simply generates more profit

Industrial Application of Gas Turbines (IAGT)

Introduction to HRSGs

HRSG

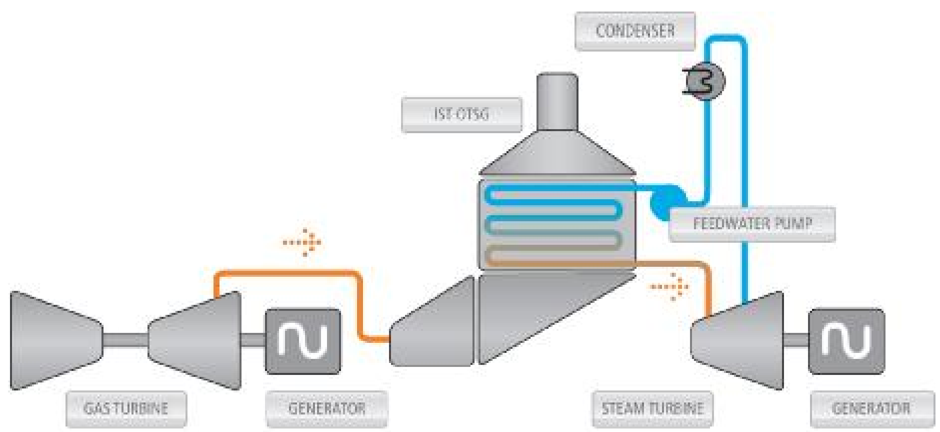
Heat Recovery Steam Generator

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

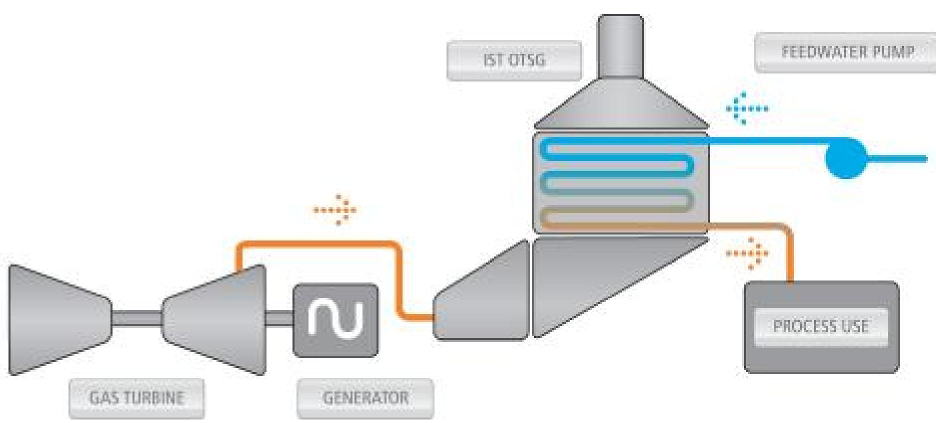
HRSG

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

Combined Cycle Plant



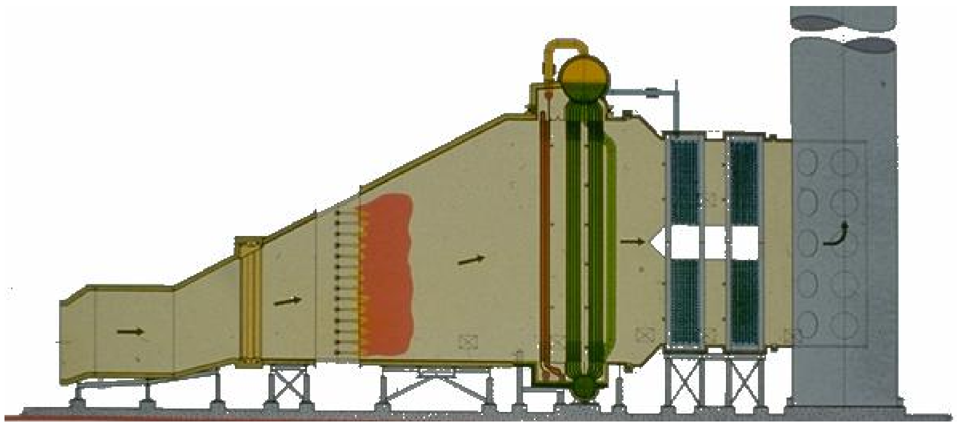
Cogeneration Plant



FUNDAMENTAL PARTS OF HRSG

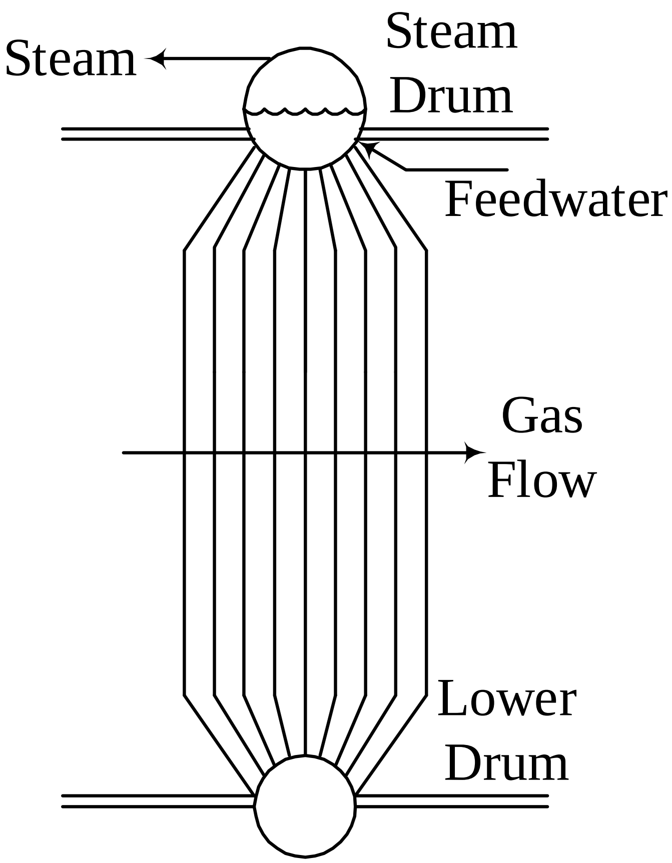
Four Basic HRSG Components

- 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)



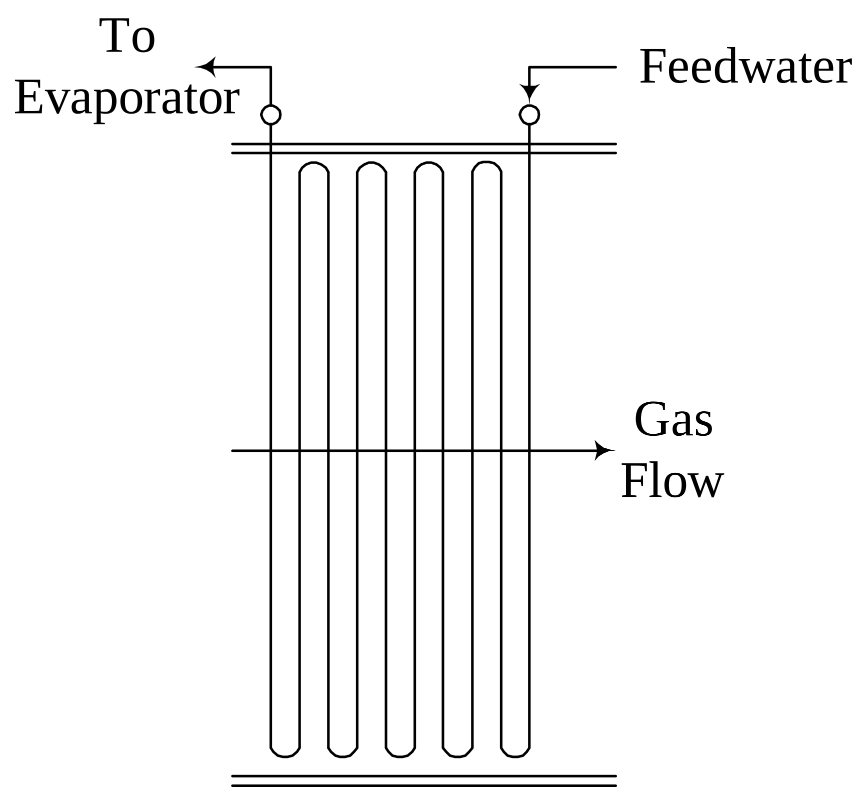
EVAPORATOR

- 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



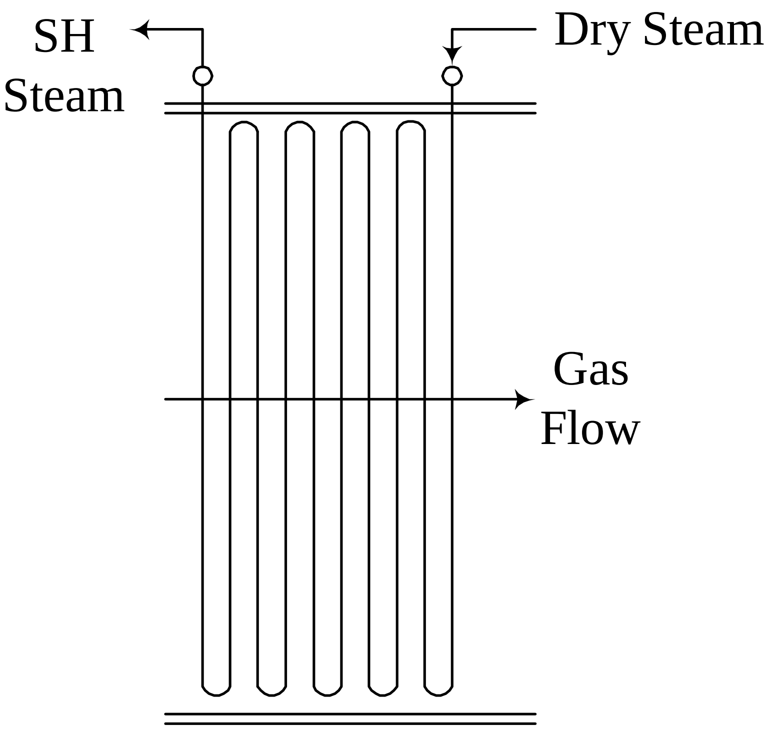
ECONOMIZERS

- 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



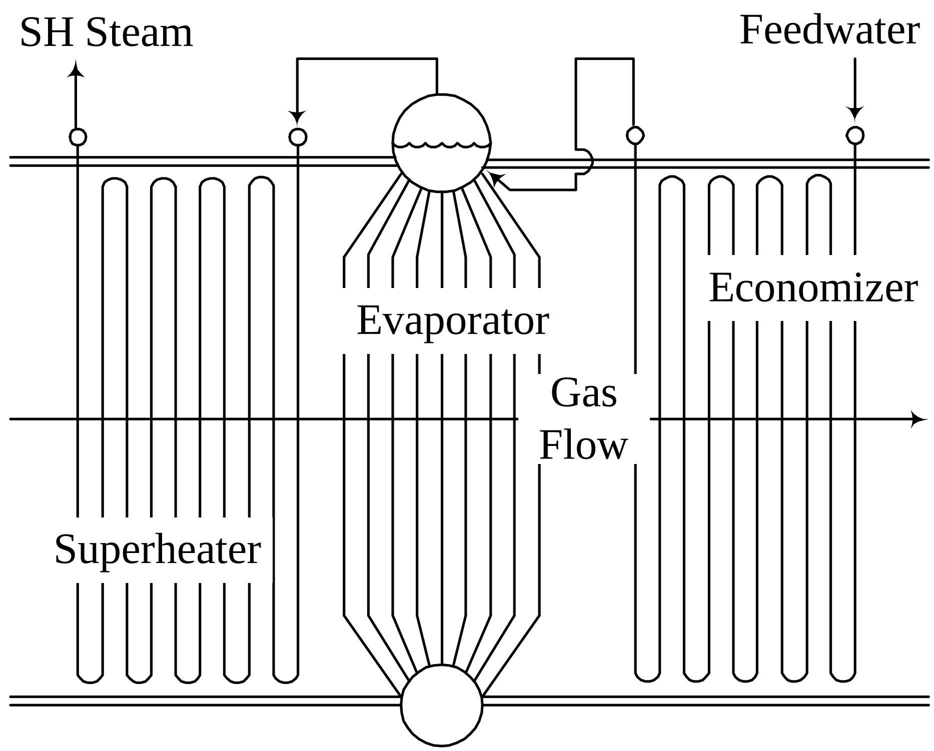
HRSG TYPES

Three (3) Main Types

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

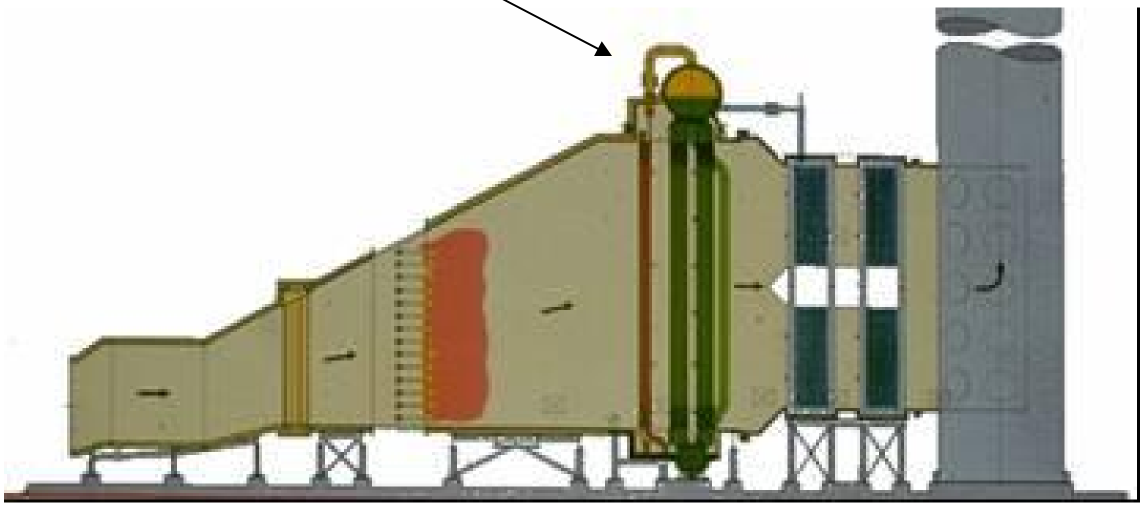
NATURAL CIRCULATION HRSG

- 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



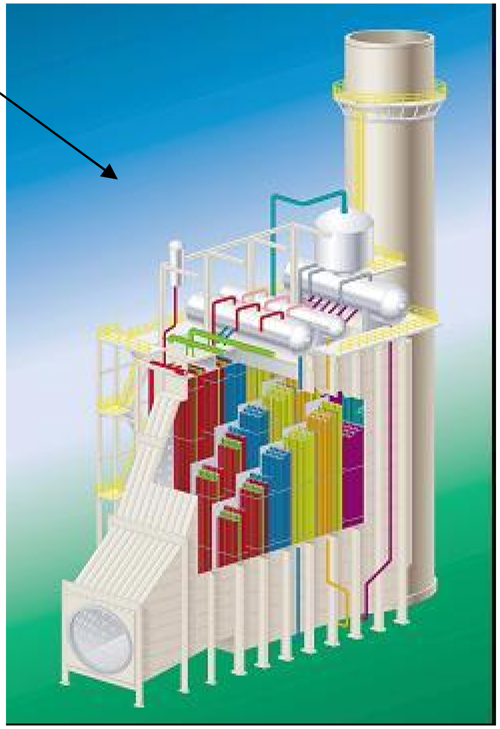
INTEGRAL STEAM DRUM

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



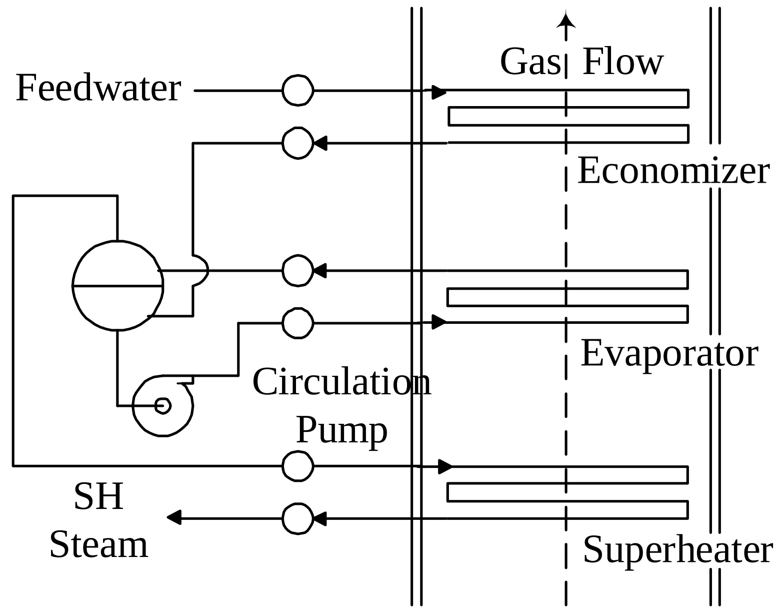
SEPARATE STEAM DRUM

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



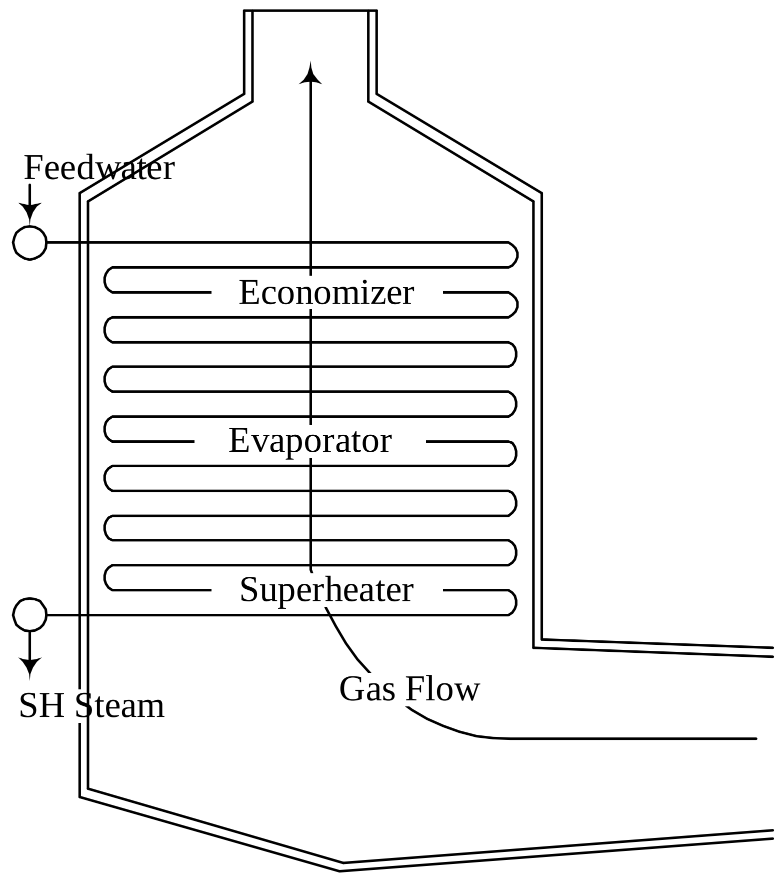
FORCED CIRCULATION HRSG

- 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



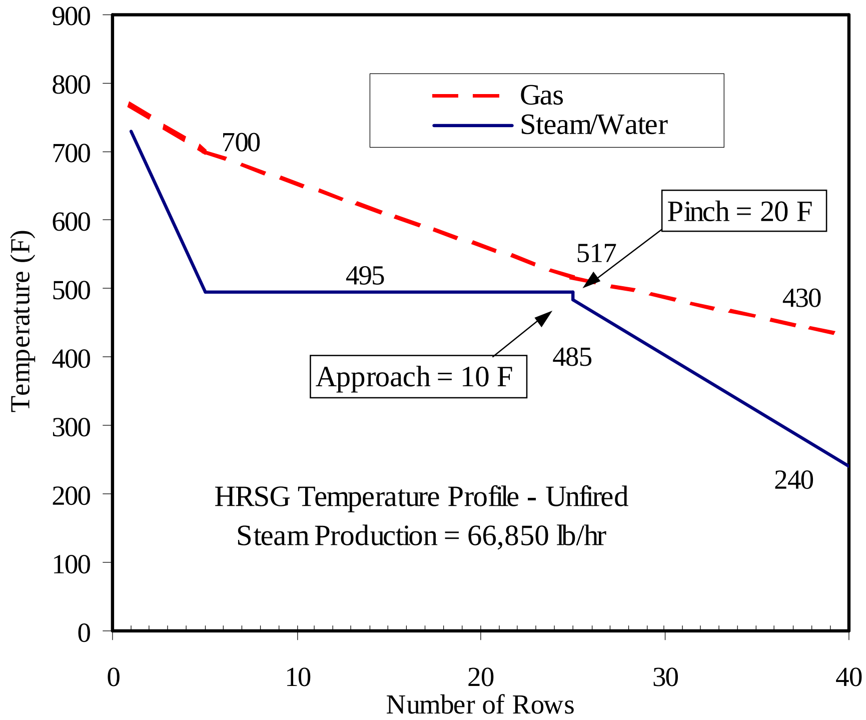
ONCE THROUGH HRSG

- 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



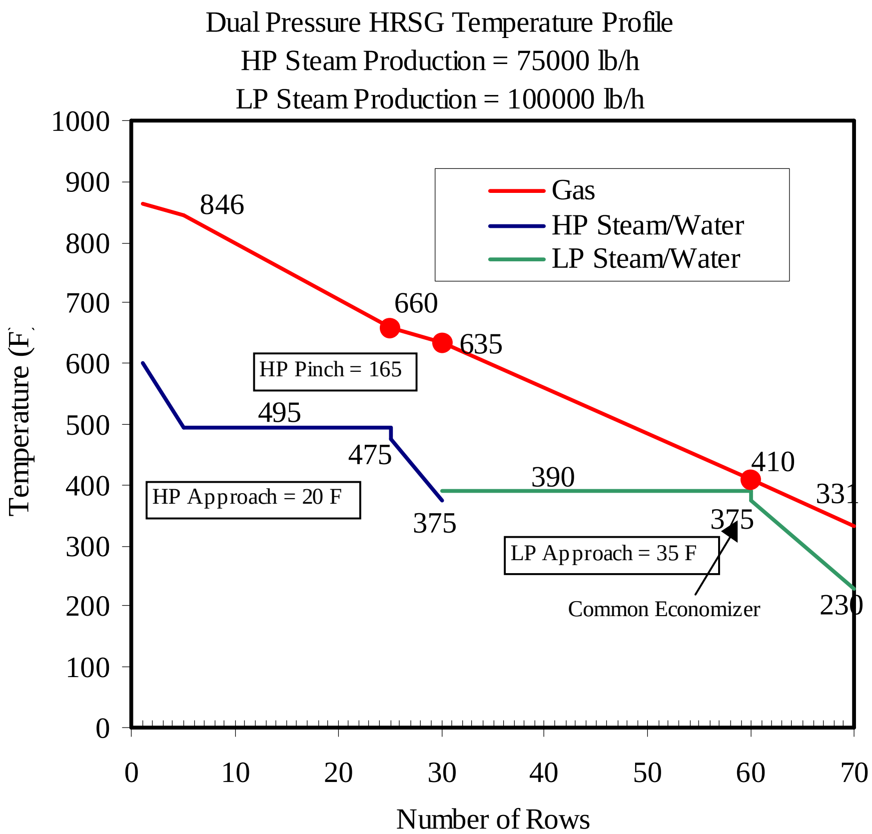
HRSG DESIGN PHILOSOPHY

- 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

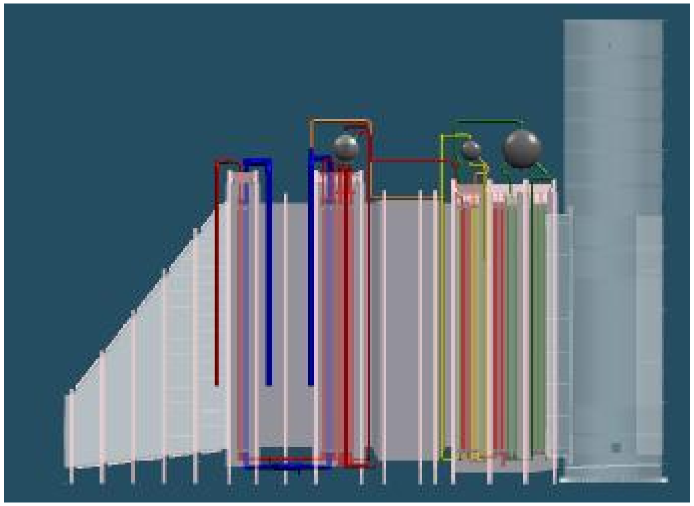


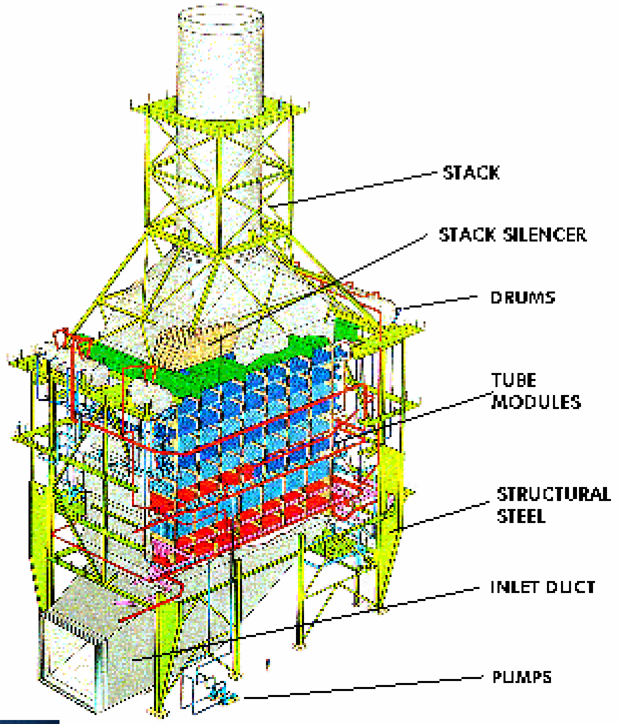
SINGLE VS MULTIPLE PRESSRE HRSG

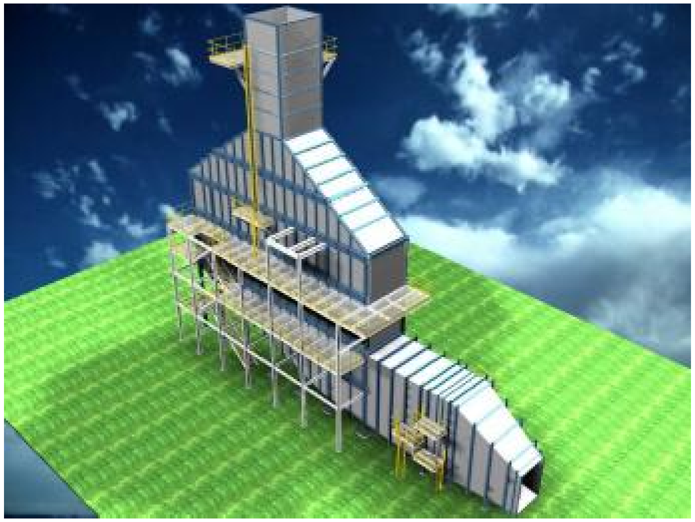
- Adding additional pressure levels in the HRSG can increase the amount of heat that can be recovered from the exhaust gas
- As the saturation temperatures are lower at successive pressures, the stack temperature can be lowered



HRSGs




STACK
STACK SILENCER
DRUMS
TUBE MODULES
STRUCTURAL STEEL
INLET DUCT
PUMPS



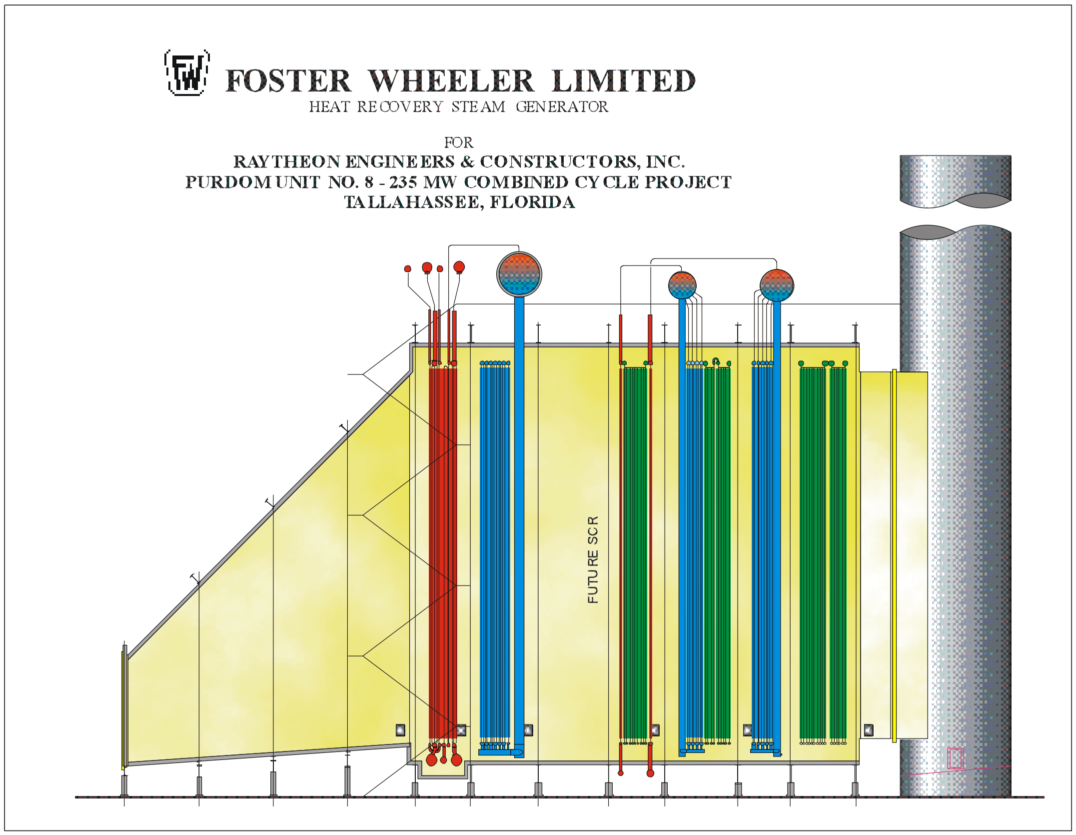
HRSGs vs Conventional Boilers

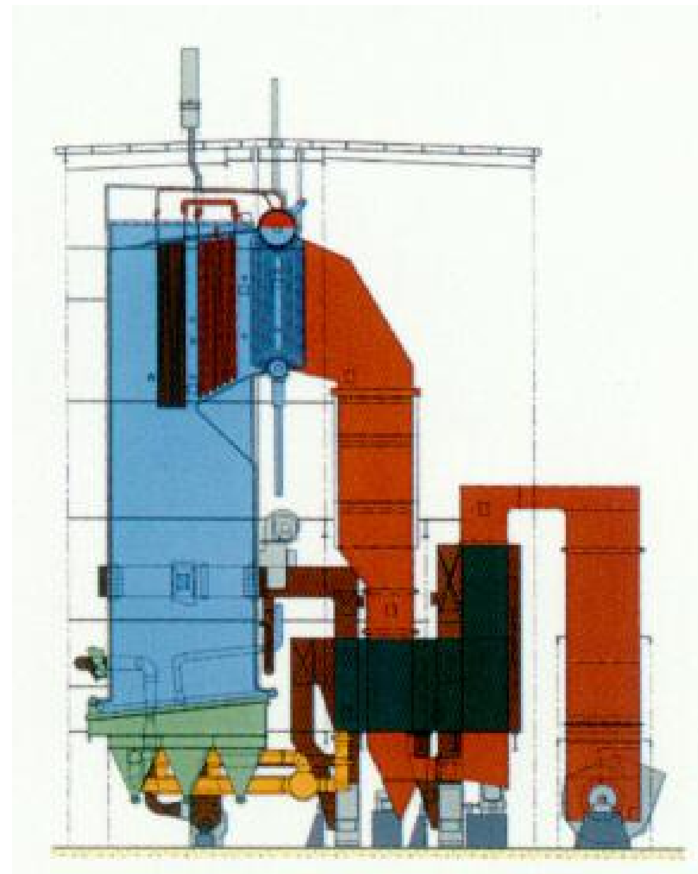
Differences between HRSGs and Conventional boilers

- 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

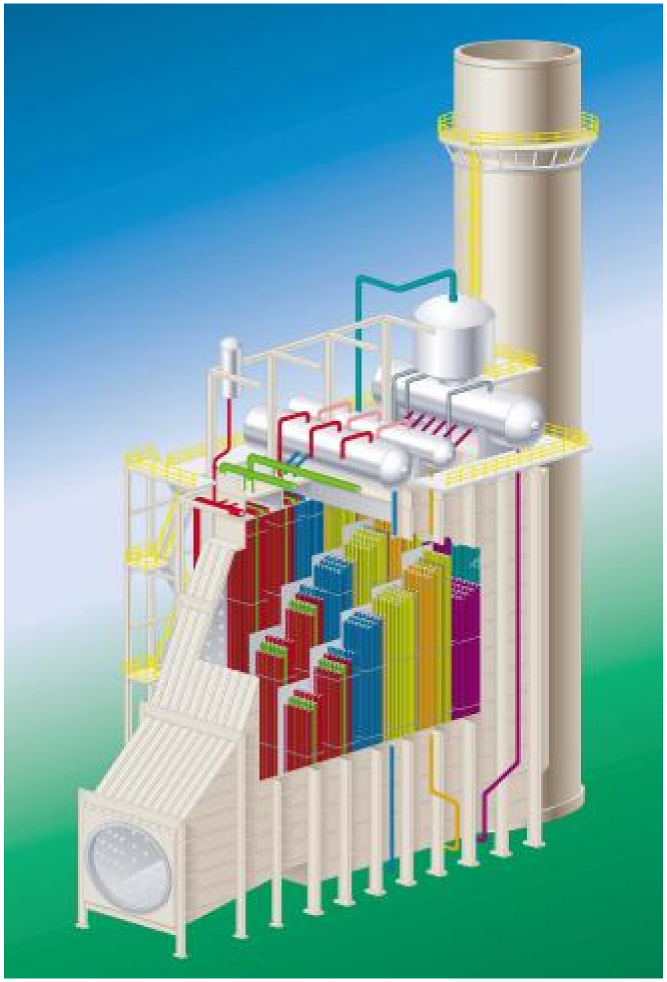
Finned Tubing

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

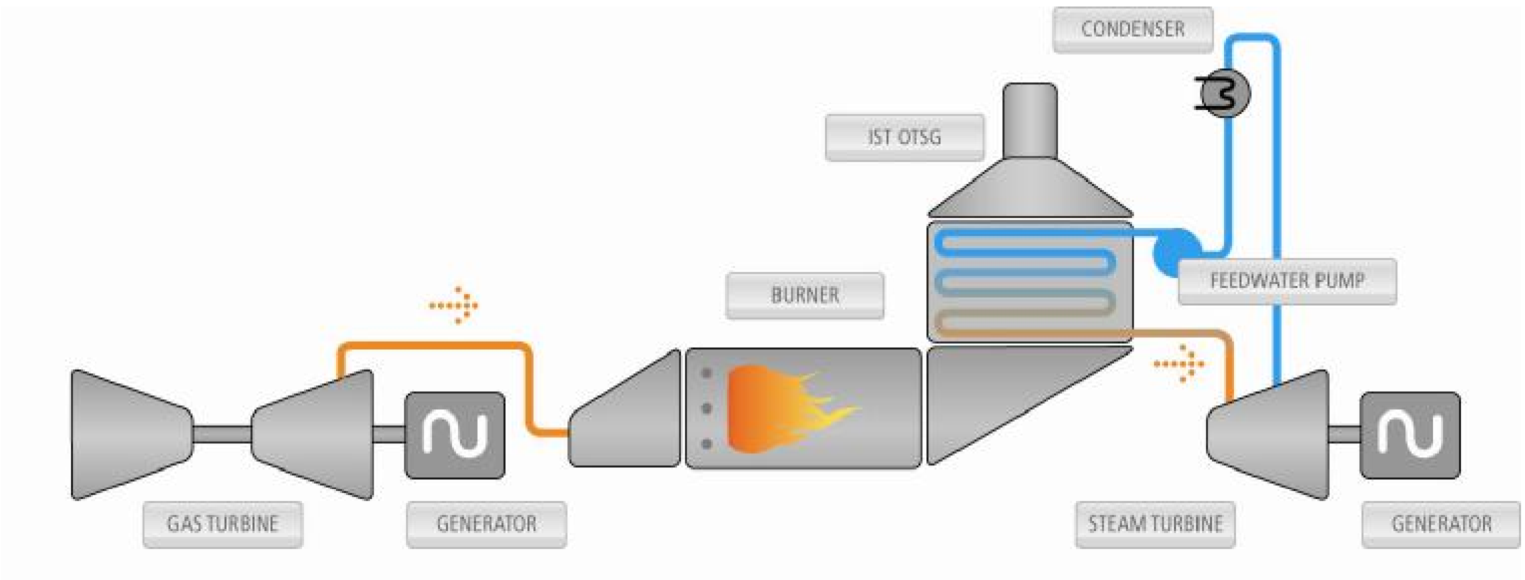
- Steam drum sent to site separately
- Exhaust stack sent to site in multiple sections

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

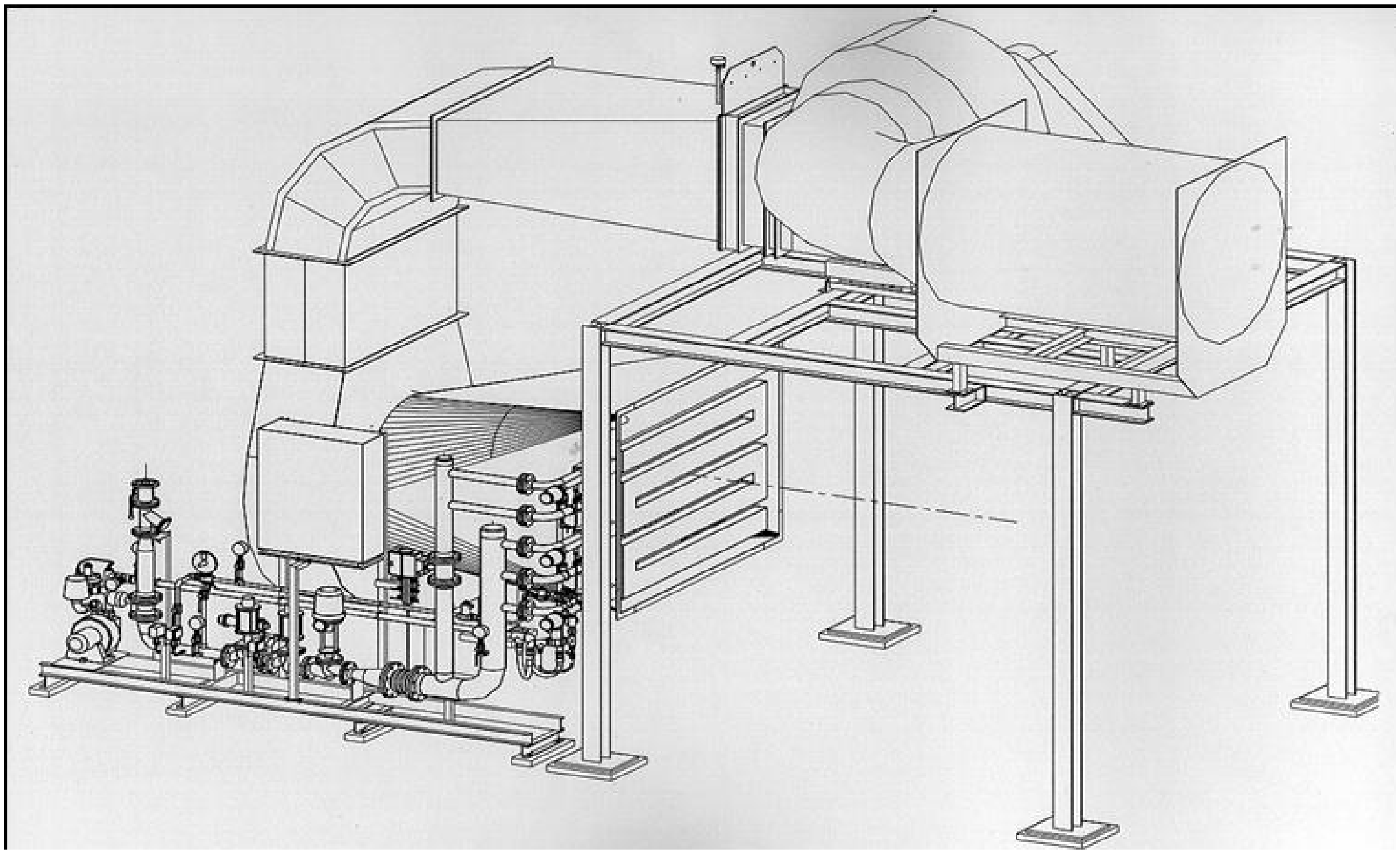
- Steam demand increases without any change in the gas turbine exhaust
- Desired steam flow of final steam temperature cannot be achieved with the available heat from the gas turbine
- Gas turbine is completely down but steam is still needed (Fresh air firing)

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

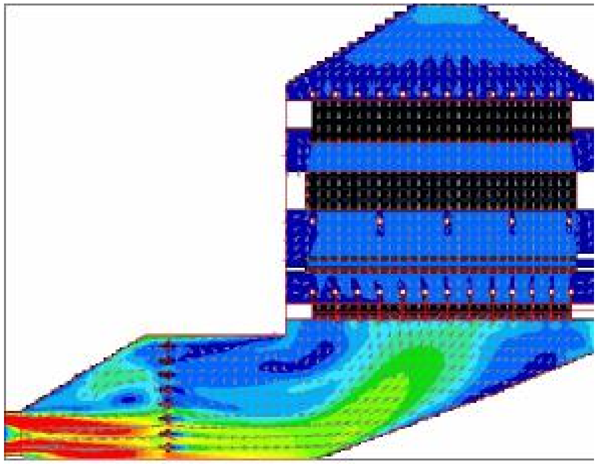


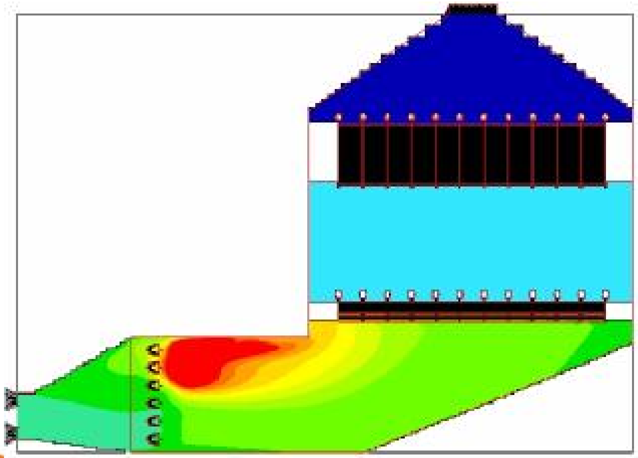
DISTRIBUTION GRIDS

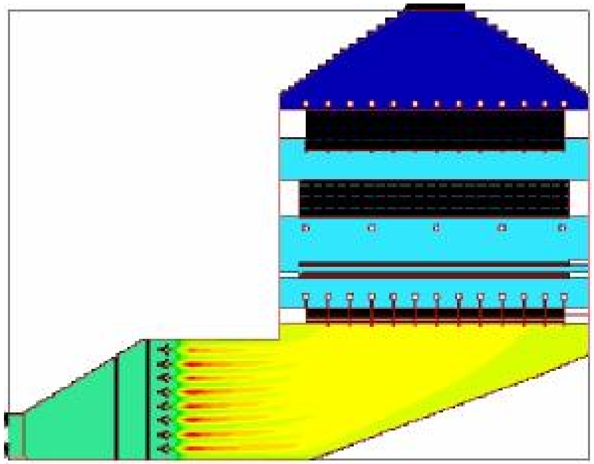
- Used to correct flow maldistribution
- Variable porosity plates and turning vanes commonly used
- Typical gas side pressure drop for a variable porosity plate ranges from 0.5 inches H_2O to 3 inches H_2O

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

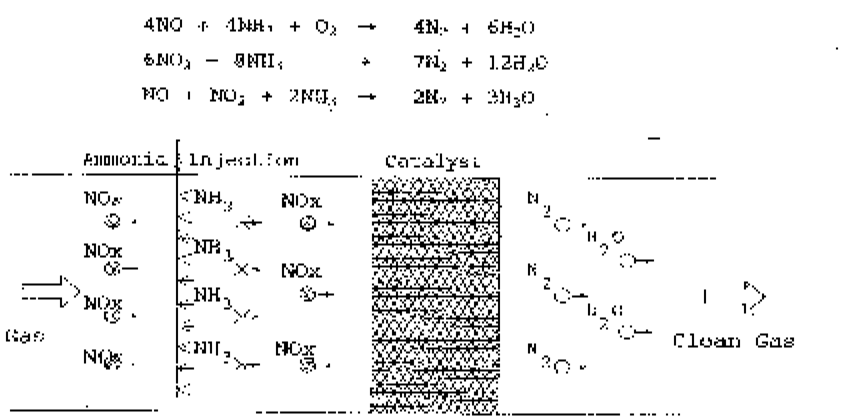


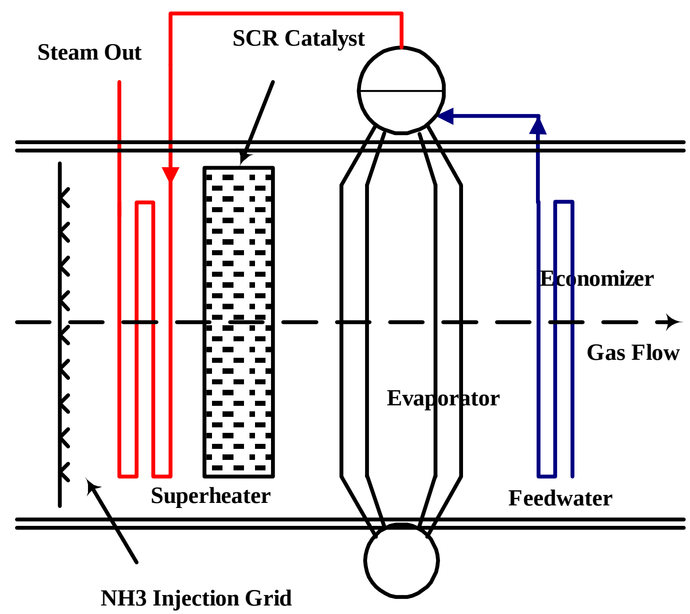




NOx REMOVAL PROCESS

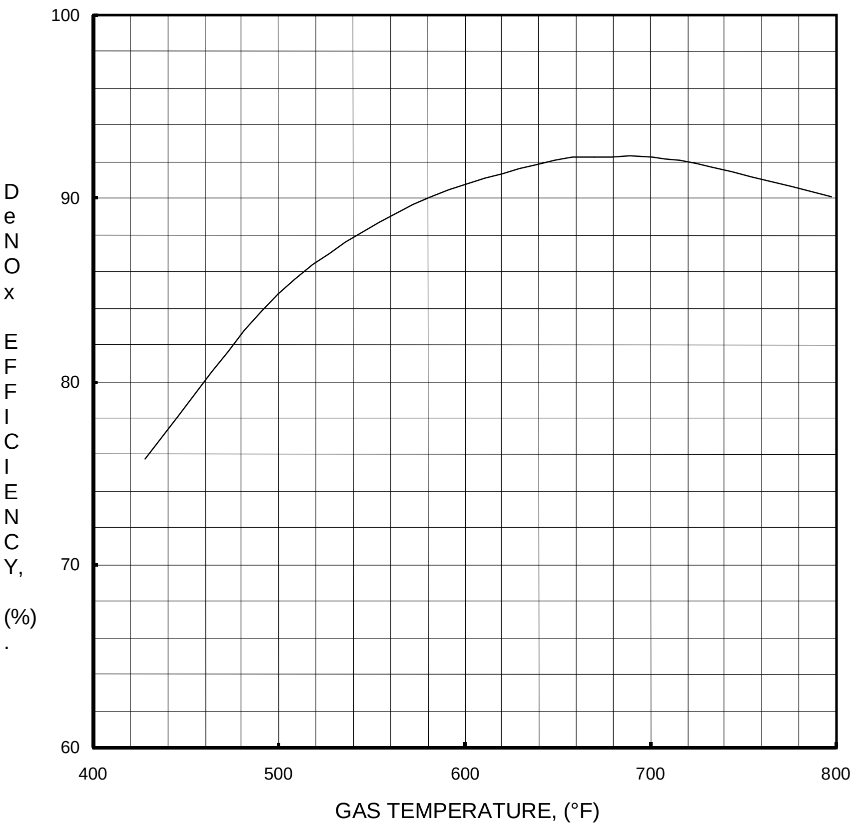
- Ammonia (NH3) is injected into the gas stream upstream of SCR catalyst
- Catalyst layer decomposes NOx (nitrous oxides, principally NO and NO2) into harmless N2 and H2O





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

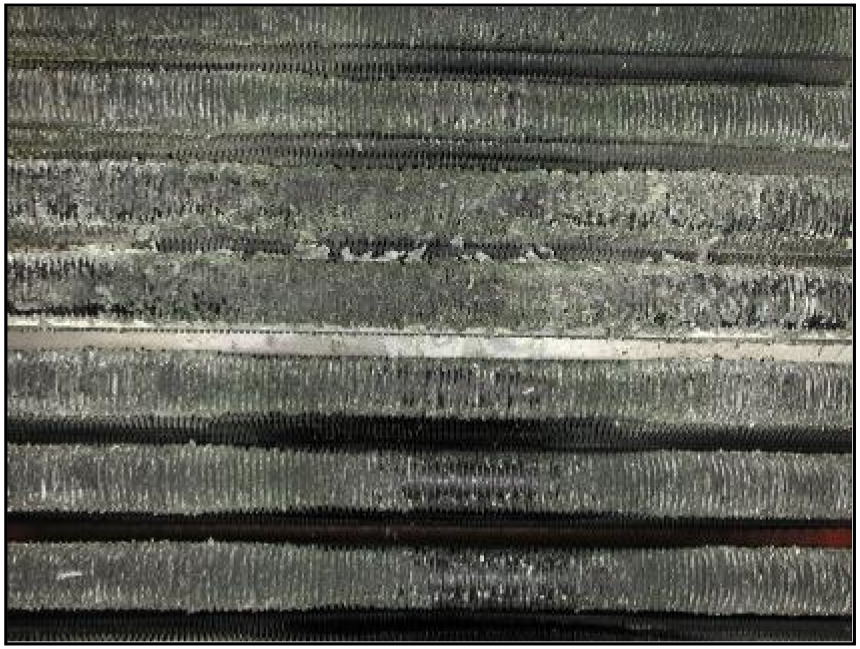
CORROSION IN HRSGs

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



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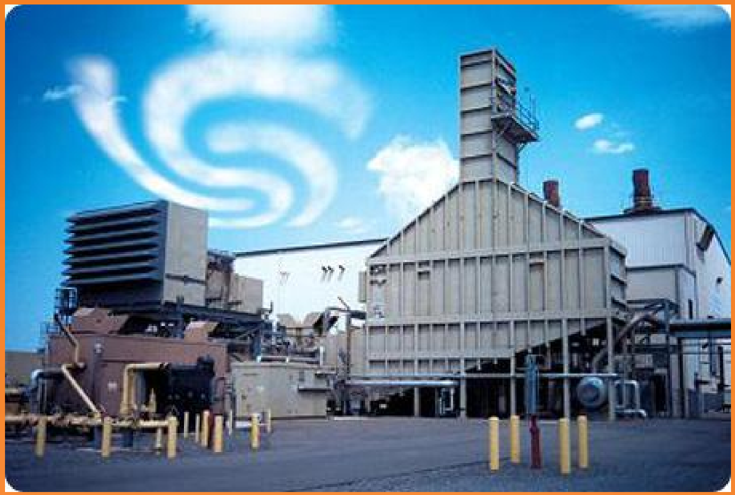

simply generates more profit

QUESTIONS ??????

once
through
steam
generators