Amines in Air Cooled Condensers

San Diego Annual Conference

September 24, 2014

Bill Stroman

KAAM GROUP inc.

Products for the Power Industry

AIR COOLED CONDENSER

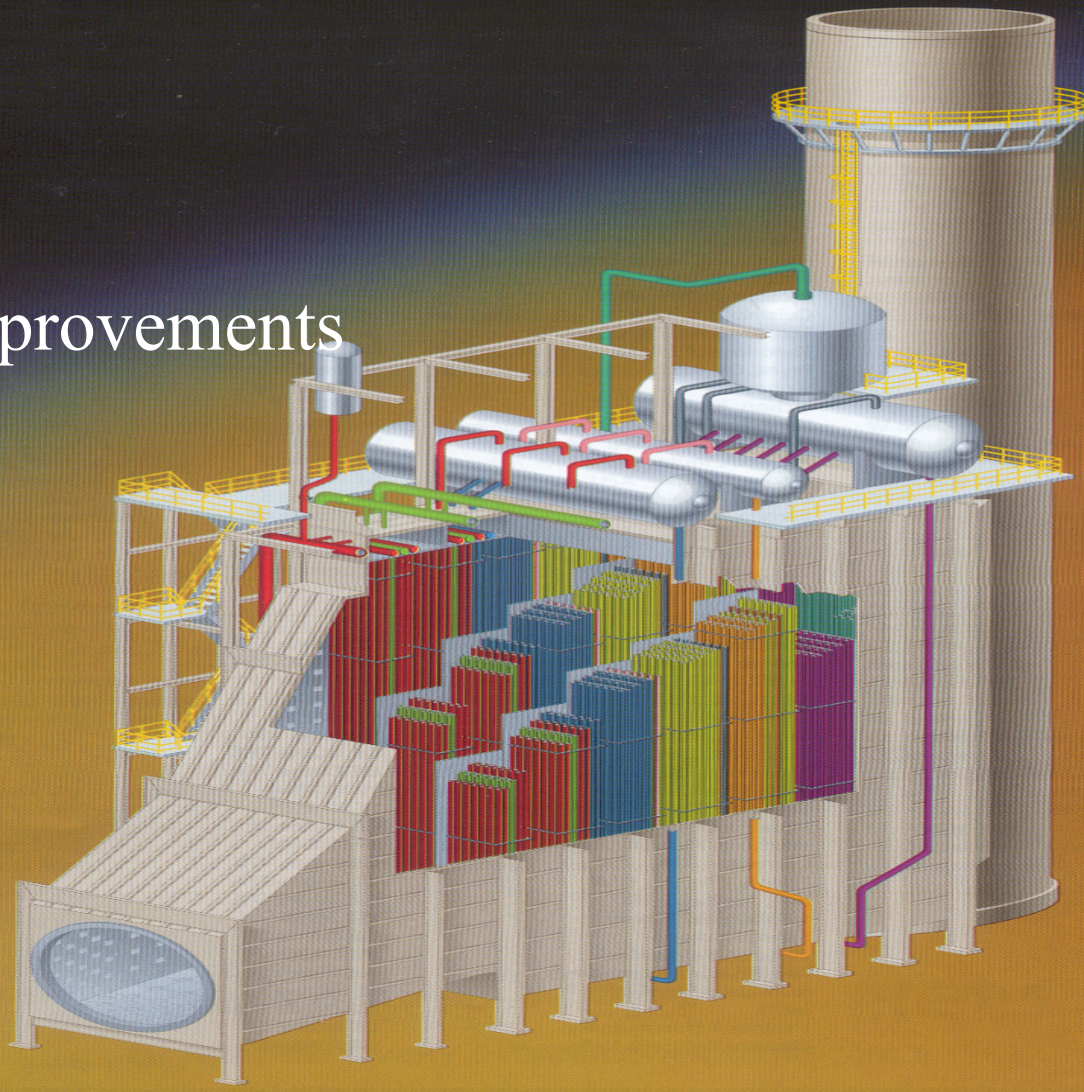
- Large iron surface area
- Potential for air inleakage
- Air inleakage can lead to problems with freezing

Chemistry Control Limits and Action Guidelines for Addressing:

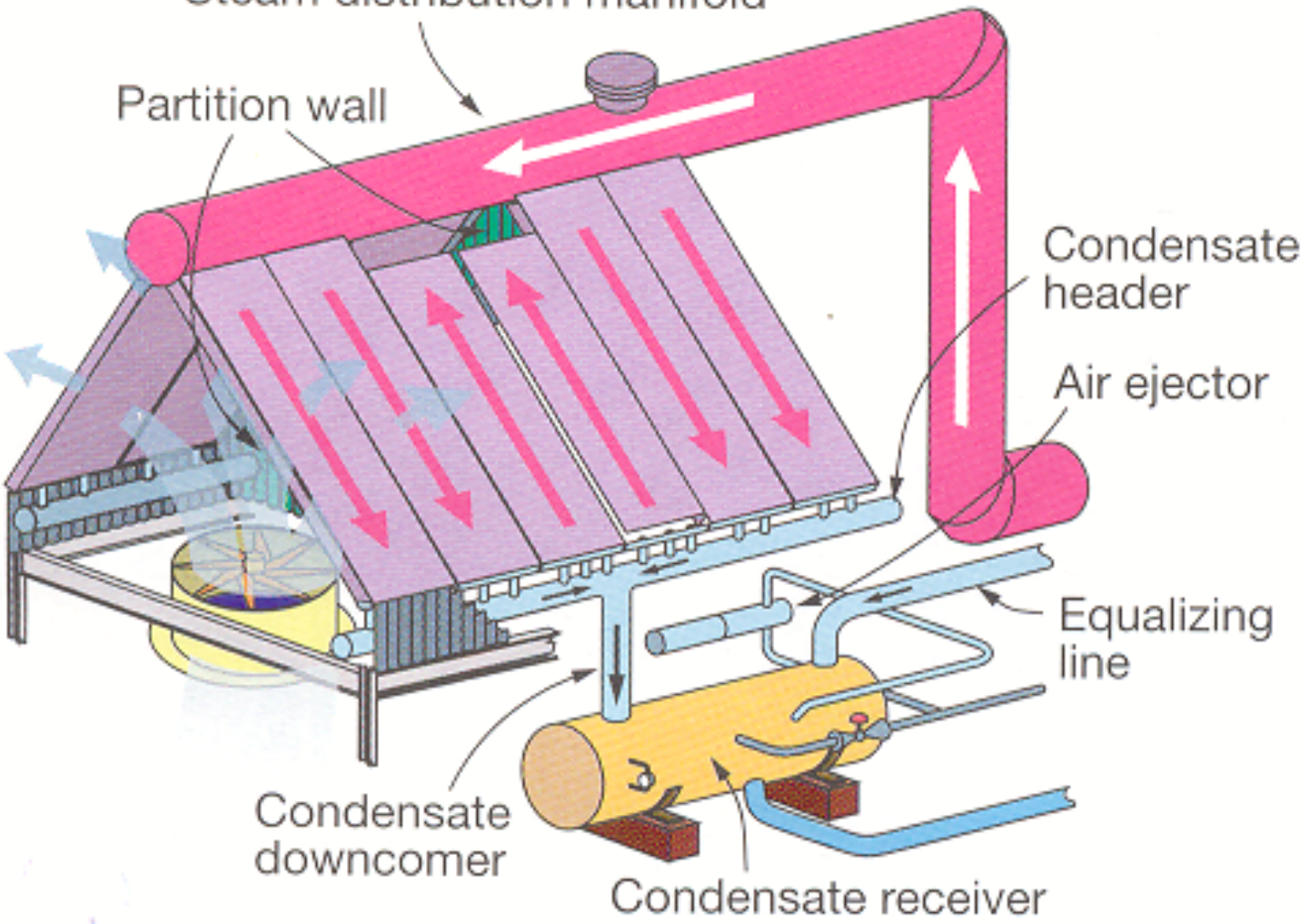
- Steam Cycle Chemistry
  - Preboiler, Boiler, Steam, Condensate
- Online Monitoring
- Routine Grab Sample Testing
- Abnormal Conditions-What is done?
- Cycling conditions for Startup & Shutdown
- Layup

Chemistry Program Requires Representative Sample In Order To:

- Measure
- Maintain
- Manage
- Make Improvements



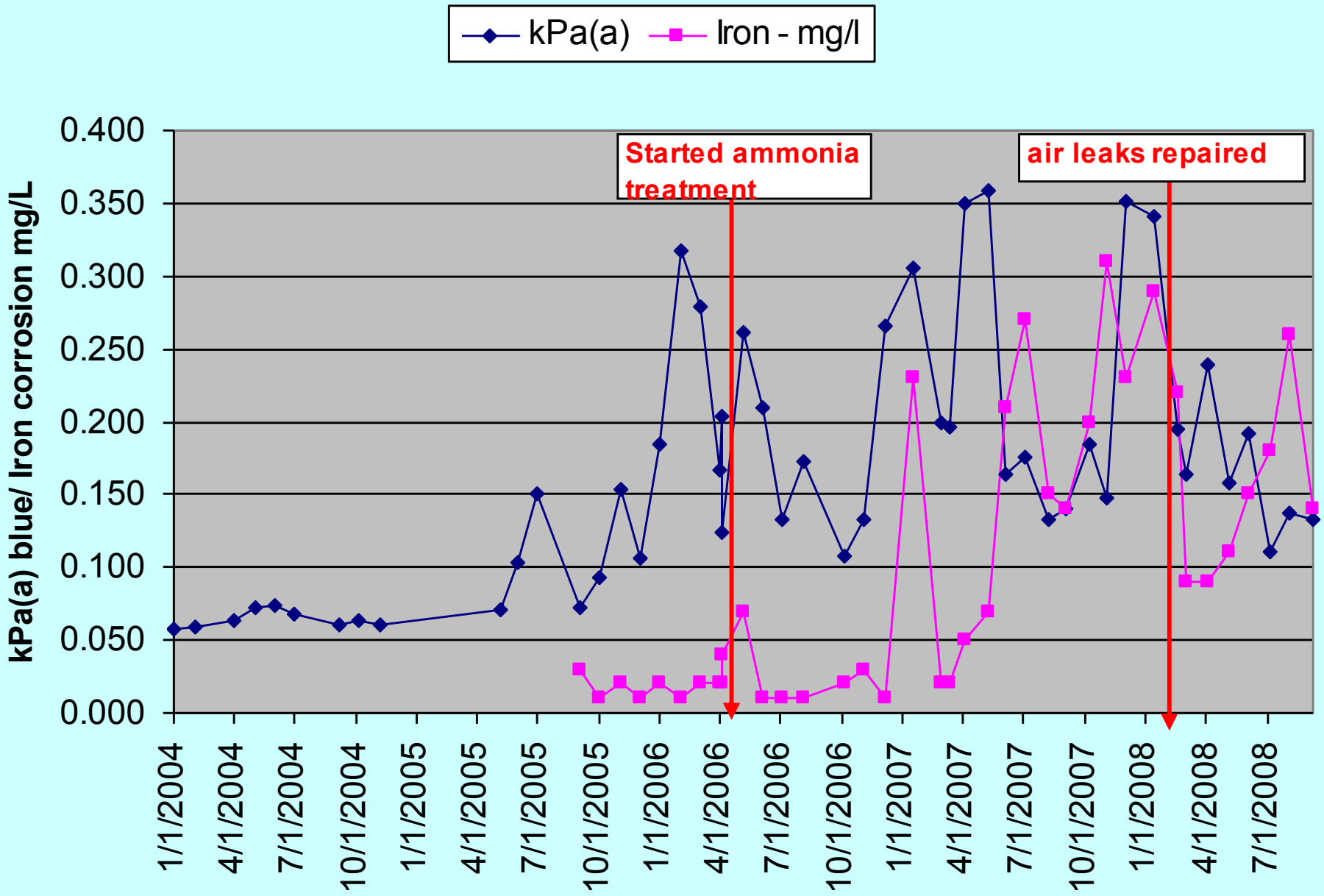
FAC corrosion in duct and
Inlet tube areas



For ~10 years the chemistry was hydrazine/morpholine then was changed during 2006 to ammonia treatment.
Problem was not previously noted.
This picture was provided to use as DHACI #4

18 inch crack below steam turbine exhaust

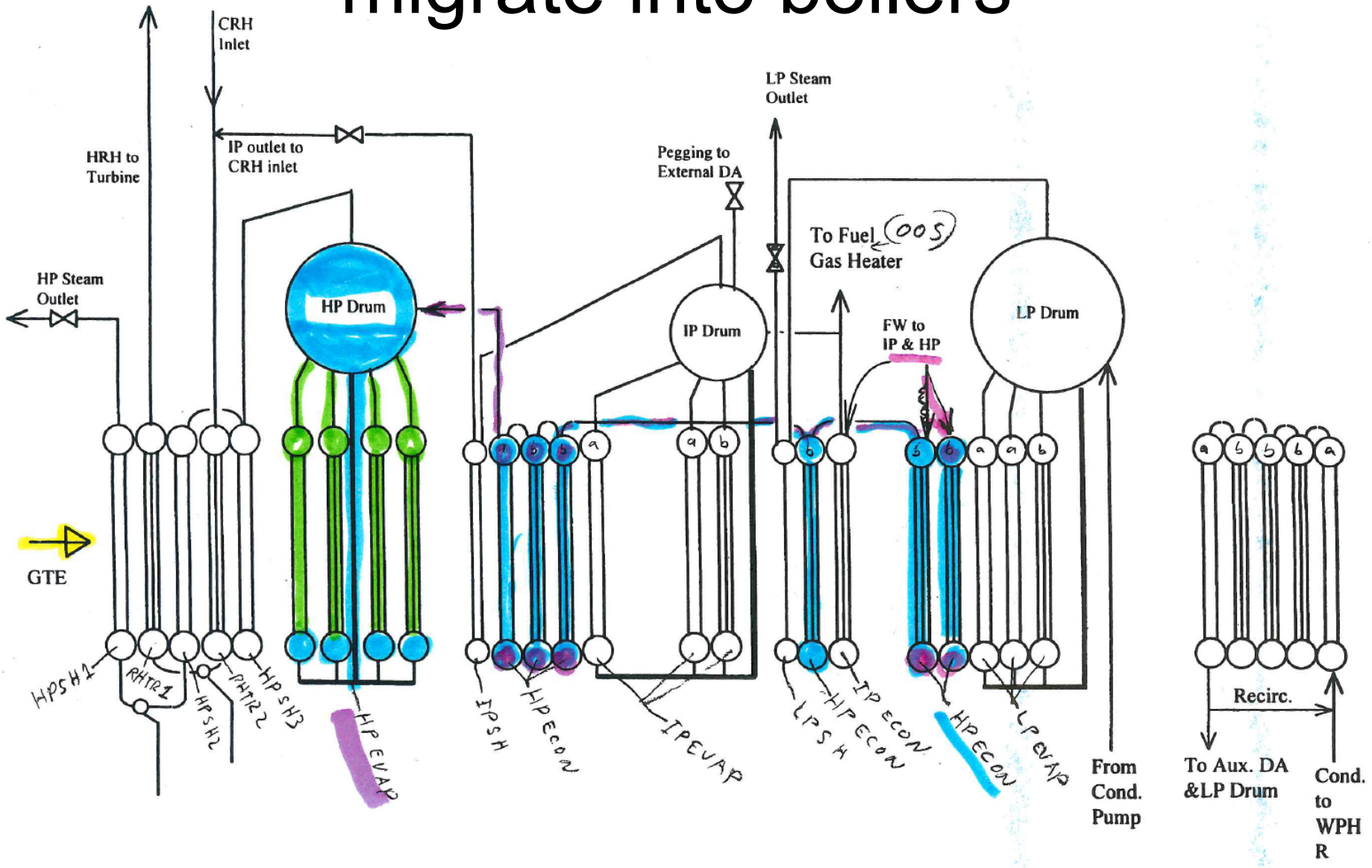
Vacuum kPa(a) vs Iron Corrosion

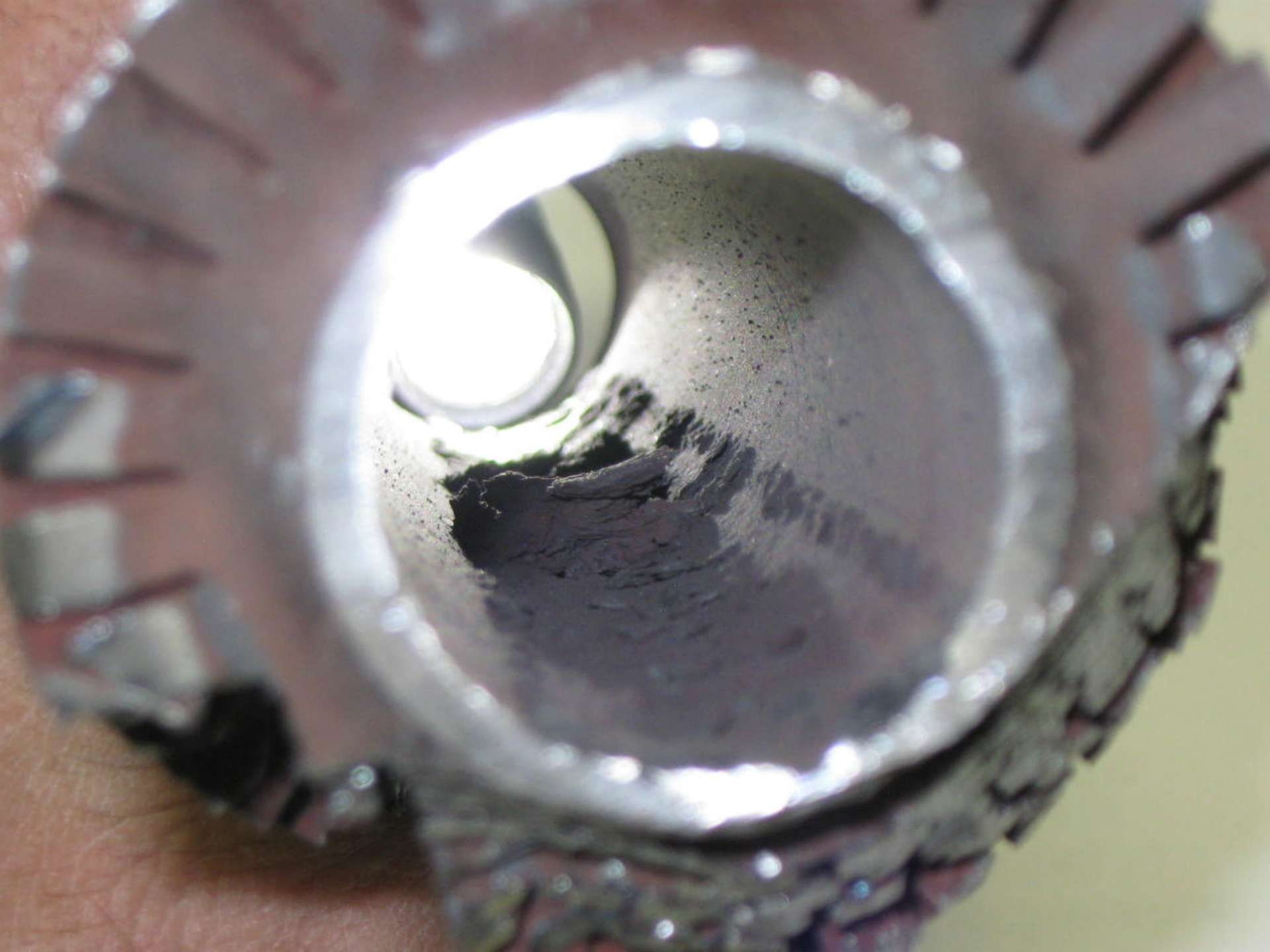


Corrosion byproduct accumulation

- Leads to deposition and corrosion related failures
- Cost to chemical clean HRSG boilers is very expensive
- Cost to dispose of post chemical cleaning waste is very expensive
- HRSG units are not designed for conventional chemical cleaning methods to address tube corrosion issues

HRSG corrosion by products migrate into boilers



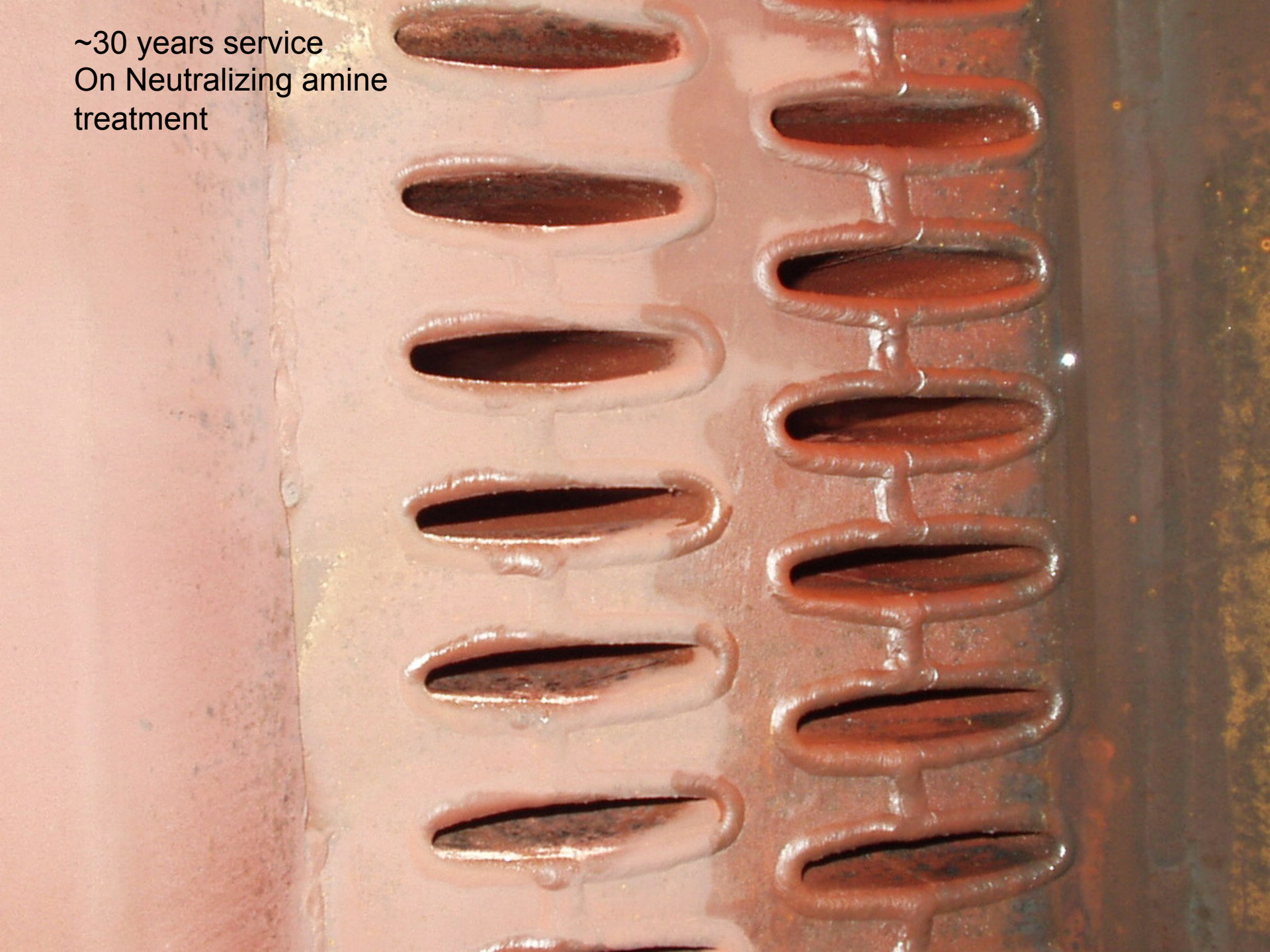


Underdeposit Corrosion

- Problem with HRSG units is the tubes have fins. NDE for oxide thickness not viable.
- If underdeposit corrosion has developed can do some NDE but only the leading row.
- When was a tube specimen removed to evaluate the internal condition?

Amine Use

- Have been successfully used in steam generating equipment for >40 years
- Used in essentially all US Nuclear facility steam generators
- EPRI recommends the use of ammonia for feedwater pH control in all ferrous systems but needs to be maintained in desired pH control range.
- However, if not controlled in desired pH range corrosion occurs in ACC.


~30 years service
On Neutralizing amine
treatment

Feedwater pH

- pH must be alkaline to minimize iron corrosion
- For all ferrous units 9.2-9.6 is recommended units with ACC 9.4-10 with 9.8-10 preferred.

Common Amines in Steam Production

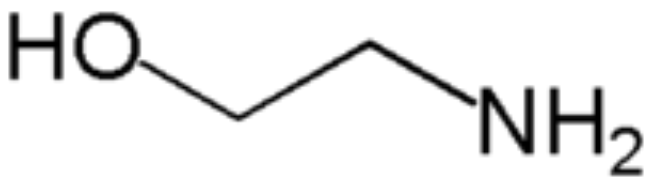
- Cyclohexylamine
- Morpholine
- Ethanolamine (monoethanolamine) [MEA]
- Methoxypropylamine (MOPA)
- Diethylaminoethanol (DEAE)

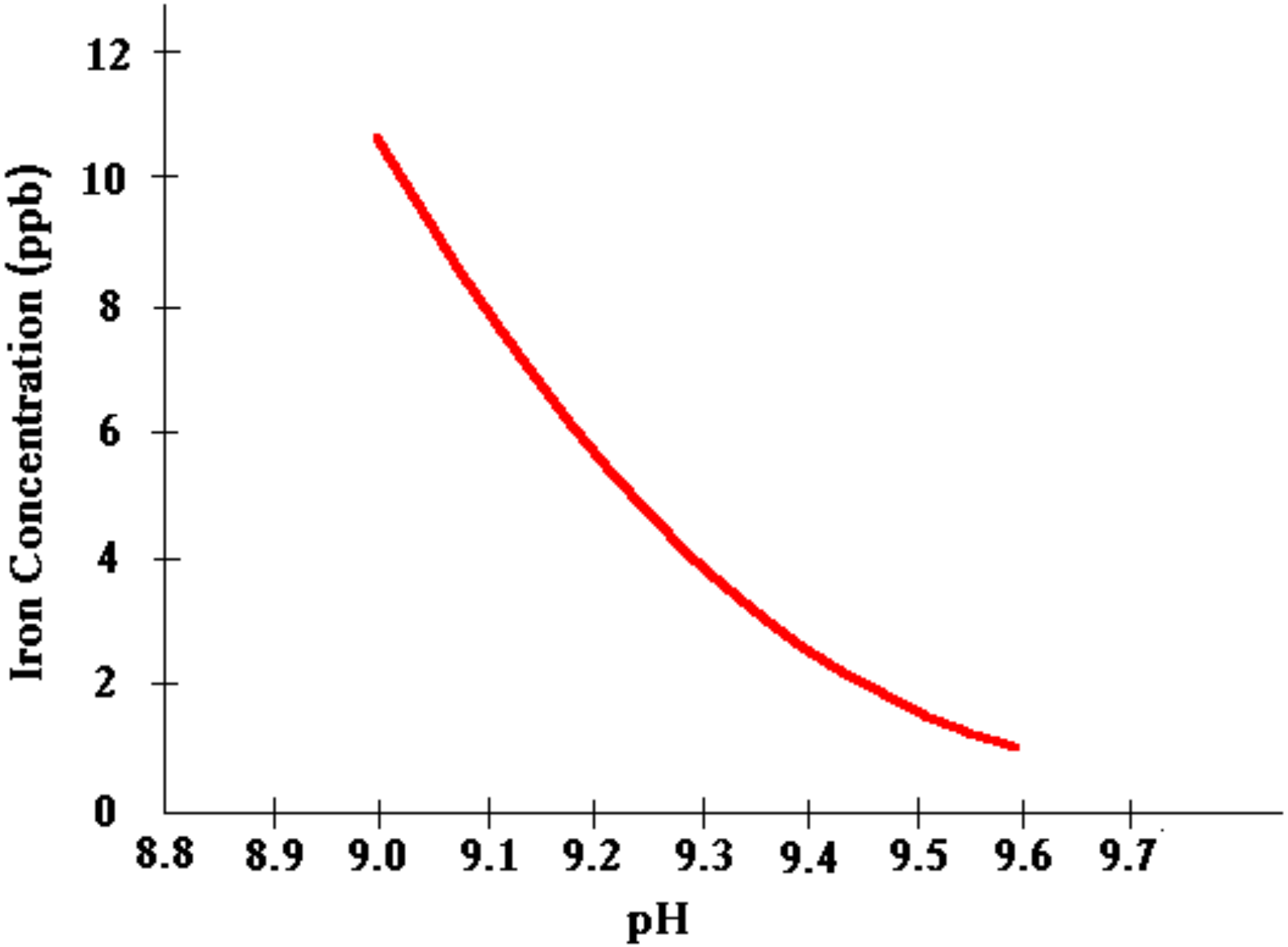
MEA/Ammonia blend

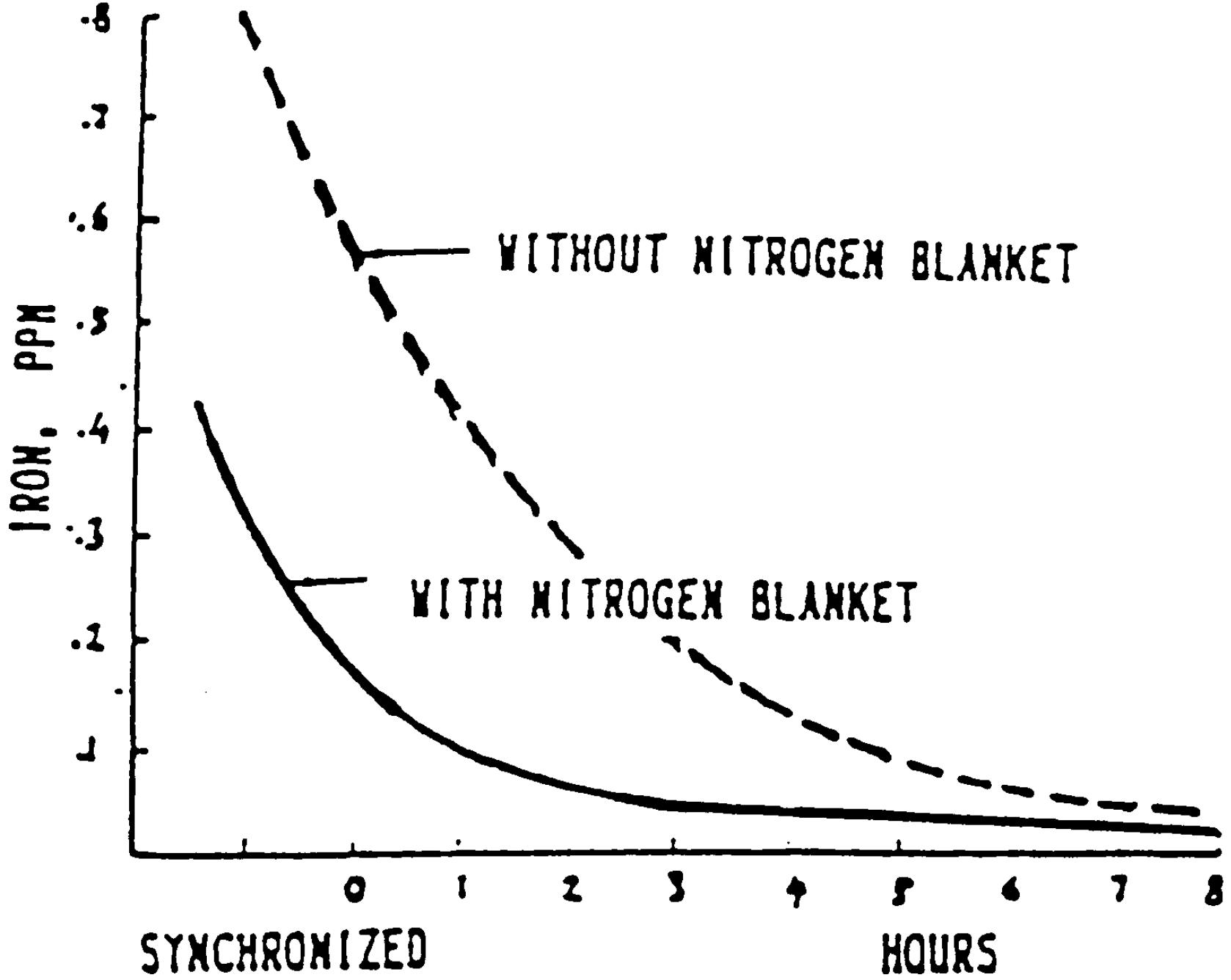
- Plants with discharge limits that prevents operation in the high 9 pH range require a chemistry treatment to provide better metal passivation.
- MEA/Ammonia was evaluated and found a reduction in iron transport and better passivation with slight increase in specific and cation corrected conductivity.
- Anodamine is in the process of being evaluated to address intermittent operation for better protection while off line.

Ethanolamine (MEA)

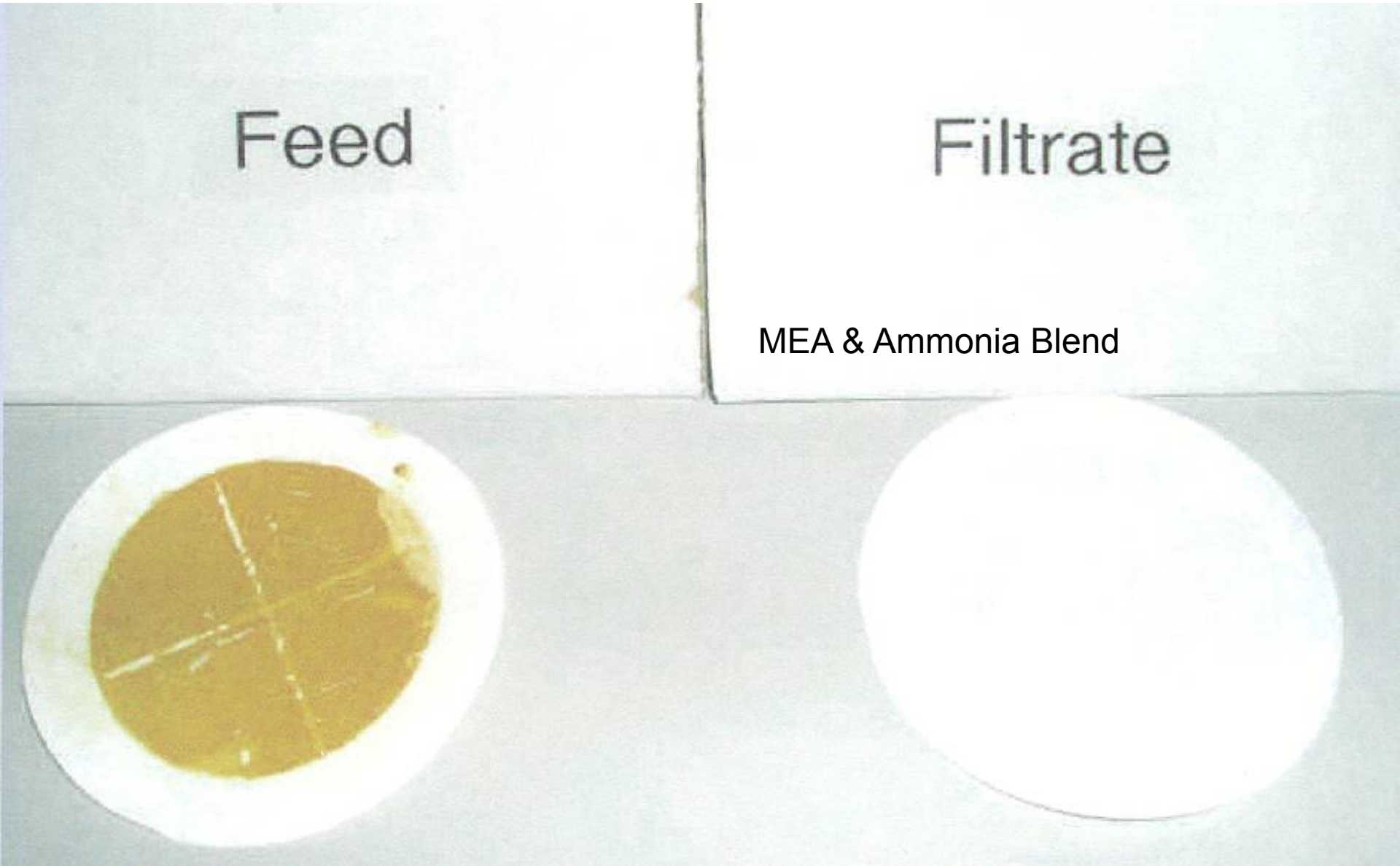
- Also called monoethanolamine
- Formula: C_2H_7NO
- Molecular Weight : 61.08
- Amine Type Primary
- Carbon: Nitrogen ratio 2:1




Iron Concentration (ppb)
12
10
8
6
4
2
0
8.8
8.9
9.0
9.1
9.2
9.3
9.4
9.5
9.6
9.7
pH


IRON, PPM
.8
.7
.6
.5
.4
.3
.2
.1
WITHOUT NITROGEN BLANKET
WITH NITROGEN BLANKET
0
1
2
3
4
5
6
7
8
SYNCHRONIZED
HOURS

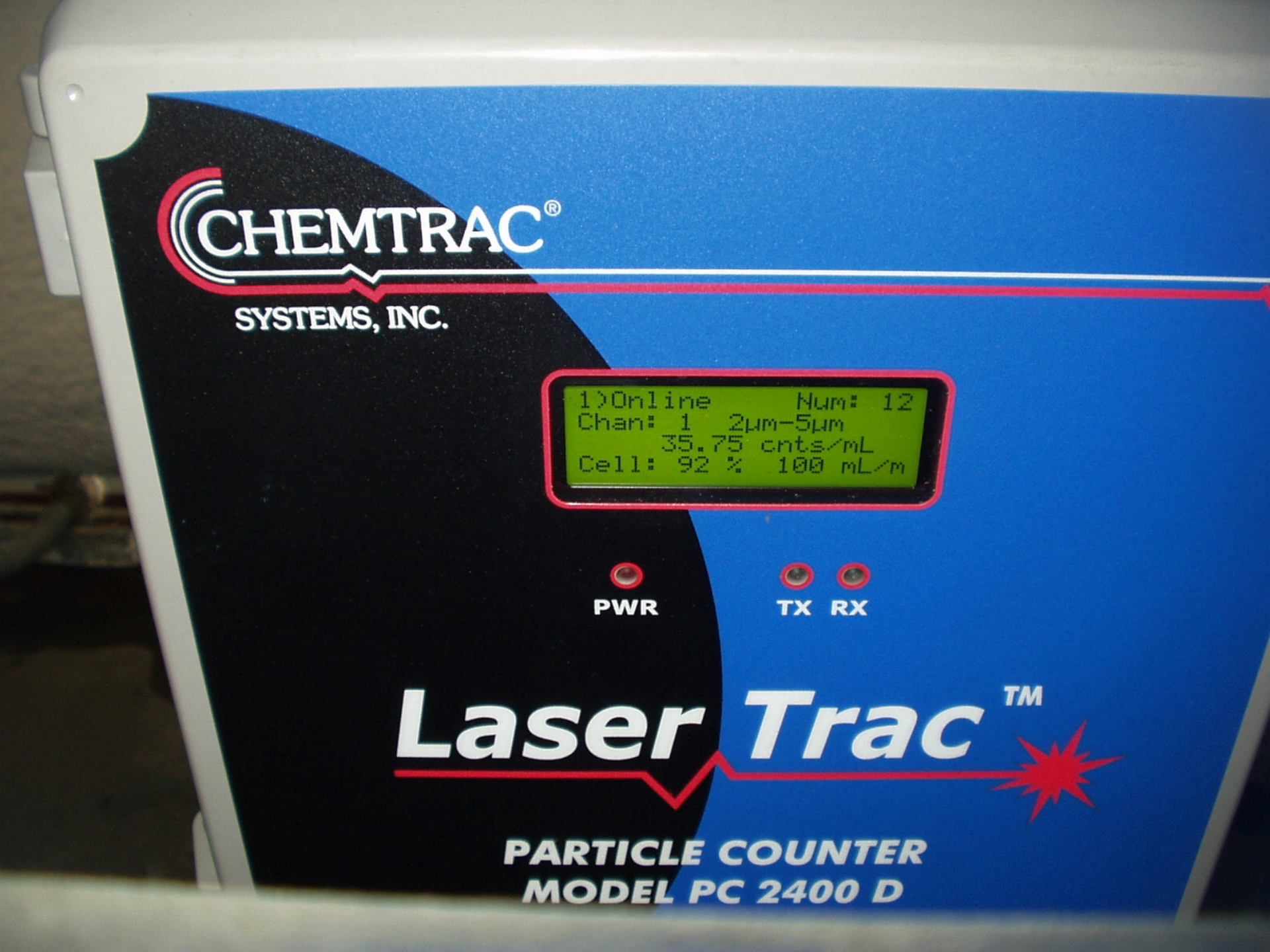
B&W filter iron test

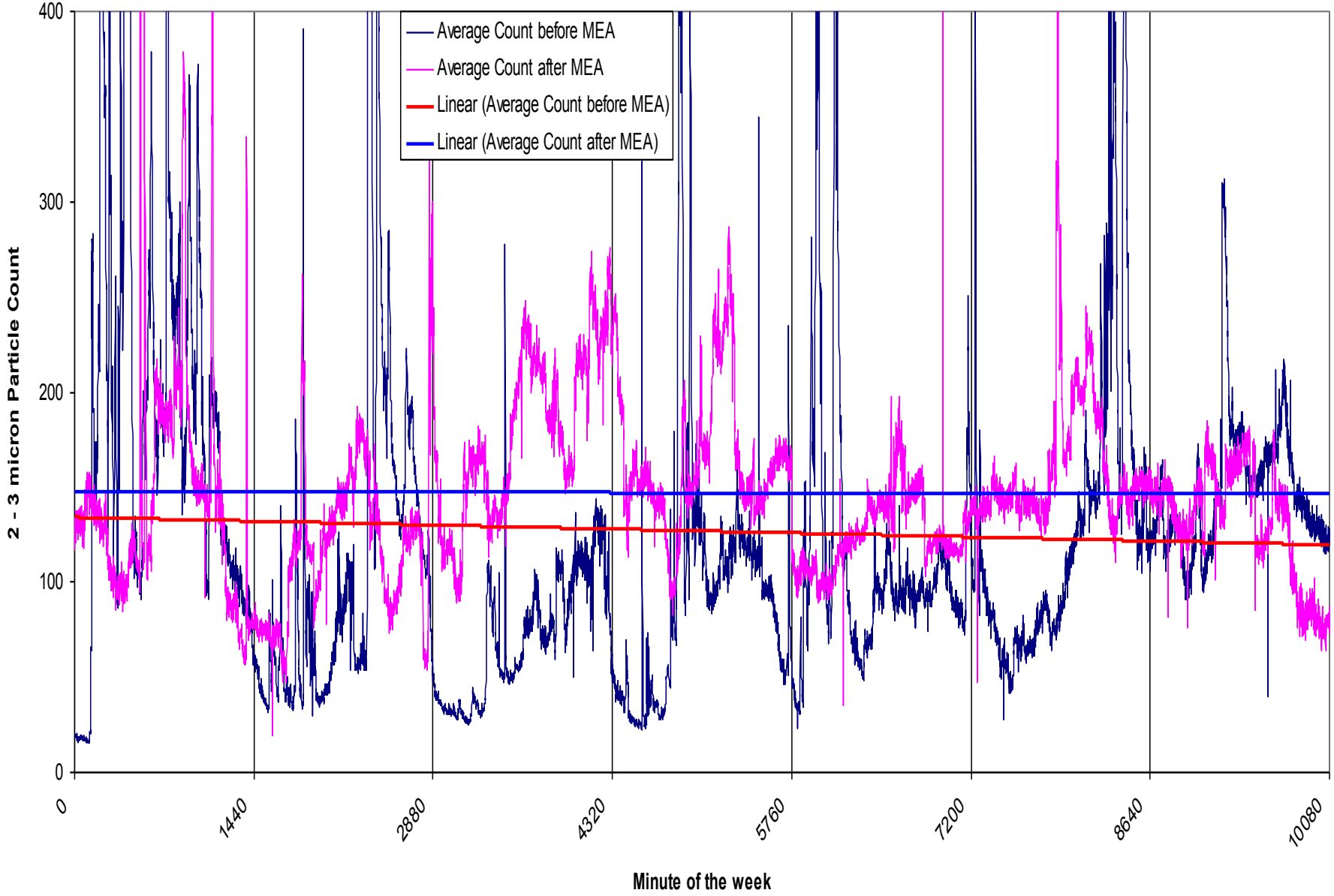


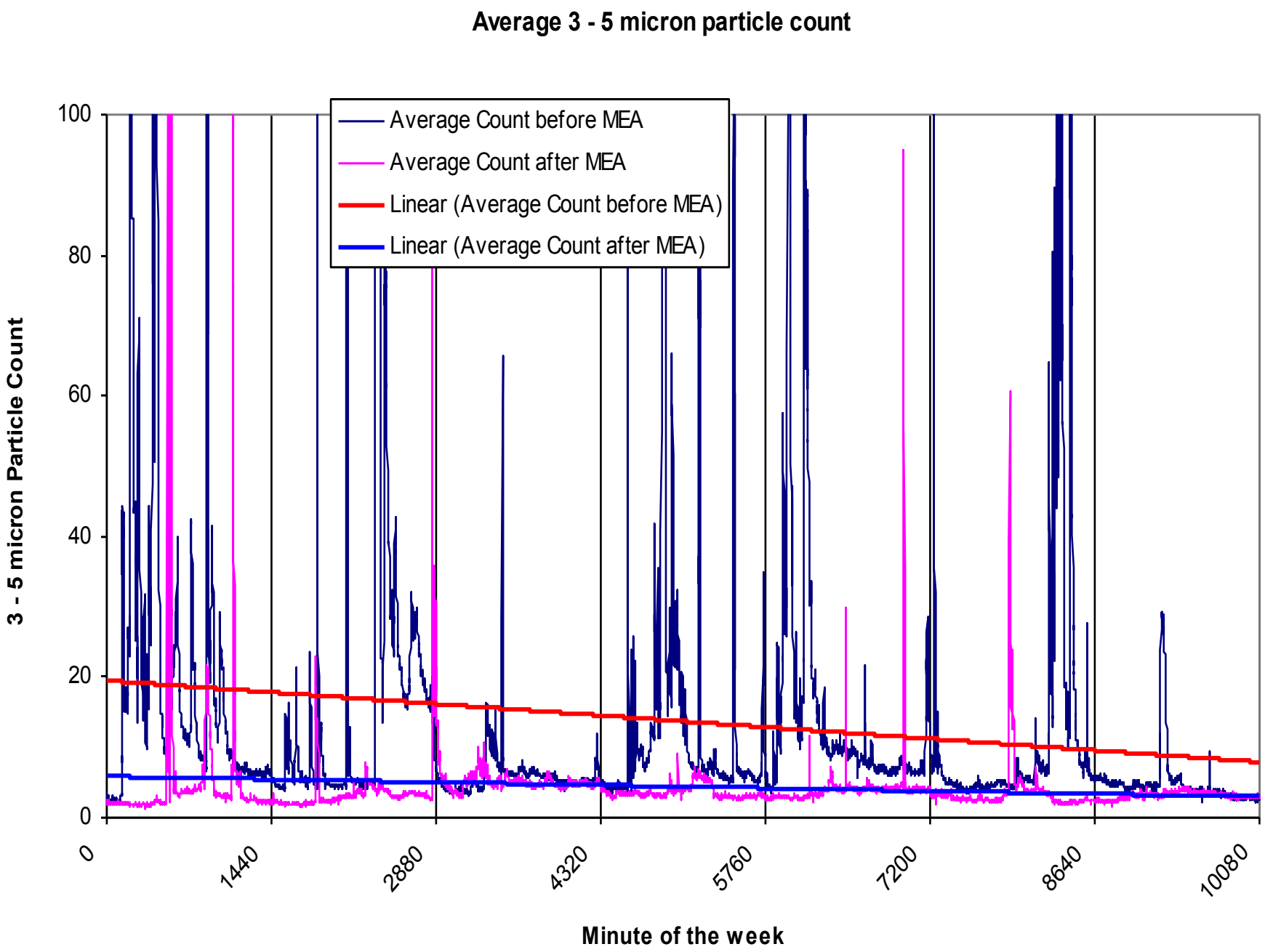
Problem with Grab Sampling

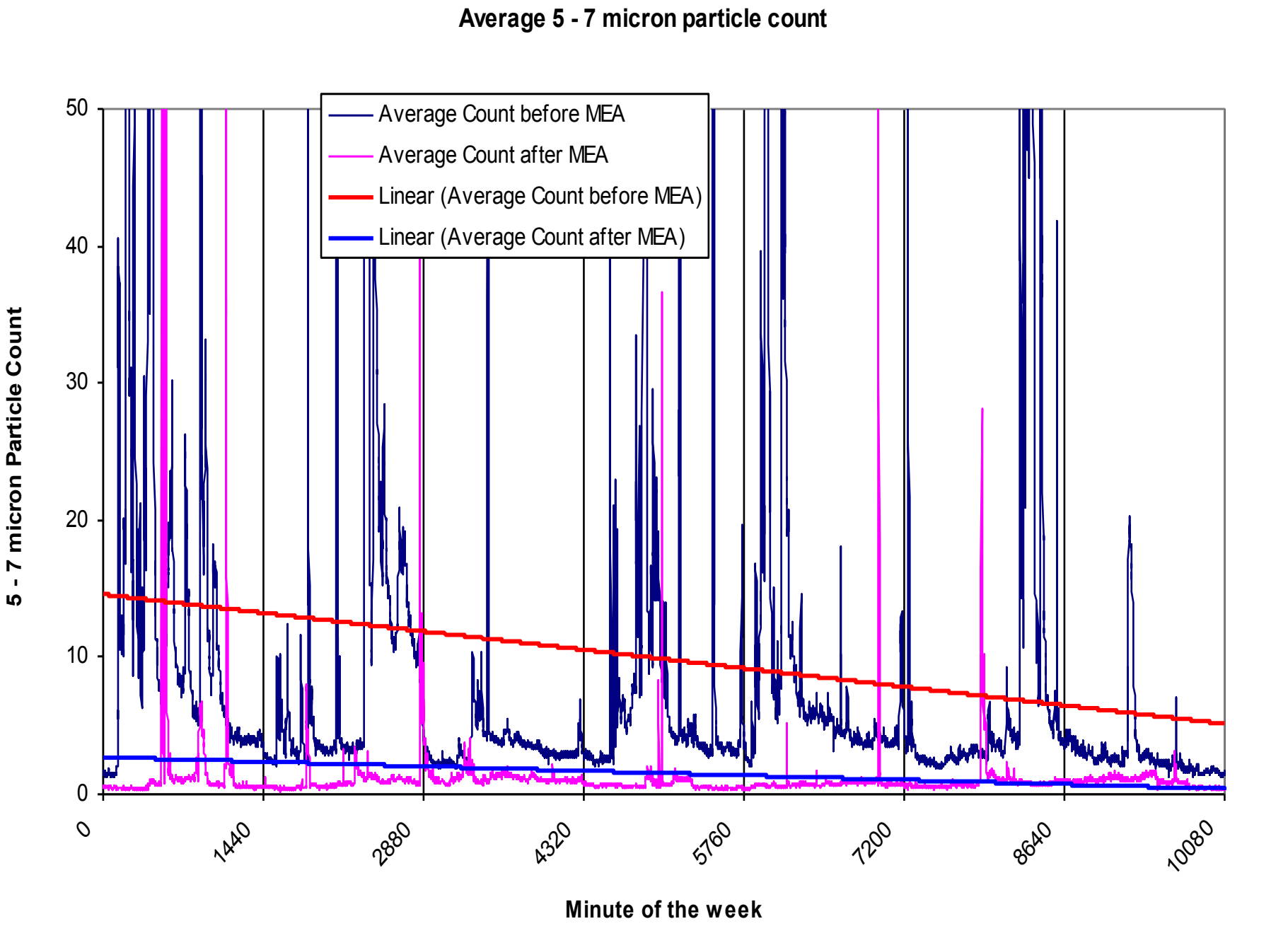
- Filter and iron grab sample is only representing the time when sample was taken and does not capture events that continuous sampling would observe.
- Turbidity and particle counter & monitors can provide continuous monitoring.

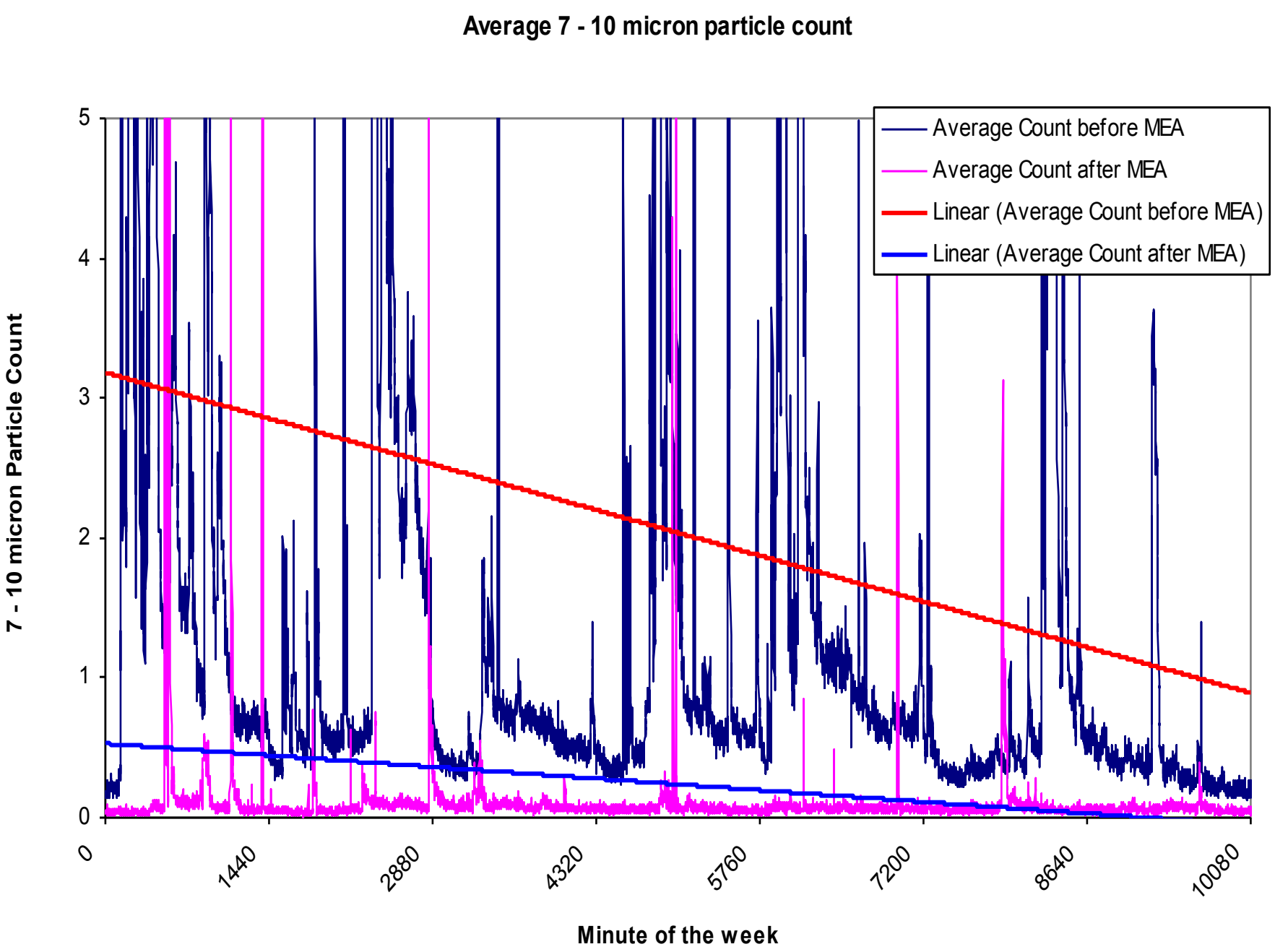

CHEMTRAC
PWR
TX RX
LaserTrac™
Particle Counter
PC2400
CHEMTRAC
Particle Monitor
PM2500


CHEMTRAC®
SYSTEMS, INC.
1)Online Num: 12
Chan: 1 2µm-5µm
35.75 cnts/mL
Cell: 92 % 100 mL/m
PWR
TX RX
Laser Trac™
PARTICLE COUNTER
MODEL PC 2400 D


Average 2 - 3 micron particle count
Average Count before MEA
Average Count after MEA
Linear (Average Count before MEA)
Linear (Average Count after MEA)
2 - 3 micron Particle Count
400
300
200
100
0
0
1440
2880
4320
5760
7200
8640
10080
Minute of the week


Average 3 - 5 micron particle count
Average Count before MEA
Average Count after MEA
Linear (Average Count before MEA)
Linear (Average Count after MEA)
3 - 5 micron Particle Count
100
80
60
40
20
0
0
1440
2880
4320
5760
7200
8640
10080
Minute of the week


Average 5 - 7 micron particle count
Average Count before MEA
Average Count after MEA
Linear (Average Count before MEA)
Linear (Average Count after MEA)
5 - 7 micron Particle Count
0
10
20
30
40
50
0
1440
2880
4320
5760
7200
8640
10080
Minute of the week

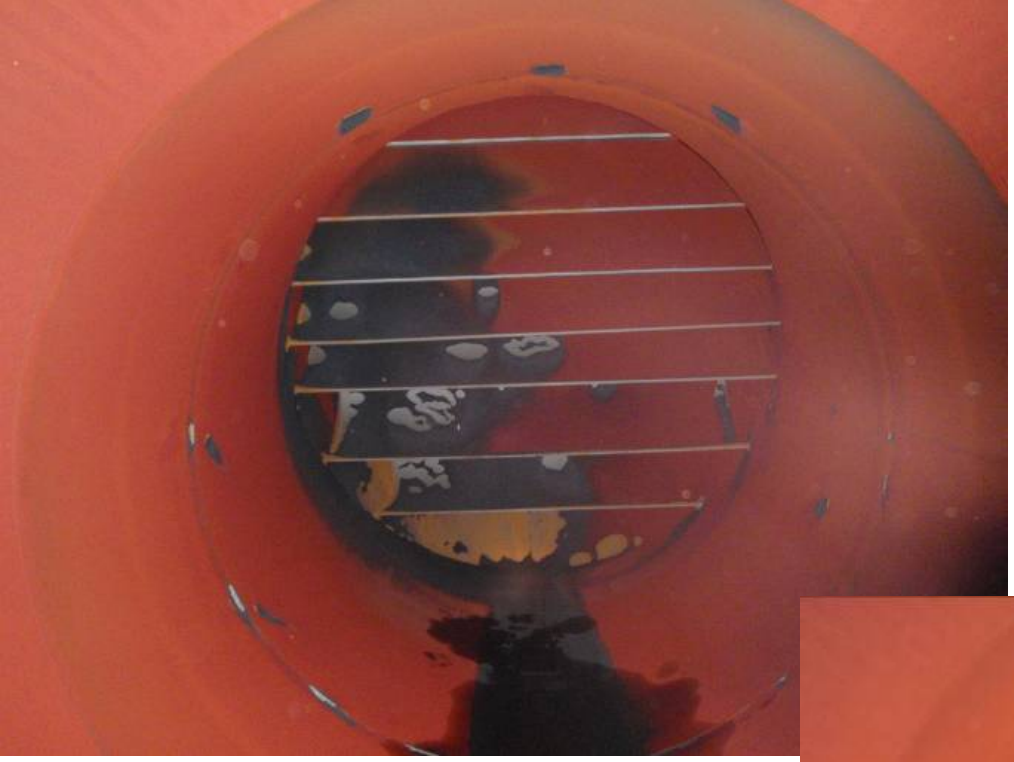

Average 7 - 10 micron particle count
Average Count before MEA
Average Count after MEA
Linear (Average Count before MEA)
Linear (Average Count after MEA)
7 - 10 micron Particle Count
0
1
2
3
4
5
0
1440
2880
4320
5760
7200
8640
10080
Minute of the week

validation

- Physical inspections

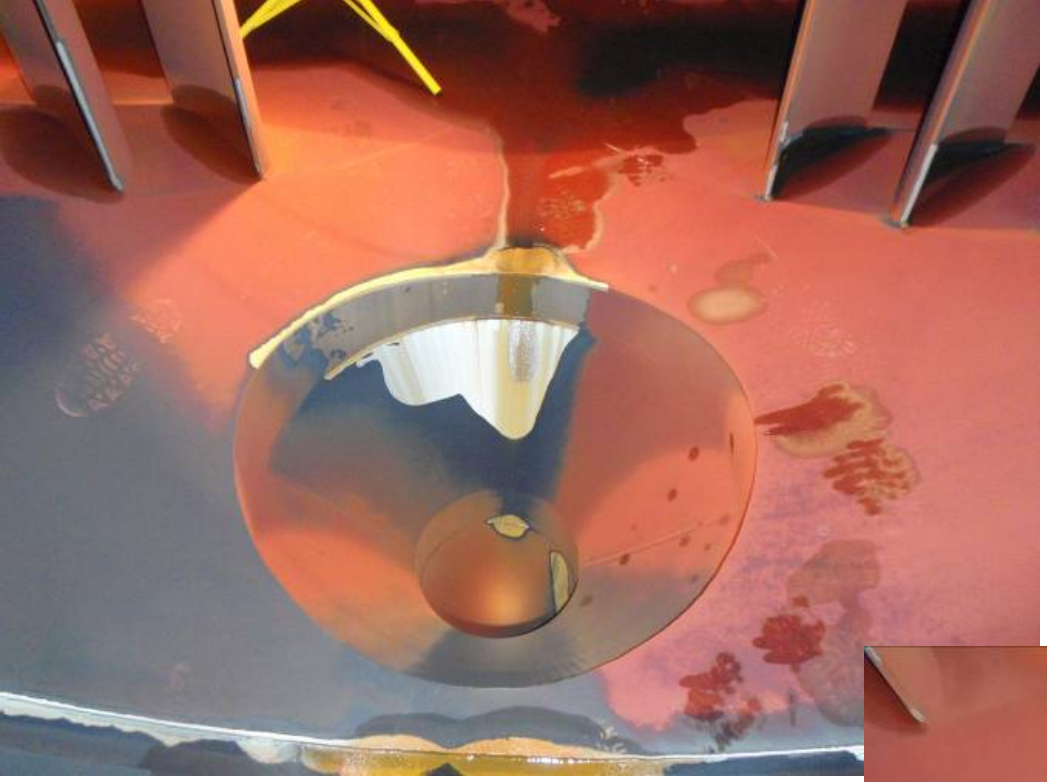
2009 inspection

2011 inspection



2009 inspection

2011 inspection



2009 steam turbine condensate
Duct drain.

2011 inspection

Air Cooled Condensers

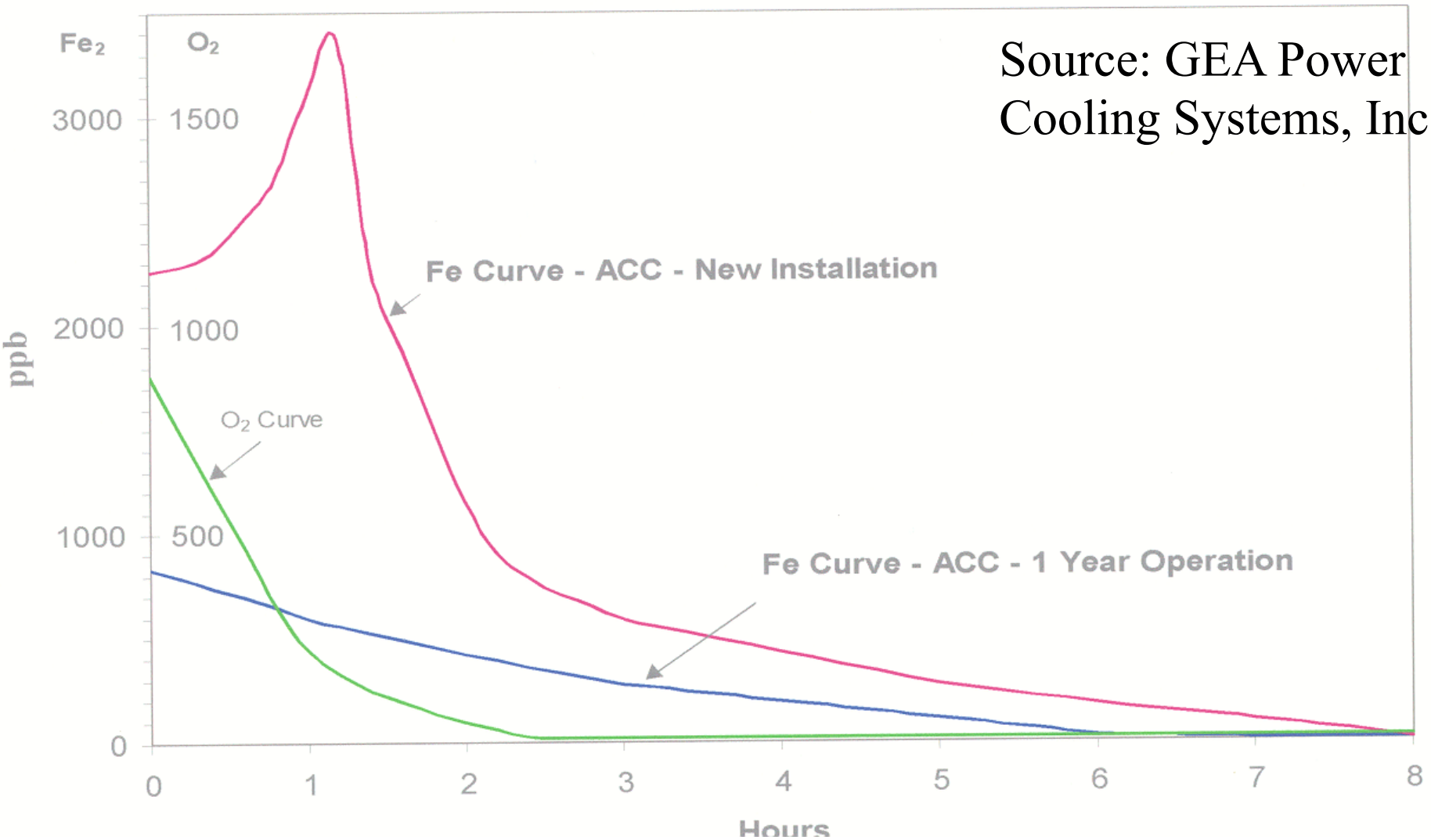
- Backpressure for air cooled condensers is higher than water cooled condensers.
- When air in-leakage is high enough to affect backpressure it is more difficult to detect with air cooled condensers.
- Elevated air in-leakage increases the potential for corrosion that can affect the rest of the steam cycle.

Concerns-Cycling

- Maintaining condenser vacuum is recommended when cycling.
- Air in-leakage potential is high when offline.
- High dissolved oxygen and carbon dioxide promote corrosion in oxygen pitting, corrosion fatigue, stress corrosion cracking and corrosion byproduct transport and down stream deposition.

Typical Iron & Oxygen Content

ACC Condensate during Start-Up



Source: GEA Power Cooling Systems, Inc.

Continuous Monitoring

- Provides detection of increases in air in-leakage before backpressure is affected.
- Provides real-time air in-leakage rates.
- Awareness is required in order to implement corrective measures.


Armor-Flo®
FLUID
AIR
MODEL
3611-08T1-114
SERIAL
094034
TAG
PRESSURE
1.5 OP
200 MAX
psig
VISCOSITY
TEMPERATURE
120 OP
185°F MAX
SG
1.00
ERDCO®
EVANSTON, ILLINOIS 60202 USA
ERDCO ENG CORP EVANSTON IL
2
5
10
15
20
SCFM

Vacuum Decay Test

Arrived onsite approx 0630 to run a vacuum decay test. Operator held load and fans steady and closed the SJAE suction valve. Start time of test 0716 BP 4.08" HgA. Stop time 0719 BP 6.57" HgA. Rate of decay 0.83" Hg/min, allowable rate of decay is 0.2" Hg/min.

Anodamine Filming Amine

- An Alternative to other off line storage programs?
- Following industry publications such as Power Plant Chemistry, The International Edition, May 2011 publication showing significant corrosion rates improvement to fossil units that were regulated to intermittent service.
- Conference presentations showing favorable reductions in iron corrosion
- Plant decided to evaluate.

Dosing Anodamine

Manufacturer recommends achieving a 2 – 3 ppm Anodamine residual throughout cycle and once this is reached a 300 – 400 ppb injection is recommended to maintain residual.

Plant began trial on an intermittent operation unit with ACC

- Unit did not run much during 2013.
- Unit did run for couple of months beginning 2014 that allowed for the Anodamine to get established.
- The following are inspection pictures during March 2014 scheduled maintenance outage

Plant Status

- Plant to continue to dose Anodamine/MEA
- Plant in process of installing particle monitor
- Plant in process of installing continuous air meter on air removal system
- Operations noted that when returning to service from being off line the samples not longer have color (corrosion by products) present.
- Upper ACC duct inspection next spring.