Industrial Application of Gas Turbines (IAGT)

Introduction to HRSGs
HRSG

Heat Recovery Steam Generator
- Also referred to as waste heat boiler
- Cools hot gases – most commonly the exhaust of a gas turbine
- Generates steam and regains energy
HRSG

- Critical link between the gas turbine and steam turbine in combined cycle and cogeneration plants

Combined Cycle Plant

Cogeneration Plant
FUNDAMENTAL PARTS OF HRSG

Four Basic HRSG Components

• Evaporators (gas to wet steam heat exchanger)
• Economizers (gas to water heat exchanger)
• Superheaters/Reheaters (gas to dry steam heat exchanger)
• Preheaters (gas to water/glycol/air etc. heat exchanger)
EVAPORATOR

- Vaporize water and produce steam
- Water/steam circulates from lower drum to steam drum
- Steam exits from the steam drum after passing through steam separating equipment
- Water level must be carefully maintained
ECONOMIZERS

• Preheats water prior to entry into the steam drum
• Desirable to prevent steam from forming in the economizer
SUPERHEATERS/REHEATERS

- Saturated steam from evaporator is sent to superheater to produce dry steam
- Dry steam is required for steam turbines
HRSG TYPES

Three (3) Main Types

- NATURAL CIRCULATION HRSGs
- FORCED CIRCULATION HRSGs
- ONCE THROUGH HRSGs
NATURAL CIRCULATION HRSG

- Typically horizontal gas flow and vertical tubes
- Tube bundles typically grow thermally down
- For gas turbines less than 50 MW, evaporator is shipped to site in single pieces
- For larger gas turbines the evaporator is shipped in multiple sections
INTEGRAL STEAM DRUM

- Evaporator shipped to site in single section (up to approx. 400,000 lbs)
SEPARATE STEAM DRUM

- Evaporator shipped to site in multiple sections
- Increased field erection costs
FORCED CIRCULATION HRSG

- Typically vertical gas flow and horizontal tubes
- Steam/water mixture circulation through evaporator tubes and to/from drum with a pump
- Historically common in Europe due to small footprint
ONCE THROUGH HRSG

- Typically vertical gas flow and horizontal tubes
- OTSGs eliminate the need for steam drums
- Phase change from water to steam is free to move throughout the bundle
HRSG DESIGN PHILOSOPHY

• Exchange heat from the exhaust gas to the fluid at the highest temperature difference available
• Accomplished by making the exhaust gas and the fluid (steam/water) temperature gradients as nearly parallel to each other as possible

HRSG Temperature Profile - Unfired
Steam Production = 66,850 lb/hr
Pinch = 20 F
Approach = 10 F
SINGLE VS MULTIPLE PRESSURE HRSG

- Adding additional pressure levels in the HRSG can increase the amount of heat that can be recovered from the exhaust gas.
- As the saturation temperatures are lower at successive pressures, the stack temperature can be lowered.

Dual Pressure HRSG Temperature Profile

HP Steam Production = 75000 lb/h
LP Steam Production = 100000 lb/h
HRSGs
HRSGs vs Conventional Boilers
Differences between HRSGs and Conventional boilers

- HRSGs use exhaust from a gas turbine as a heat source and do not need a dedicated firing system (burner, fan, motor etc.)
- HRSGs typically do not use fans (draft is from gas turbine exhaust)
- HRSGs generate steam at multiple pressure levels to improve heat recovery efficiency
- Heat transfer is by convection rather than radiation
- HRSGs do not use membrane water walls
- HRSGs use finned tubes to maximize heat transfer
HRSGs vs Conventional Boilers

- Differences between HRSGs and Conventional boilers
Finned Tubing

- Finned tubing is used to increase heat transfer
- Two types – solid fins and serrated fins
- Heat transfer can be adjusted by changing fin height, fin thickness, fin density, fin materials
- Fins are spiral wound onto tubes using various processes:
  - Brazing
  - Welding
Finned Tubing

Serrated Finned Tube

Solid Finned Tube
Fabrication of HRSGs

- Large HRSGs typically made from pressure part modules referred to as "harps"
- Significant field assembly
Erection of HRSGs

- Shipment of harps, cased or uncased sent to site
- Modules stacked up to three (3) wide
Erection of HRSGs

- Steam drum sent to site separately
- Exhaust stack sent to site in multiple sections
Fabrication of HRSGs

- Smaller HRSGs such as the OTSG maximize shop fabrication, minimizing field assembly
DUCT BURNERS

- Add heat to the gas turbine exhaust stream
- Exhaust gas typically has enough oxygen to sustain stable combustion
DUCT BURNERS

• Steam demand increases without any change in the gas turbine exhaust
• Desired steam flow of final steam temperature cannot be achieved with the available heat from the gas turbine
• Gas turbine is completely down but steam is still needed (Fresh air firing)
DUCT BURNERS

- Burners can be configured to burn a variety of different fuels from natural gas to oil
DUCT BURNERS

- Fresh air firing is used to produce steam when the gas turbine is down
DISTRIBUTION GRIDS

• Used to correct flow maldistribution
• Variable porosity plates and turning vanes commonly used
• Typical gas side pressure drop for a variable porosity plate ranges from 0.5 inches H2O to 3 inches H2O
FLOW MODELING

- Gas flow distribution leaving the gas turbine is non-uniform
- Proper performance of the HRSG, duct burner and emission equipment requires uniform flow and temperature profile
NOx REMOVAL PROCESS

- Ammonia (NH3) is injected into the gas stream upstream of SCR catalyst
- Catalyst layer decomposes NOx (nitrous oxides, principally NO and NO2) into harmless N2 and H2O

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\begin{align*}
4\text{NO} + 4\text{NH}_3 + \text{O}_2 &\rightarrow 4\text{N}_2 + 6\text{H}_2\text{O} \\
6\text{NO}_2 + 8\text{NH}_3 &\rightarrow 7\text{N}_2 + 12\text{H}_2\text{O} \\
\text{NO} + \text{NO}_2 + 2\text{H}_2\text{O} &\rightarrow 2\text{N}_2 + 3\text{H}_2\text{O}
\end{align*}
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SCR LOCATION

- SCR must be placed in the appropriate gas temperature zone for maximum efficiency.
- Typical medium temperature catalyst maximum continuous temperature is 800°F with excursions to approx. 900°F.

![Typical DeNOx Efficiency VS. Gas Temperature](image)
CORROSION IN HRSGs

Water dewpoint corrosion
• Metal temperatures fall below the water dewpoint
• Can lead to accelerated corrosion

Acid dewpoint corrosion
• Trace quantities of sulphur in fuel form sulphur trioxide (SO3) and combine with water to form acids
• Leaves deposits on fin tubes
simply generates more profit

QUESTIONS ?????