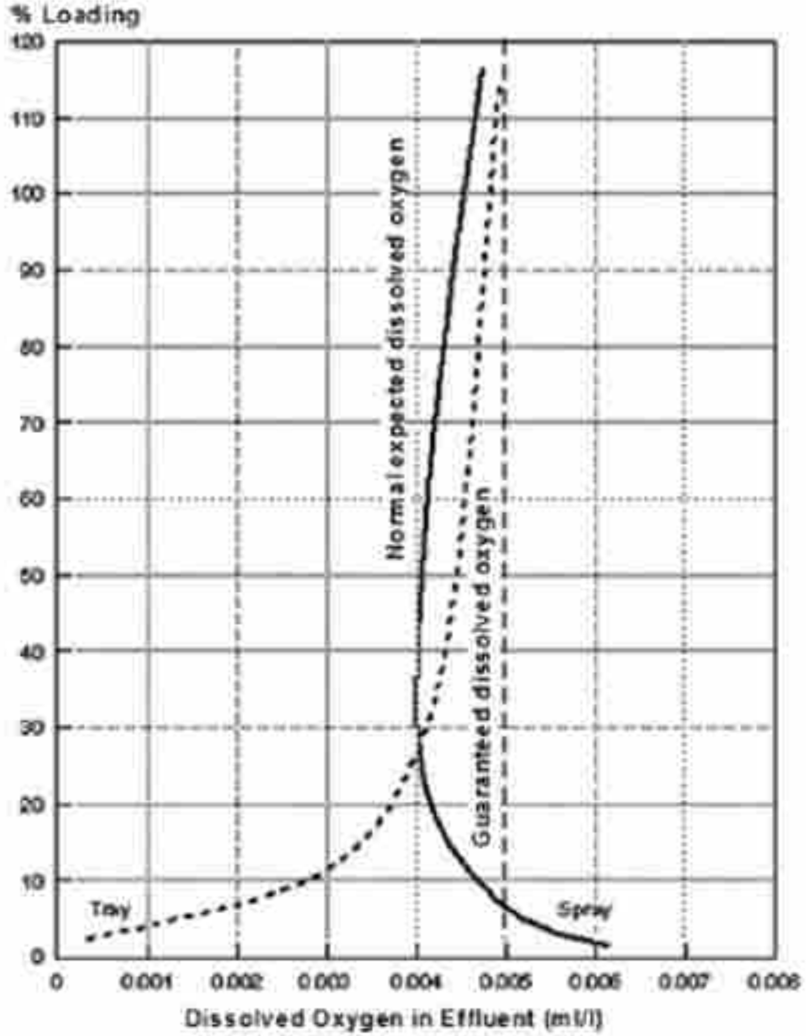
A) Charge Condensate - condensate pumps on, turbine seals, vacuum, steam on deaerator
B) Fill boiler - N_2 system off, SH vents open, treated condensate/demineralized water
C) Fire the Boiler - ignitors in up to 300 psi drum pressure
D) Roll Turbine/On-line - steam flow through turbine, no extractions except deaerator
E) Ready to Ramp - all turbine heat and rotational soaks complete, operating at minimum load
F) Full Load Capable - at full load or unit available to go to full load

Notes:
pH 9.2-9.6 All-Ferrous Metallurgy - corresponds to specific conductivity of 4.0 - 10.0
Boiler water sodium, silica, and cation conductivity limits based on concentration versus drum pressure curves.

Start up Clean up



Three Feed Water Clean-up loops



Three guiding principles that should govern all layup decisions and practices

Principle 1: Keep the Chemical Oxidation-Reduction Potential of the Water in the Cycle the Same During All Operating Conditions − This refers not only to excluding air, but to maintaining chemical residuals that exist during operation. If reducing agents (i.e., hydrazine) are used during normal operation, they should be used during layup. If they are not, they should not be introduced just for layup.

Principle 2: Keep Water from Becoming Oxygenated by the Surrounding Environment – Regardless of the chemistry during operation, water in the steam cycle should never be allowed to become saturated with oxygen by unrestricted contact with air as it will cause corrosion.

Principle 3: Keep Water and Moisture out of Steam Touched Components and any Water Touched Surface to be Maintained Dry during the Shutdown Period − Any successful layup practice will require consideration of all the water/steam-touched equipment in the steam cycle and should begin as the equipment is being removed from service. The partial layup of the system or layup of only some of the equipment (boiler) will not produce the desired results or provide adequate corrosion protection.

Dispatch requires that the unit be generating electricity in the shortest possible time

Pressure can be maintained on the boiler and DA and vacuum can be maintained on the condenser throughout the outage of the shutdown

Outage duration is anticipated to be hours (overnight)

Recommend:

Hot Standby

Require access to the boiler, deaerator or other steam cycle equipment that normally contains water or steam

Boiler water has been chemically contaminated and needs to be drained and rinsed

Protection against freezing is required

There will be sufficient notice to refill the boiler and feedwater piping and equipment before restart

Outage duration is anticipated to be weeks or months or is unknown

Recommend:

Dry Layup

No access to the water/steam-side of the boiler, deaerator, or other steam cycle equipment is anticipated during the outage

Ability to produce high purity water is limited

Need to respond quickly to a request for the unit. (do not have time to refill)

Have the capacity to maintain a blanket of nitrogen or exclude air from wet equipment

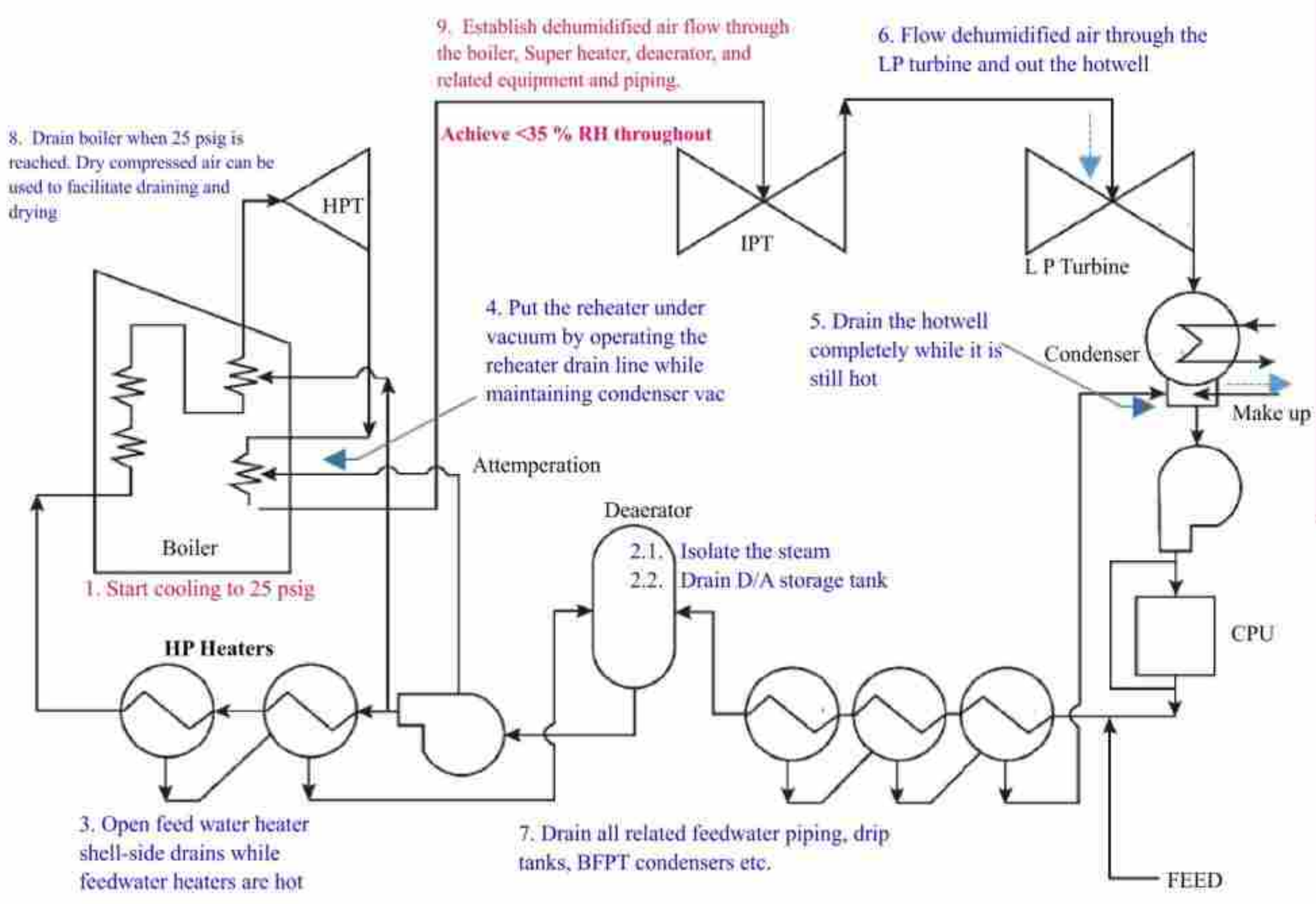
Outage duration is anticipated to be a few days to a week

Recommend

Wet Layup

Decision matrix for layup practices

Hot stand by
Maintain condenser vacuum
Prior to or during shut-down ensure boiler pH>9.5
Fire boiler as needed to maintain positive pressure on the boiler and deaerator
Blanket any equipment with nitrogen that would be exposed to air



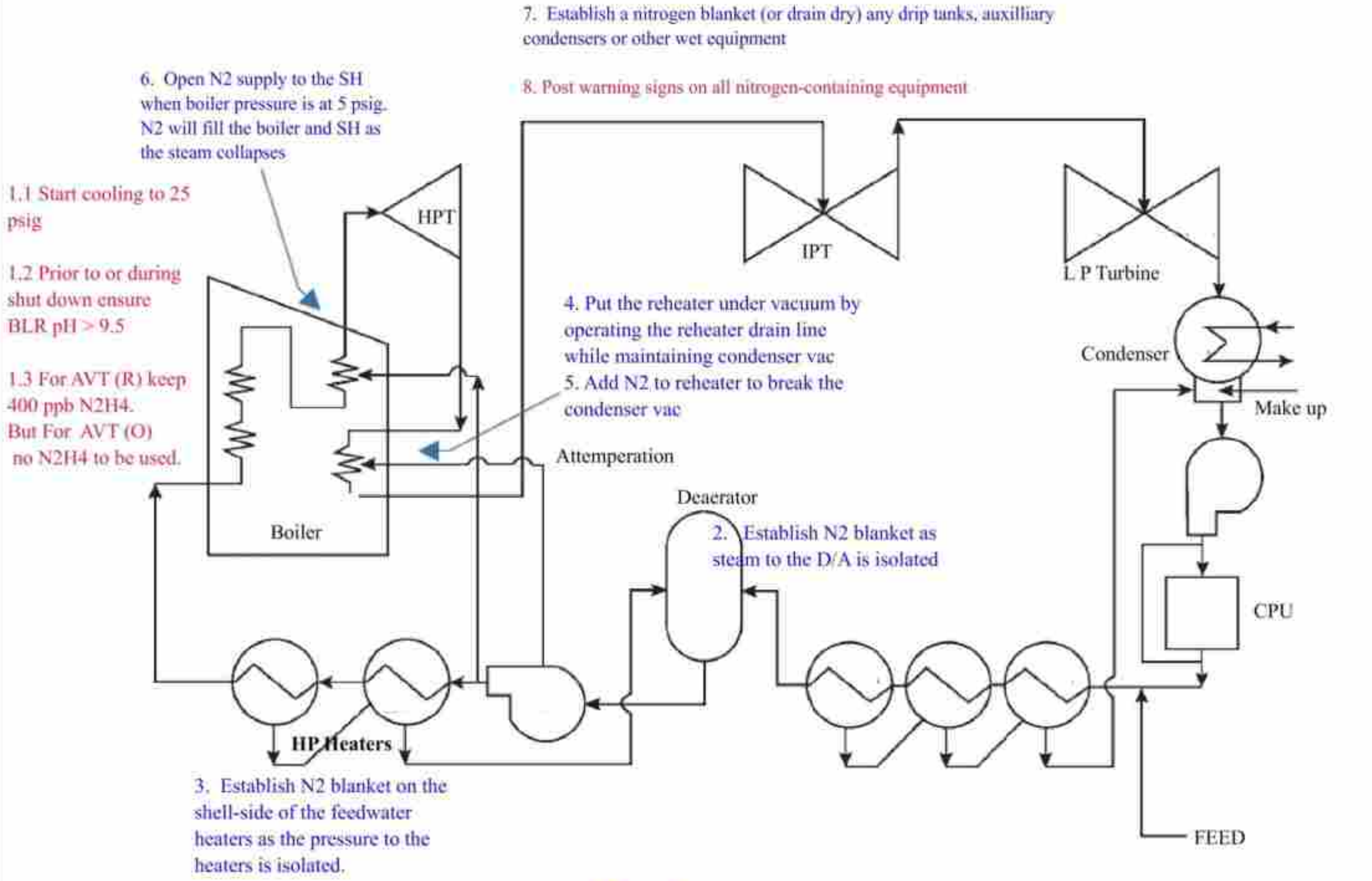
For N2 preservation:
upto sequence 7 same as dry air lay up, and then as follows:

8. Apply N2 to the super heater vent and drain the super heater and boiler under N2 when the boiler reaches 25 psig

9. Post warning sign on nallnconfined spacesin the steam cycle that equipment is nitrogen filled

10, maintian a slight positive pressure of nitrogen on the boiler during the entire lay-up and through the subsequent boiler fill

Dry Lay-up Air


7. Establish a nitrogen blanket (or drain dry) any drip tanks, auxilliary condensers or other wet equipment
8. Post warning signs on all nitrogen-containing equipment
6. Open N2 supply to the SH when boiler pressure is at 5 psig. N2 will fill the boiler and SH as the steam collapses
1.1 Start cooling to 25 psig
1.2 Prior to or during shut down ensure BLR pH > 9.5
1.3 For AVT (R) keep 400 ppb N2H4. But For AVT (O) no N2H4 to be used.
HPT
IPT
L P Turbine
Condenser
Make up
4. Put the reheater under vacuum by operating the reheater drain line while maintaining condenser vac
5. Add N2 to reheater to break the condenser vac
Attemperation
Deaerator
2. Establish N2 blanket as steam to the D/A is isolated
Boiler
CPU
HP Heaters
FEED
3. Establish N2 blanket on the shell-side of the feedwater heaters as the pressure to the heaters is isolated.

Wet Lay-up

Flexible Operation is a reality be better prepared for it!

Thank you