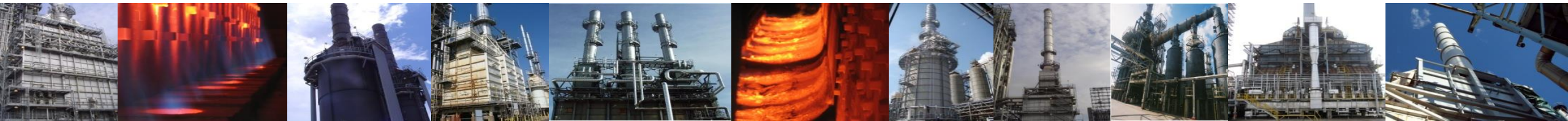
Fired Heaters
Key to Efficient Operation of Refineries and Petrochemicals

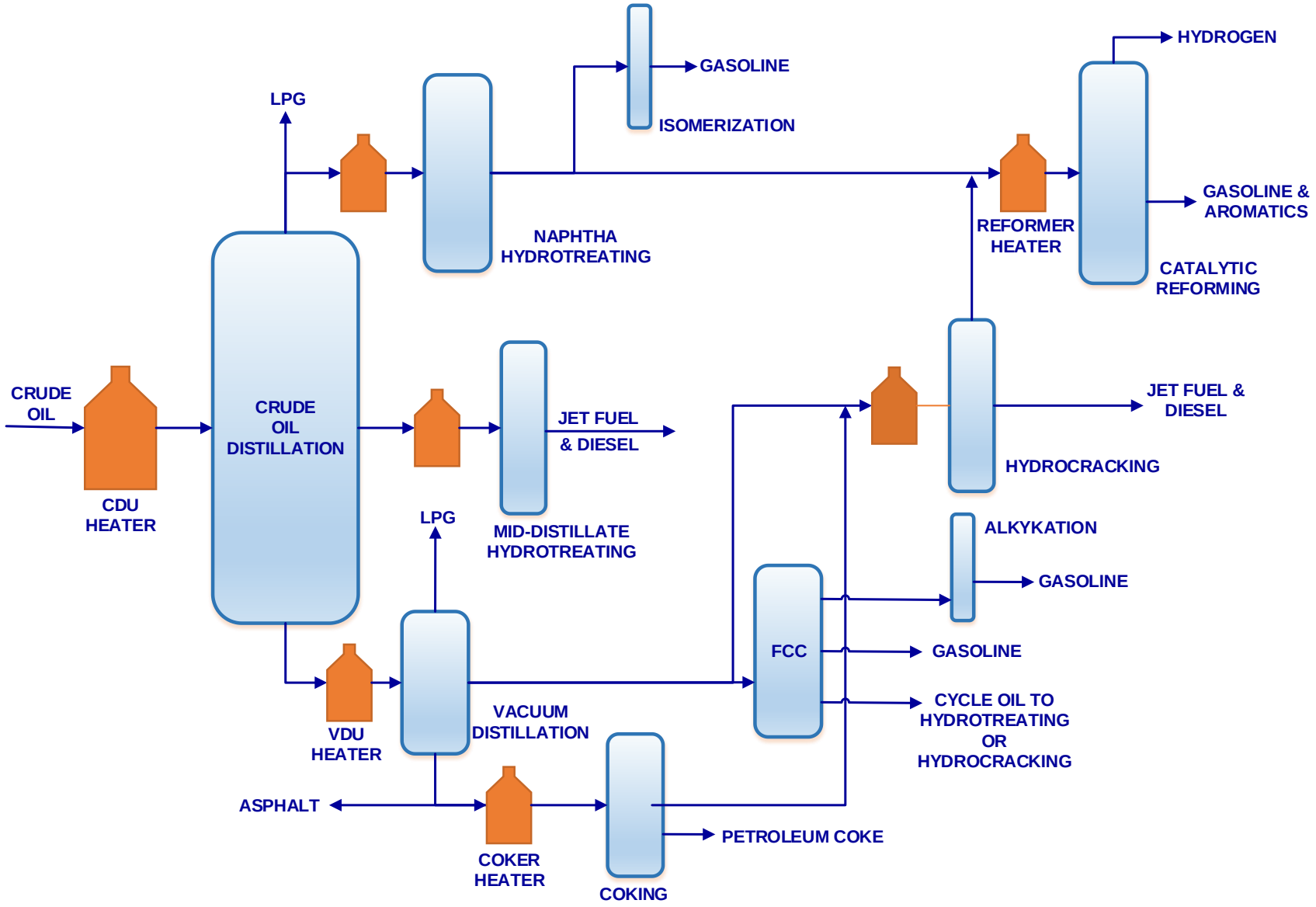
Ashutosh Garg

Furnace Improvements Services

Sugar Land, TX



Typical Refinery Process Flow Diagram



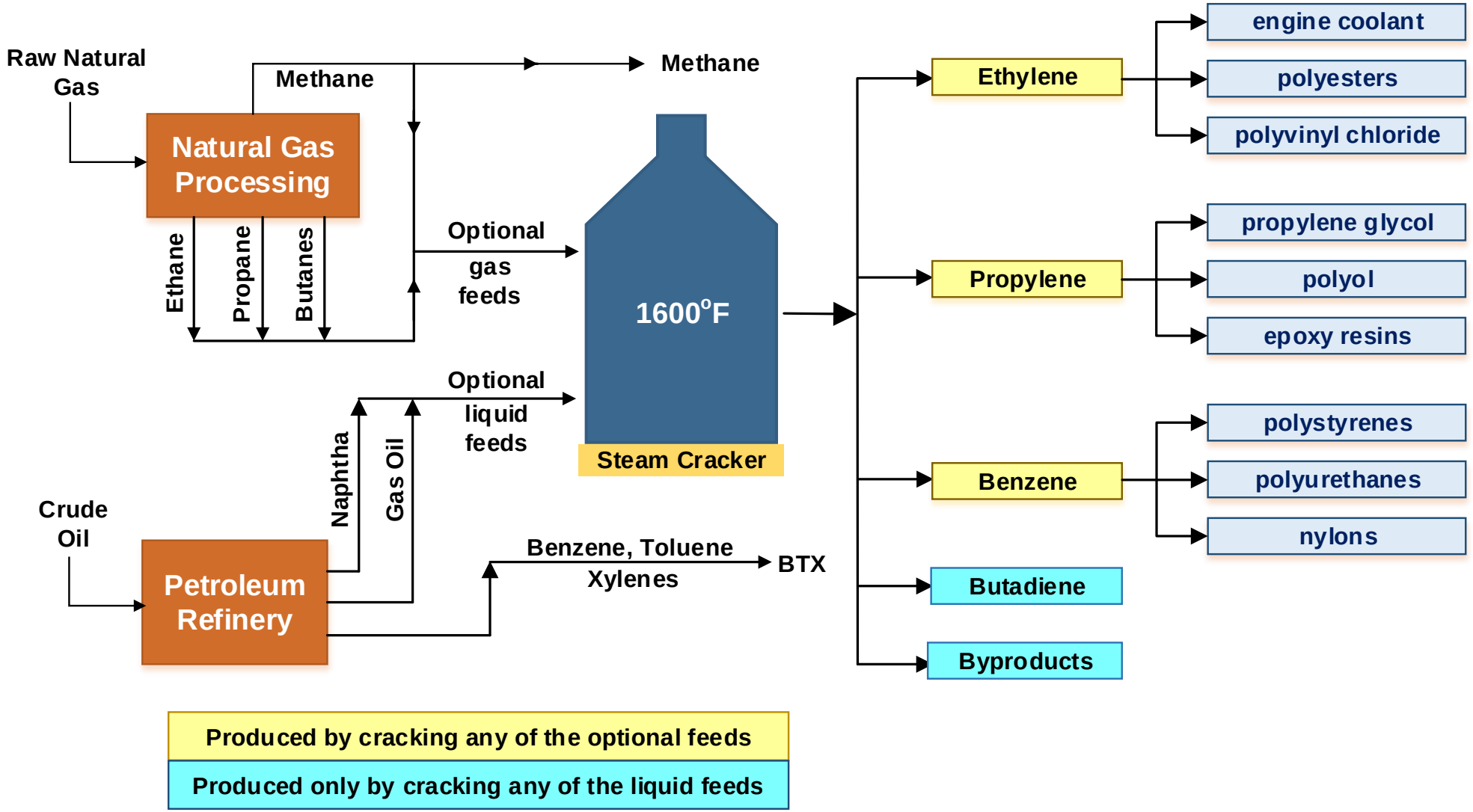
Major Refinery Building Block

- Majorly used in refinery processes which require very high temperatures
  - Crude Unit – 650-750^{o}F
  - Vacuum Unit – 700-800^{o}F
  - Coker Unit – 950^{o}F
  - Reforming Unit – 1000^{o}F
- Heating options-
  - Steam
  - Hot Oil/Molten Salts
  - Electric

Fired Heaters in Petrochemical Industry

- Most common petrochemical classes - Olefins & Aromatics
- Processes involved:
  - Steam Cracking – To Produce Olefins (Using Ethane to Gas Oils), Propane Dehydro to produce Propylene
  - Catalytic Reforming – To Produce Aromatics (Using Naphtha)
- Global Production
  - Ethylene – 140 Million Tonnes
  - Propylene – 100 Million Tonnes
  - Aromatics – 85 Million Tonnes

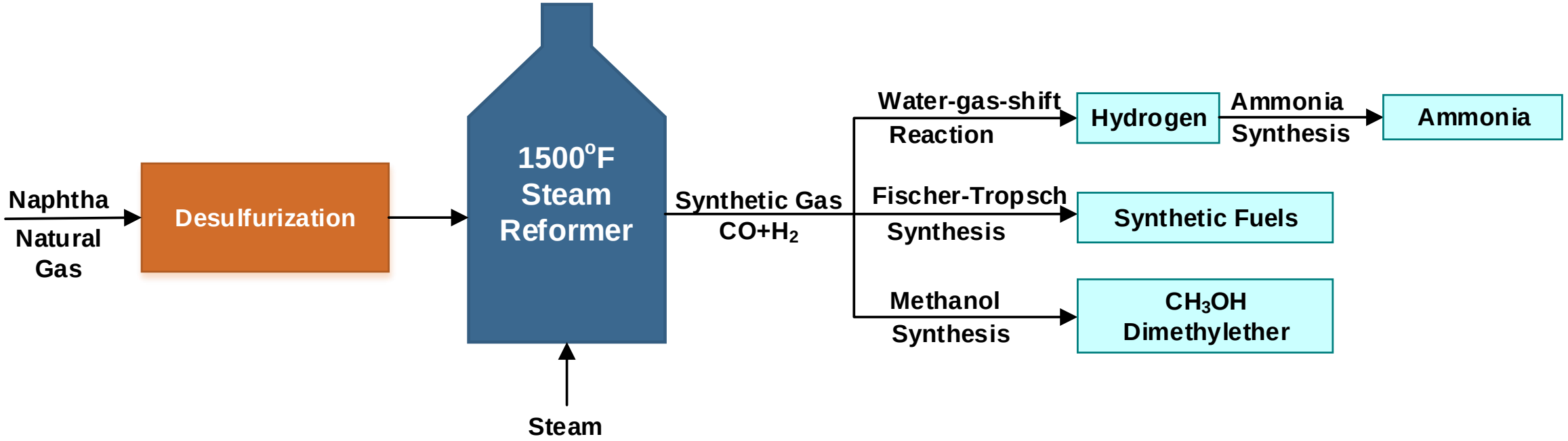
Steam Cracking



Produced by cracking any of the optional feeds

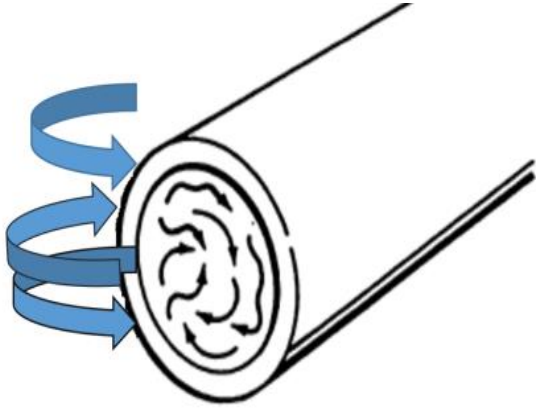
Produced only by cracking any of the liquid feeds

Steam Reforming

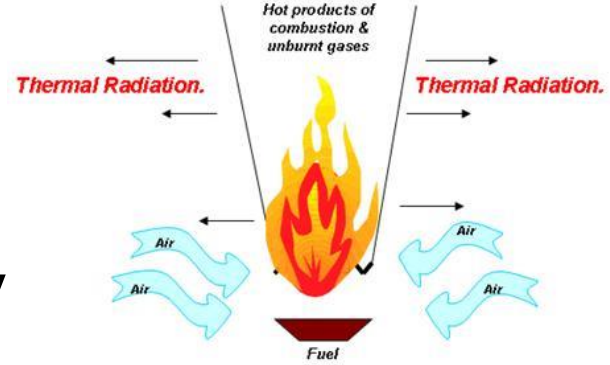


Heat transfer modes

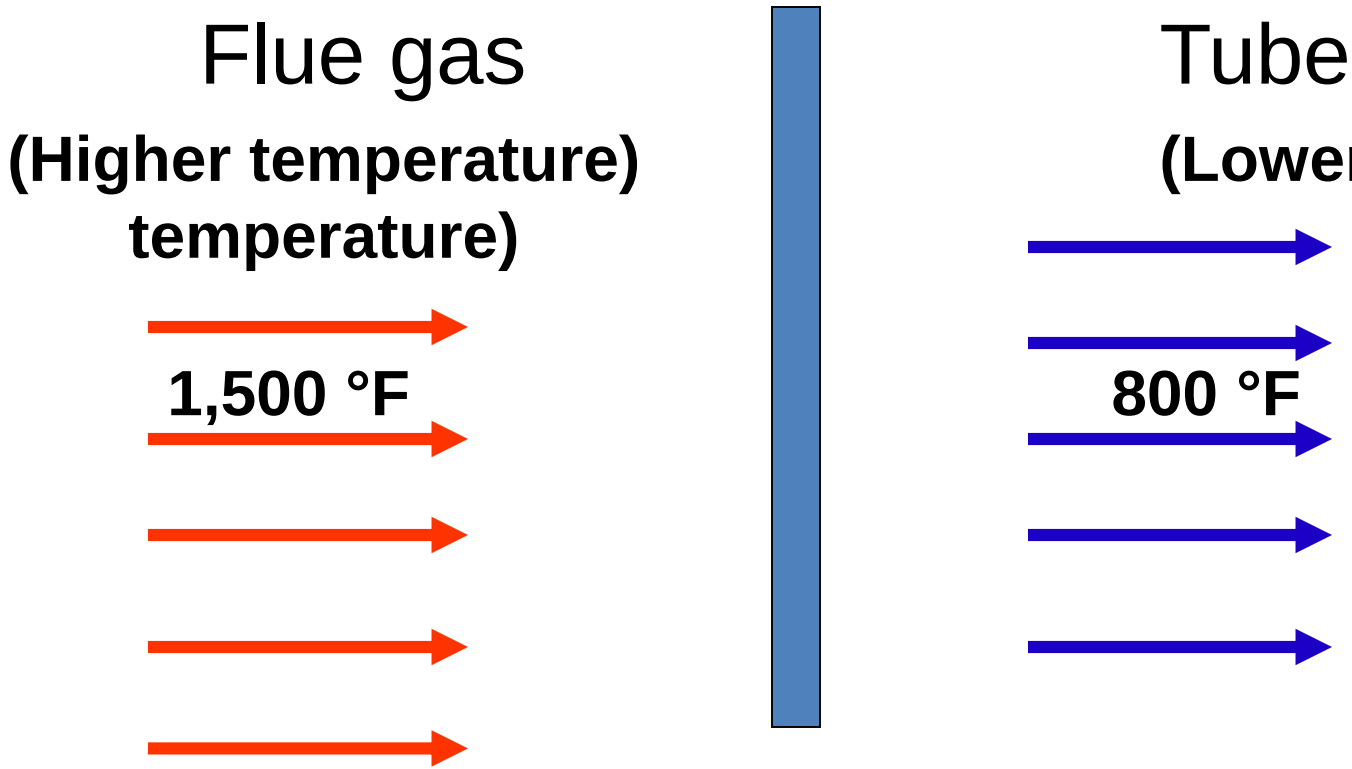
- Conduction-Solids
  - Heat is transferred by direct contact between two objects



- Convection-Fluids
  - Heat is transferred with in a medium due to movement of molecules
- Radiation
  - Transmission of heat from a heated body by electromagnetic waves



Heat transfer requires difference in temperature of two bodies



Heat transfer is proportional to temperature difference.

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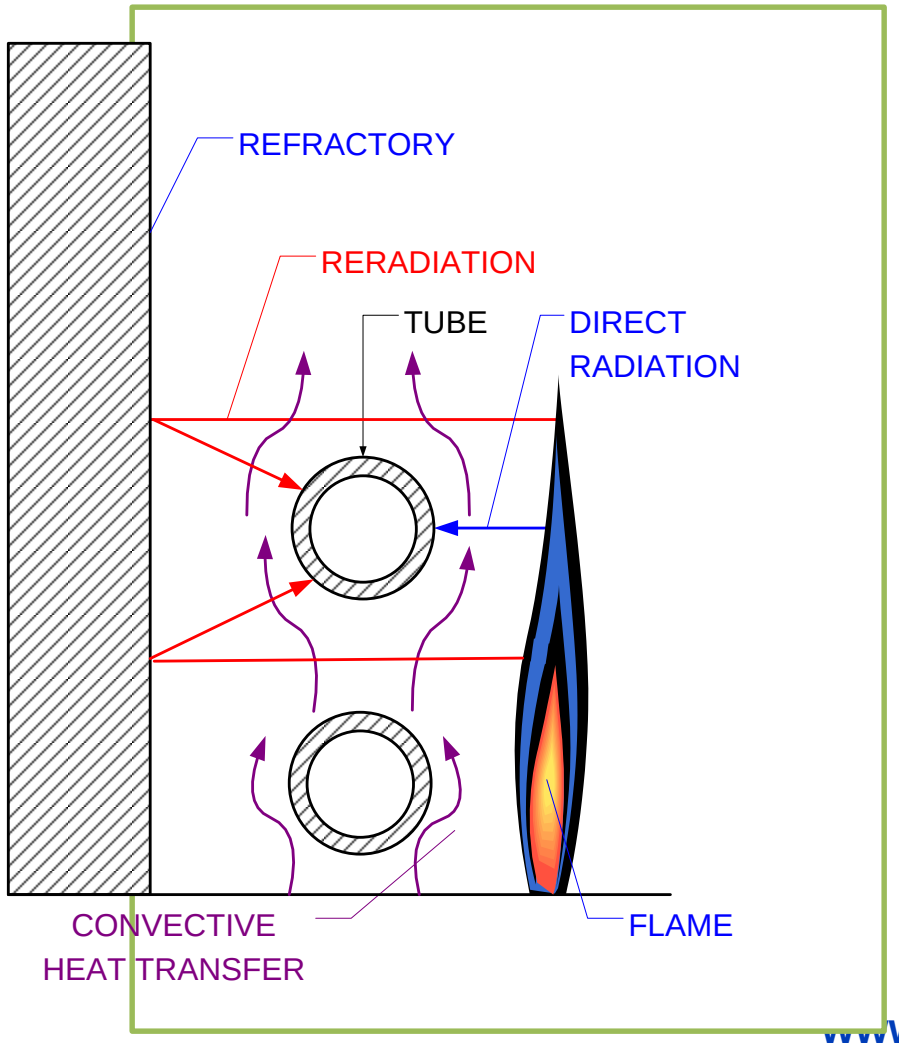
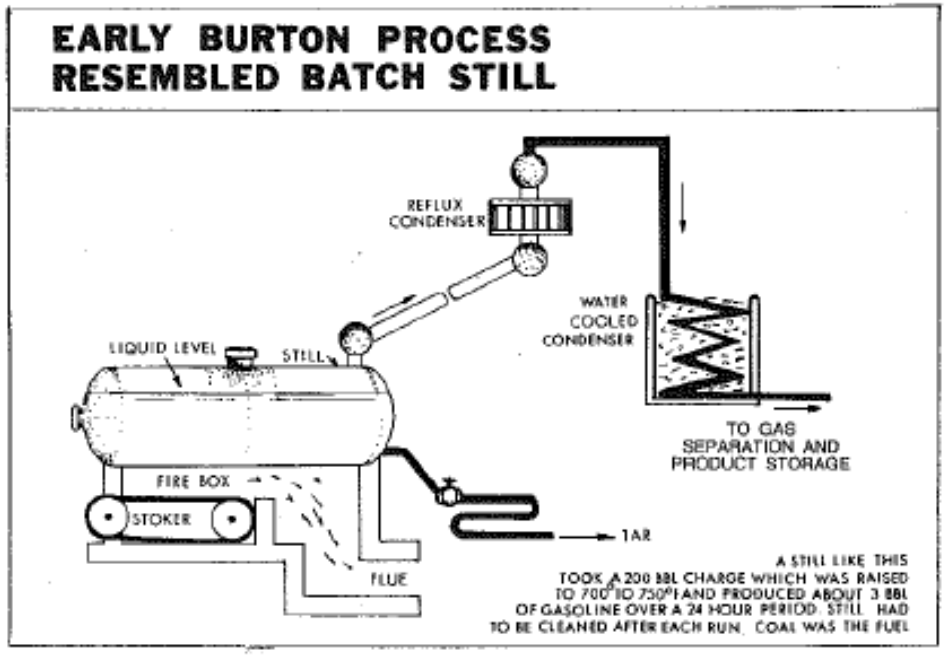
How is Heat Transferred to the Fluid?



- Direct Radiation from hot gases to tubes
- Re-radiation from refractory walls to tubes
- Convection from hot gases to tubes
- Conduction through wall of tubes
- Convection into process fluid

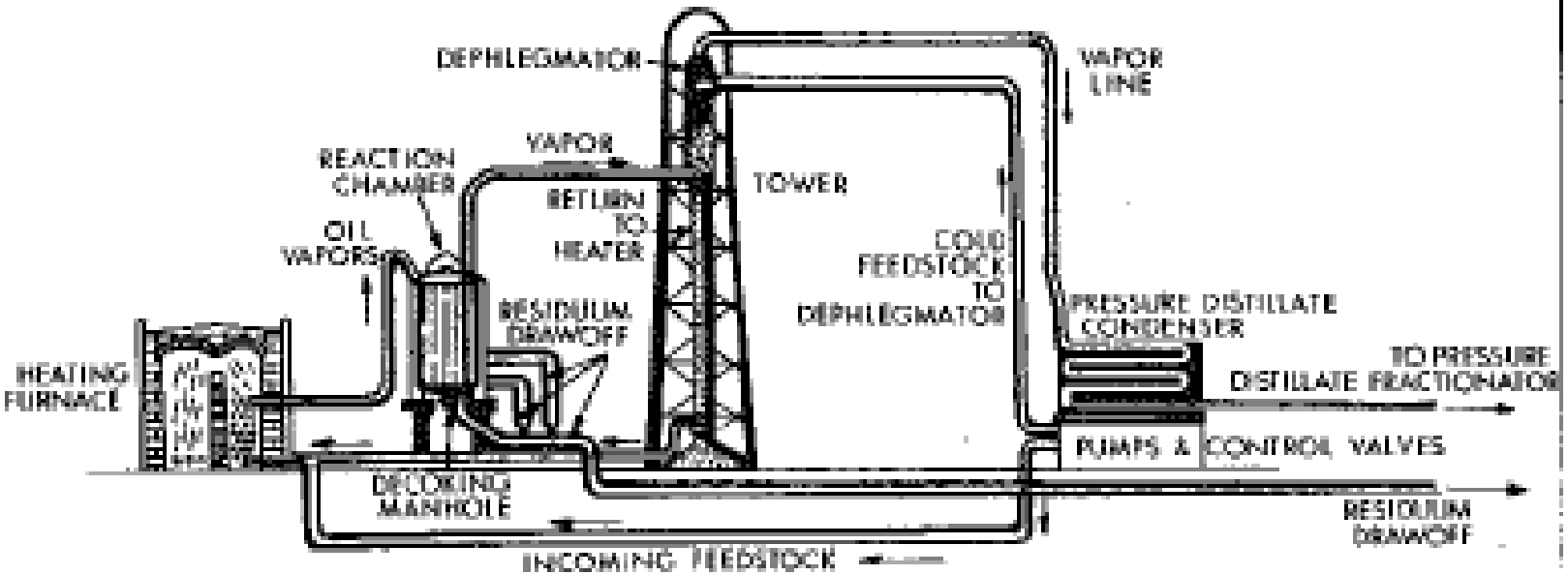
Fired Heaters Evolution

- Developed in late 1800s for growing demand of petroleum products
- Earlier designs – Shell Still-Batch Process-unable to heat viscous liquids efficiently
- Led to development of tubular coil arrangements in 20th century
- Earlier designs were based on convection section heat transfer and flue gas recirculation



Courtesy- Refinery Operations by Bill Berger

FLOW DIAGRAM OF EARLY DUBBS UNIT



Courtesy- Refinery Operations by Bill Berger

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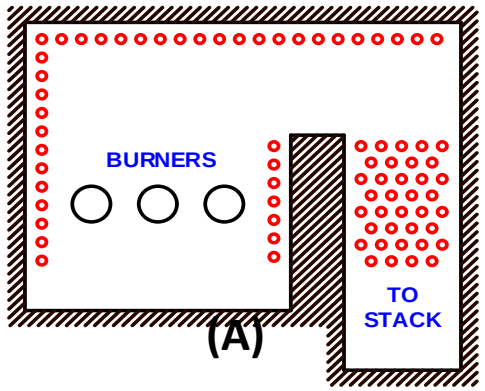
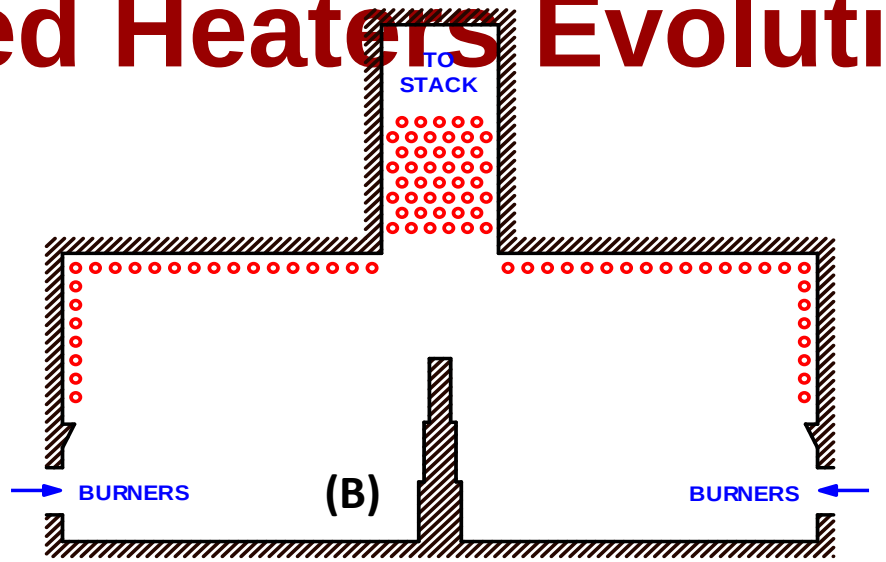
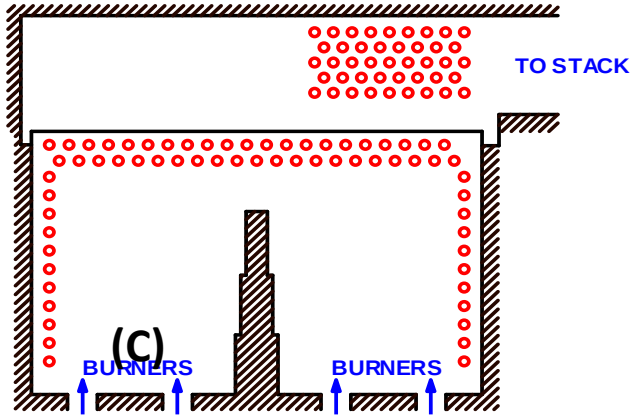
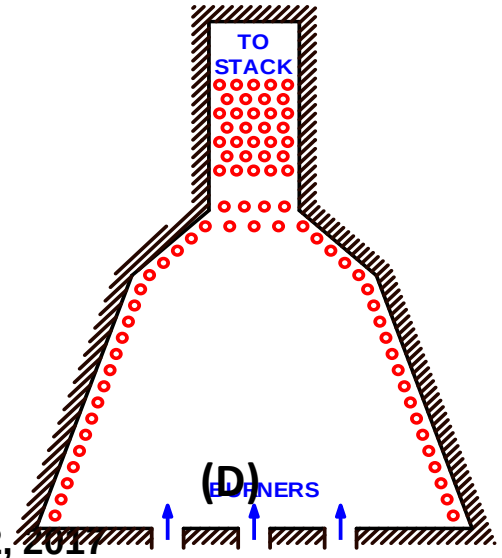
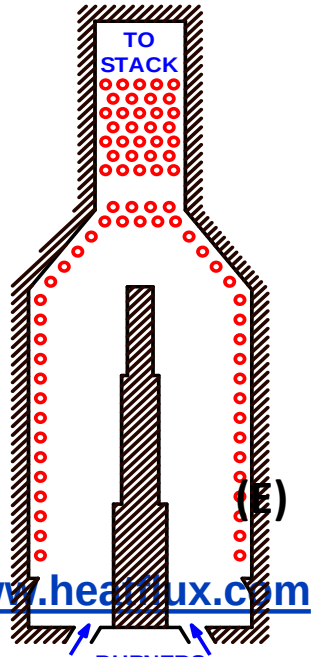
Fired Heaters Evolution

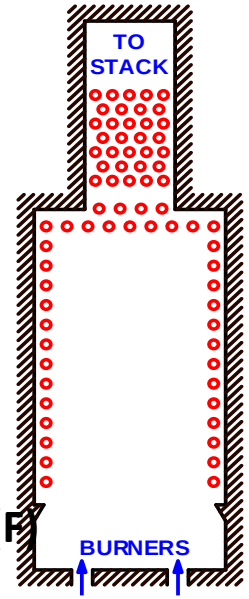




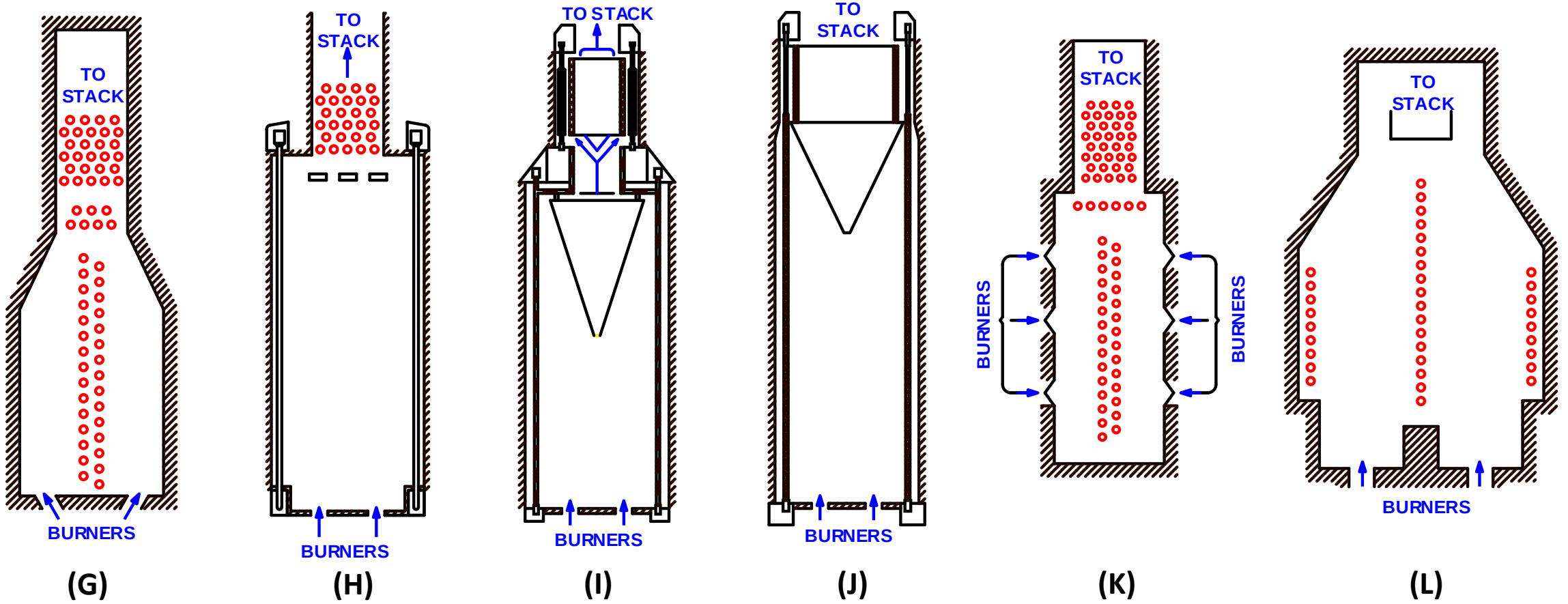






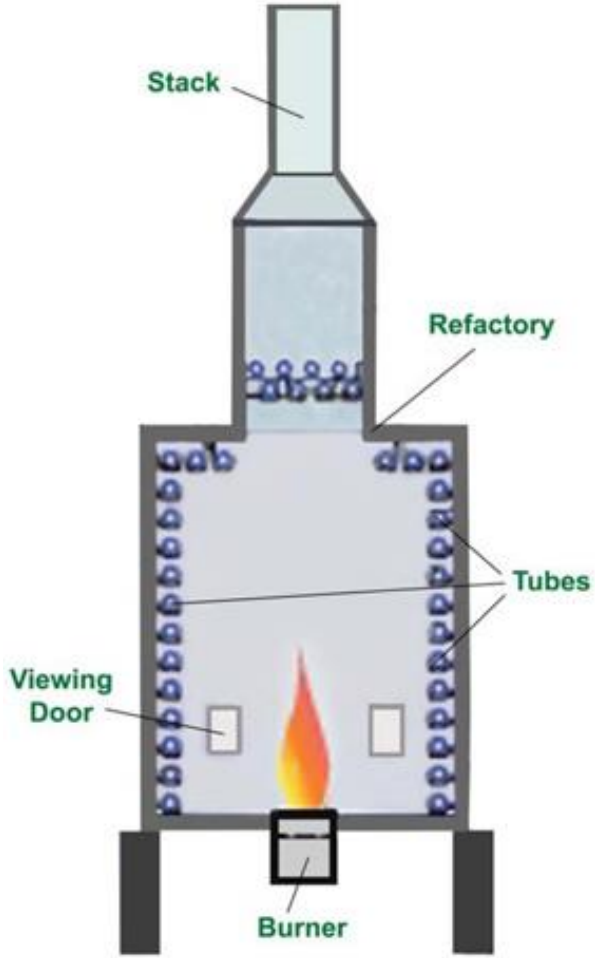


Fired Heater Evolution-2



Fired Heater – Evolution

- Fired heaters- initially box type radiant shape with horizontal tubes and end wall fired burners
- Initially two rows of tubes backed by the refractory
- In 1950s, designs used single row of tubes
- New designs go for double fired tubes
- Vertical tube configuration with Vertical Cylindrical Radiant Section
- Vertical up fired burners



Fired Heaters - Importance

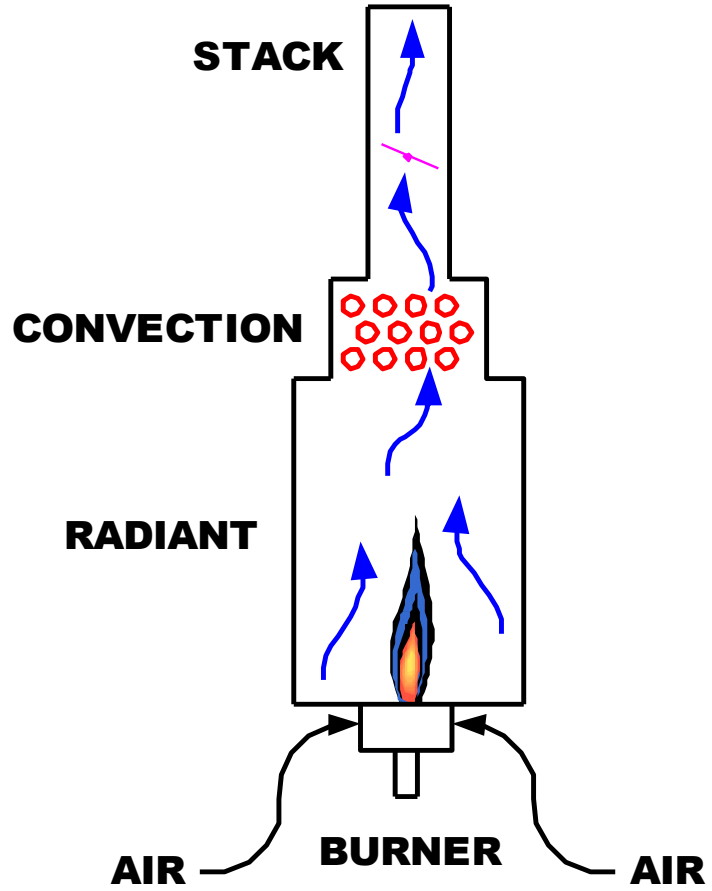
- Major energy consumer
- High temperature
- Exposed to flames
- Major source of green house gases
- Major source of NOx emissions
- Coking of tubes
- Run length

Fired Heaters in Refining Industry

- About 3000 Heaters in the USA
- Natural Draft Heaters- 89.6%
- Forced Draft Heaters-8% without APH
- Balanced Draft Heaters- 2.4% with APH
- Natural Draft Heater- 72 MMBtu/hr (Avg Size)
- Balanced Draft Heater-110 MMBtu/hr (Avg. Size)

Heater Nomenclature

- **Three major components**
  - Radiant Section
  - Convection Section
  - Stack
- **Radiant / Convection split**
  - In refinery heaters, radiant section heat transfer is predominant (60-80%).
  - In high temperature heaters the radiant heat duty drops down to 50% of the total duty.

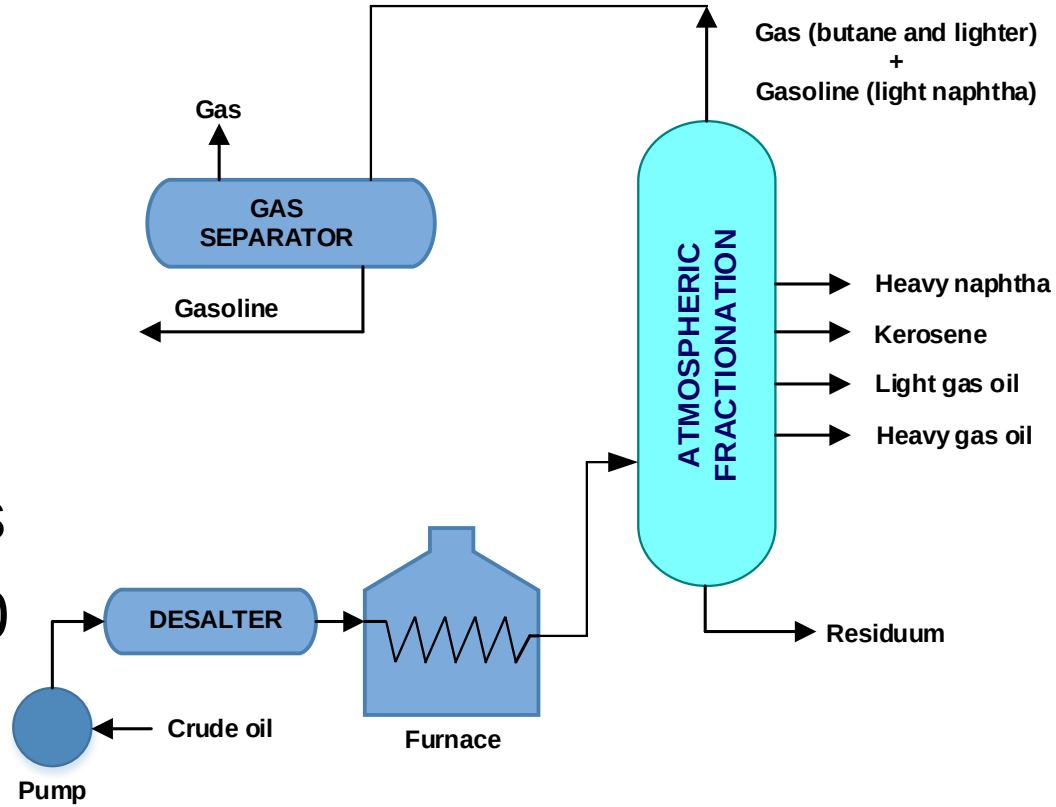


Major Refinery Heaters

- Four major building blocks
  - Atmospheric heater
  - Vacuum heater
  - Coker heater
  - Catalytic Reforming heater

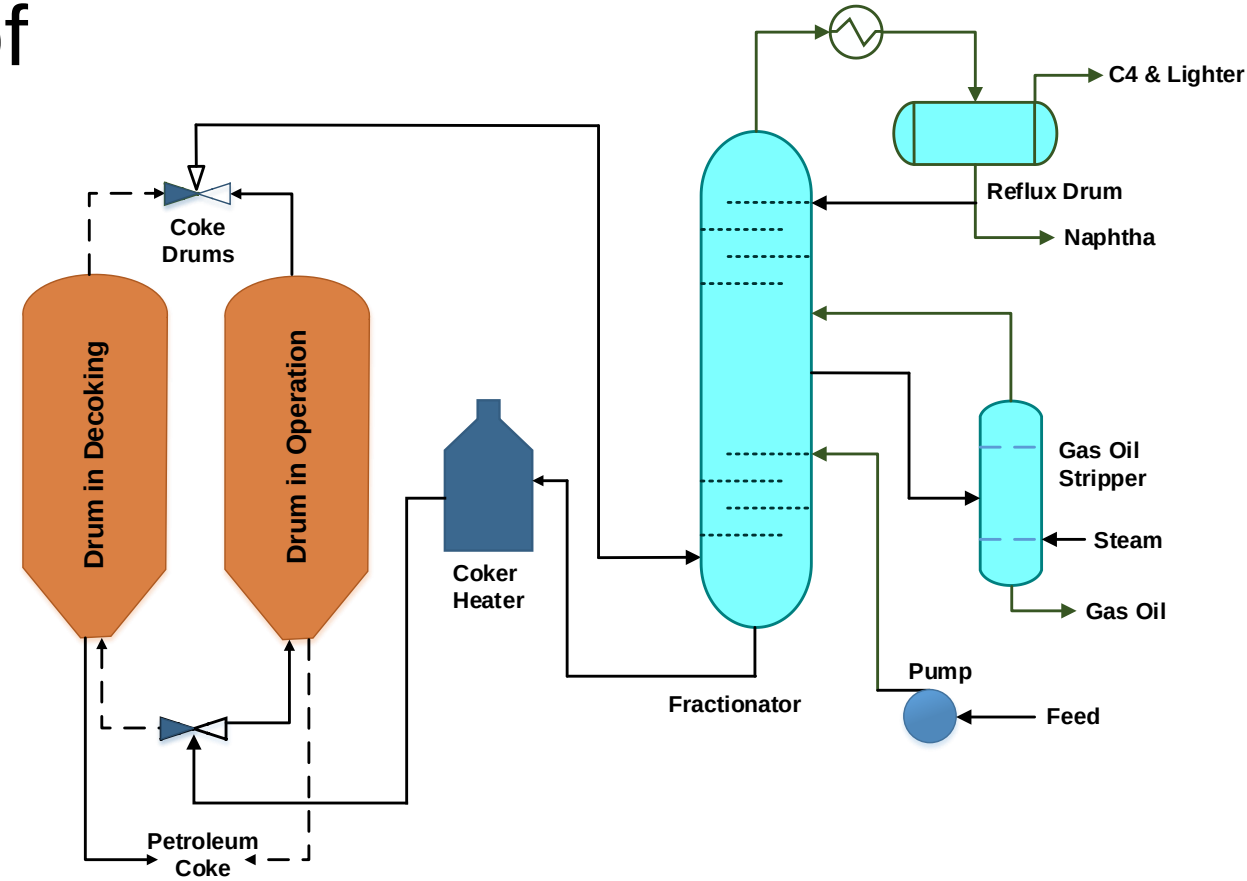
Atmospheric Heater

- Crude or topping heater
- Inlet temperature: 400-600°F
- Outlet temperature: 625-725°F
- Outlet pressure: 25 psig
- Pressure drop: 100-200 psi
- Typical run lengths: around 3-4 years
- Avg. Radiant heat flux:10,000-12,000 Btu/hr ft^2
- Coil material-
  - 5 Cr -1/2 Mo
  - CS for sweet crudes, low temp. service

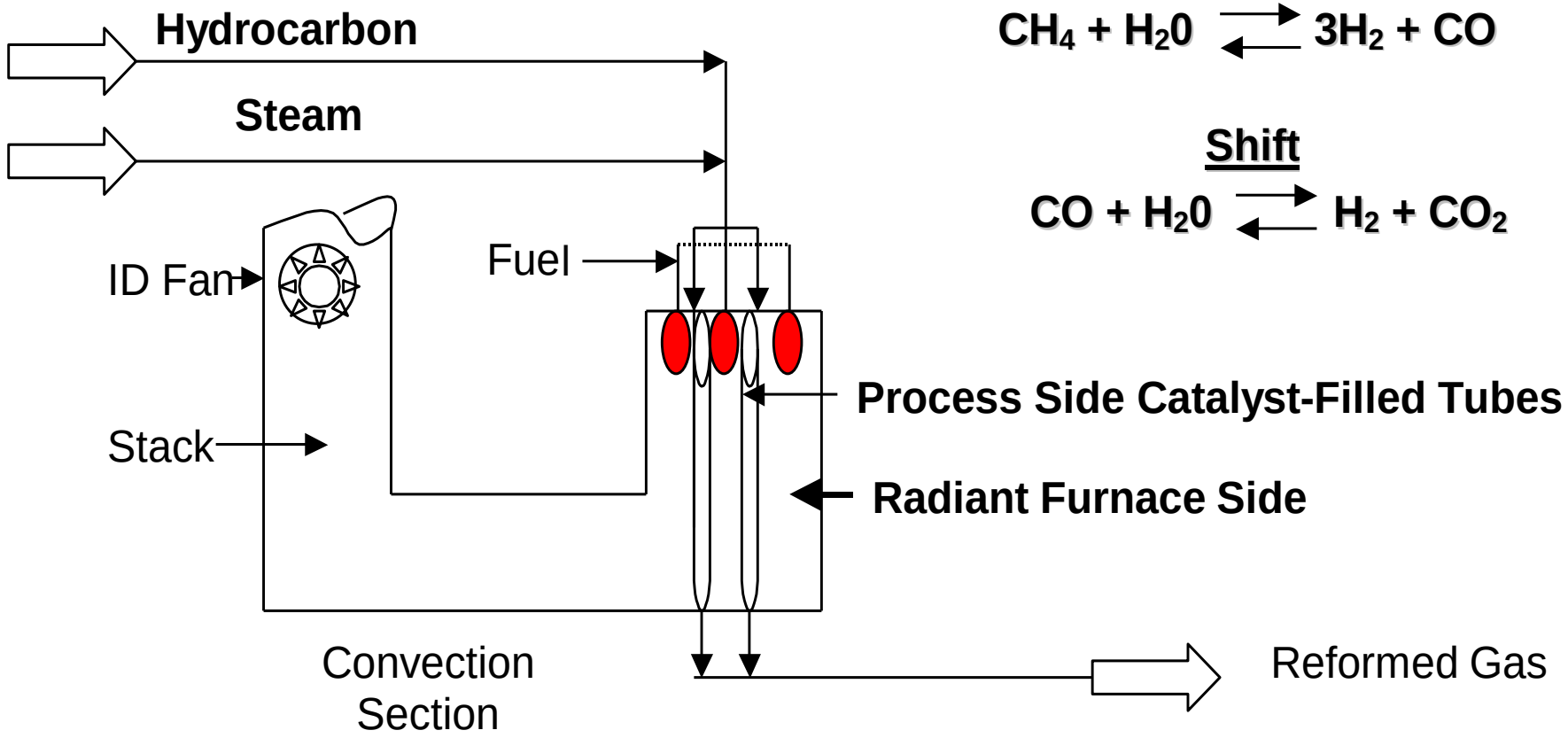


Coker Heaters

- Converts all the bottom of the barrel in to gases, naphtha and coke.
- Coke is shipped to other countries for burning in powerplants.
- Very popular high gasoline demand
- Endothermic reaction- heater supplying the heat



Reformer- Furnace Radiant Section



Reforming

$$CH_4 + H_20 \rightleftharpoons 3H_2 + CO$$

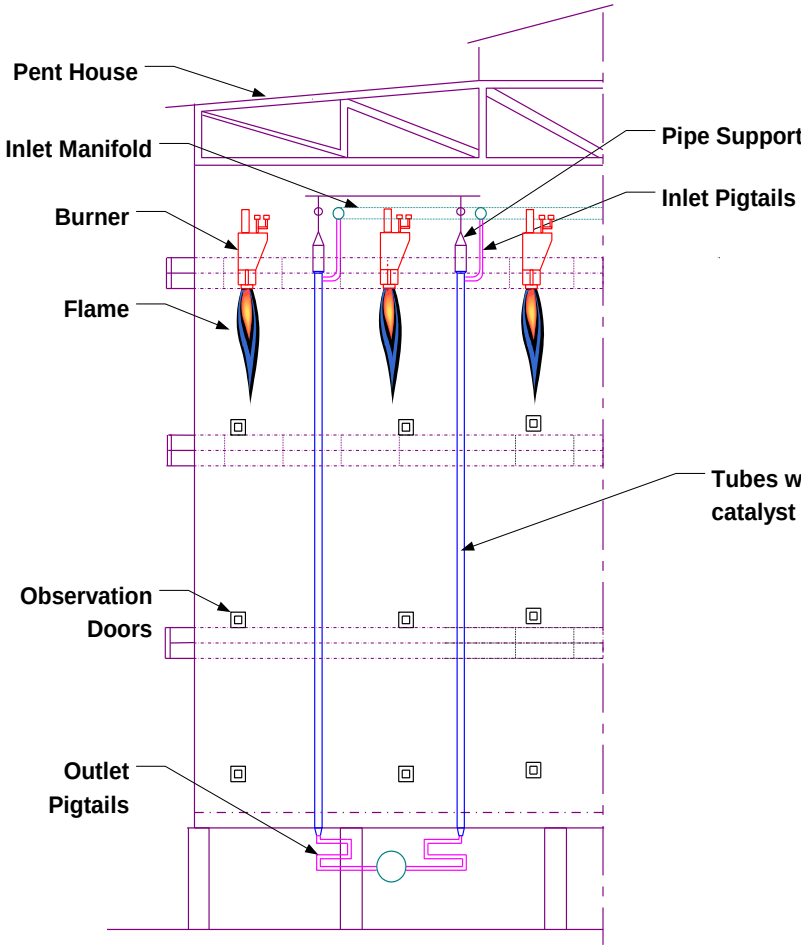
Shift

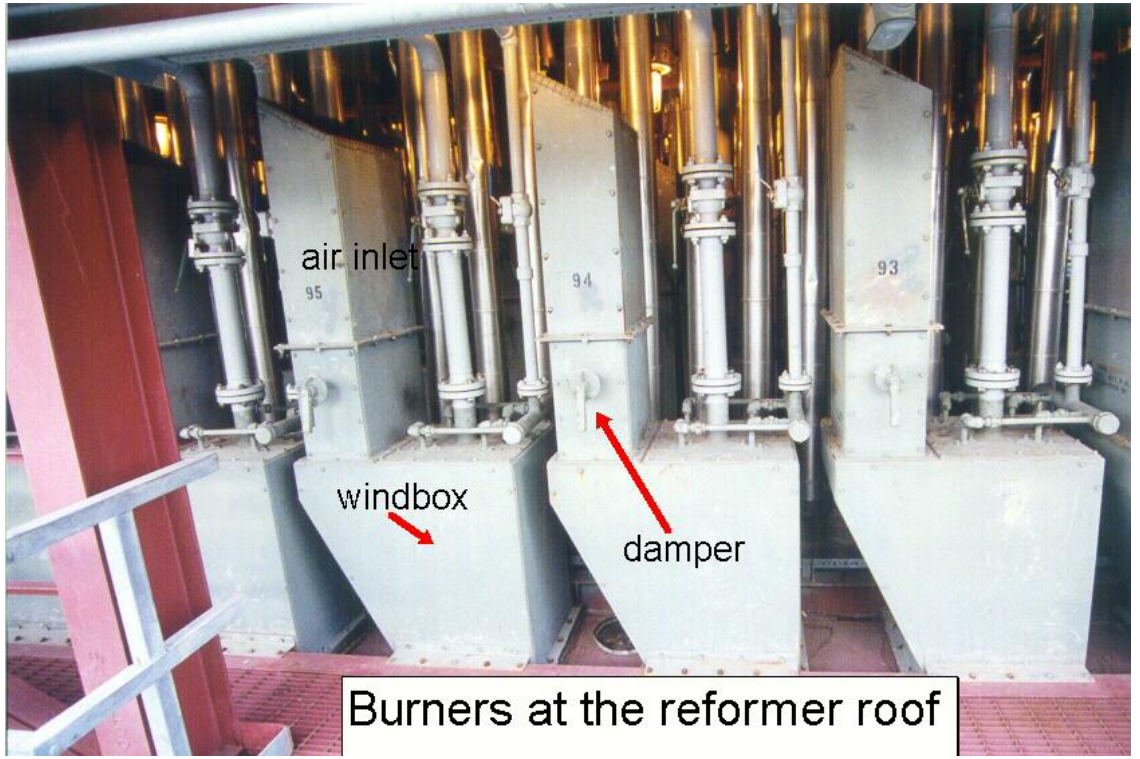
$$CO + H_20 \rightleftharpoons H_2 + CO_2$$

Typical Operating Conditions

- Steam to Carbon Ratio of 2.5 to 4.5
- Radiant section
  - Temperature, in / out - 950/ 1560 F
  - Pressure, in / out - 330/290 psig
- Radiant section efficiency: 45-50%
- Overall thermal efficiency: 88-92%
- Typical tube diameter-3-5 inches
- Typical lengths - 25-45 ft.
- High Chrome Nickel tubes

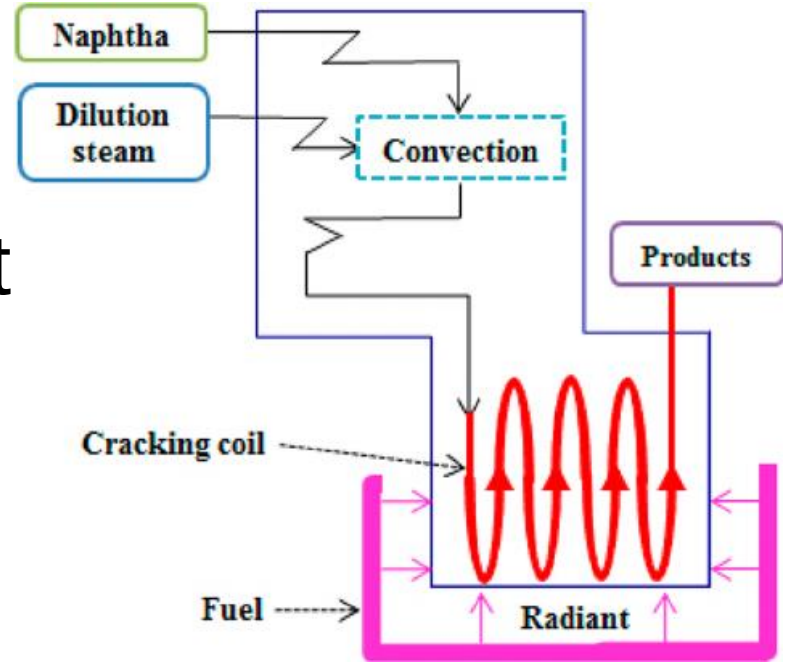
Down Fired Steam Reformer





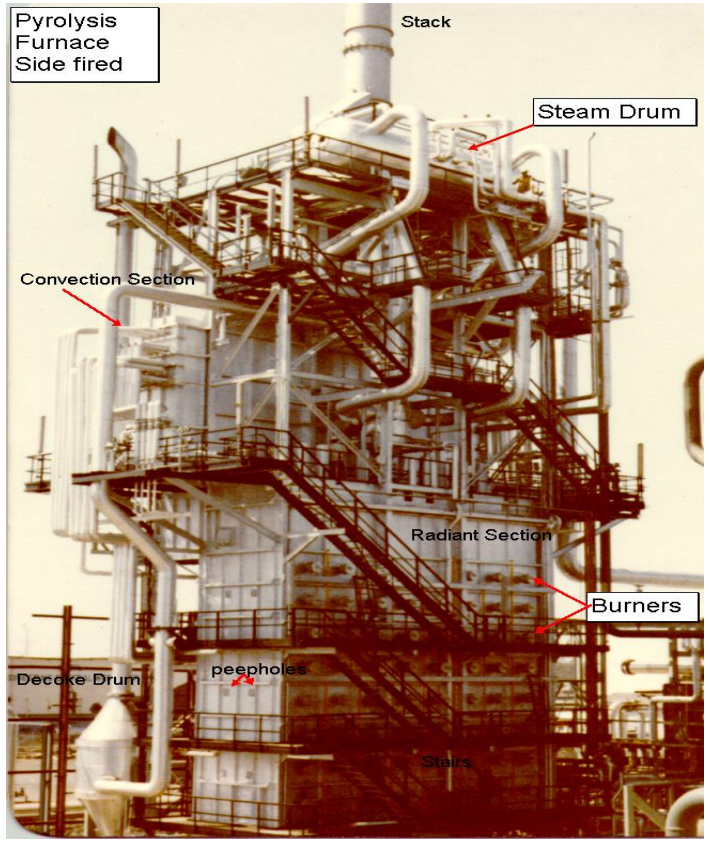
Pyrolysis-Cracking Furnaces

- Breaking the molecule with fire or heat
- Heavier parafinnic hydrocarbons are heated to a high temperature at a low pressure to produce ethylene, propylene, butadiene etc.
- Tubular furnace in the presence of steam.



Historical data for cracking heaters

Year	1940	1970	1990
Max TMT	1400 F	1950 F	2050
Avg. Flux	14400	25000	30000
Tube Matl	321 H	Cast 310	3545Cr Ni
Arrngmt.	Horizontal	Vertical	Vertical
Burners	Wall&Roof	Floor& side	Floor
Heater Size	30 MMBtu	200 MMBtu	400 MMBtu



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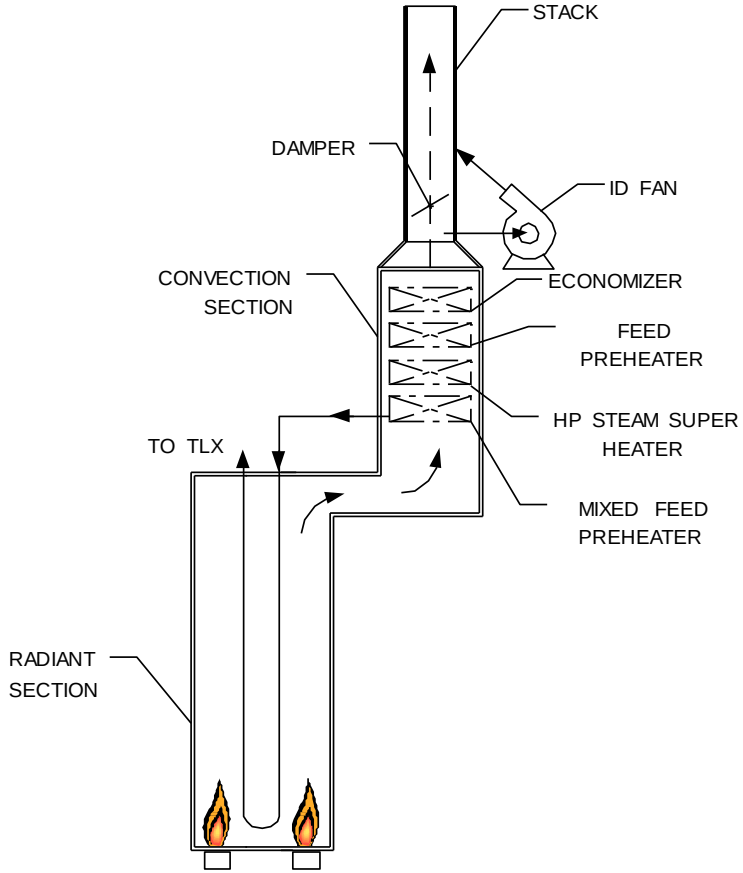
Furnace Configuration

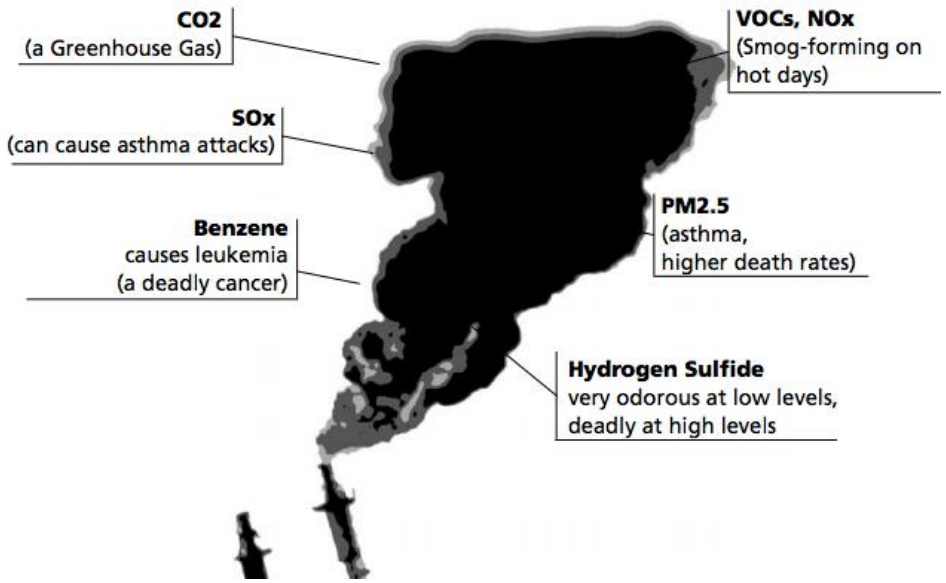
- Vertical coils fired from both sides
- Tubes are supported from top by spring hangers
- Burners are located on floor and side walls
- Radiant flux density, Btu/hr ft^2
  - Ethane /Propane - 20,000-26,000
  - Naphtha - 24,000-30,000

Floor Fired



Air Pollution by Fired Heaters

- Nitrogen Oxides
  - 50% of total NOx emissions are from industrial processes
  - 2 types of NOx produced:
    - Fuel NOx (due to fuel bound nitrogen)
    - Thermal NOx (due to high temperature



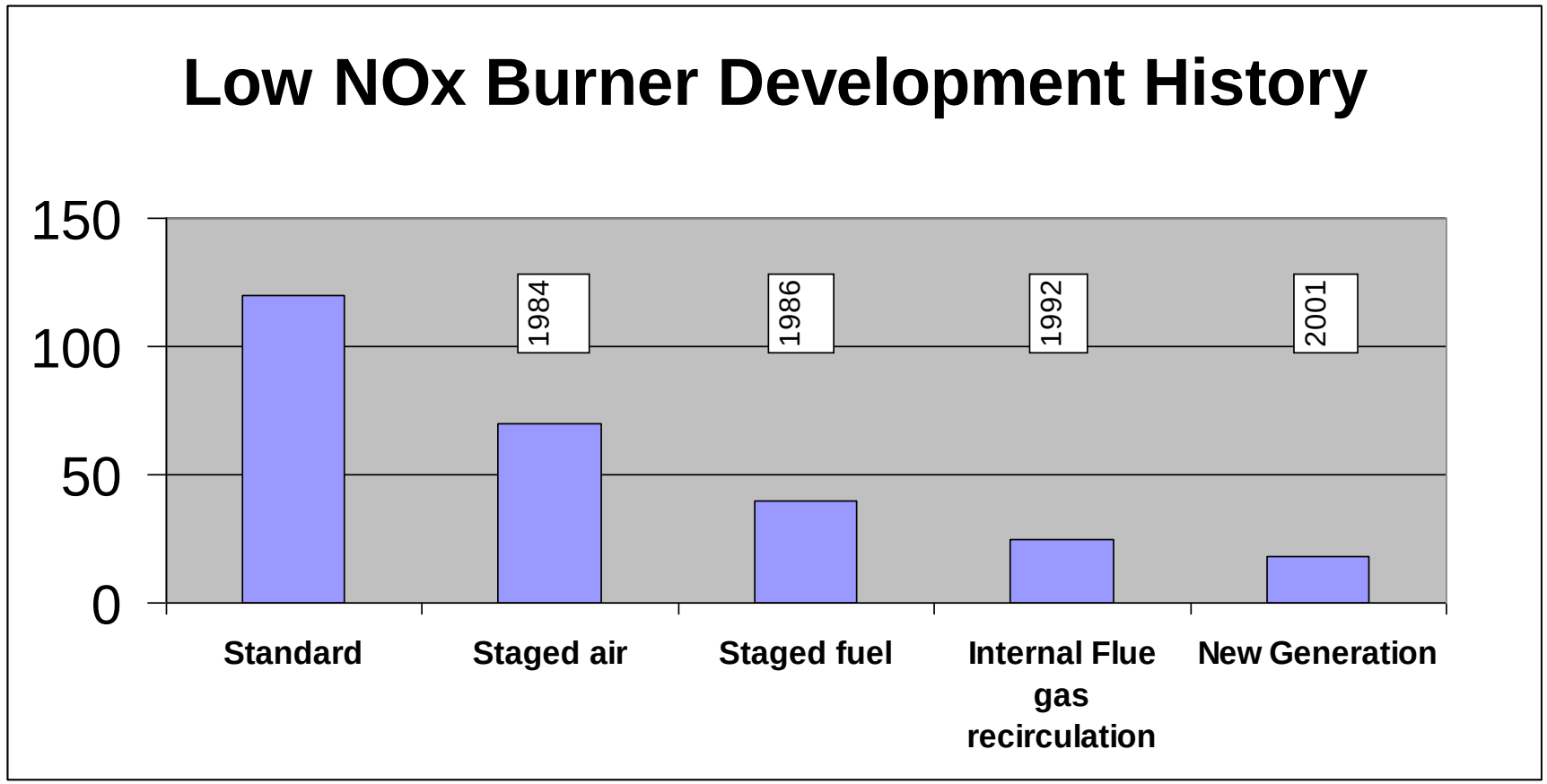
Air Pollution by Fired Heaters

- Carbon Dioxide
  - Generally 200,000 BPD capacity refinery emits 1.5 million tons/year of CO2 (2/3rd is from Fired Heaters)
- Carbon monoxide
  - produced by incomplete combustion
  - EPA limit is 50 ppmvd
- Sulfur Oxides
  - By-products of combustion
  - Fuel gas contains upto 160 ppm of H2S
- Others– trace amounts of VOCs, PM10 and PM2.5

Typical NOx emissions

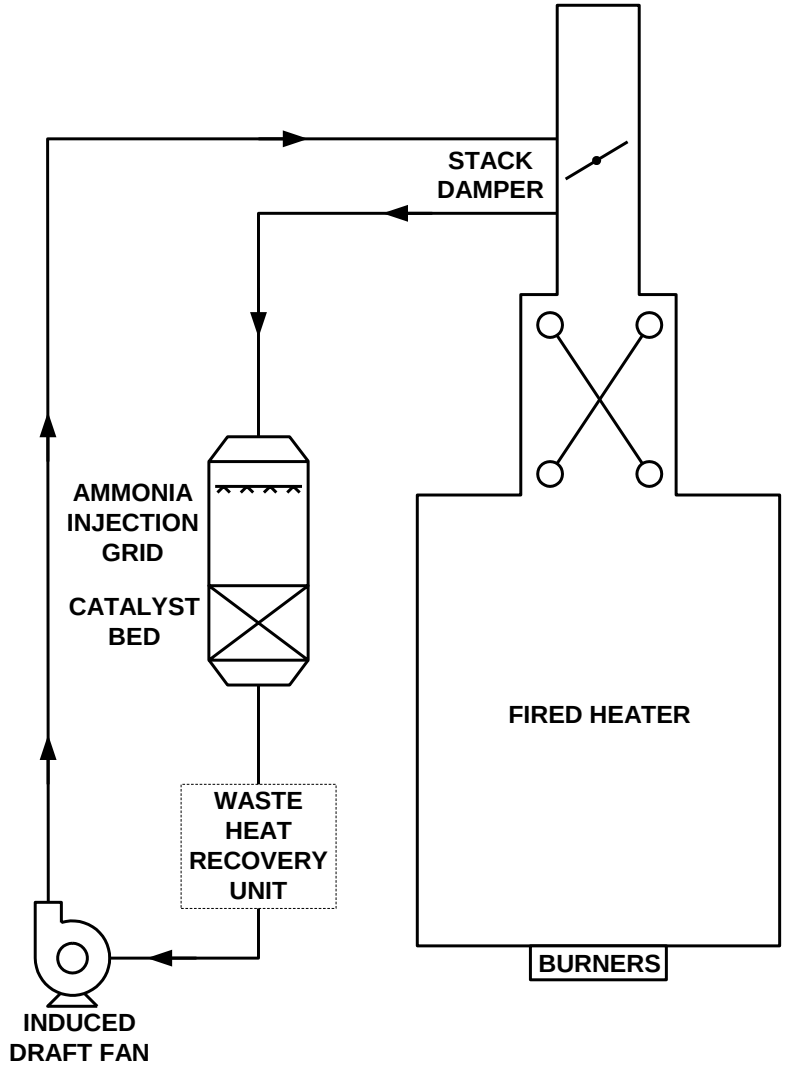
- Gas firing- 0.05-0.2 lb./MMBtu
- Oil firing-0.2-0.4 lb./MMBtu
- A 100 MMBtu/hr gas fired heater will emit approx..... 5.5-22 lb./hr or 20 -80 tons /year.
- A typical refinery having 40 heaters will be emitting approx.....--- 8,00-3,200 tons/year.

Low NOx/ Ultra Low Burners



Selective Catalytic Reduction Systems

- Nitrogen Oxides are reduced to Nitrogen by of Ammonia in the presence of catalyst.
- First tried out in Japan in 1963
- First commercial installation began in 1978.
- Most proven technology for reduction of NOx (can accomplish greater than 95% reduction)

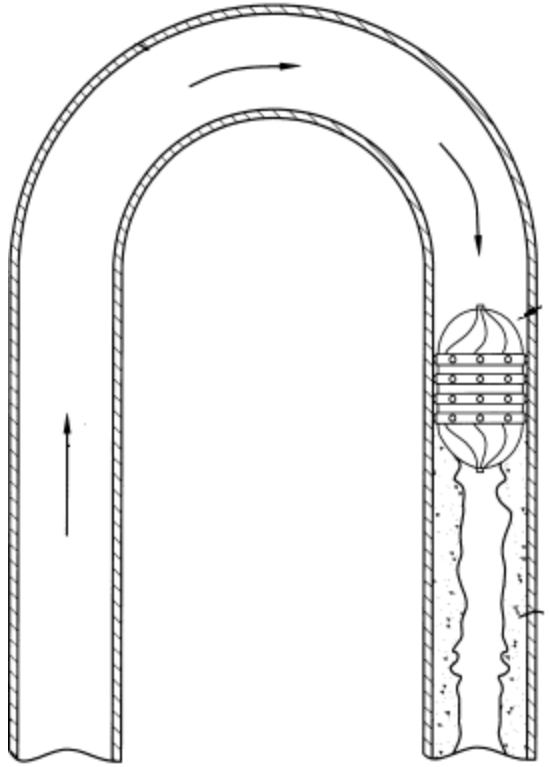


How to reduce air pollution

- Improving heat recovery in the heat exchangers to minimize the heat duty
- Improving fired heater efficiency to 90+% to minimize the fuel firing
- Car pooling/Electric Cars

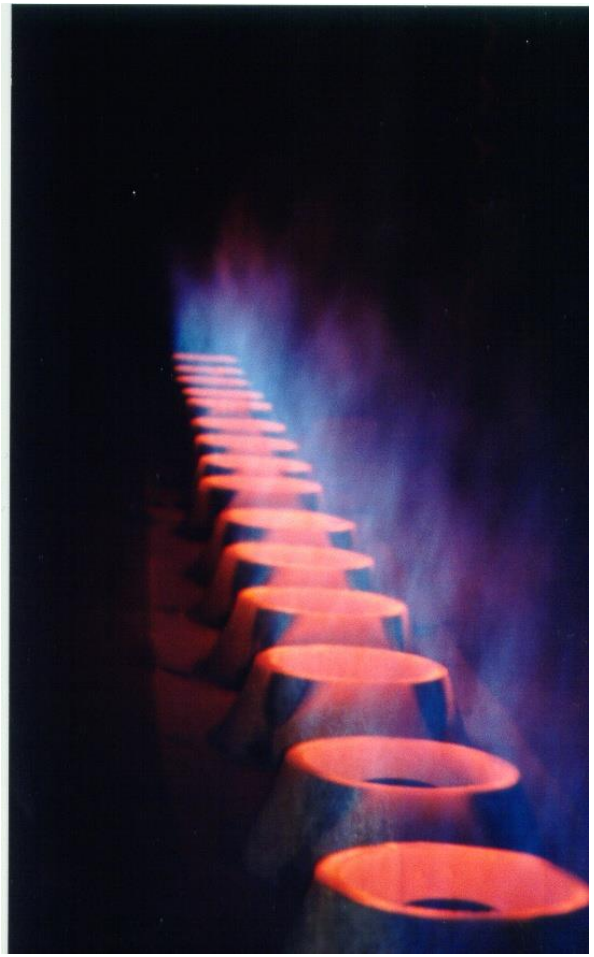
Coking in Tubes

- Coke deposits on the inside of heater tubes
- Pressure drop goes up
- High tube metal temperature
- Exceeds design limit- time for decoking
- Run length 9-12 months
- How to clean the tubes?
- Pigging vs. decoking vs. on-line spalling



Energy Consumption

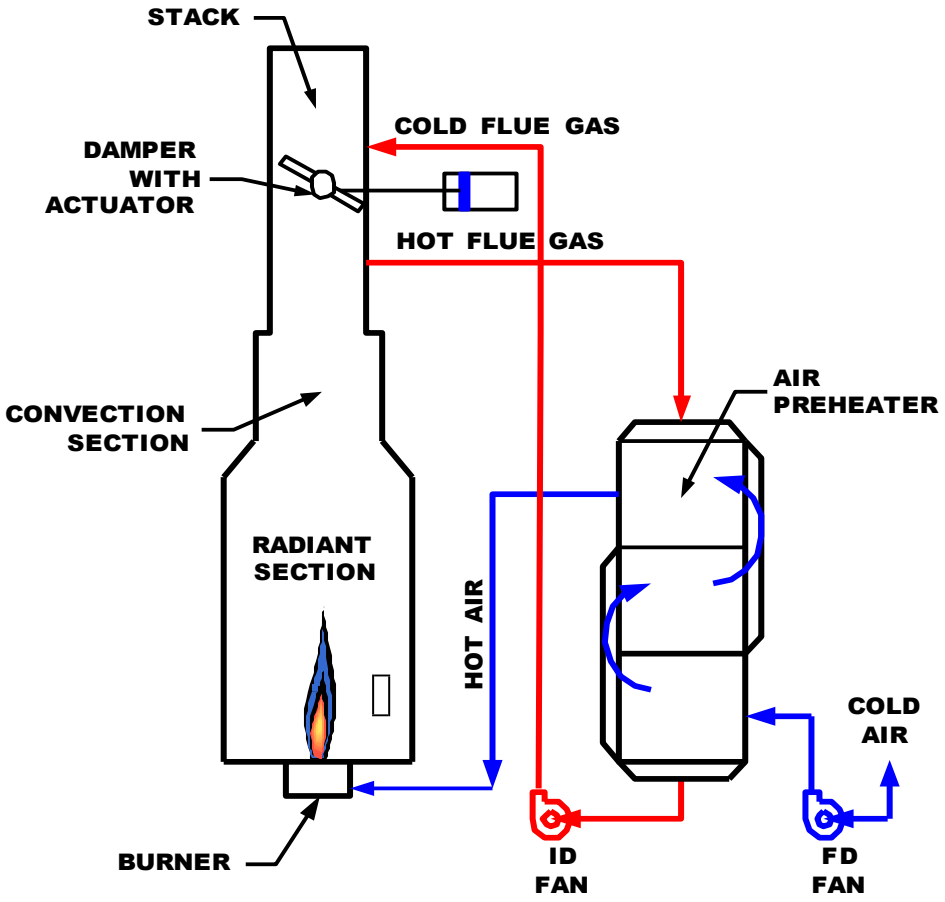
- Typical Refinery
  - 44 MMBtu/ BBL of oil
  - 67% of the energy used in Fired heaters
  - 134,000 BPD (Average Size)
  - Fuel Cost-$3/MMBtu
  - Energy Bill → **$4.32 Billion/Year**
  - **Efficiency improvement 1%= 43.2 Million Dollars**



A dollar saved is a dollar earned.

Fired Heaters Efficiency Improvement

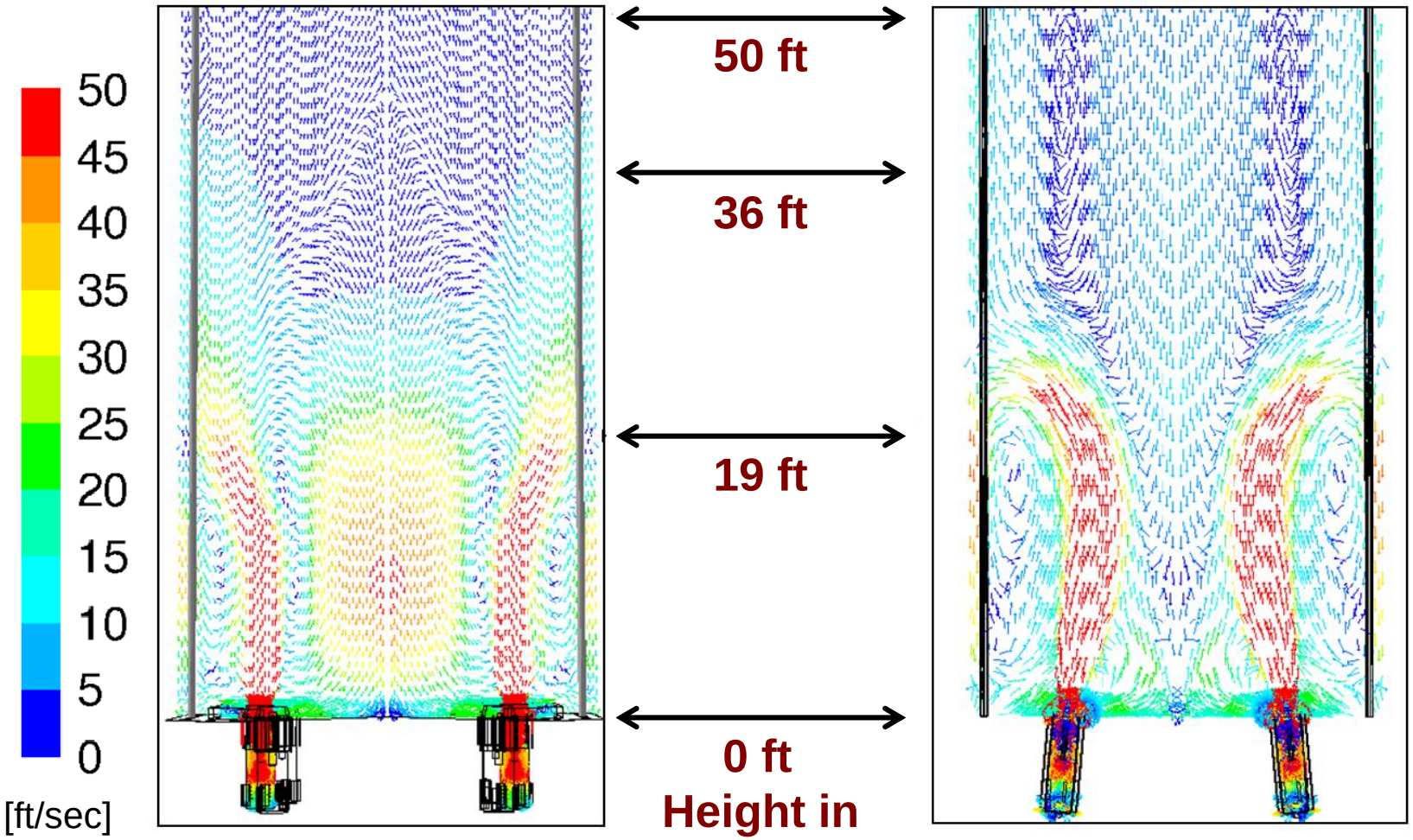
- Fired Heaters Efficiency can be improved by:
  - Installing Air preheater
  - Waste Heat Steam Generator
- Efficiency improvement potential of 8-15%
- Low energy prices do not provide good payback



New Developments

- Better design correlations- still using 70 years old design methods
- CFD Modeling of the burners and heaters
- Better materials for tubes and refractory
- Better flue gas analyzers
- Better burner management systems and controls
- IIoT-Industrial Internet of Things
  - Sensors
  - Advanced analytical capabilities

CFD Modeling of Heaters



Existing Case with Vertically Fired Burners

Proposed Case with Inclined Firing System

Thank you very much!

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