Impact of Combustion Turbine Upgrades on HRSGs

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Combustion Turbine Upgrades – Driving Factors

- Disruption in the North American power market from renewables
- Combined cycle units stepping in to support renewables
- Increasing need for turndown operation of combustion turbines
- Need for Peak Capacity, Low load and spinning reserve requirements are increasing in the current power market
- CT Upgrades become a logical solution to address these issues

Image Source: Seattle Times

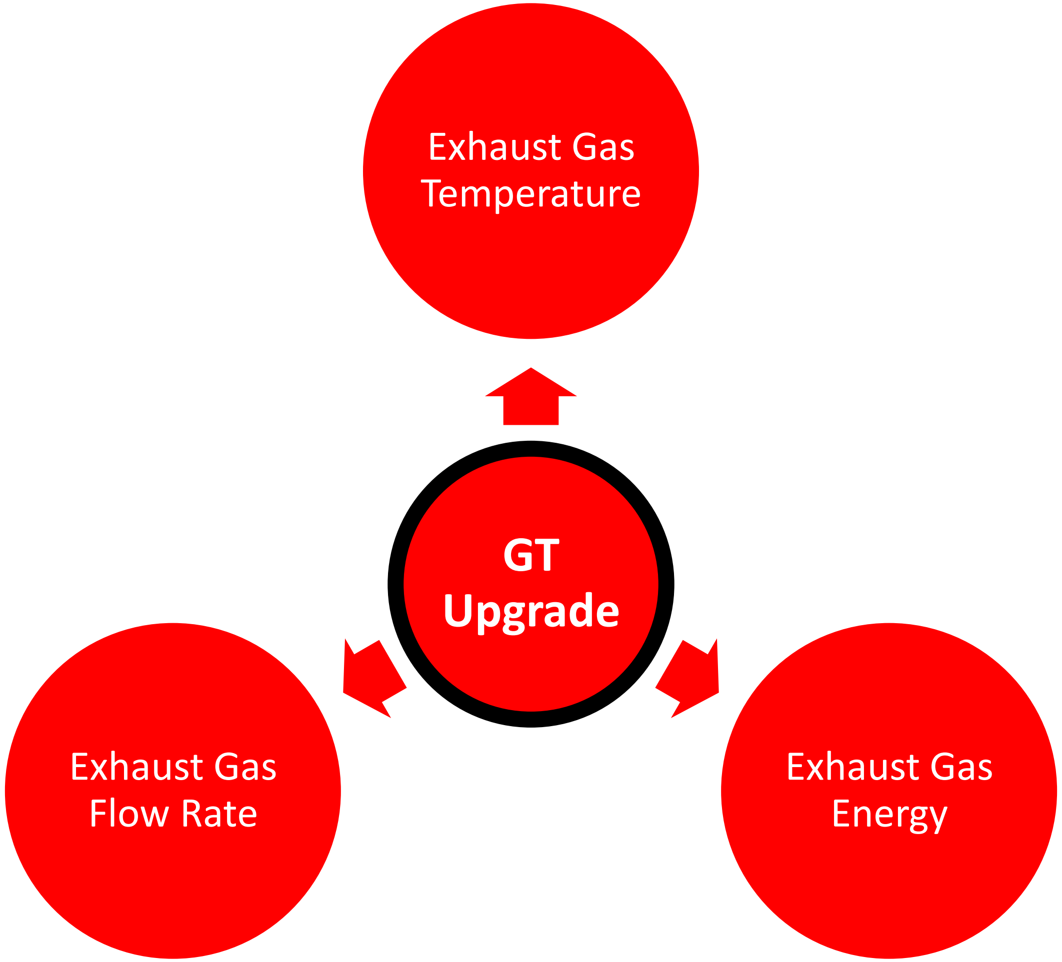
Combustion Turbine Upgrades

CT Upgrades – Typical Expectations

- Increased output by 3%-10%
- Decreased heat rate by 0.5%-1.5%
- Increased exhaust gas temperatures (~+50°F at base load)
- Increased exhaust gas flow rate (0.1%-2% at base load)
- Higher exhaust gas temperatures at startup/low load (+1200°F)

Impact on HRSG Post-Upgrade - What Happens?

- During base load operation with and without supplemental burner firing
- Low Load / Part Load Operation



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Combustion Turbine Upgrades – Key Concerns

Increased Temperature

- Overheat of Tubes, headers and piping
- Non pressure part overheat (tube ties, baffles, liners, etc.)
- Attemperator Overspray
- Low Load Capabilities and Emissions

Increased Energy

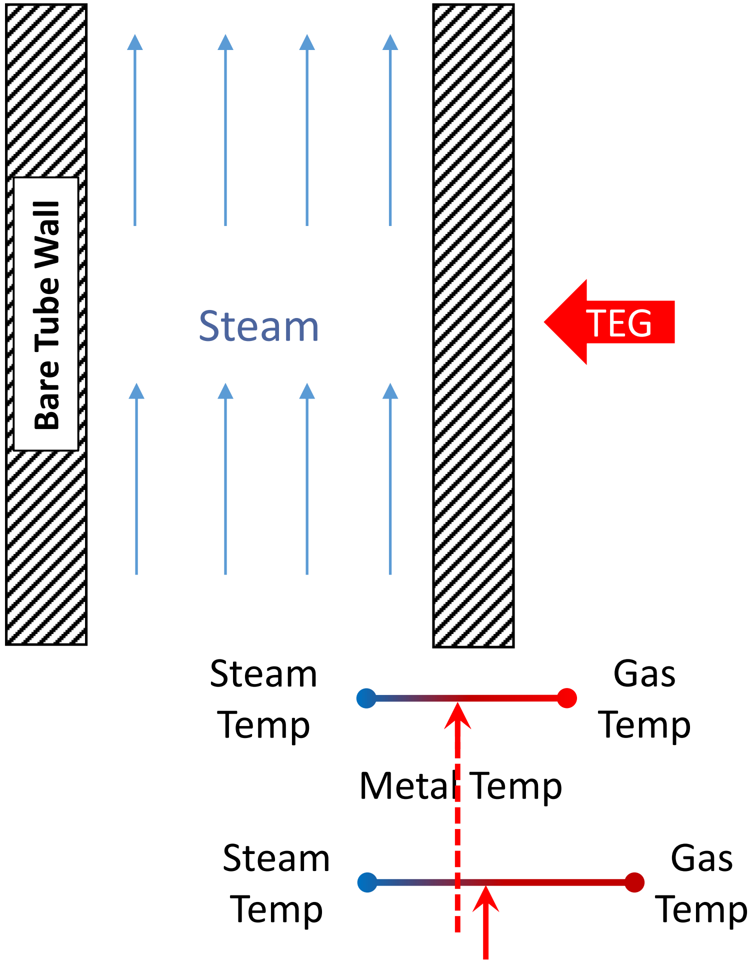
- Steam production
- Will a re-rate be needed?
- Safety valve capacities
- Final steam separator design limits

Increased Exhaust Flow Rate

- Proper catalyst sizing
- Gas side pressure effects on casing, expansion joints and upstream module penetration seals

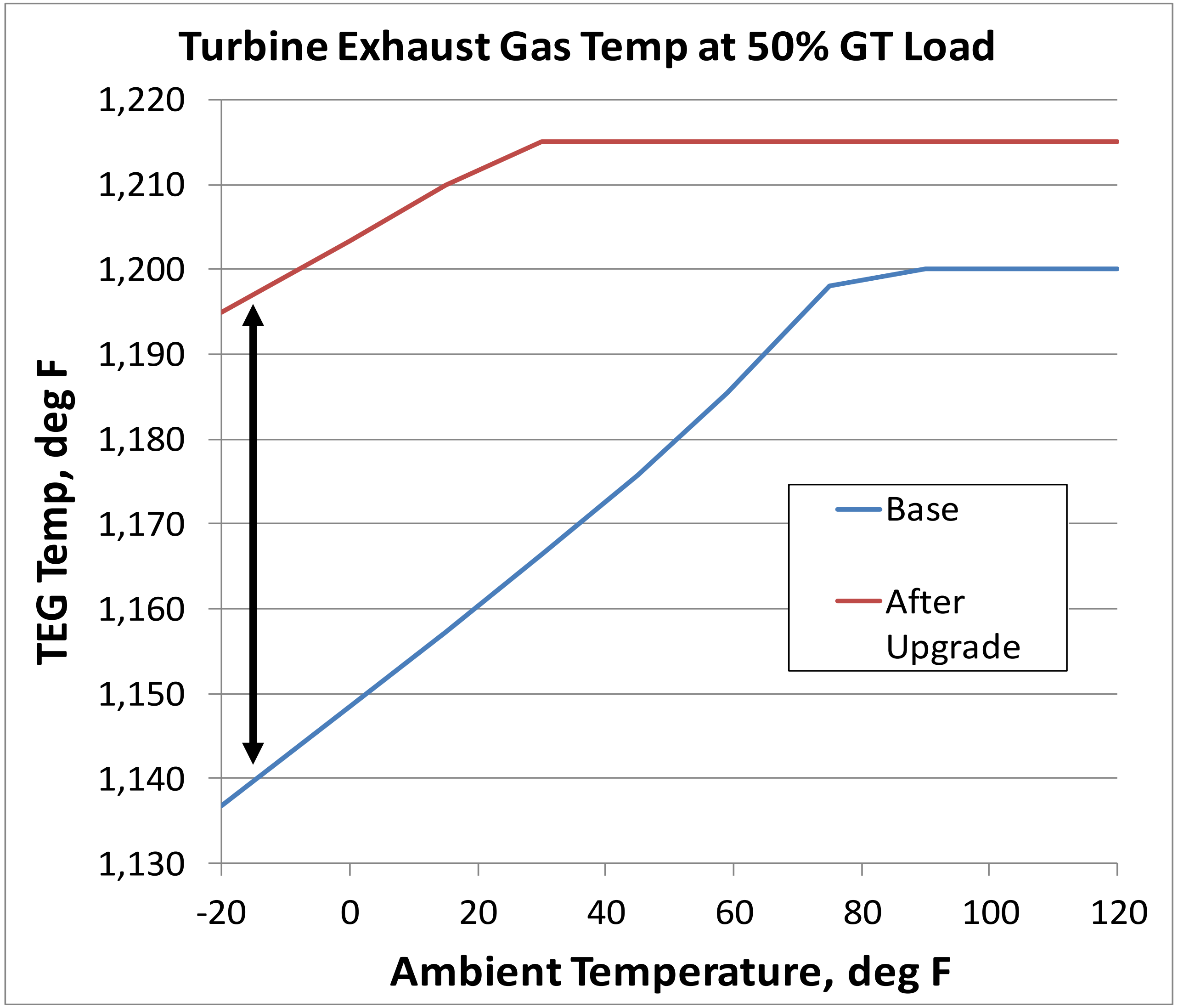
Tube Metal Temperatures

- TMT is between steam and gas temperature
- Proportion remains constant before and after upgrade
- Temperature of metal increases with increased gas temperature
- If gas temperature increases significantly the TMT could overheat the tube



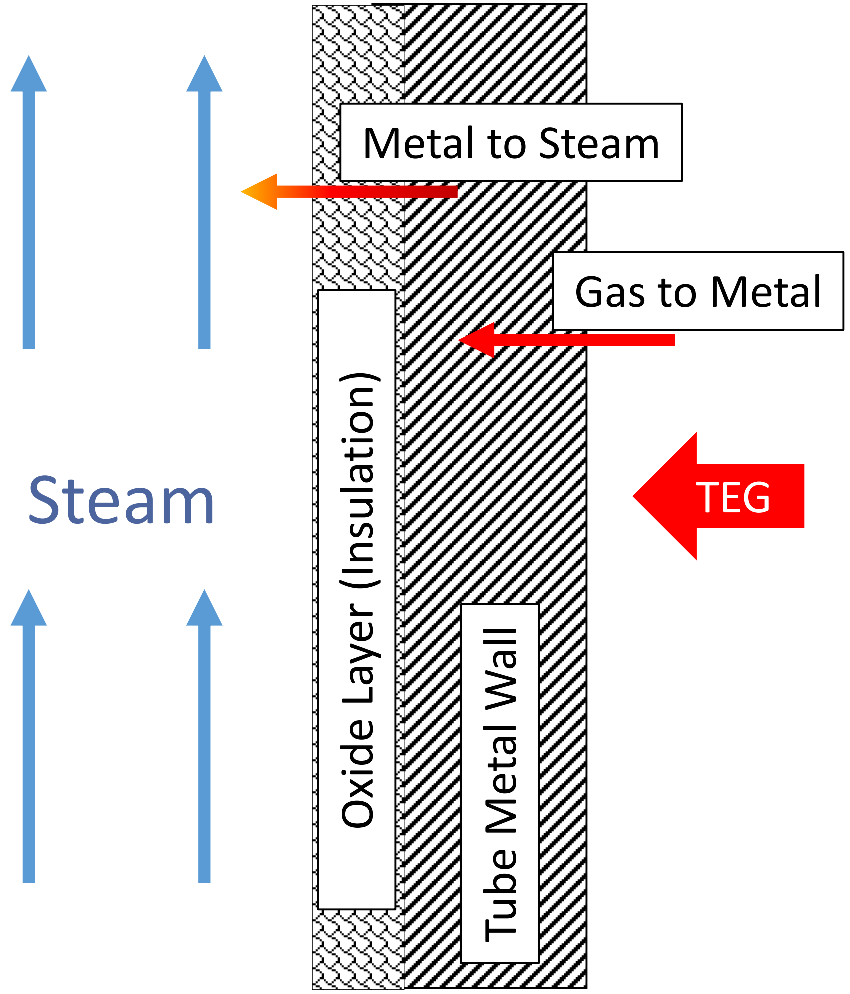
Tube Metal Temperatures

- CT Upgrades can push TMT over design limits
- “Low Load Unfired” operation can be the limiting case for HP Superheater and Reheater Tubes
- Note: CT hits ~1215°F isotherm at a lower ambient temperature after upgrade – Low load cases experience higher gas temperatures
- Even if TMT design limit is not exceeded, the service life of the pressure parts are reduced



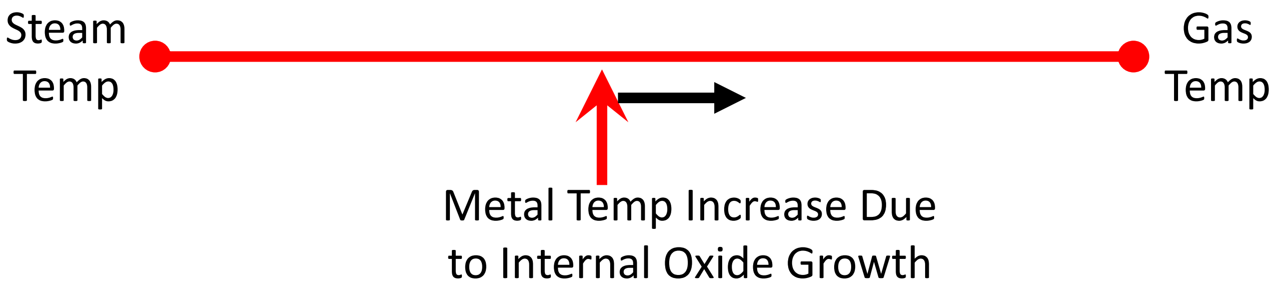
Tube Overheat

- Overheat results in oxide layer growth on the tube surface
- Oxide layer acts as an insulator in the path of heat transfer increasing the tube metal temperature
- Cyclical operation with an overheating tube results in exfoliation and eventual failure

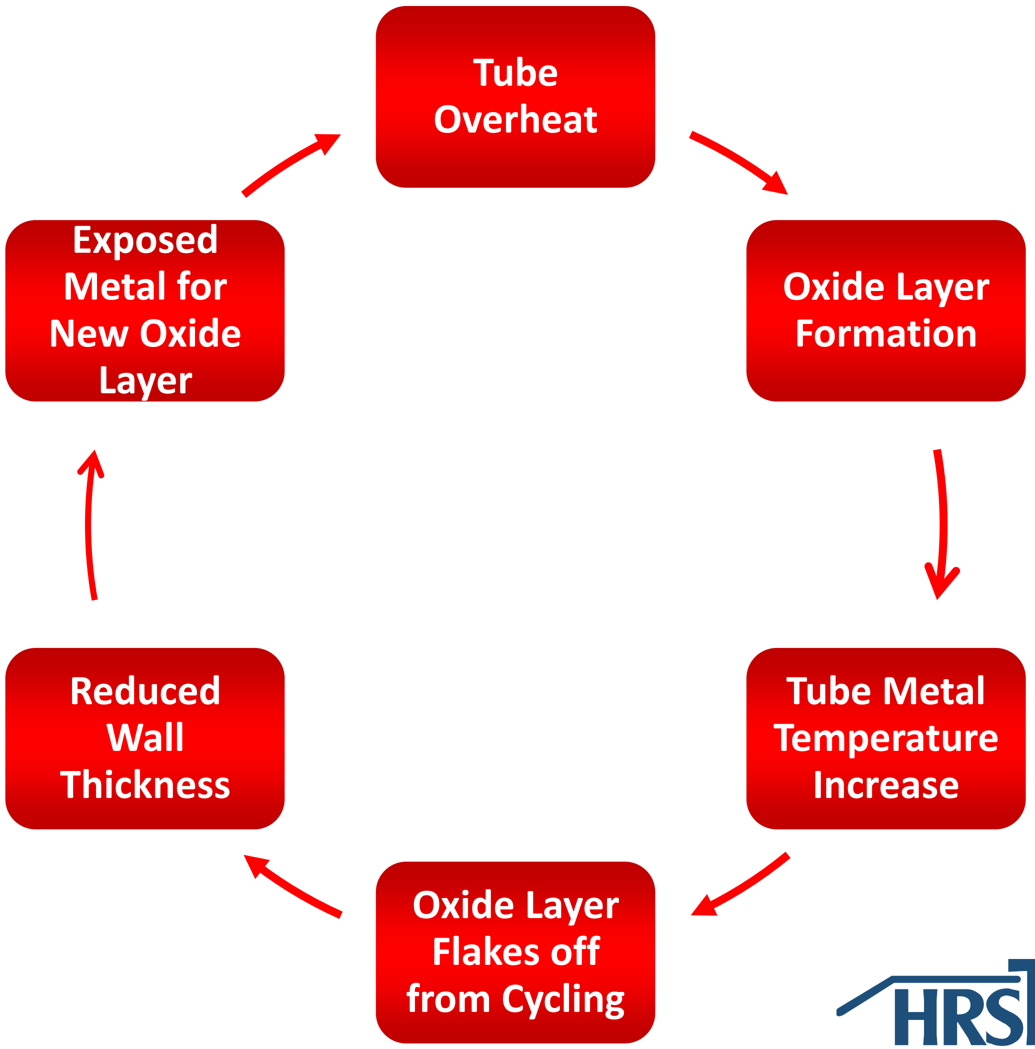


Tube Metal Temperatures – Internal Oxide Growth

- Internal oxide growth tube metal temperature to increase



- Increased metal temperature reduces creep strength
- Coincident reduction in wall thickness increases stress
- The combined effects shorten tube life significantly

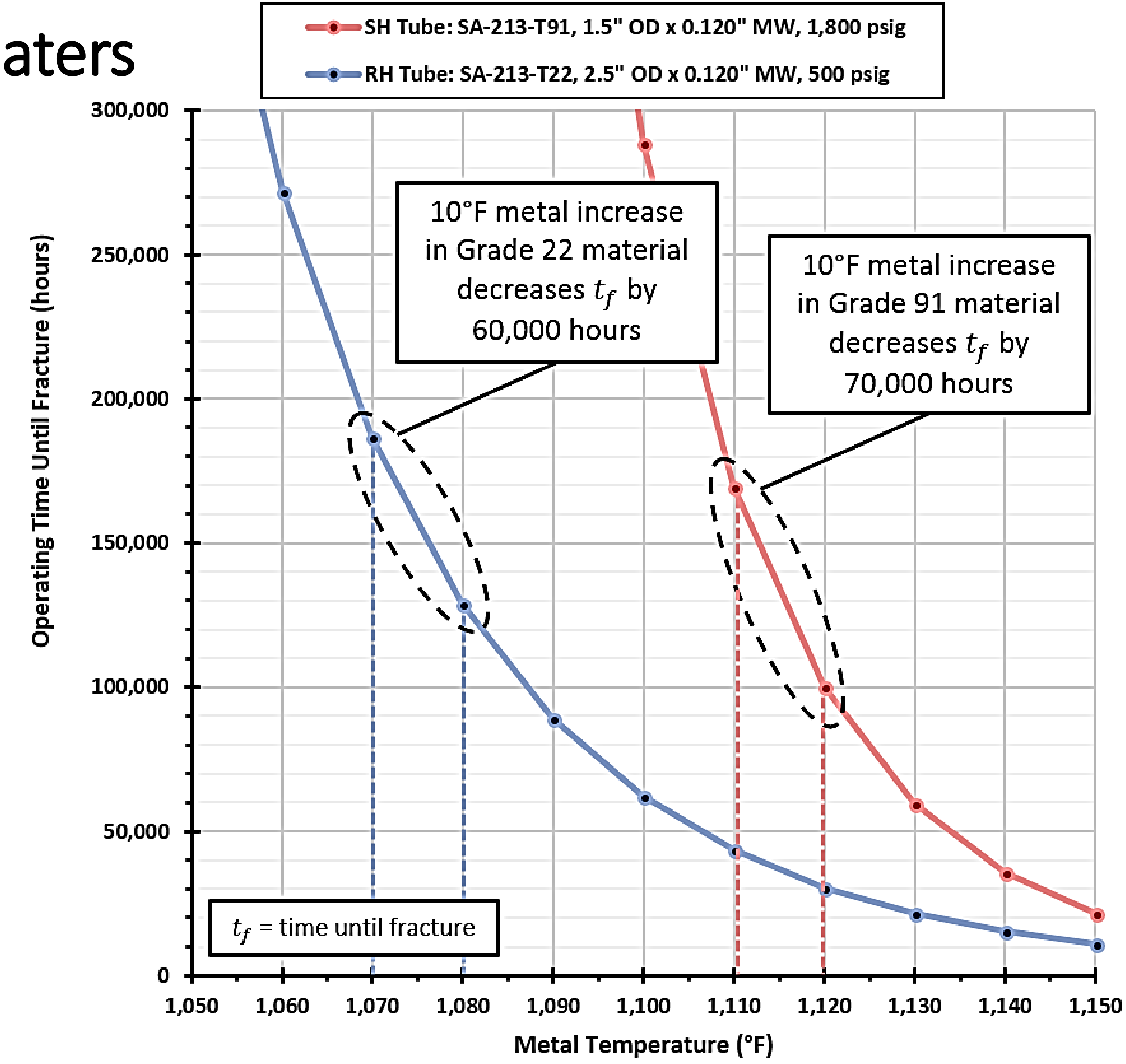


Creep in Reheaters and Superheaters

Small changes in metal temperatures can significantly reduce creep life

- Calculated using Larson Miller Parameter (LMP)
- Grade 22
  - 1070°F / 577 C - ~185,000 hrs
  - 1080°F / 582 C - ~130,000 hrs
  - 30% life decrease*
- Grade 91
  - 1110°F / 599 C - ~169,000 hrs
  - 1120°F / 604 C - ~100,000 hrs
  - 40% life decrease*

*<u>Note:</u> the remaining life is a function of both operating pressure and tube thickness as shown in box above graph



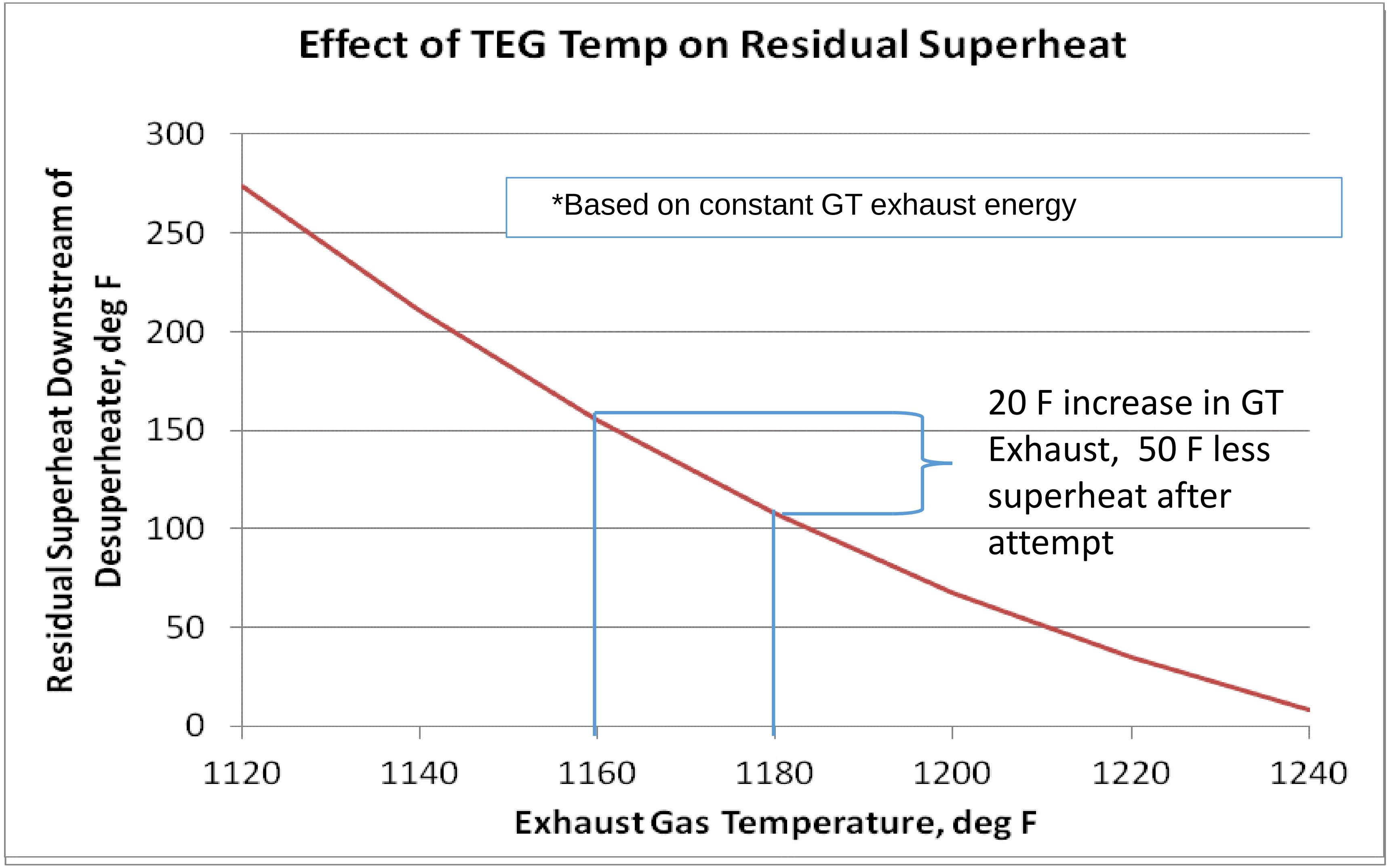
Attemperator Overspray Risk

Post Upgrade Conditions:

- Final steam temperature still at ~1050°F
- Exhaust gas temperature & massflow increase to Module 1

Result:

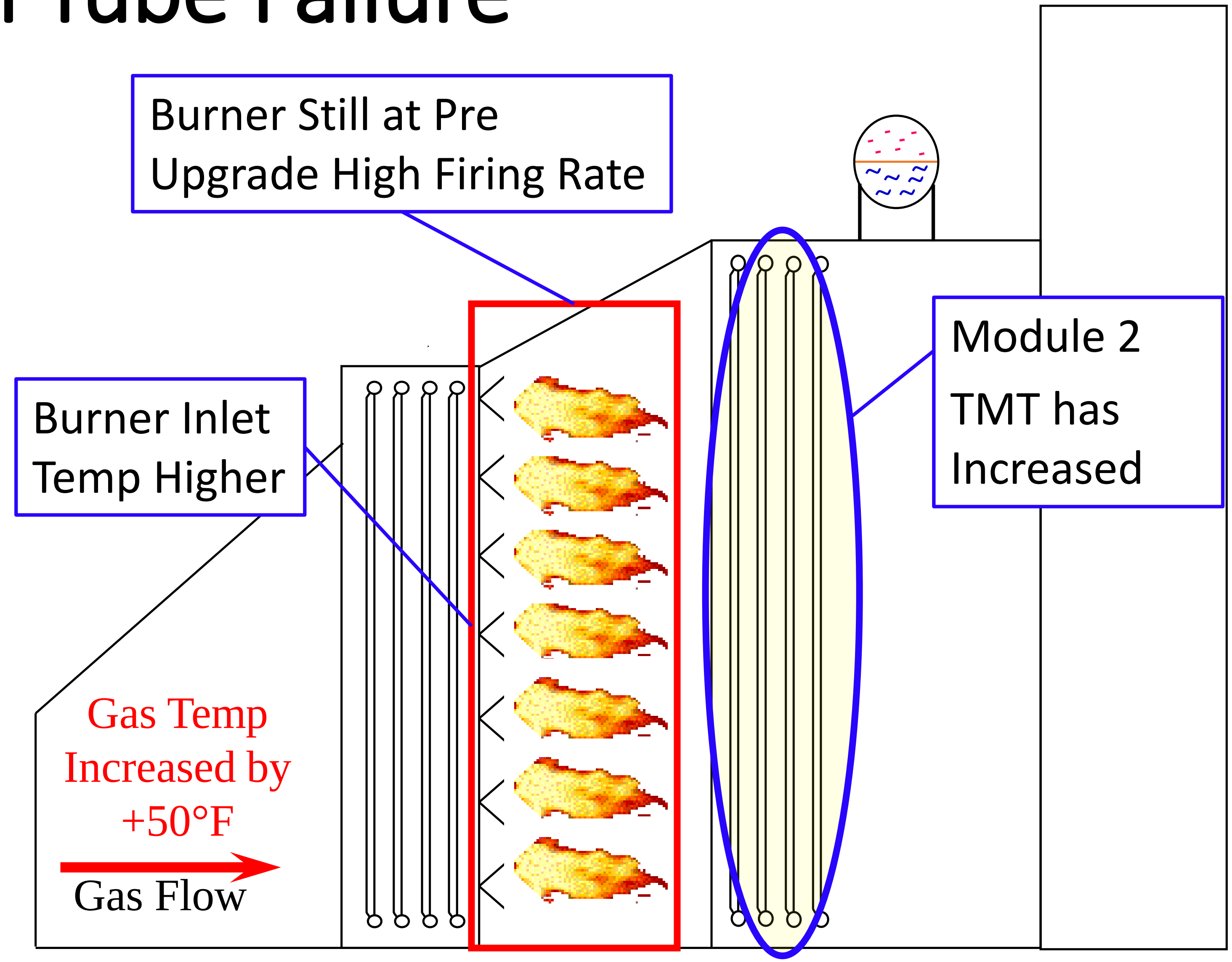
- Higher attemperator spray water flow required to maintain the final steam temperature setpoint
- Attemperator and control valve could run out of capacity
- Higher spray flow rate could mean “overspray” and pressure part damage downstream.



$$T_{RSH} = T_{DSH(Out)} - T_{Sat}$$

Case Study 1 – RH SH Tube Failure

- Frame 7F unit underwent CT Upgrade
- CT Exhaust Gas temperature increased by about 50°F after the upgrade
- Duct Burner was operating at the same high firing rate after upgrade
- Higher burner inlet gas inlet temp and high pre upgrade firing rate caused burner outlet temperature be higher after upgrade



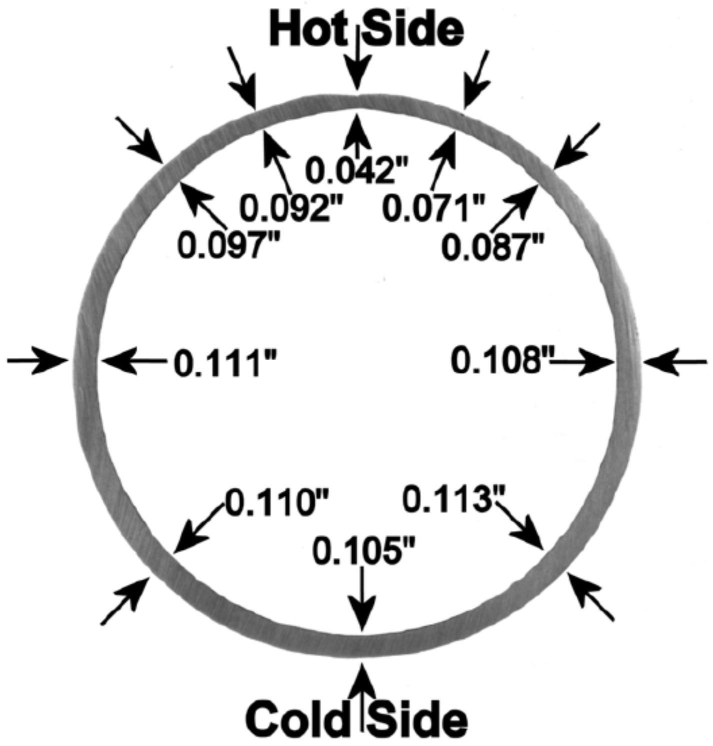
Case Study 1 – RH SH Tube Failure

- Post upgrade operation with high firing rate resulted in failure of Reheater tube immediately downstream of burner
- HRST performed an RCFA of the failure
- Metallurgical assessment revealed failure mechanism as Long Term Overheat

Case Study 1 – RH SH Tube Failure

RH SH Tube Specs:
2.5 inch OD 0.12 inch min wall
Material: T23 (ASTM A213/SA-213)
Design Pressure: 650 psig
Design Temp: 1119°F

Fissures and Oxide Layer on ID of Tube



Wall Thickness Measurement after Oxide Removal

Higher Exhaust Gas Energy

- Higher than expected energy going into the HRSGs
- Higher steam production can be expected due to the increased energy which could potentially exceeding the nameplate capacity
- New operating conditions could lie beyond the relieving capacities of the installed PSVs
- Higher amount of interstage attemperation required to control final steam temperature

Case Study 2 – Post Upgrade Steaming Capacity

- GE 7FA turbine, 3 pressure w/RH HRSG, 2x1 configuration, no duct burner
- Client approached HRST prior to CT Upgrade for an assessment
- Additional attemperation required after upgrade
- Thermal modeling determined HP Steam flow increase by 2-5% post upgrade
- This causes HRSG to exceed rated capacity and PSV capacities

	High Pressure (HP)	IP/ Reheat (RH)	Low Pressure (LP)
Current Name Plate Capacities	573,135 lb/hr	606,294 lb/hr	39,255 lb/hr
Current Pressure Safety Valve Capacity	579,619 lb/hr	614,193 lb/hr	40,673 lb/hr
Calculated expected max flow after AGP upgrade	**591,245 lb/hr**	**632,194 lb/hr**	**29,731 lb/hr**

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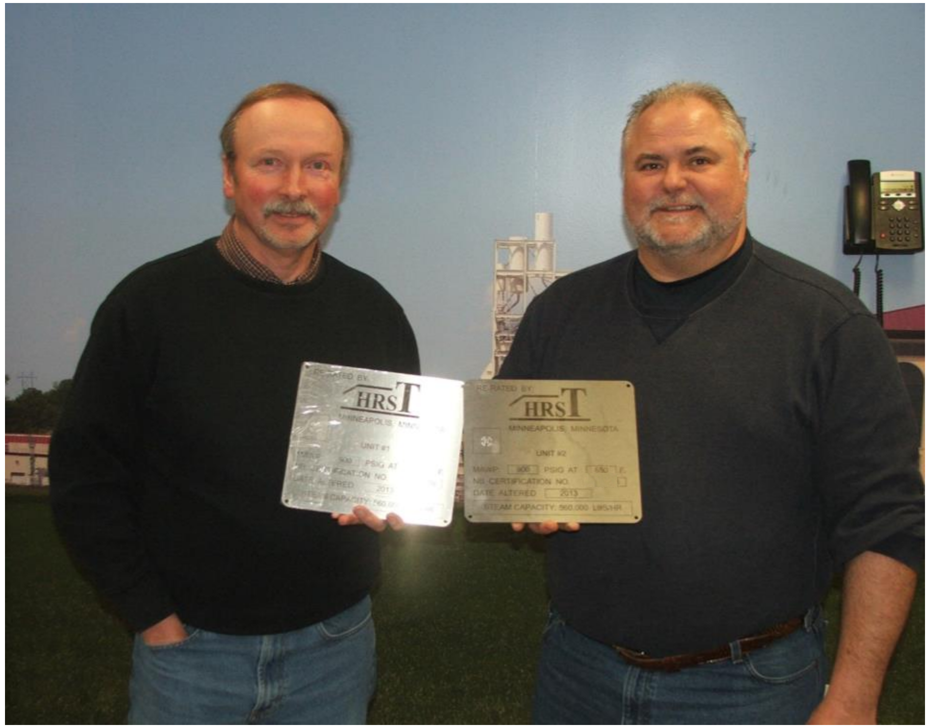
Case Study 2 – Post Upgrade Steaming Capacity

Additional Checks included:

1. Superheater tube metal temperatures
2. Superheater header design temperatures
3. Inlet duct liner & insulation temperature limits
4. SCR gas inlet temperatures
5. Boiler Feed Pump capacity
6. Feedwater control valve sizing
7. Steam and water side pressure drops
8. Steam drum separator capacity
9. Safety valve relieving capacity.



Results:

- New specifications of PSVs provided to client.
- Re-rate of the HRSG nameplate was required with an R-stamp

CT Upgrade Considerations on Catalysts

- Increased CT Gas Flow Rate – Decreased residence time in catalyst
- Variation in Exhaust Gas Temperature – Decreases catalyst effectiveness
- Temperature also plays a key role in catalyst fouling
- What happens at low load after upgrade? Gas temperatures could be lower after upgrade

Non-Pressure Overheat

- Non-pressure parts operating close to or above design temperatures
- Areas affected
  - Perforated Plate (Flow Distribution Grid)
  - Tube ties
  - Baffles
  - Flow devices
  - Inlet Duct Liner
  - Firing Duct Liner

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Non-Pressure Overheat

Conclusions - Things to Consider …

Before an Upgrade

- **HRSG Rated Capacity**
  - Post upgrade steam generation
  - PSV relieving capacity
- **Overheat Concerns**
  - Possibility of tube TMT exceeding design temperature
  - Existing overheat damage in HP&RH Superheaters
  - Evaluate full load and low load!
- **Catalysts, Pumps, Valves**
  - Catalyst residence time and operating temperature shift
  - Will attemperators, control valves and pump limits be exceeded?

After an Upgrade

- **Is the pre-upgrade operational profile still valid?**
  - Can burner operation be the same?
  - Low load operation
- **Indications of overheat?**
  - Look for indications of overheat outside and possibly inside panels
  - Monitor condition of inlet duct and firing duct liner for signs of overheat
  - Observe attemperator operation, are there indications of overspray or difficulty maintaining setpoint temperature

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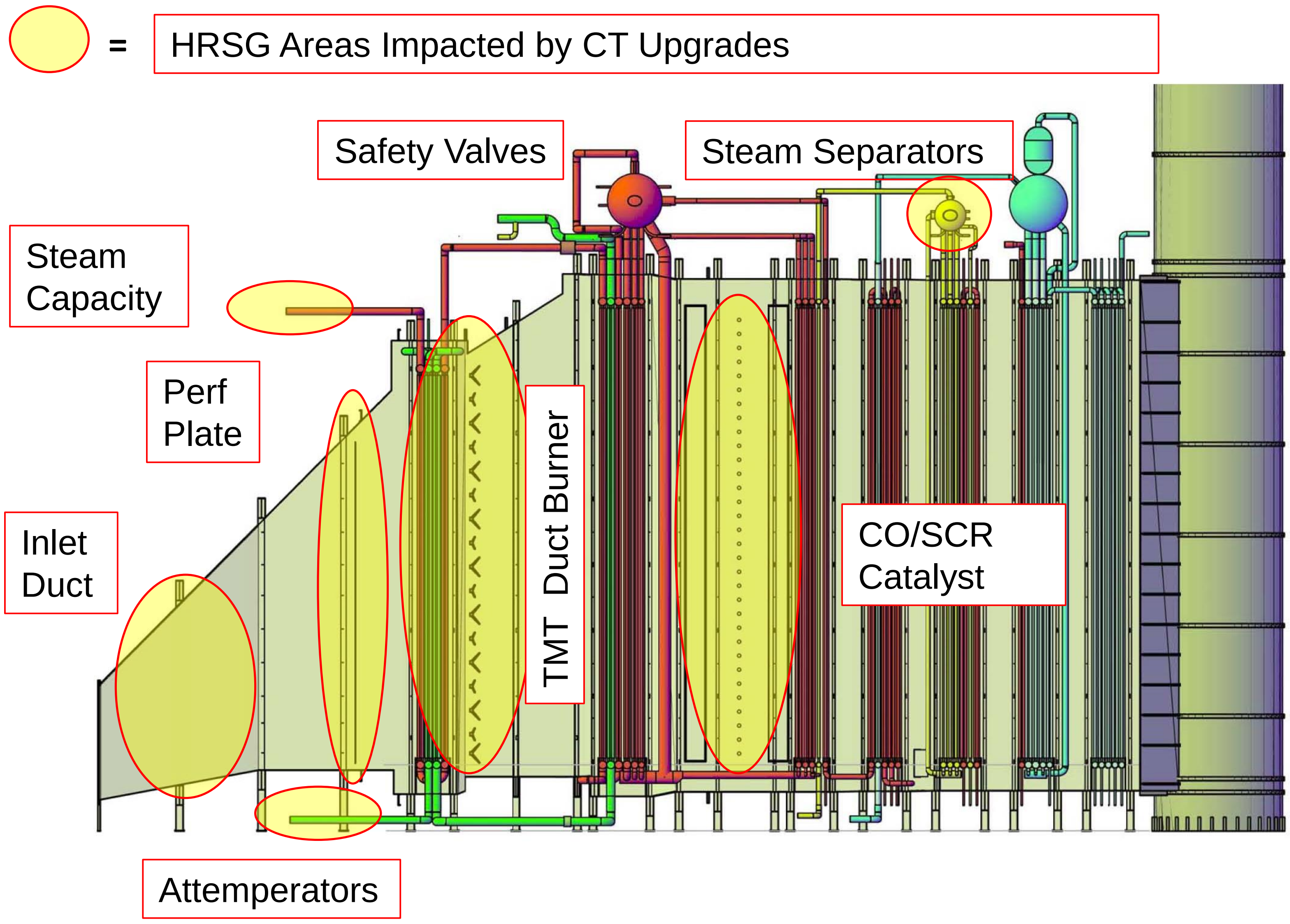
Conclusions – The Big Picture



Additional Areas of Concern

- Boiler Feed Pump
- Recirculation Pump
- Drum Level Control Valves

Questions ?

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