The Total Condenser Performance™ Workshop

Condenser Cleaning, NDE and Leak Detection

Part I: Condenser Cleaning

What is Total Condenser Performance™ ?

Achieving the perfect balance of condenser efficiency and reliability is achievable through effective cleaning and testing.

Implementing these strategies will maximize MW output and minimize condenser related outages during your operating cycle.

Three sections:

- Fouling and Condenser Cleaning
- Air and Water In-leakage Testing
- Eddy Current Testing

Condenser Fouling and Cleaning

- Fouling of tube surfaces
- Tube materials and their corrosion characteristics
- Prevention of tube fouling
- Deposit sampling
- Cleaning options for fouled tubes
- Innovation of cleaning technology
- Selecting a cleaning procedure
- Cases

Fouling of Tube Surfaces

Fouling of tube surfaces cause a variety of challenges for your condenser to overcome:

- Loss of heat transfer
- Under-deposit corrosion

Condenser Tube Fouling

The Fouling 5

- Deposition or Particulate
- Scaling or Crystallization
- Microbiological
- Debris and Macrofouling
- Corrosion and Corrosion Product

Let's look closer at each fouling category

Deposition / Particulate Fouling

- Particulate debris that settles on the tube surface
- Natural sediment, bio-growth, solids precipitated as particulates
- Result of low flow conditions
- Stimulates under-deposit corrosion

Fresh water silt removed from condenser

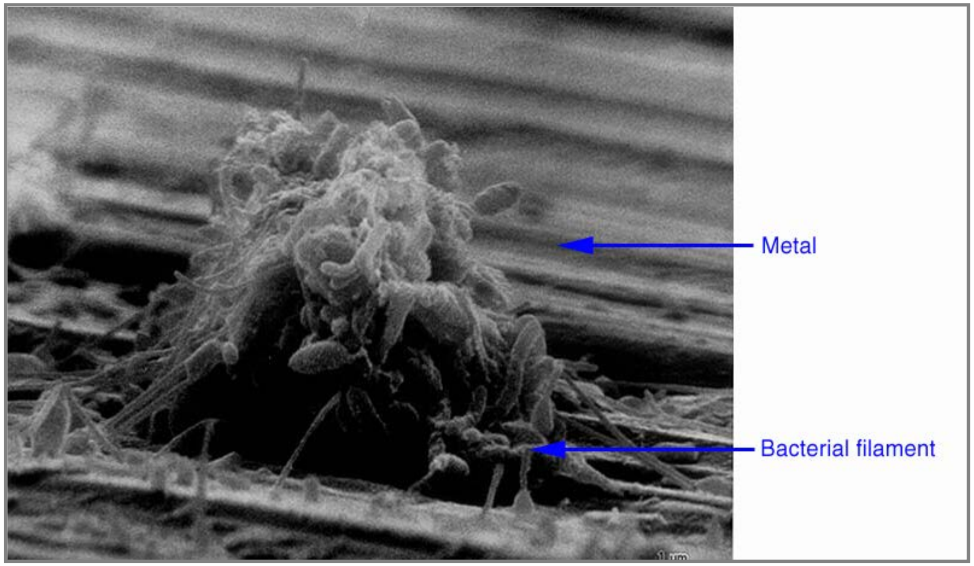
Scaling / Crystallization Fouling

- Saturation point of dissolved constituents in the cooling water is exceeded
- Scales form under higher temperature conditions
- Detrimental to heat transfer
- Under-deposit corrosion
- Removal of scale is required

Scaling distributed throughout condenser

Microbiological Fouling

- Bacteria present will form biofilm
- Forms when cooling water is at low velocities
- May support fine particulate deposition
- Produces corrosive by-products that consume base metal
- In stagnant conditions under deposits or scale, pitting will occur



Bacterial Colony Attached to Tube Surface

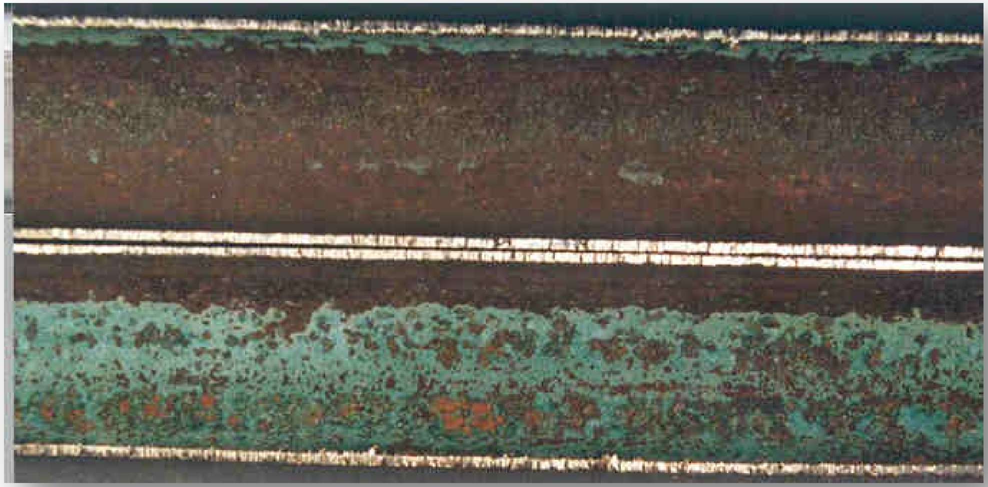
Debris and Macrofouling

- Condenser inlet tubesheet and tubes
  - Debris
  - Aquatic animals, shell fish
- Partial flow blockage
  - Slower flow allowing particulates to accumulate
  - Local flow around the item may cause erosion-corrosion

Flow reduction due to macrofouling

Corrosion Product

- Insert corrosion product description here.



Corrosion product on copper-alloy tube

Fouling Characteristics: Copper Alloy Tubing

- Tubing
  - Admiralty Brass
  - Aluminum Brass
  - Copper-Nickel

Copper & Copper Alloy Tubing

- Corrosion Characteristics
  - Crevice corrosion, pitting
  - Dealloying-dezincification or denickelification
  - Erosion-corrosion
    - Inlet end
    - Down tube
  - Ammonia corrosion, stress cracking corrosion

Fouling Characteristics: Stainless Steel Tubing

- Tubing
  - 304
  - 316

All 300 series, lean and intermediate duplexes are susceptible to:

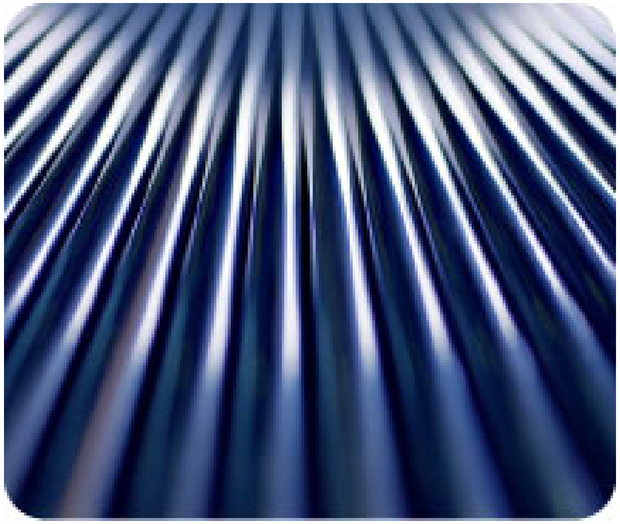
- Crevice corrosion, under-deposit corrosion, pitting
- Microbiological influenced corrosion (MIC)
- Chloride pitting

Corrosion Resistant

- SEA-CURE®
- AL6XN

Fouling Characteristics: Titanium Tubing

- Corrosion resistant
- Still must be kept clean



Chemical Fouling Prevention

- pH control
- Scale inhibitors
- Dispersants
- Biocides
- Corrosion inhibitors

Mechanical Fouling Prevention

- Screens
- Filtration
- Cleaning systems
- Increasing flow

Performance Indicators

- Back pressure deviation
- Cleanliness factor
- Inlet and outlet cooling water temperature differential
- Heat rate
- Megawatt output

Economic Consequences

- Increased unit heat rate
- Increased losses to cooling water
- Increased CO_2 or NO_x emissions
- Reduced generation capacity
- Tube failures lead to damage in other equipment

Potential Causes for Performance Loss

Increased backpressure can be attributed to fouled and blocked condensers and excess air inleakage into the condenser

In this section of the workshop, let's discuss how Conco mechanical tube cleaning can restore condenser performance and reliability

Industry Standard Tube Cleaners

C4S C3S C2X C3X C4SS Cal-Buster SSTB H-Brush XL Brush Type P

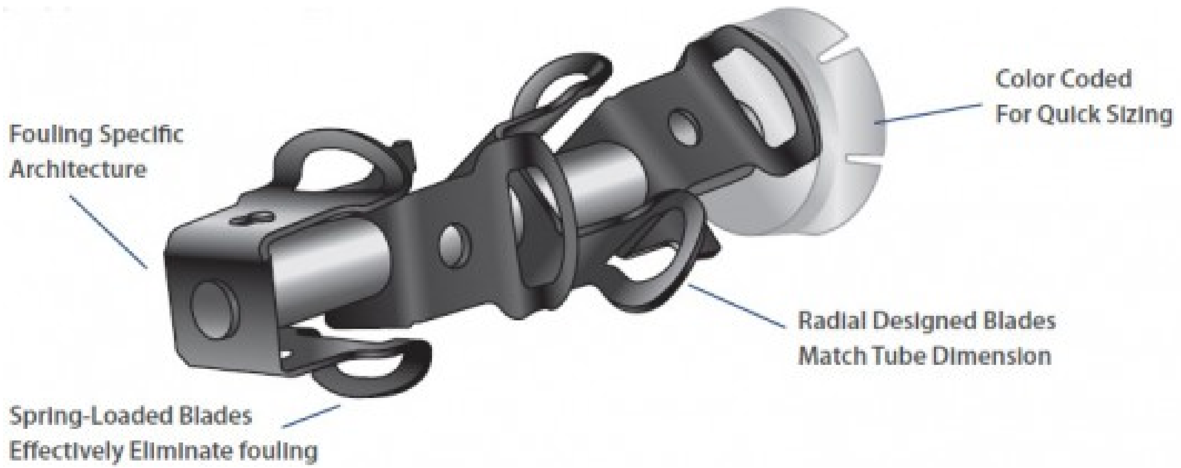
Innovations in Tube Cleaners

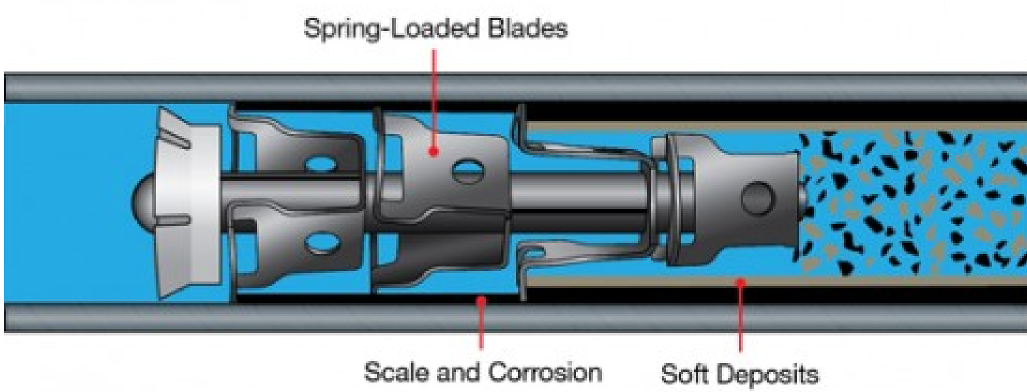
Hex Cleaner

Cal-Buster™

Stainless Steel Tube Cleaning Brush

Spring-Loaded Cleaner in Action





Results of Elemental Analysis

Element	%
Manganese	10-20
Aluminum	0.1-1.0
Potassium	0.1-1.0
Iron	5-10
Phosphorus	0.1-1.0
Titanium	0.1-1.0
Silicon	5-10
Sulfur	0.1-1.0
Nickel	0.1-1.0
Calcium	1-5
Chlorine	0.1-1.0
Elements <0.01%	Not Listed
Loss on ignition	Not Listed

Tube Sample Deposit Density

Dry Weight g	Density g/sq.ft.
217.30	17.5945
129.89	10.5170
126.12	10.2118
111.10	8.9956
98.62	7.9851
95.56	7.7374
93.54	7.5738
36.37	2.9448
25.26	2.0452
4.95	0.4007
1.79	0.1449

Tube Cleaning Variables

- Cooling Water System
- Tube Material
- Deposit Type(s)
- Corrosion
- Tube Quantity and Size
- Schedule
- Tube Cleaning System

Tube Quantity and Size

Quantity

- How many water boxes?
- How many tubes?
- Main Section?
- Air Removal Section?

Size

- Outer Diameter (O.D.)
- Gauge (BWG) or (I.D.)
- Length
- Other considerations
  - Coatings
  - Inserts

Schedule

- Unit Size
- Availability
- Peak or off peak demand
- On-line or reduced load
- Time requirement for cleaning

Tube Cleaning

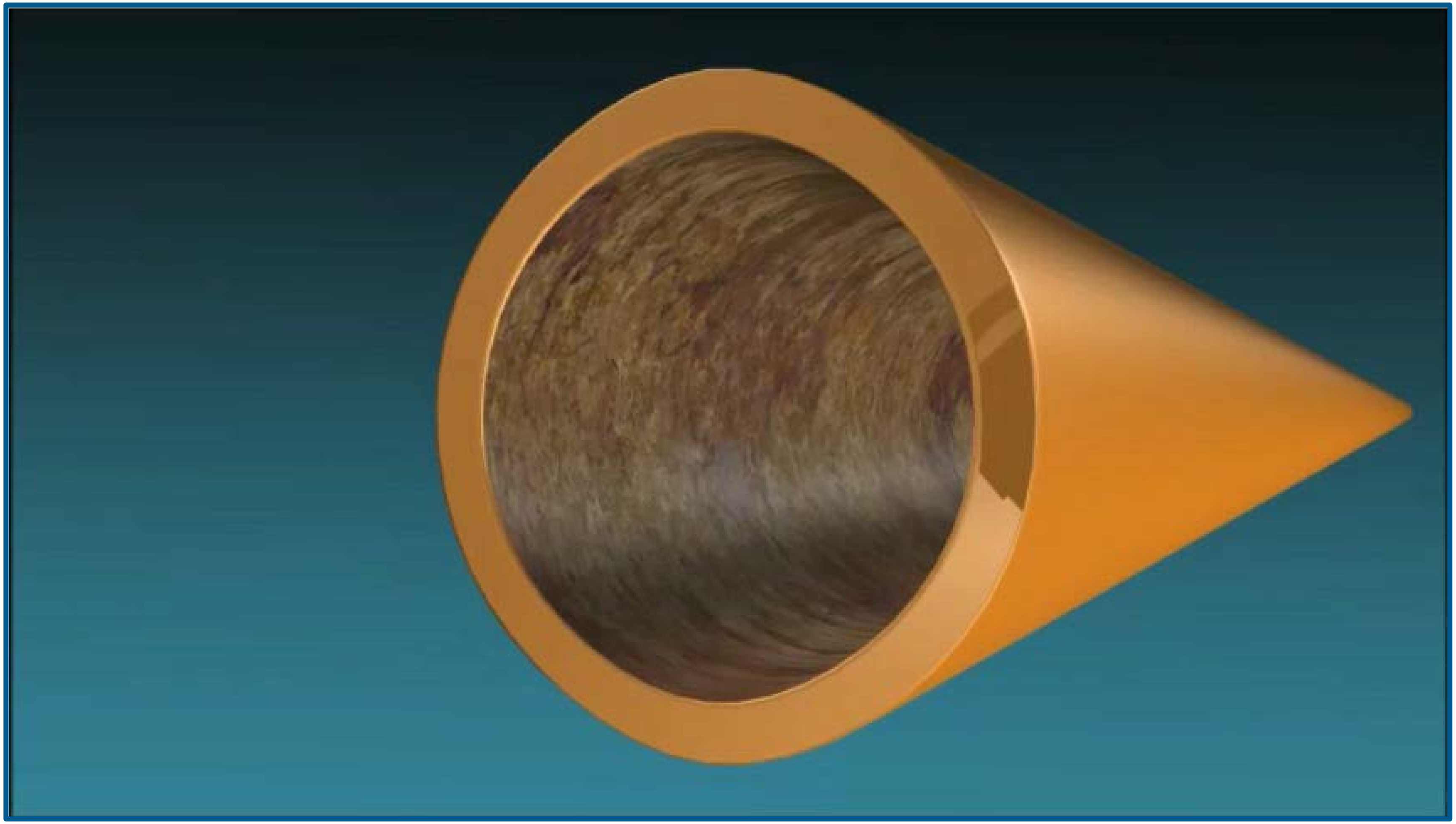
- Select the most effective tube cleaner.
- Insert the tube cleaners into each tube.
- Utilizing the water gun and pump system the cleaners are “shot” through the tubes.

Water Gun and Pump System

Water Gun

Mobile Pump System

Tube Cleaner in Action



Expectations

- Performance improvement
- Most effective deposit removal
- Corrosion protection
- Remove obstructions
- Clean each and every tube, maintain consistency throughout
- Smooth tube surface

Mechanical Cleaning Summary

- Minimizes downtime: 5000+ tubes per shift

- Cleaners are effective on all types of fouling:
  - Fouling Deposits (better heat transfer)
  - Corrosion Product (tube failure mechanism)
  - Physical Obstructions (improved performance)
  - Improved Surface Roughness (improved flow rate)

Additional Benefits

- Economic Benefit
  - Immediate Return on Investment
  - Reduced Costs
- Recovery of lost megawatts or increased generation capacity
- Fuel savings
- Reduction in CO_2 emissions
- Extended useful life of the condenser

Quick Calculations

Heat Rate

- Assume the reduction of .3 hg in condenser backpressure is equivalent to approximately 10% improvement in condenser performance
- Each 10% improvement in condenser performance correlates to a 1% improvement in heat rate (10,000 btu/kWh) or MW output

Ex: .6 hg = 20% CF = 2% HR = 2 MW

MW loss

- 8760 hrs./yr.
- Capacity Factor
- Price per MWh
- MW

Ex: 8760 x .70 x $60.00 x 2 MW = $ 735,840.00

Ex: 8760 x .70 x $60.00 x 3 MW = $1,103,760.00

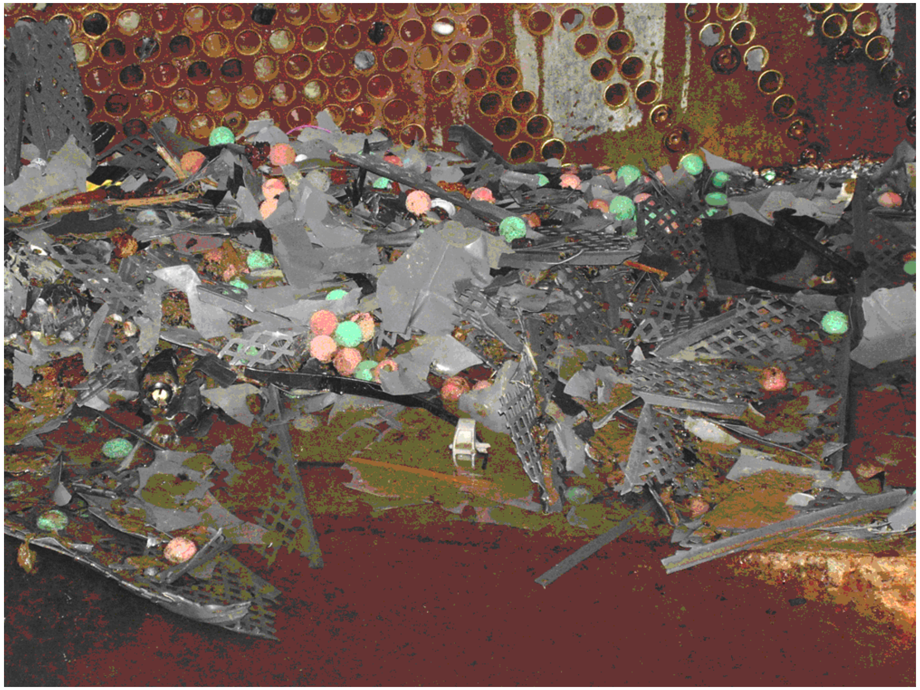
Omaha Public Power

18,390 lbs. of $CaCO_3$ scale removed

River Bend Nuclear

River Bend Nuclear

- 936 MW BWR
- River water
- 16,395 Brass tubes
- Macro Fouling: Tower Fill, Sponge Balls



Results

- Recovered 2.5 MW per hour/60 MW per day
- Cleaning cost recouped in 2 weeks

Tube Cleaning Wrap Up

- The return on investment by having deposits removed before they cause major loss of heat transfer, tube corrosion or ultimately tube failure can be significant.

- Not only are there losses in performance to consider, but major equipment repairs often follow tube failures due to cooling water contaminants in the boiler or turbine.

Questions?

Gary Fischer
National Sales Manager
CONCO | Systems Services Industrial
1-800-345-3476 or +1-412-828-1166
gfischer@concosystems.net

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Condenser Cleaning, NDE and Leak Detection

Part II: Leak Detection

This Presentation Will Cover

- Why perform tracer gas leak detection?
- When to perform leak detection
- Benefits of tracer gas leak detection
- Selecting the ideal tracer
- Air inleakage detection
- Condenser tube leak detection

Why Plants Need to Test

Leakage of air or water into the condenser will adversely affect plant efficiency, reliability and availability

- Increased plant heat rate
- Increased risk to turbine components
- High levels of dissolved O_2 in feedwater means increased deterioration of boiler and feed systems

When Plants Need to Test

Proactive Testing

- Routine inspection to understand where potential failures will occur
- Before an outage so components in need of repair are scheduled for repair
- After an outage to insure all repairs were made successfully

Reactive Testing

- Emergency inspections as a result of catastrophic failure or because inleakage has exceeded the air removal system capability

Condenser Leakage Indicators

Condenser backpressure climbing

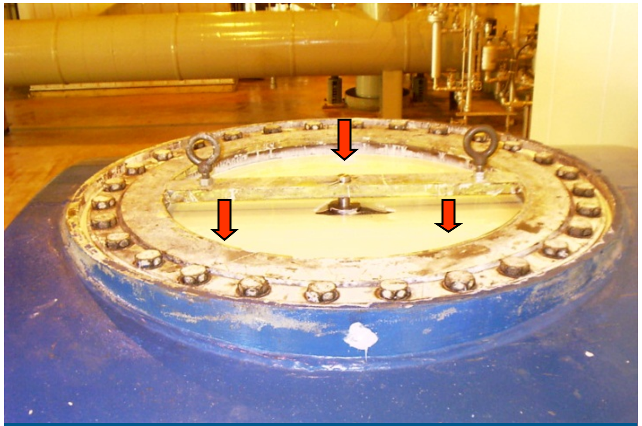
- Other factors such as fouled condenser tubes can contribute to increased backpressure, however, an air inleakage inspection should be the first option as it can be performed online and for minimal cost

Dissolved O_2 levels increasing

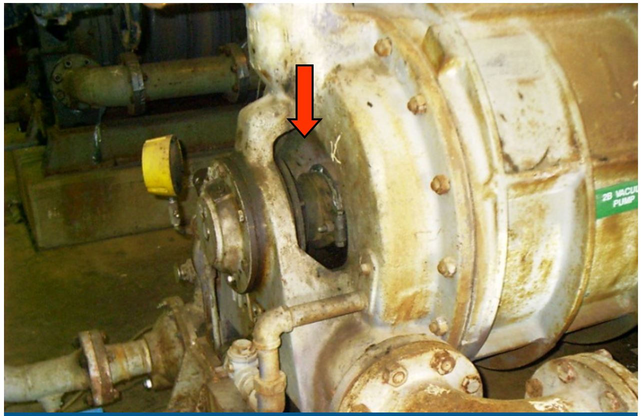
Increased usage of phosphates

Sources of Air Inleakage

- Inleakage to shell
- Rupture discs
- Shaft seals
- Test probe penetrations
- Man ways
- Vacuum pumps
- Flanges
- Bolt holes



Rupture Disc

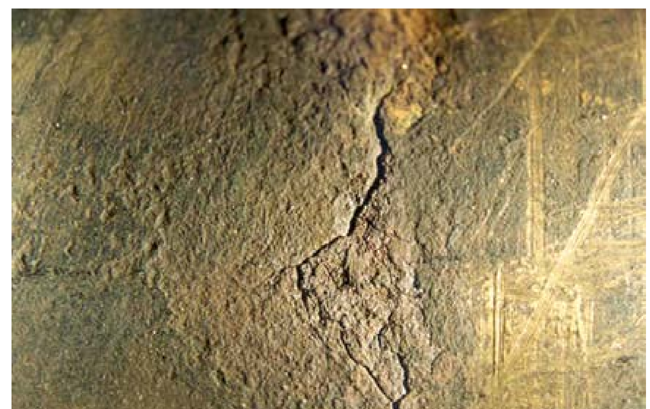


Vacuum Pump Shaft Seal

Sources of Water Inleakage

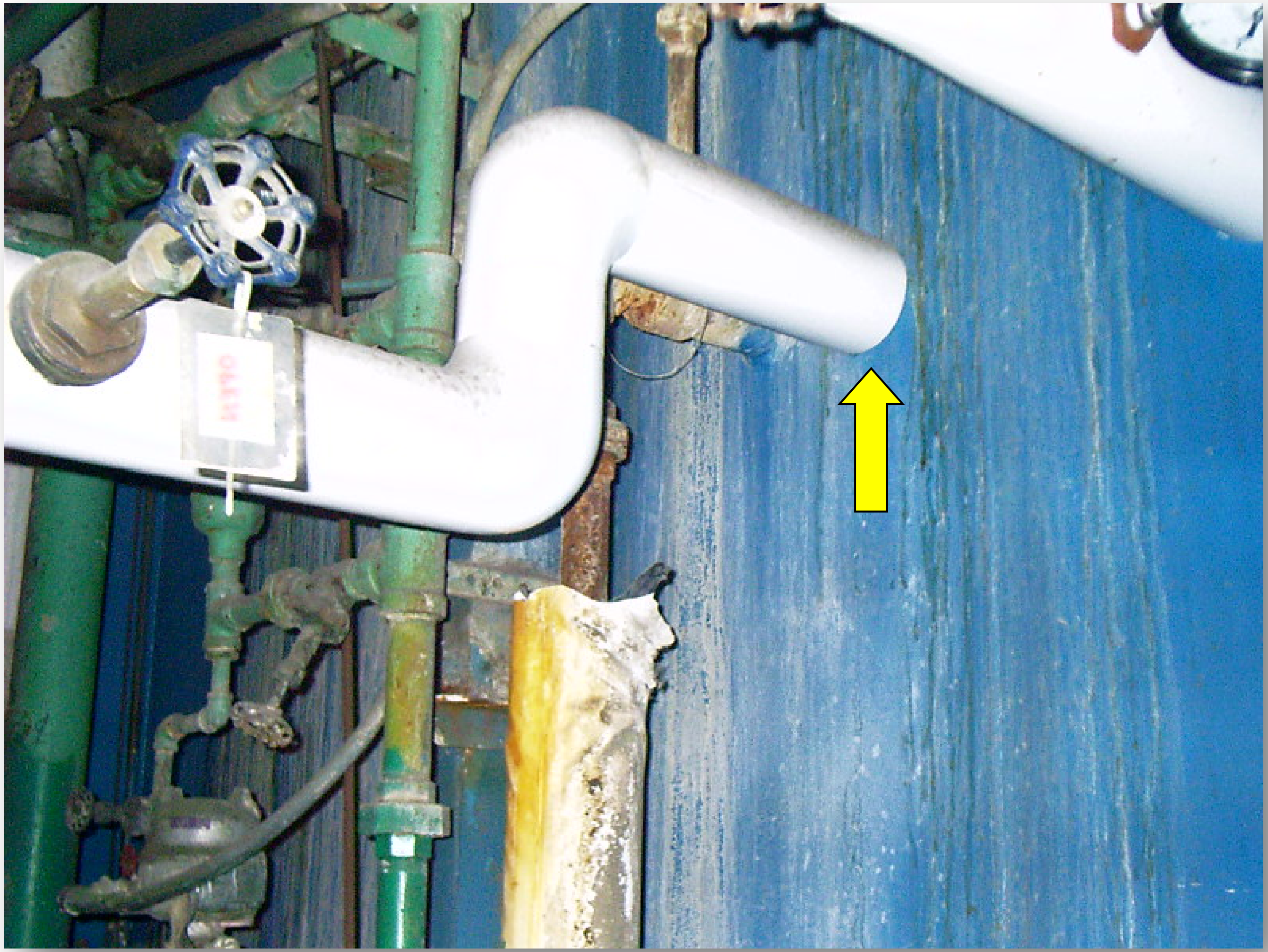
- Water box flanges
- Faulty tube plugs
- Leaking hotwell components
- Through-wall penetrations
- Tube to tubesheet joints

Tubesheet joints



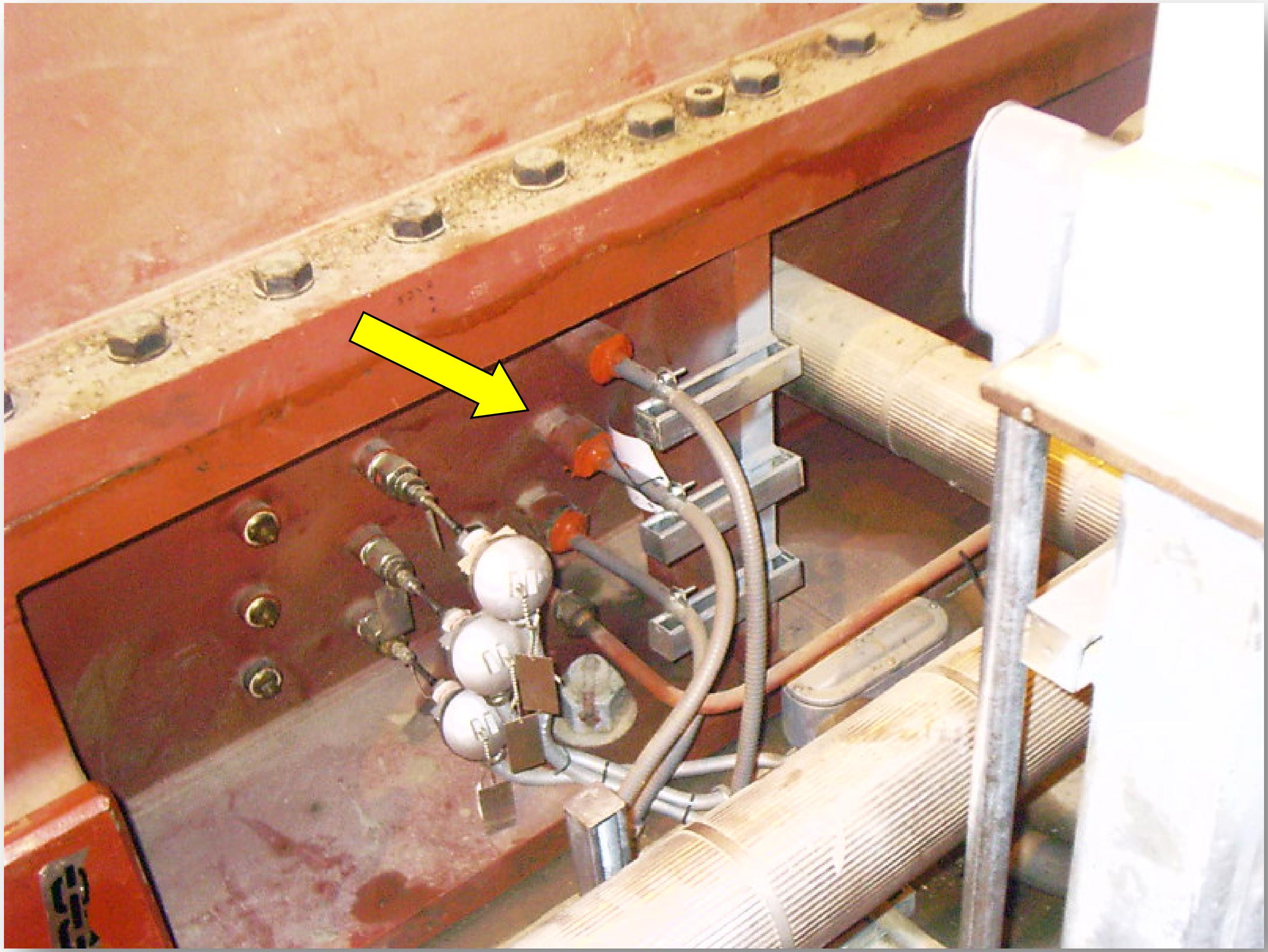
Through-wall penetrations

Condenser Penetrations

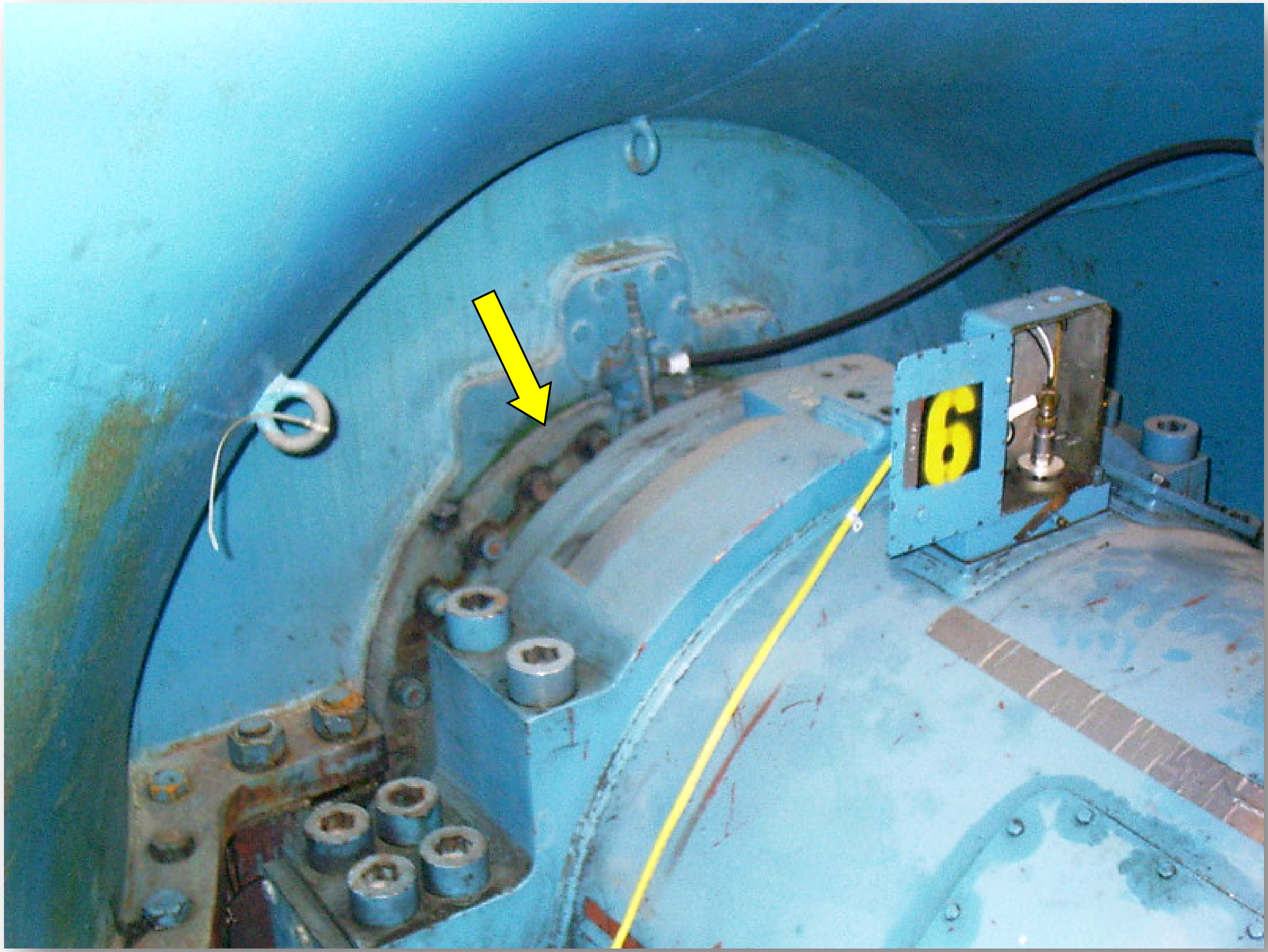


Crossover Bellows

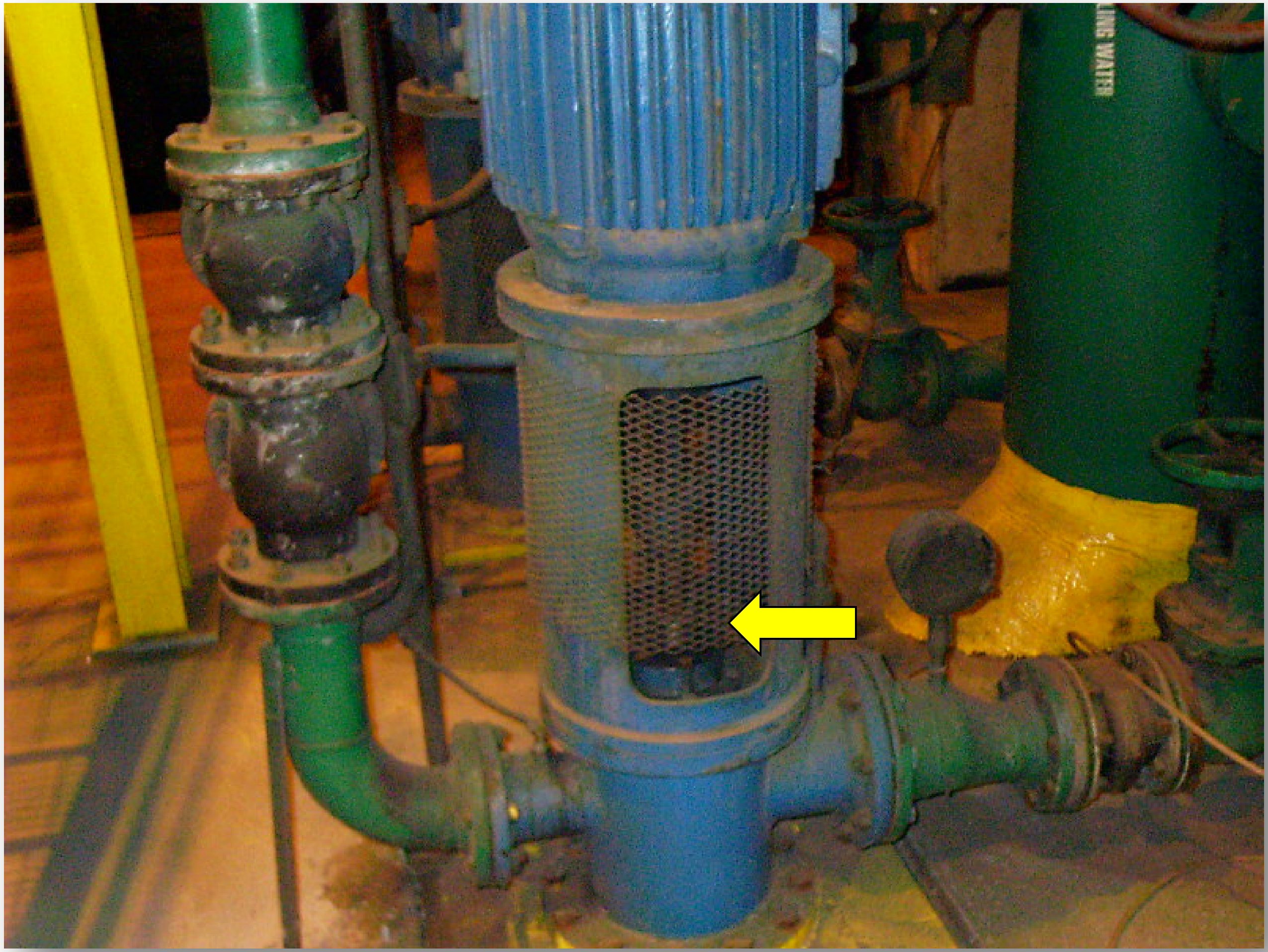
Test Probe Penetrations



LP Turbine Shaft Seal



Heater Drain Pump Shaft Seal



Choosing the Ideal Tracer

Choosing the most appropriate tracer gas for your site specific conditions is important. Some contractors may only have expertise with one type of gas, so choose wisely as a less ideal tracer will cost you time and money

- Helium
- Sulfur Hexafluoride (SF_6)

Tracer Gas Selection Criteria

Air inleakage

- Total amount of air inleakage
- Characteristics of specific leakage
- Leak quantification
- Dissolved oxygen considerations

Condenser tube leakage

- On-line injections
- Tubesheet inspections
- Leak characteristics

Tracer Overview: Helium

The helium mass spectrometer was developed to find extremely small leaks in the gas diffusion process in the Manhattan Project during WWII

- Quick and reliable, non-toxic, non-hazardous
- Detection range, 1 part per 10 million above background (~5ppm)
- Suitable for “most” leaks

Tracer Overview: SF_6

In 1976, SF_6 was used as an airborne tracer to track plume migration and EPRI explores its use as a tracer in power plant leak detection

- Inert, odorless, incombustible
- Detection range is 1 part per 10 **billion**
- Non-reactive to H_20
- Detection accuracies can be 40 times greater than those obtained using helium
- Suitable for small or hard to locate leaks

System Comparisons

Mass Spectrometer

Fluorotracer™ Analyzer

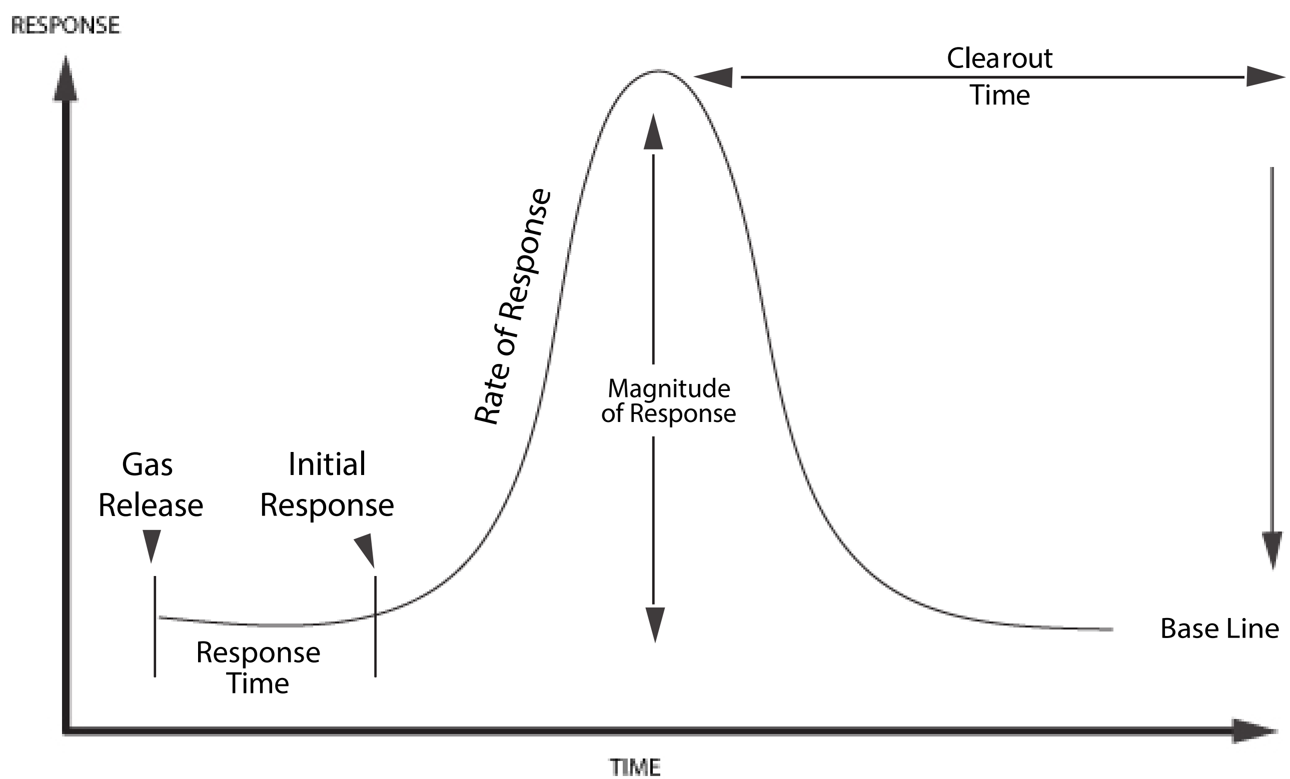
Unit Operating Conditions

A minimum of 15% turbine power is required for successful leak detection to occur

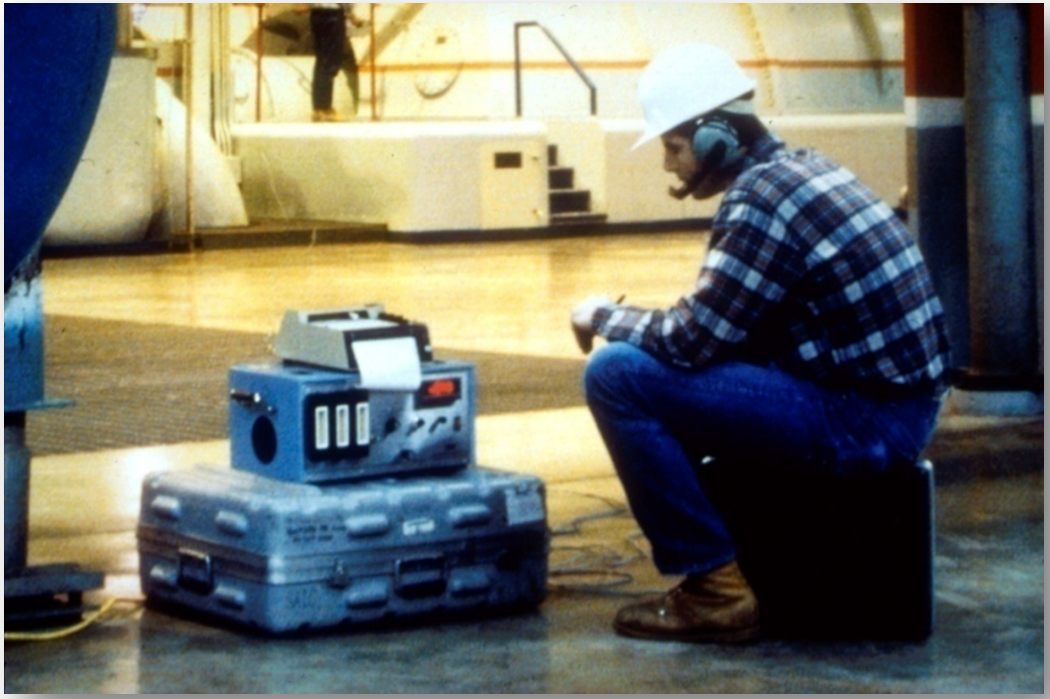
Steam Flow:

- Crucial to successful leak detection
- Clears tracer out of condenser
- Response time is quicker
- Analyzer recovery time is quicker
- Without Steam flow: Tracer gas background will continue to rise, making isolation of leak virtually impossible

Typical Leak Response



Air Inleakage Detection



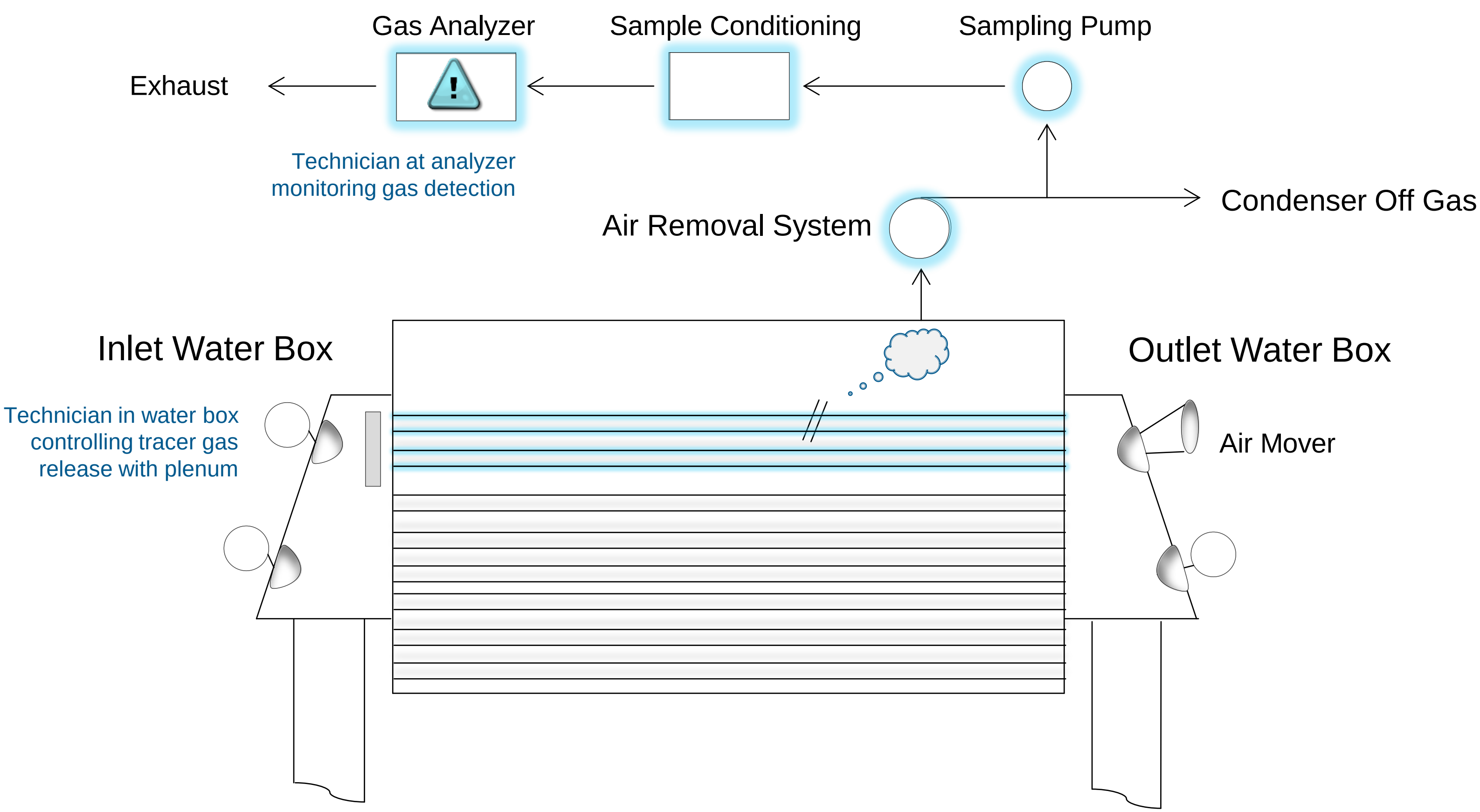
Condenser Tube Leak Inspection

- Detecting tube leaks
- Use of plenums
- Reduce size of plenum
- Single tube shooter

Large-Sized Plenum

Mid-Sized Plenum

Tube Inspection Set Up



Online Injection of SF_6 Tracer

SF_6 allows for online injection into water boxes under full load to determine leaking bundle

- Fluorotracer™ Analyzer is sampling the off-gas
- SF_6 cylinder is connected to injection point below the waterline
- Gas injected into circulating water @ ~10 cfm for 30 seconds
- Capable of identifying 1gpd leak

In Closing

- Air and water inleakage continues to cost generators hundreds of thousands to millions of dollars annually
- Condenser tube leaks cause more than 6,000 forced outages annually and rank as one of the highest concerns among plant chemists
- In addition to reactive leak detection, a proactive regimen of testing can keep total air inleakage in check
- ROI for leak detection maintenance dollars spent are usually in the 1000% + range, so don't wait!

Questions?

Eric H. Fayard
Director, Technical Marketing
CONCO | Systems Services Industrial
1-800-345-3476 or +1-412-828-1166
eric@concosystems.net

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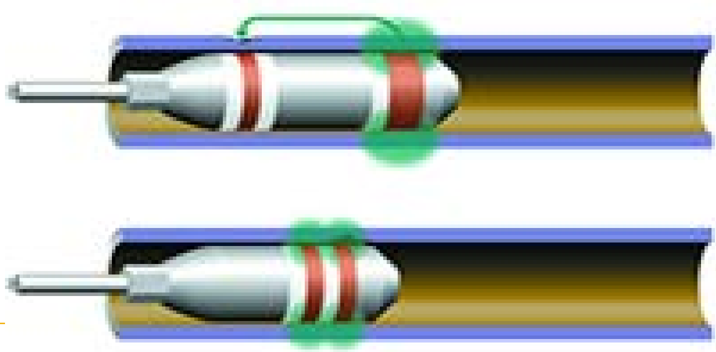
Part III: NDE with Eddy Current

Eddy Current Testing

Eddy Current Testing (ECT)

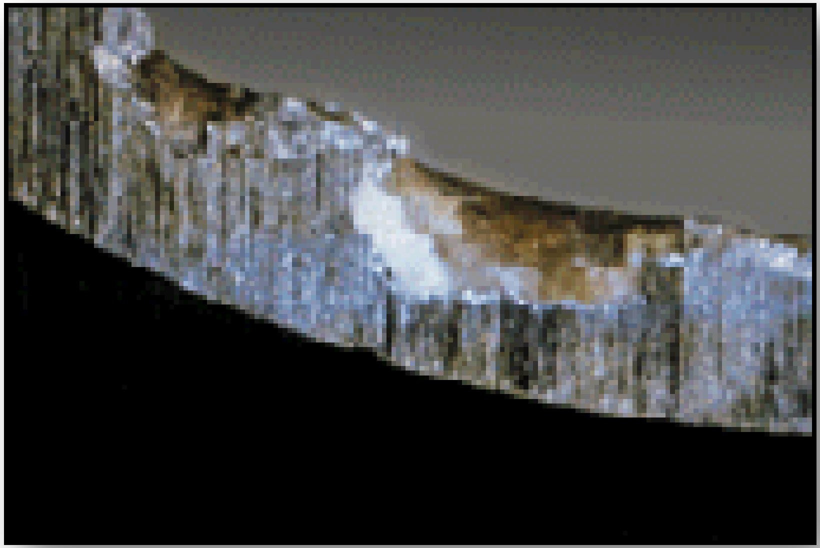
Is a nondestructive test technique based on inducing electrical currents in the material being inspected and observing the interaction between those currents and the material.



Eddy currents are generated by electromagnetic coils in the test probe, and monitored simultaneously by measuring probe electrical impedance.

What Can be Detected?

- Various defects
- Pitting
- Cracking
- Erosion
- Corrosion
- Grooving
- Dents



Why Eddy Current Test?

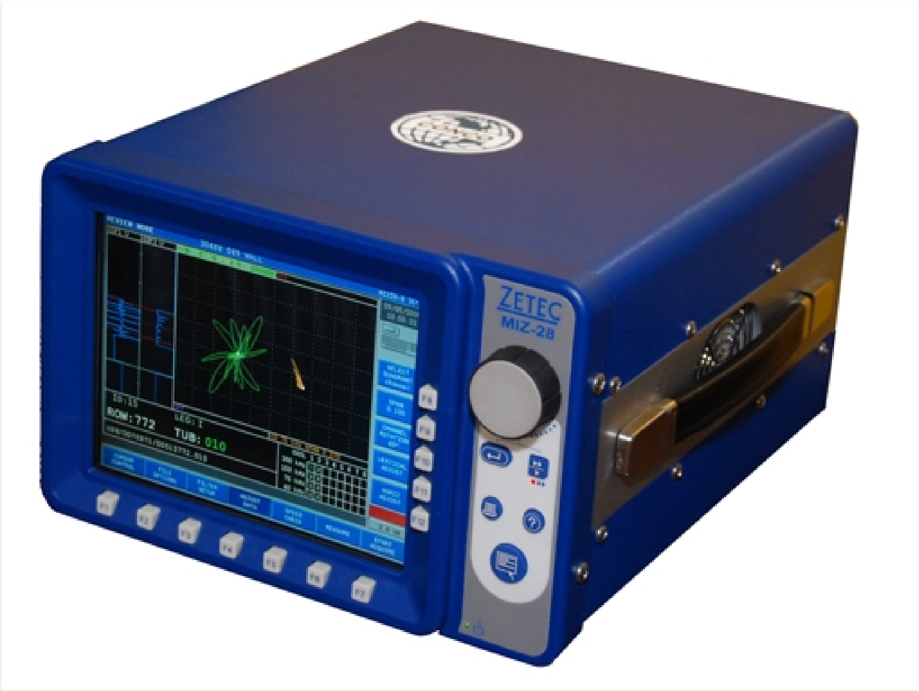
- To decrease forced outages due to tube failure
- To minimize losses associated with availability
- Early detection of potential failure mechanisms
- Estimate remaining useful life of the tubes
- Planning and budgeting / equipment replacement
- Summary of overall unit condition
- Baseline and annual trending reviews

Testing Requirements

- Technicians certified in accordance with the American Society of Nondestructive Testing standards.
- Quality assurance program that meets your company or industry guidelines.
- Current equipment calibration.
- Clean tubes.

Typical Multi-Frequency Testing Equipment

- Multi-frequency
  - Corestar Omni
  - Zetec MIZ 28
- Probes
- Computerized Data Interpretation



Two Modes: Absolute and Differential

- The need for testing in two modes.
- Gradual Wall thinning detected in absolute mode.
  - Steam erosion
  - Inlet end erosion
- Small defects such as pitting and cracking can be detected in differential mode.

Multiple Frequency Benefits

Higher Frequencies

- e.g. Stainless Steels (.028)
- Near surface flaws
- ID Pitting

Lower Frequencies

- e.g. Brass / Copper Alloys (.049)
- Subsurface Flaws
- Severe Pitting

The Necessity of Multiple Frequencies

- Identification of ID and OD pitting simultaneously
- To achieve complete depth of penetration of the tube wall
- Most accurate characterization of defects.
- Allows for mixing out of signals that represent support plates (non defects)
- Allows for discrimination of metallic deposits that may remain

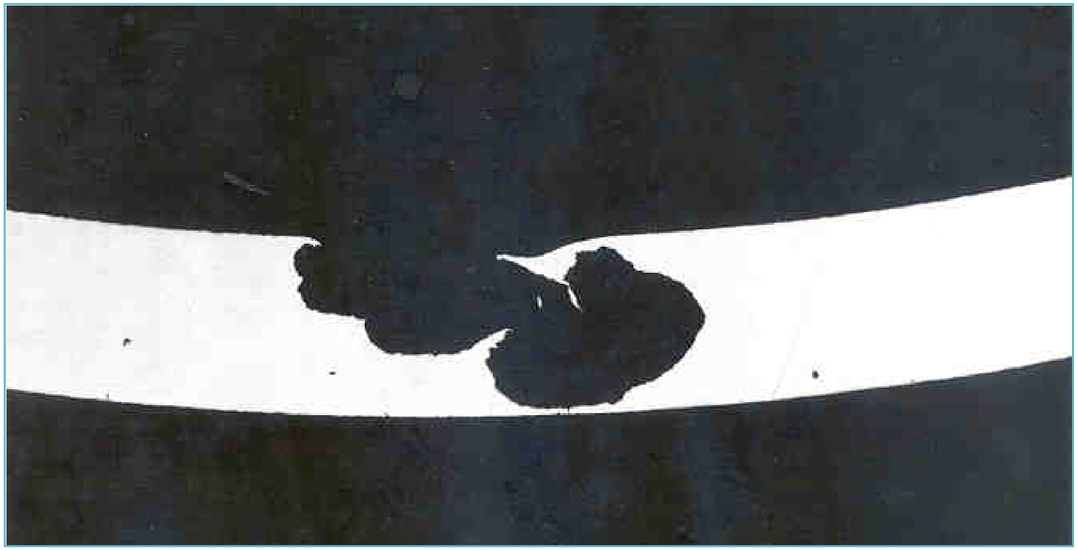
A Bit More on Depth of Penetration

Effective Depth of Penetration

- “The minimum depth beyond which a test system can no longer detect a further increase in specimen thickness.”
- The penetration potential of a frequency is limited!

And Why Depth of Penetration is so very important

Cross-sectional view of cavern



Without the benefits that multi-frequency full depth of signal penetration, this tube would have simply revealed a pit, rather than a tube that would have caused a forced outage during the next operating cycle

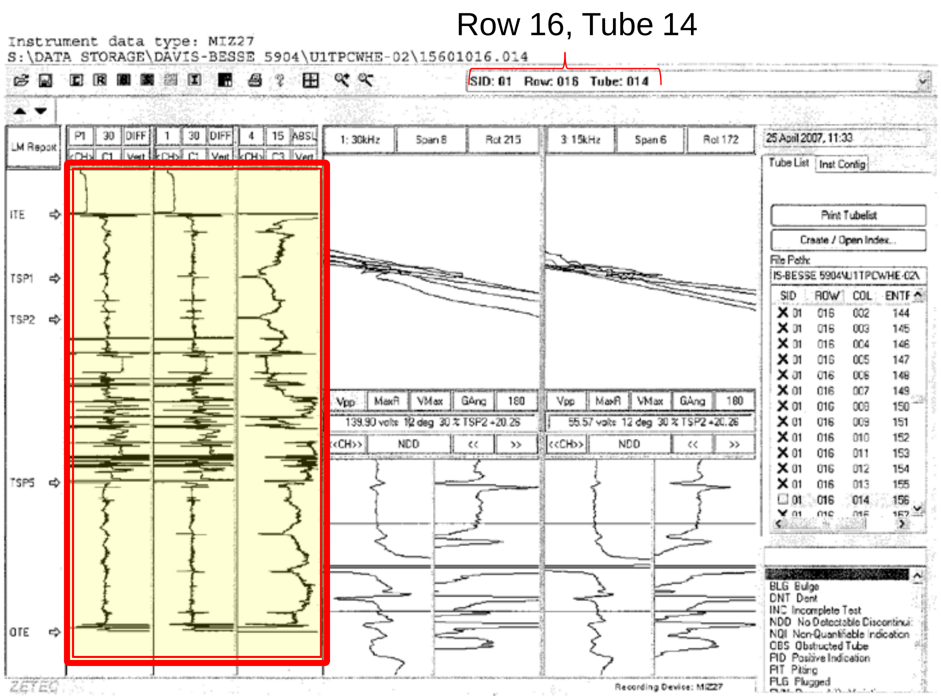
Two Primary Challenges

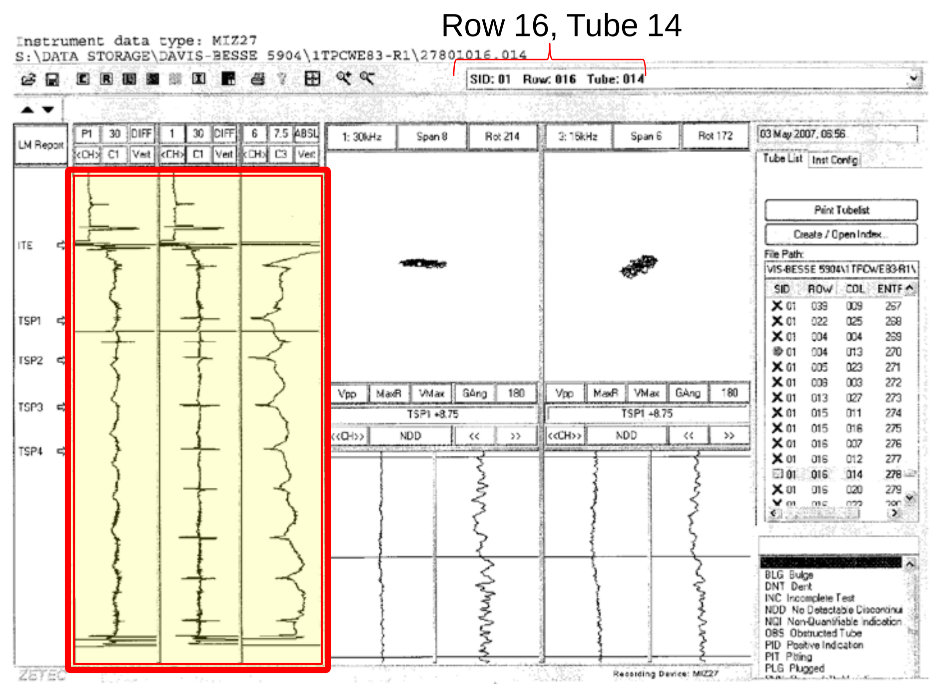
Surprisingly, one of the primary challenges for achieving the most accurate test results, is based on the cleanliness of the tube being tested.

“Effectively cleaned tubes allow for;

- Optimal “Fill Factor” 80% or greater
- Improved probe speed
- Ideal centering of probe head in tube
- Reduced chance of damaging probes causing additional expense/time for plant

Impact of Ineffective Cleaning on ECT Results





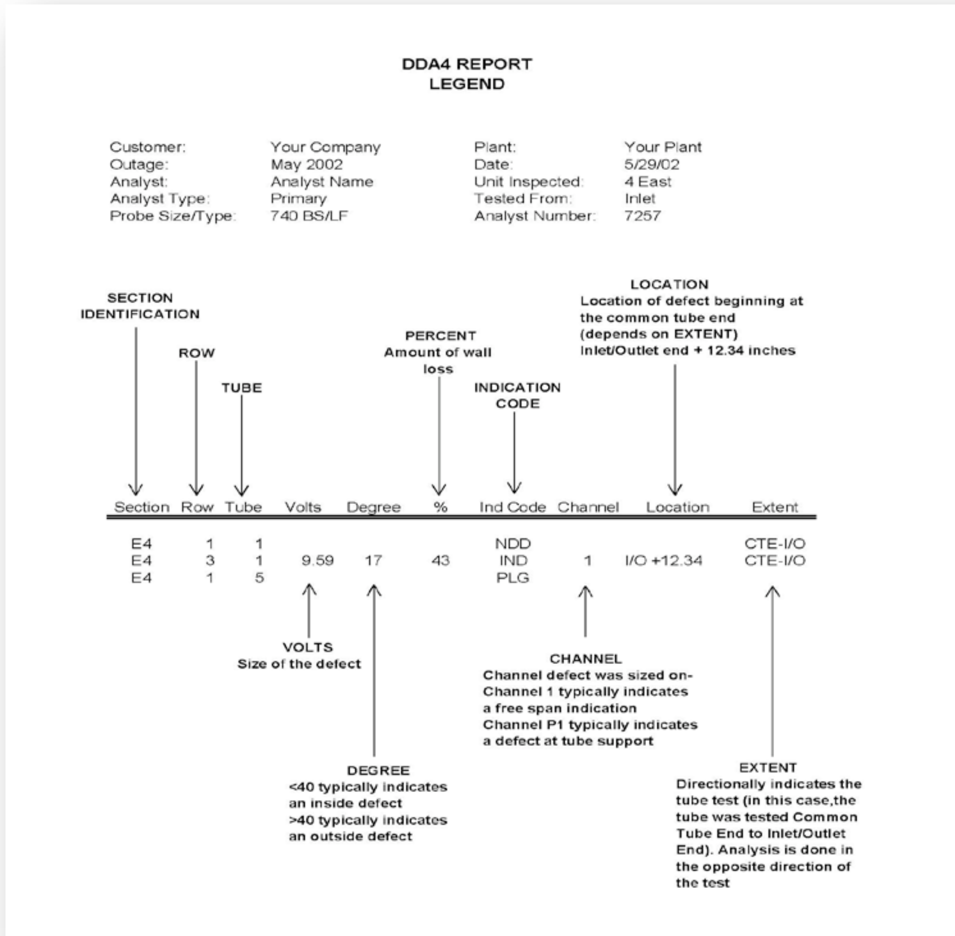
Tube Ineffectively cleaned on left

Same tube following effective cleaning

The Report

- Executive Summary of condition
- Detailed data on each tube tested
- Results
- Color coded tubesheet map
- On site analysis option

Detailed Data

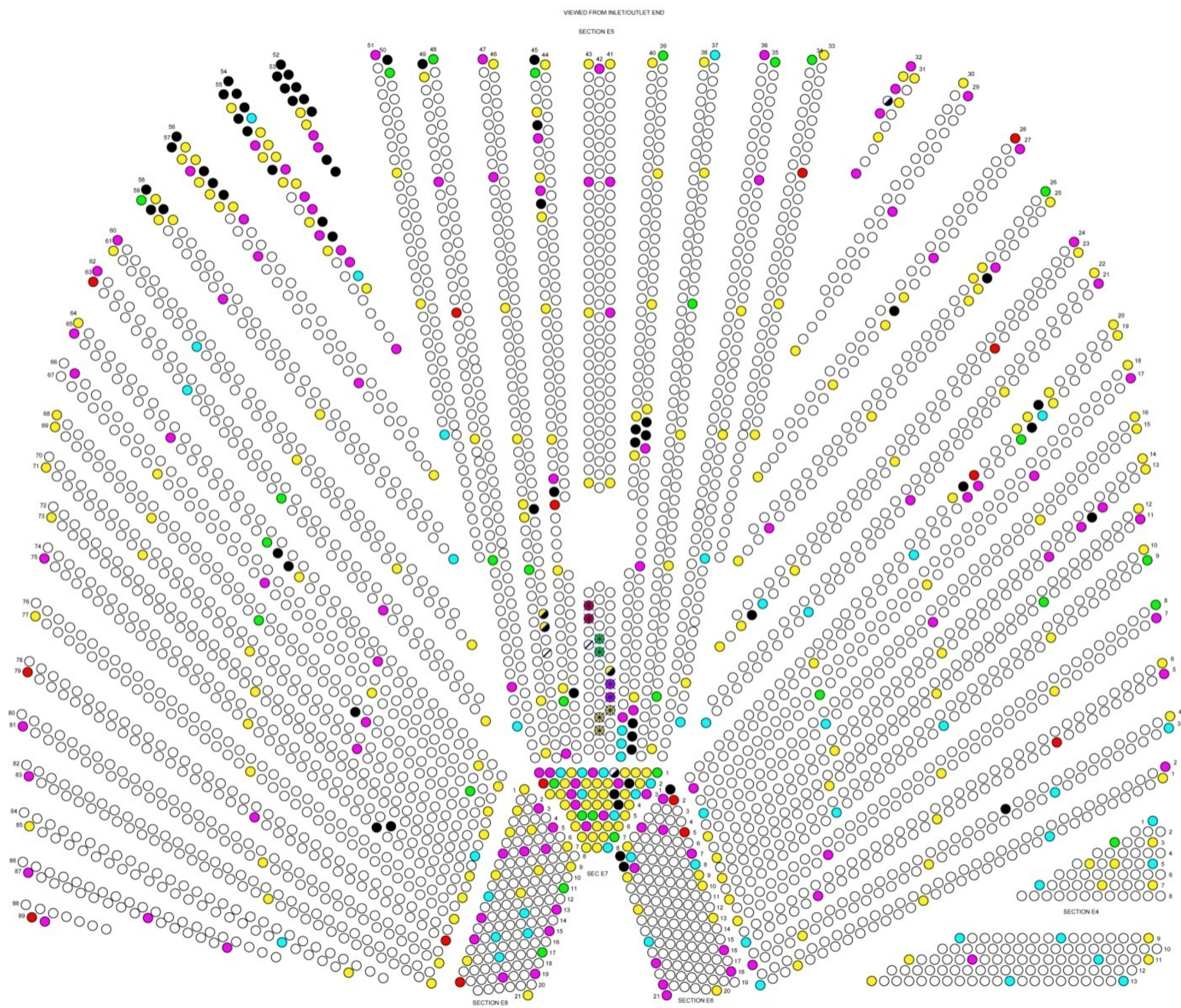

DDA4 REPORT
LEGEND

Customer:	Your Company	Plant:	Your Plant
Outage:	May 2002	Date:	5/29/02
Analyst:	Analyst Name	Unit Inspected:	4 East
Analyst Type:	Primary	Tested From:	Inlet
Probe Size/Type:	740 BS/LF	Analyst Number:	7257

Section	Row	Tube	Volts	Degree	%	Ind Code	Channel	Location	Extent
E4	1	1				NDD			CTE-I/O
E4	3	1	9.59	17	43	IND	1	I/O +12.34	CTE-I/O
E4	1	5				PLG			

Tubesheet Map

A color-coded tube sheet map can be produced to quickly identify problem areas



- Plugged Tube
- 80-100% Wall Loss
- 60-79% Wall Loss
- 40-59% Wall Loss
- 20-39% Wall Loss

Proactive Tube Plugging

Plugging tubes before they cause an unplanned outage is the goal

A good rule of thumb is to maintain enough plugs in stock equal to 2% of your tube quantity.

A 10,000 tube unit should have 200 plugs on hand for new plugging as well as replacement for worn or damaged plugs

Summary

- Reduced number of forced outages due to tube leaks
- Early detection of potential failure mechanism
- Estimate remaining useful life of the tubes
- Summary of overall unit condition
- Improved reliability and availability

Questions?

Gary Fischer
National Sales Manager
CONCO | Systems Services Industrial
1-800-345-3476 or +1-412-828-1166
gfischer@concosystems.net