

7<sup>th</sup> annual Air-Cooled Condenser Users Group

Gettysburg, Pennsylvania

21<sup>st</sup> - 24<sup>th</sup>, September 2015

# How to Diagnose/Troubleshoot Air Ingress

**Martin Cyr – Commissioning Manager**  
**SPX Cooling Technologies, Inc.**

Who, What, When,  
Where, Why.....

.....and How??????

# What is air ingress?

**Air ingress is unwanted and excessive air leakage into the power plant vacuum boundary.**

# Where does air ingress occur?

It can occur anywhere within the vacuum boundary of your respective power plant

- Vacuum Boundary size and complexity varies from plant to plant
- Vacuum Boundary size varies with plant load
- Important to know and understand the vacuum boundary.
- Can save you time and \$\$

## **Who** does air ingress impact?

Operations Staff – ACC is sluggish, slow to respond

O&M Manager – Delays in plant start-up, loss of production, expensive trouble-shooting

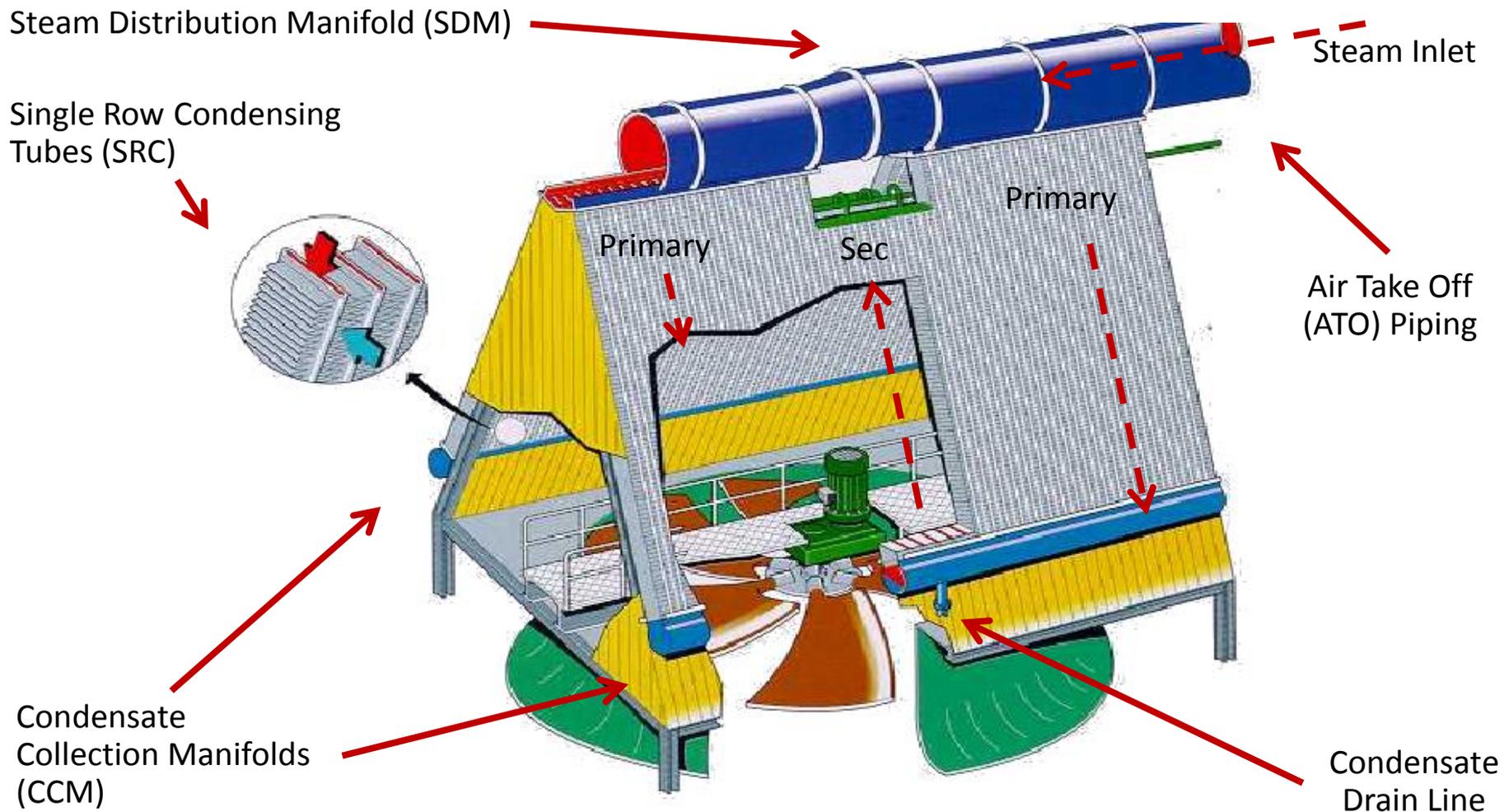
Plant Manager/Owner – Revenues are down

Steam turbine performance is reduced due to increased back pressure

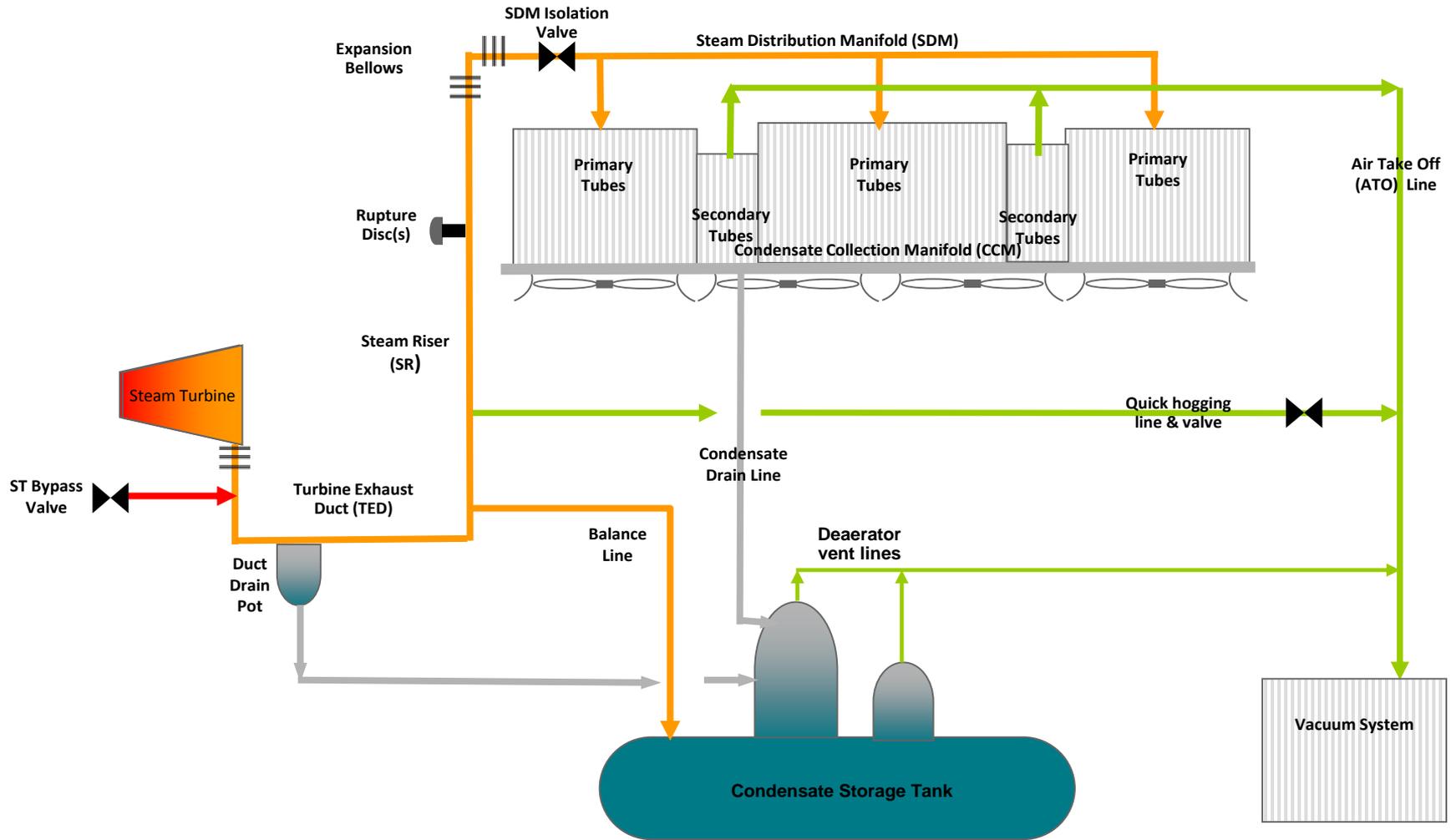
**When** are the impacts of air ingress noticed the most?

1. When the Plant Manager is questioning the O&M Manager who in turn is questioning you the operator about the loss in production?
2. When the demand for power is the highest and \$\$\$?
3. MY EXPERIENCE - Air ingress is rarely a concern on anyone's mind until plant performance is impacted OR.....the ACC freezes.

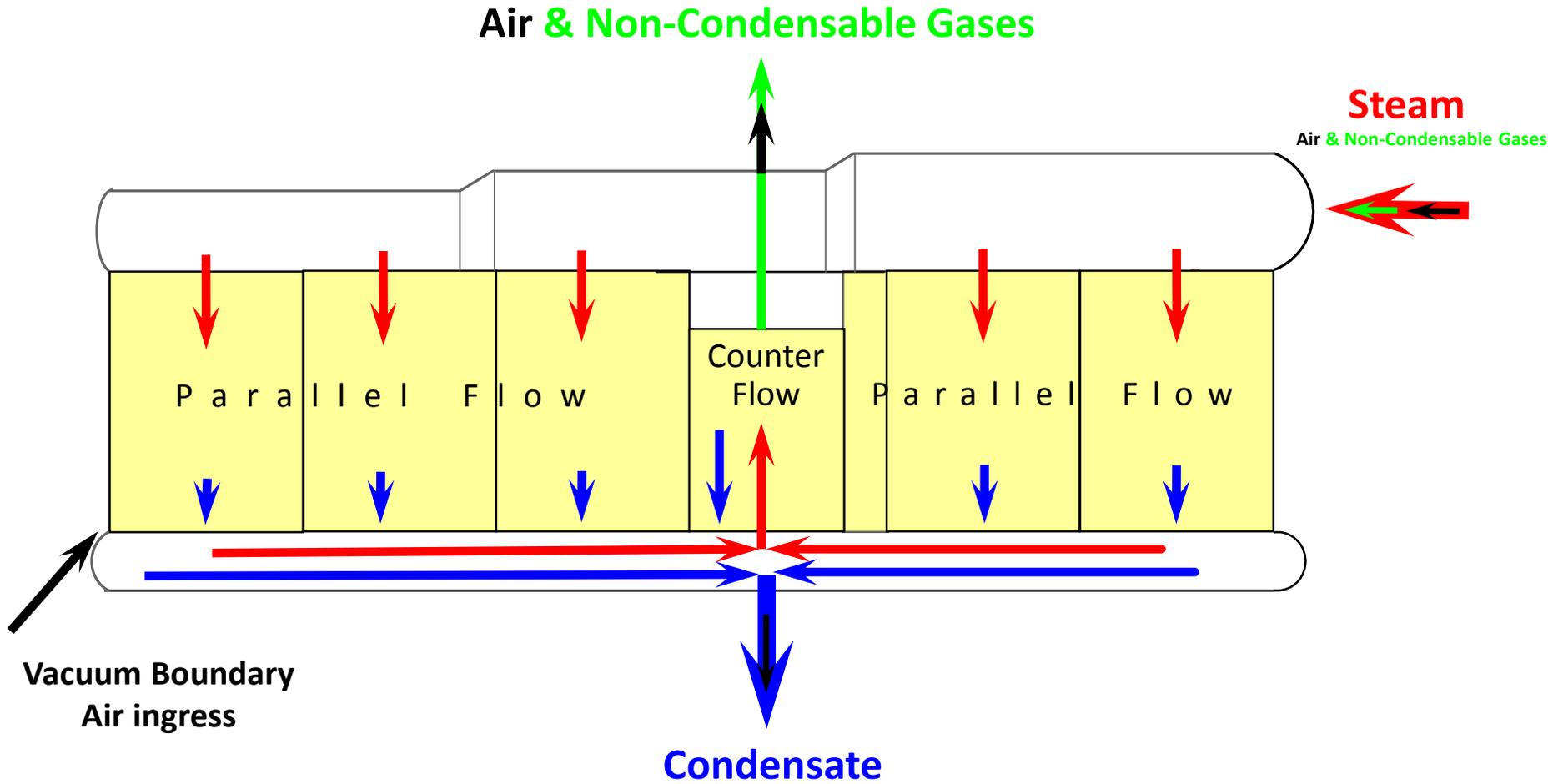
# AIR INGRESS – Typical Air Cooled Condenser Cross-Section



# AIR INGRESS – Typical Vacuum Boundary



# AIR INGRESS – Typical ACC Flow Paths



# AIR INGRESS – WHAT?

## What are the common locations of air ingress?

- Open Valves
- Leaking Flanges
- Bad Mechanical Seals
- Loose Instrument Fittings



# AIR INGRESS – WHAT?

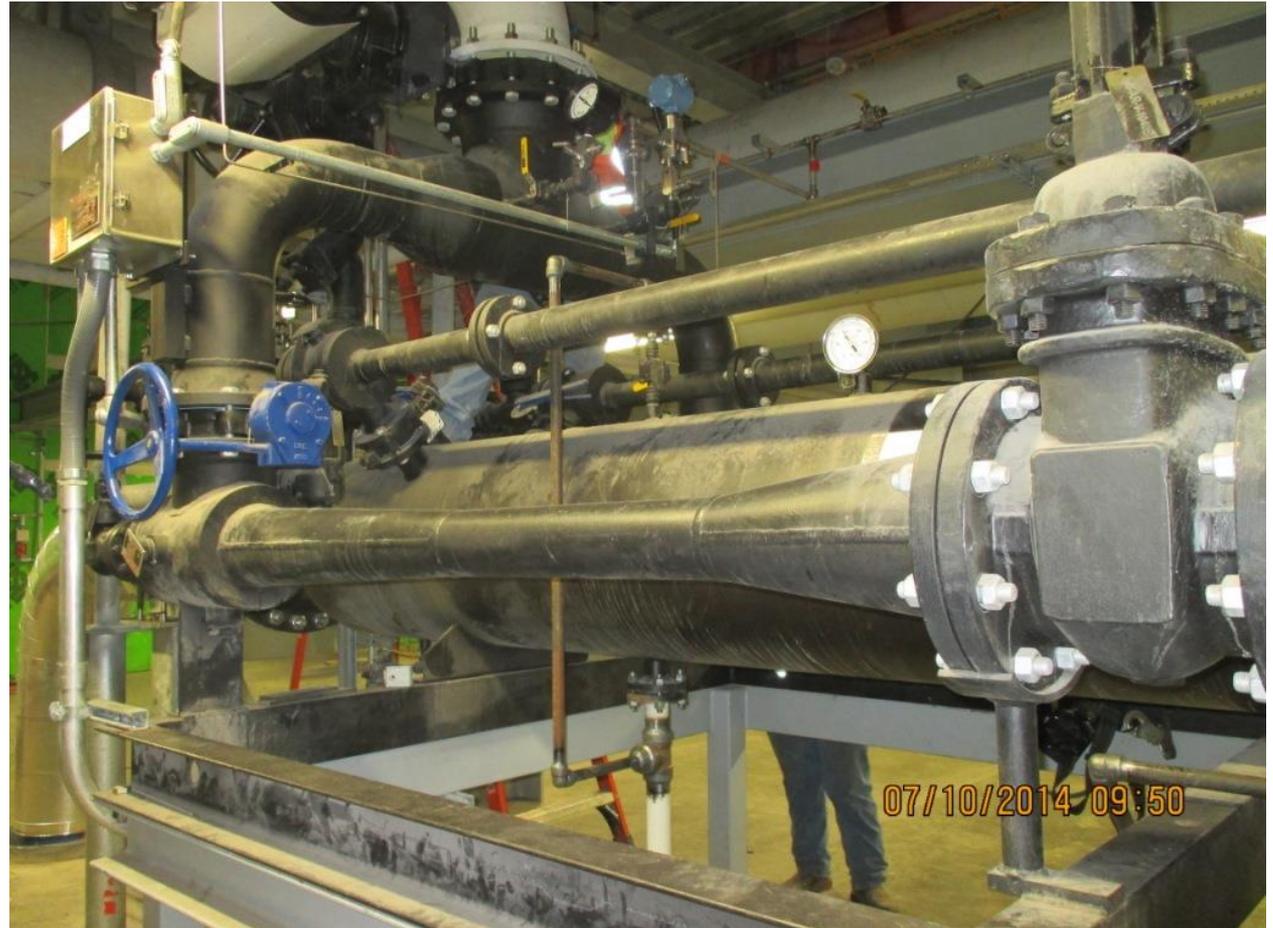
## What are the common locations of air ingress?

- AC drain float trap stuck OPEN
- IC drain loop seal dry
- Causes recirculation of Air and NCG's



## What are the common locations of air ingress?

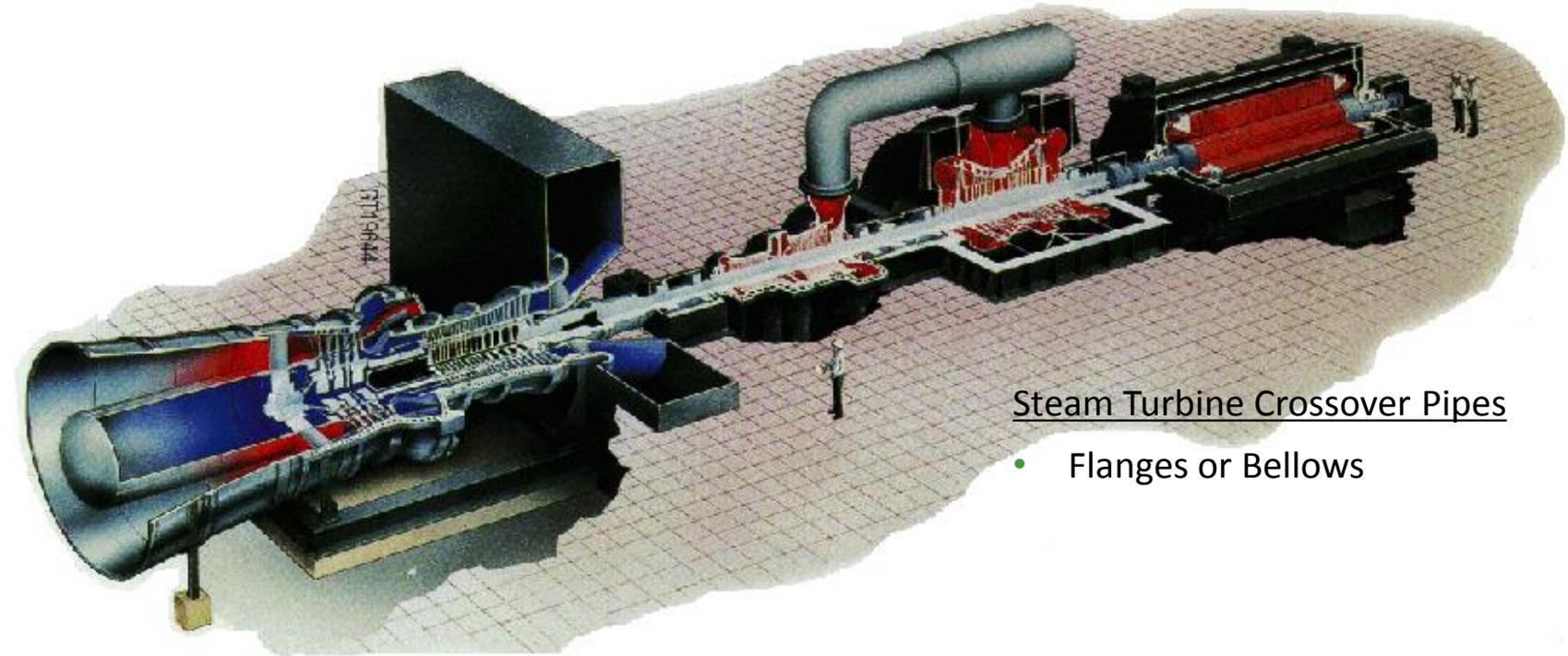
- Loose factory or field tightened flanges



## What are the common locations of air ingress?

Steam Turbine shaft seals or shaft seal housing flanges

Steam Turbine Rupture Discs



Steam Turbine Crossover Pipes

- Flanges or Bellows

## What are the common locations of air ingress?

- Temporary Steam Blow or Make-up Water piping during plant Start-up



## What are the common locations of air ingress?

- Cracked Welds
- ACC Modifications -  
Leaking cleanout ports



## What are the common locations of air ingress?

- Cracked Welds

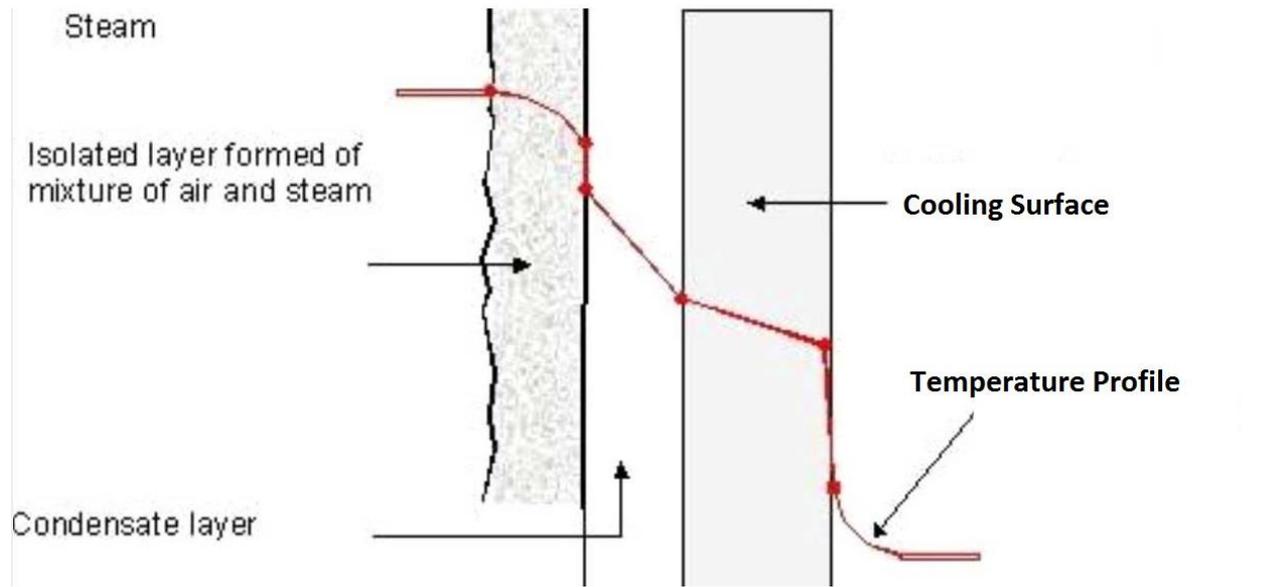
Seal plate butt welds



## Why do I need to be concerned?

### Poor heat transfer

- The thermal conductivity of air is 0.000049 compared to 0.002 for water and 0.20 for iron, Air, including nitrogen and other gases, is the **best insulator**, or worse conductor: 1/100 inch of air isolates as well as 11 feet of copper, 15½ feet of steel or 1/5 inch of water. .



## Why do I need to be concerned?

### Corrosion

Corrosion is one of the most common problems in steam systems and can cause premature degradation of equipment and can be responsible for production downtime.

**Oxygen (O<sub>2</sub>)** that enters a steam system through air oxidizes and corrodes the metal parts of the system. Oxygen corrosion, also known as “pitting”, creates small, but deep holes that can eat through a steel pipe in less than two years.

When **carbon dioxide (CO<sub>2</sub>)** gets in contact with condensate, it dissolves in it and deteriorates into carbonic acid, a highly corrosive compound which attacks the steel of pipes and equipments.

Acidic condensate eats through pipes, causing a characteristic trough in the bottom of pipes. By-products of corrosion are then returned to the boiler where they can create iron deposits.

Oxygen is the main cause of corrosion in steam systems, but if carbon dioxide is also present then the pH will be low, the water will tend to be acidic, and the rate of corrosion will be increased.

## Why do I need to be concerned?

- Business 101 – Because you are in the business to make energy not waste it
- Air ingress affects ACC performance which in turn affects STG performance
- Air ingress can accelerate freezing in cold climates
- More fans operating than normal (i.e. than with no air ingress)
- Fans operating at higher speed (e.g. VFD or 2-speed)
- Condensate is sub-cooled
- May have to down-rate unit output due to increased exhaust pressure/temperature
- Losses vary from unit to unit

# AIR INGRESS – HOW?

## HOW does it occur?

### Human Error – Most times it is the result of the simple avoidable errors

- Someone forgot to close vent or drain valve after outage....
- Improper valve alignment
- Failure to replace flange gasket with new
- Failure to properly clean flanges
- Failure to properly torque flange bolts in correct sequence



## HOW does it occur?

### Breaking Vacuum, Making Steam, and from Make-up water

Condensers systems are obviously filled with air when the vacuum is broken.

Even when the vacuum is not broken and idle condenser under vacuum can slowly fill with air through defective joints or the smallest leaks.

Air can also enter the system in solution within the make-up water .

Boiler feedwater contains a small percentage of non-condensable gases in solution. At 80° C, water can dissolve a quantity of air corresponding to about 0.6% of its volume. Carbon dioxide has a higher solubility, roughly 30 times greater than oxygen.

When boiler water changes state (liquid to vapor) the non-condensable gases are release and carried with the steam into the ACC.

## HOW does it occur?

### Accidental damage

Someone drove an alignment bar a tad bit too far.....?



## HOW does it occur?

### Accidental damage

Dropped tools on exposed tube



## HOW does it occur?

Flow Accelerated Corrosion (FAC) – Six Years in Operation



## HOW does it occur?

Flow Accelerated Corrosion (FAC) – Thirty + Years in Operation



## HOW does it occur?

### Thermal Fatigue (Excessive Cycling)

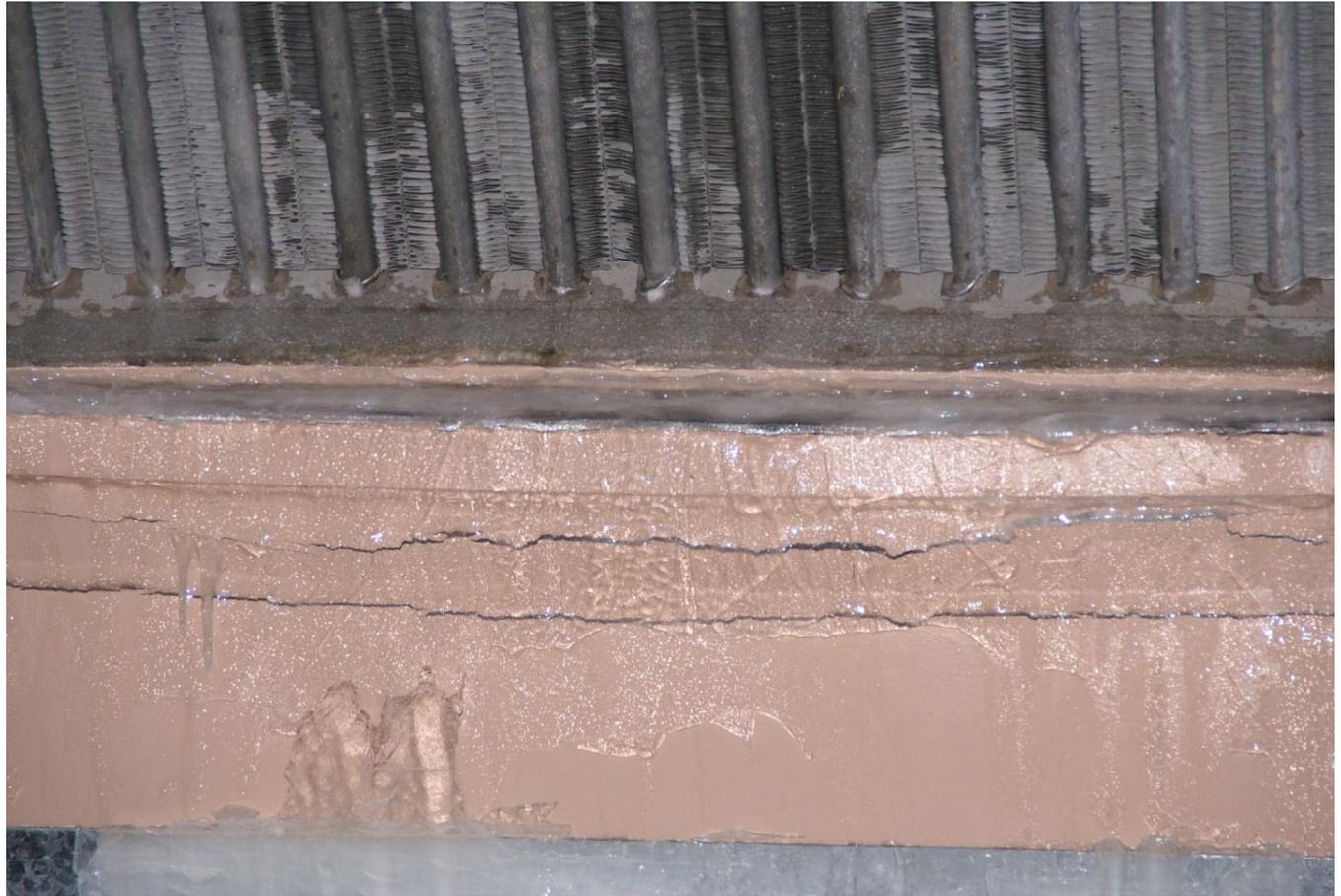
- SS Bellows Type Expansion Joints
- Rubber Expansion Joints



## HOW does it occur?

### Cracked Welds

- Freezing



# AIR INGRESS – HOW?

## HOW does it occur?

- Cracked Welds
- Freezing

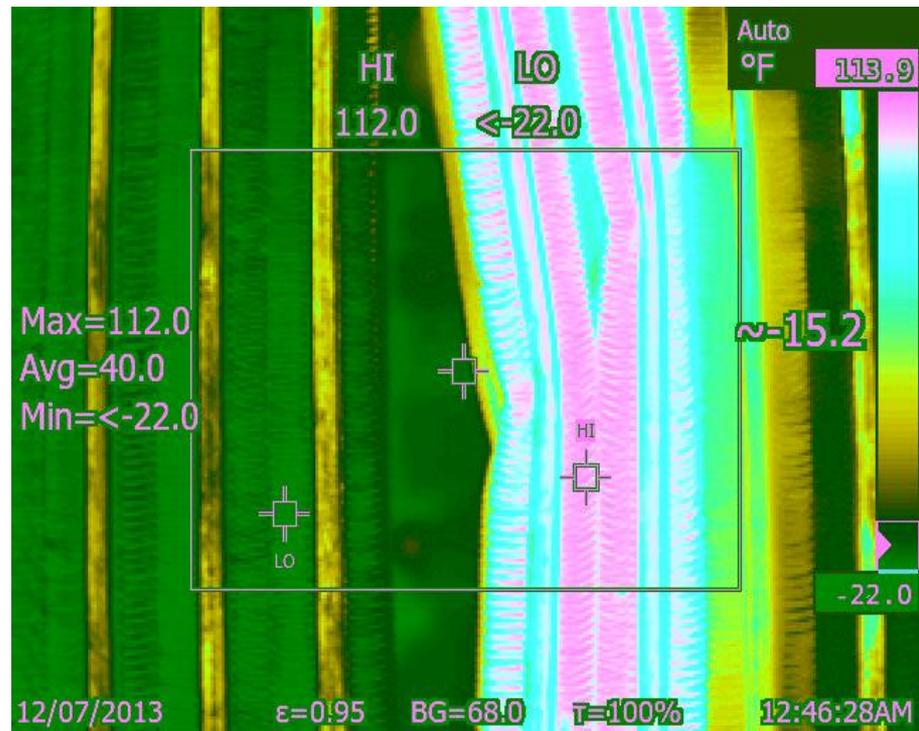


Internal tube weld cracked and the tube was pushed up out of tube sheet by approx.  $\frac{1}{4}$ "

# AIR INGRESS – HOW?

## HOW does it occur?

- Freezing
- Bent Tubes
- Prevented from Expanding



## HOW does it occur?

### Inferior Shop or Field welds

- Tell-Tale port leaking during pneumatic leak test
- Revealed bad shop weld



# AIR INGRESS – HOW?

## HOW does it occur?

- Inferior Shop or Field welds



# AIR INGRESS – HOW?

## HOW does it occur?

- Failure of a factory welds during tube bundle installation



# AIR INGRESS – HOW?

## HOW do you determine that you have air ingress?

Check the vacuum system vent line flow meter



## HOW do you determine that you have air ingress?

### Overview:

- Located on SJAE after condenser vent or LRVP separator tank
- Provides operator with real time air & NGC removal rate.
- Equipped with bypass valve to preserve flow meter life
- Vent flow indication should be observed daily
- Check datasheets (holding system)
- Leakage rate should be 25% of holding ejector design dry gas capacity IAW HEI
- Some say 50% is acceptable....I say why lower the bar?

- Vacuum system vent line flow meter



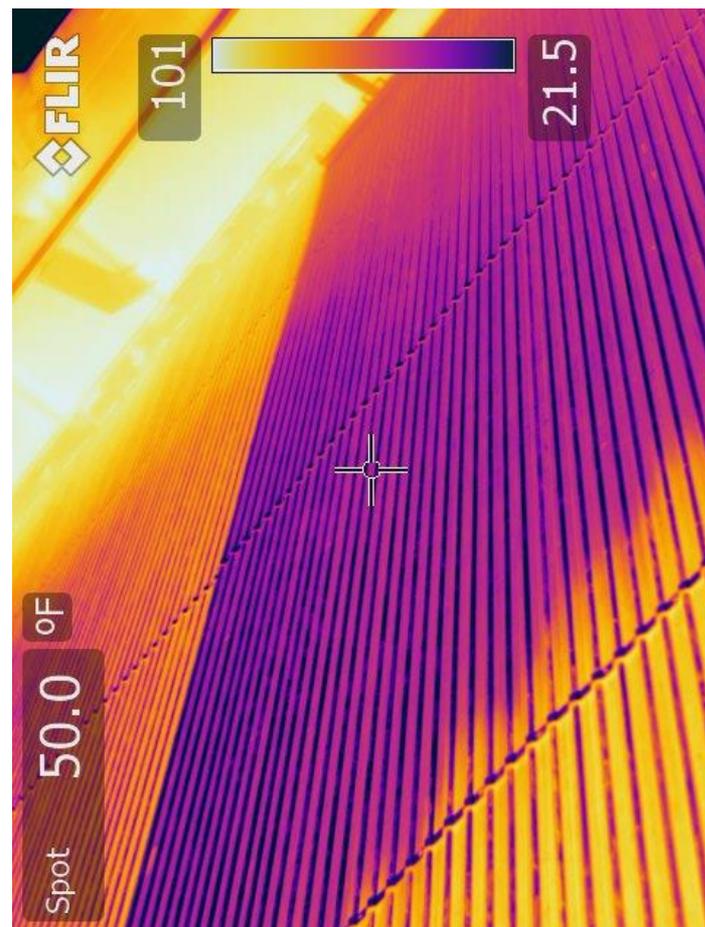
## HOW do you determine that you have air ingress?

**$\Delta T$**  between - Steam Inlet, Air Take off (ATO), and Condensate Drain Temperatures

- Are not within **10° F** of steam inlet pressure **saturation temperature** during normal (design) operating conditions.
- ATO temperature is immediately impacted by air ingress.
- ATO temperatures decrease when excessive air is present
- Condensate temperatures decrease because more fans are placed into service in order to maintain the desired back pressure set point resulting from a loss of cooling surface area
- More operating fans result in **condensate depression** ..sad..sad..sad...Nobody wants depressed condensate.
- Longer than design evacuation time.
- Cannot pull vacuum as deep
- Check datasheet guarantees for hogging duration

**HOW** do you determine that you have air ingress?

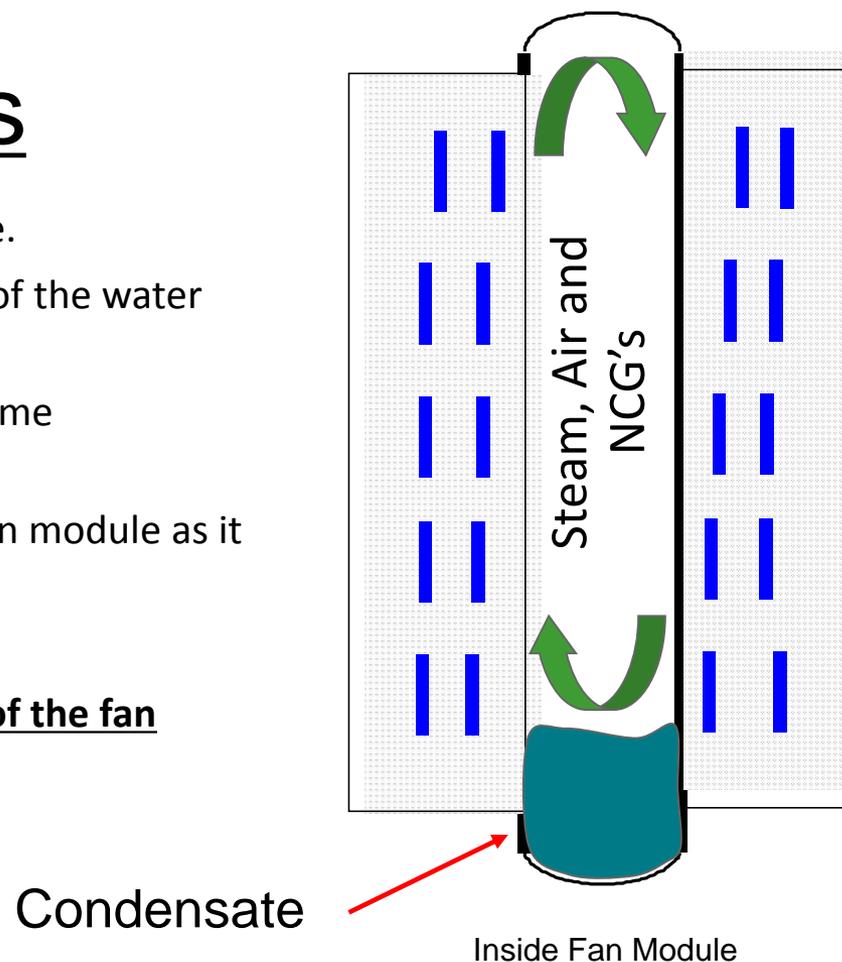
## Infrared Survey



**HOW** do you determine that you have air ingress?

## Infrared Survey Tips

- Condensate will flow along bottom surface of tube.
- Steam, Air and NCG's will flow above the surface of the water and along the top of the tube.
- Condensate will be at saturation temperature. (same temperature as the steam for a given pressure)
- Air will be hard to detect from the inside of the fan module as it will be shielded by the down flowing condensate
- Therefore for clear IR images;
- **All IR images should be recorded on the outside of the fan modules.**

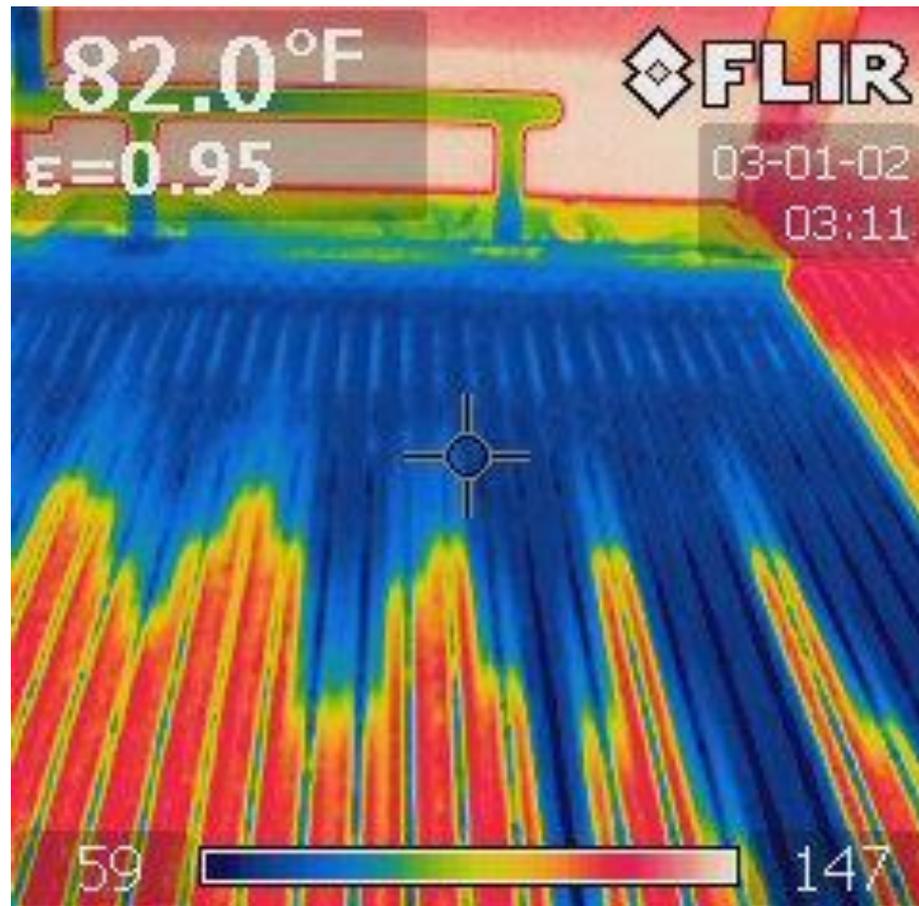
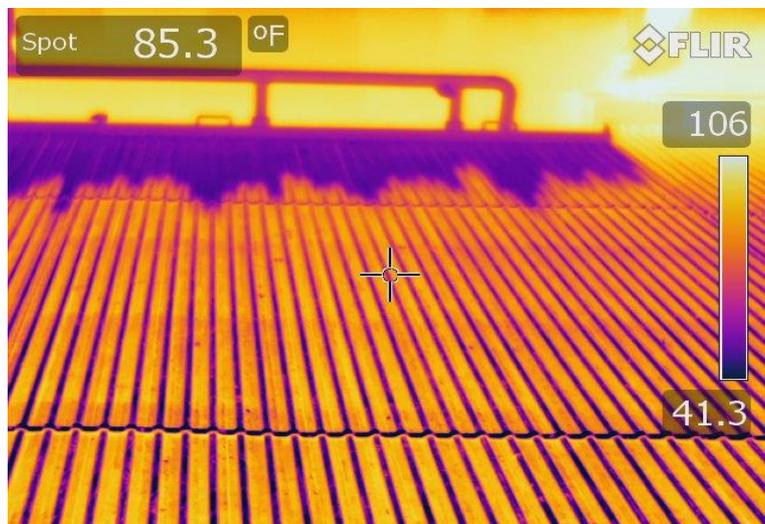


## HOW do you determine that you have air ingress?

### Infrared Survey

#### Secondary Tube Bundles

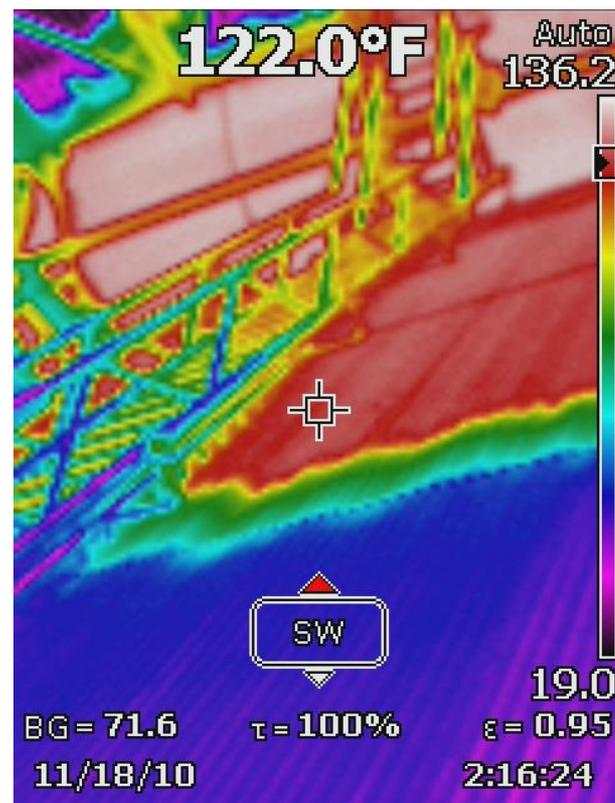
- Cooler Temps = BLUE
- Hottest Temps = RED
- Range for image? How close is tube temperature to ambient air temp?



## HOW do you determine that you have air ingress?

### Infrared Survey

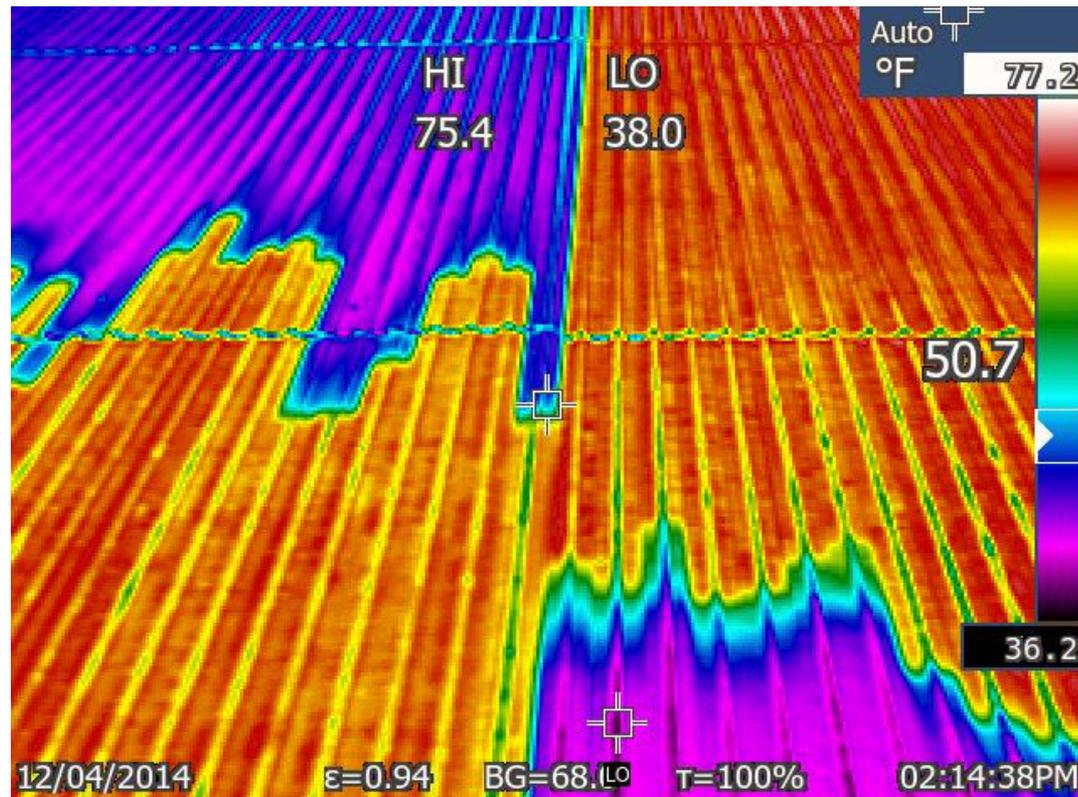
Primary Tube Bundles



## HOW do you determine that you have air ingress?

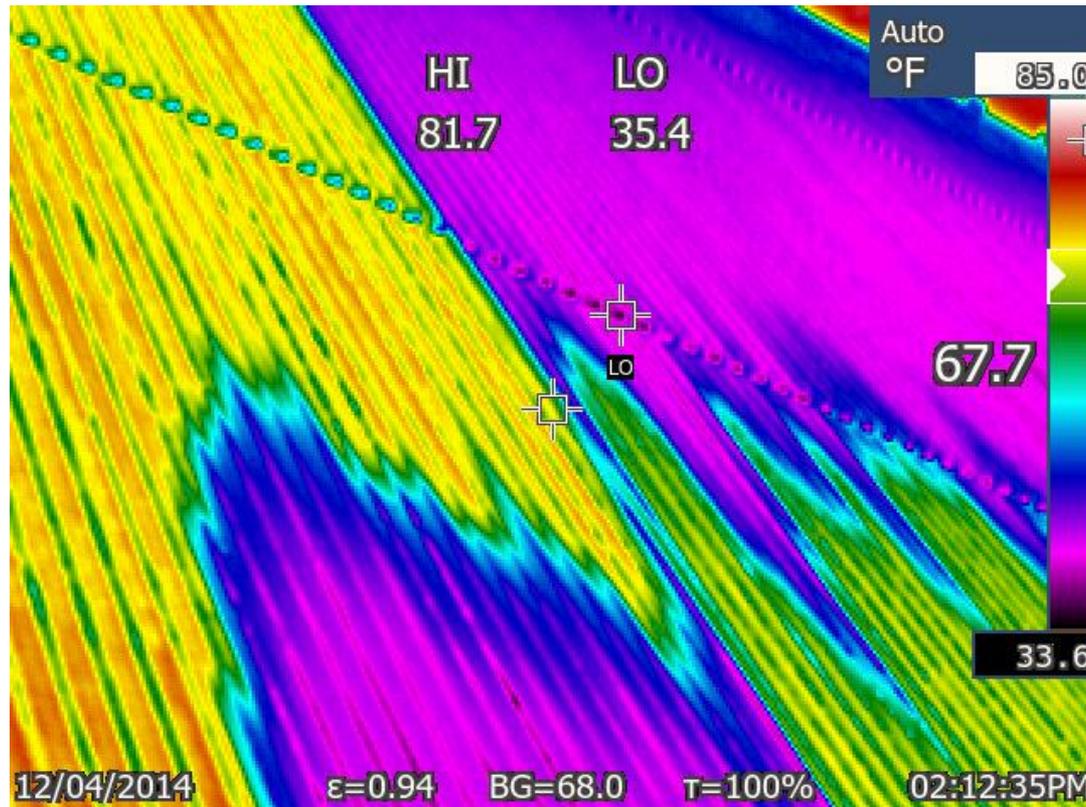
### Infrared Survey

Interface – Secondary (Left) and Primary (Right) Tube Bundles



## HOW do you determine that you have air ingress? Infrared Survey

Interface – Primary (Left) and Secondary (Right) Tube Bundles



# HOW do you determine that you have air ingress?

### Vacuum Decay Test (AKA Vacuum Drop Test)

- Should be routinely performed; monthly or on a semi-annual basis
- Vacuum Decay Test can be performed on or off line.
- Off line will provide longer test period, less interference and more accurate test results

### VACUUM DECAY TEST FORMULA

The following formula is used to determine the leakage rate into the system:

$$\frac{\text{Leakage (lbs/hr)} = 0.15 \times V \times PR}{T}$$

Where;

V = System Volume (including the turbine)

PR = Pressure Rise (Inches Hg)

T = Time for Pressure Rise (minutes)

# HOW do you locate the leaks?

### Old fashioned shaving cream

- Apply to suspected leaking flanges
- Just utilized a month ago on duct drain pot system piping and level instruments on my last project in Argentina
- System must be under vacuum

### Duct tape on flanged connections

- Tape is drawn in

### Helium Leak Testing

- Expensive but well worth the \$\$\$
- Fastest means for finding air ingress
- Most effective means

### Pressure Testing

- Set steam seals and pressurize vacuum boundary with air to 2 PSIG
- Will require large air compressor and temporary connection
- Not preferred method

### Acoustic Listening Device

- Should have parabolic dish for collecting acoustic noise from a distance of up to 30 feet

# QUESTIONS?