

FIRED HEATERS



BASIC CONCEPTS



- Selection of heaters
- Basic design of heaters
- Basic design of conversion section and stack
- Steam reforming heater
- Burners
- Forced draft system
- Convection section cleaning
- Decoking of fired heater tubes
- Air preheaters
- Inert gas generators
- Incinerators

COMBUSTION

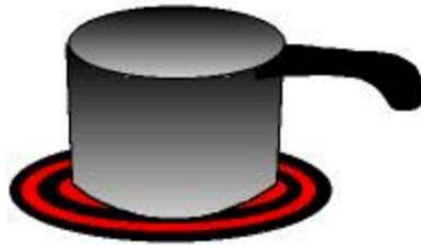


- Combustion is a chemical reaction between fuel and oxygen producing heat
- Air is usually the source of oxygen
- The chemical reaction produces “flue gases”
- Three elements required
 - Fuel
 - Air
 - Source of ignition

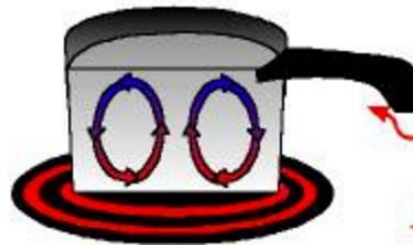
BASIC CONCEPTS OF HEAT TRANSFER

- Three kinds of heat transfer
 - Conduction
 - Convection
 - Radiation

The heat from the stove transfers to the pan via conduction



The heat is transferred through the water via convection



The element transfers heat to the kitchen via radiation



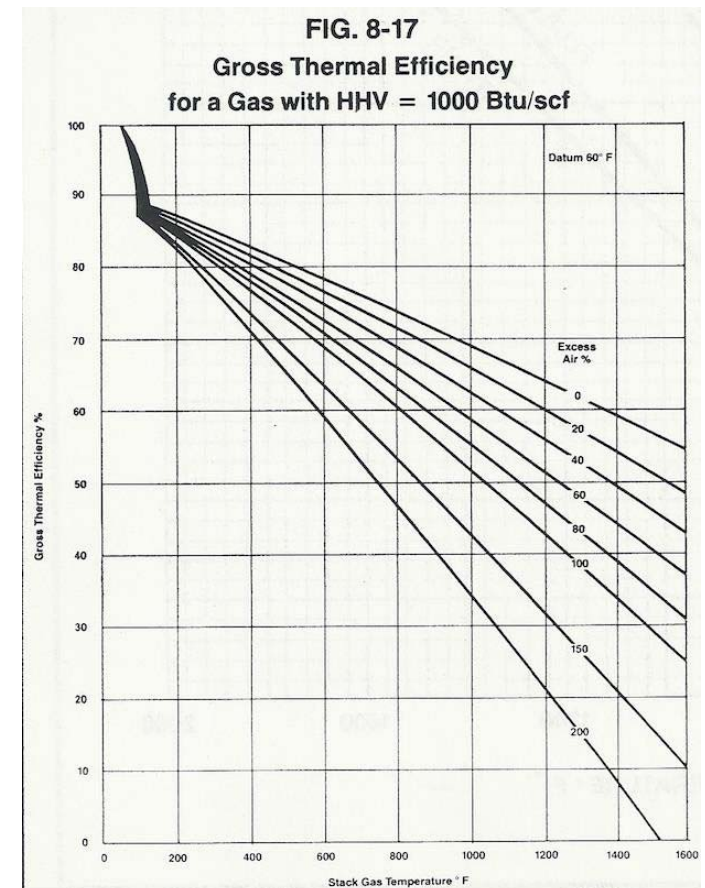
HEATER SECTIONS



- Radiant Section
 - Obtains complete combustion of the fuel with a reasonable amount of excess air (i.e. 10 to 15%)
 - Contains the flame from the burner and avoids impingement on the tubes
 - Distributes the radiant heat flux
 - Cools the combustion gases to 1500° – 1900° F to protect the convection section
- Convection Section
 - Purpose is to transfer as much heat as possible from the combustion gases leaving the radiant section

THERMAL EFFICIENCY

- Two definitions for thermal efficiency
 - Gross efficiency
 - $GTE = \frac{\text{useful Heat Transferred}}{\text{Gross Heat Input}} (100\%)$
 - Net efficiency
 - $NTE = \frac{\text{useful Heat Transferred}}{\text{Net Heat Input}} (100\%)$

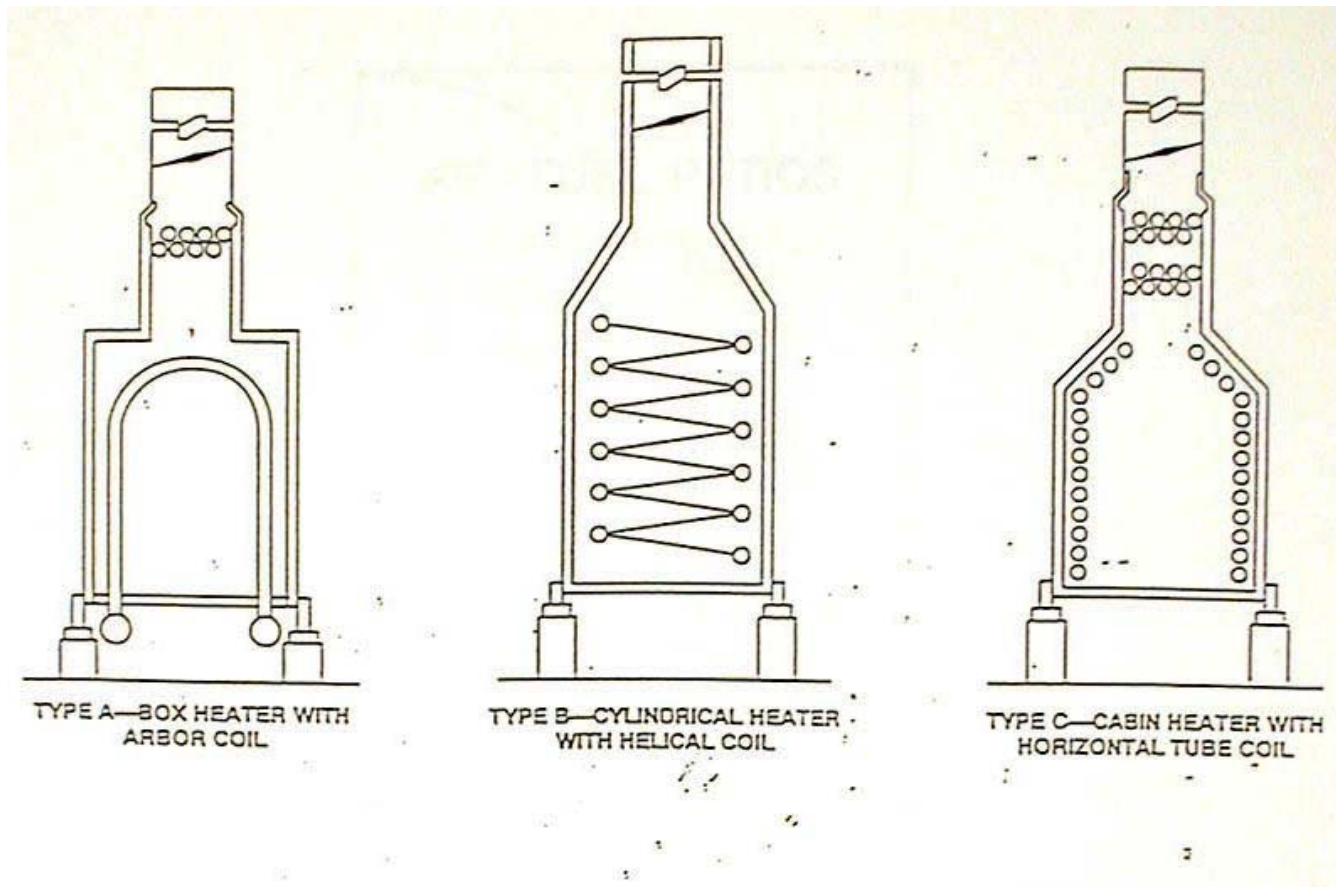


HEATER TYPES

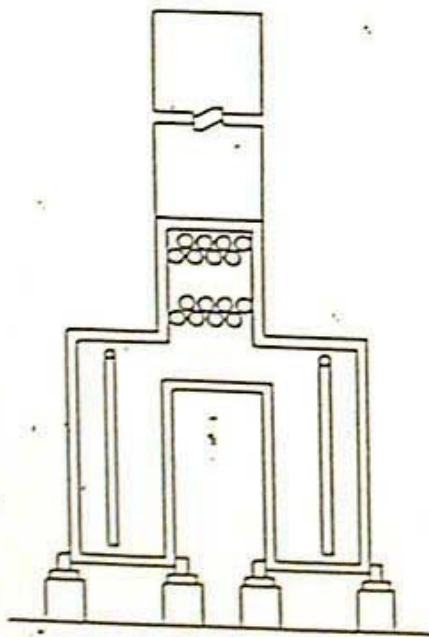


- Furnace and Heater used interchangeably
 - Furnace is an insulated box lined with tubes containing the process fluid
 - Burners inside the box are fired to heat the tubes by a mixture of radiation and convection heat transfer
- Many different furnace designs depending on the process application and the companies involved

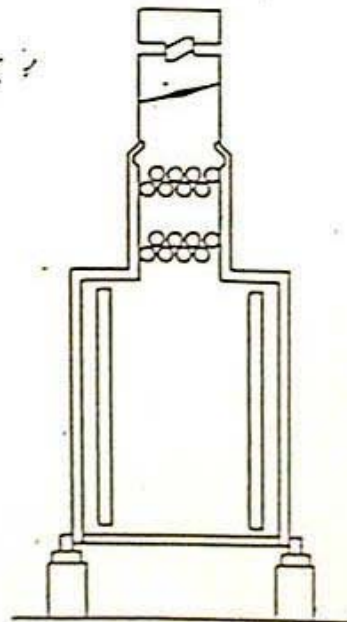
HEATER TYPES



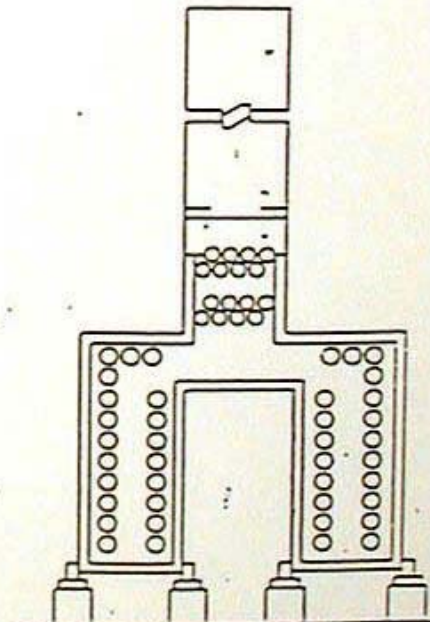
HEATER TYPE



TYPE D—BOX HEATER WITH
VERTICAL TUBE COIL



TYPE E—CYLINDRICAL HEATER
WITH VERTICAL COIL

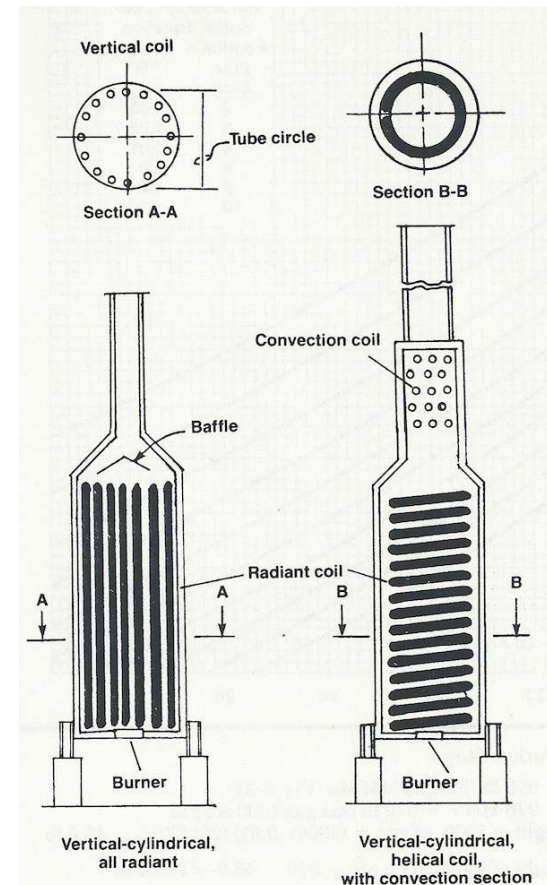


TYPE F—BOX HEATER WITH
HORIZONTAL TUBE COIL

Figure 1—Typical Heater Types

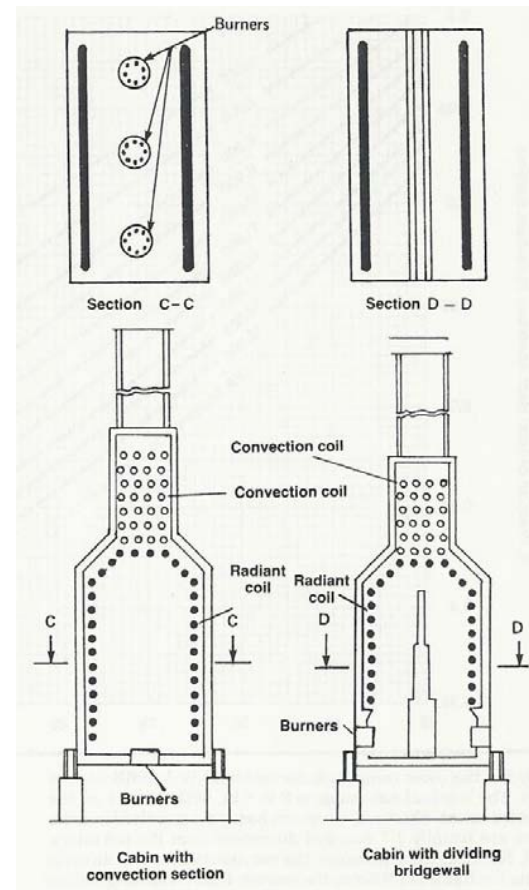
HEATER TYPES

- Vertical-cylindrical with only radiant tubes
 - NTE is about 60%
 - Stack gas temperature is 1200° F or more
 - Low cost design, suited for low cost fuel
- Vertical-cylindrical with convection section
 - NTE is about 80%
 - Higher cost than all-radiant types, but use less fuel for any given duty



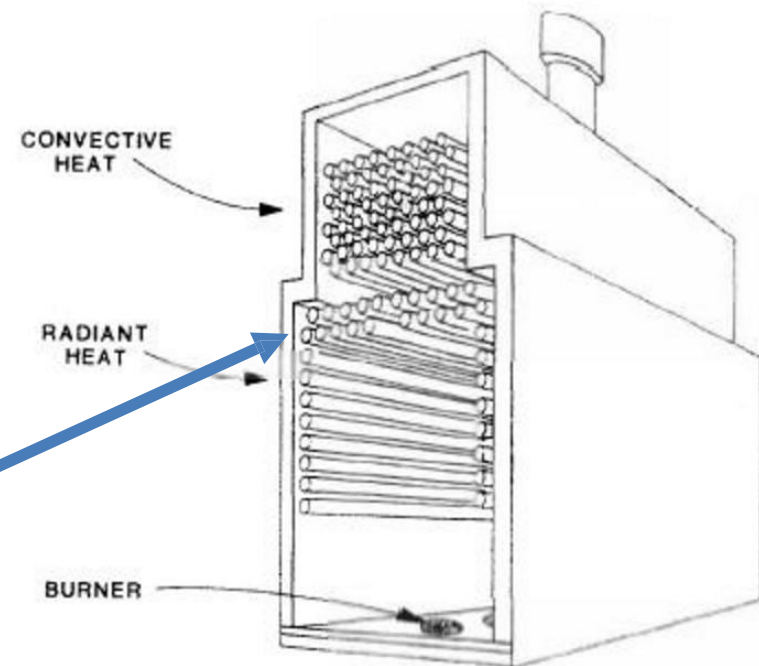
HEATER TYPES

- Furnace with bridge wall
 - Used when tube material is expensive
 - Radiant tubes are placed above the bridge wall so that they are, in effect, double fired
- Furnace with combustion air preheater or an additional convection section
 - NTE can be over 90%
 - Highest capital cost and lowest fuel requirement for any given duty



CONVECTION SECTION

- Convection section
 - Steel plate shell with internal castable or ceramic fiber insulation
 - Tubes are staggered, and the space between the sidewall and tube is filled with “corbels” to prevent the flue gases from bypassing the end tubes
 - First two rows are called shock tubes and they “see” the flames
 - First row receives the full radiant heat flux and is always bare tubes



CONVECTION SECTION CLEANING



- Furnace convection coils reduced performance and fouling occurs for a variety of reasons
 - Most serious fouling occurs on outside of convection coils
 - Fouled from carbon (coke) due to incomplete combustion
 - Fouled from refractory dust resulting from flame erosion of burner blocks and from furnace casing brickwork and insulation
 - Sometimes fouling occurs on the inside tube surface
 - This can happen when thermal cracking of the process stream in a coil occurs, producing a solid product such as carbon (also known as coke)

CONVECTION SECTION CLEANING

- Main technique relies on a long hollow lance being fed through side access doors to deliver the cleaning medium
- No standard cleaning medium, highly dependent on the process, location, available materials, etc.
- Common materials used:
 - Air blowing
 - Water jets
 - Dry Ice
 - Sandblasting
 - Various chemicals

DRAFT

- Three options
 - Natural draft
 - Uses the buoyant effect of the hot flue gases in the stack to draw air into the combustion zone
 - Forced draft
 - Uses an air blower or fan to force air into the heater
 - Induced draft
 - Refers to a blower in the stack

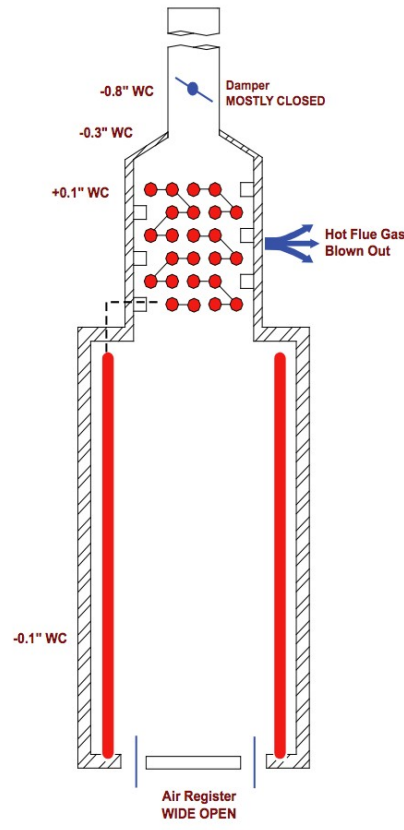
FURNACE STACKS

- Stacks are one way of controlling the flow of combustion air (other is combustion air registers)
 - Stack draft must overcome the gas friction loss in the convection section, burner, and stack
 - Stack diameter is often sized for 15– 20 ft/sec stack gas velocity
 - Stack is normally bare carbon steel but must be lined if flue gas temperatures exceed 750° F or if the fuel has high sulfur content
 - There should be a slight vacuum in a natural draft heater to prevent leakage of the flue gas

FURNACE STACKS

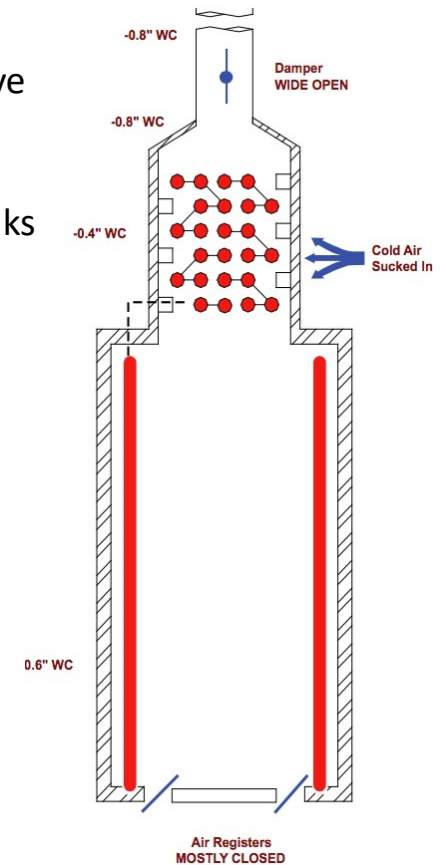
Excessive Draft – Positive Pressure Created

- Forces flue gases outward through leaks in the convection section
- Leads to serious structure damage, as well as heat loss



Excessive Draft – Negative Pressure Created

- Cold ambient air is sucked in through leaks in the convection section
- Causes tall flames which can reach the tubes, resulting in serious damage

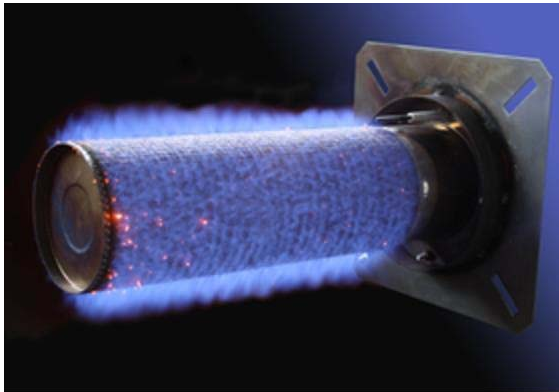


BURNERS

- Objective of a burner is to mix the fuel and air effectively to ensure complete combustion
 - The flame from a burner must be stable and in a fixed position so that heat is distributed and adsorbed effectively
 - Flame shape must be controlled to suit the specific working environment

BURNER TYPES

- Four common types
 - **Premix**
 - Raw Gas (Nozzle Mix)
 - Combination Oil and Gas
 - Low NO_x Burners
- The passage of fuel gas through a venturi pulls in the combustion air
- These burners have short dense flames that are not affected by wind gusts



BURNER TYPES

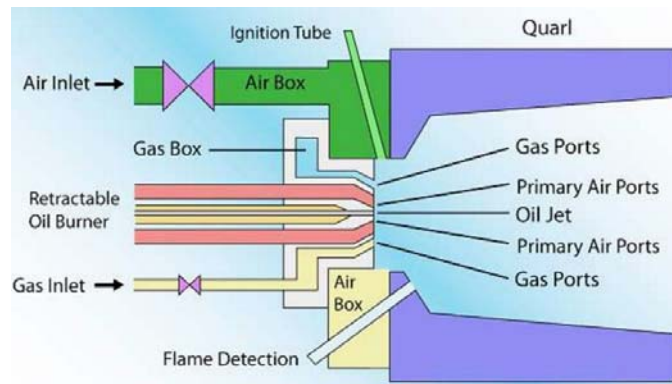
- Four common types
 - Premix
 - **Raw Gas (Nozzle Mix)**
 - Combination Oil and Gas
 - Low NO_x Burners



- Some of the air required for combustion is pulled in by a venturi
- The rest of the air is admitted through a secondary air register
- These burners have larger turndown ratios, require lower gas pressures, and are also quieter

BURNER TYPES

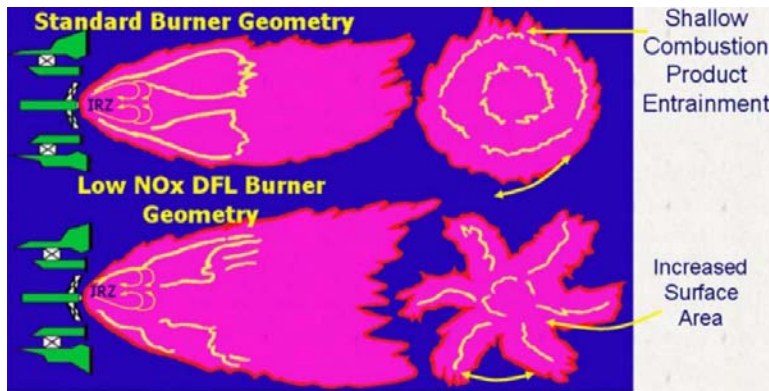
- Four Common Types
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 - **Combination Oil and Gas**
 - Low NO_x Burners



- An oil burner is added to the gas spider so that fuel oil can also be used
- One-tenth pound of steam per pound of fuel is usually required to atomize the oil

BURNER TYPES

- Four Common types
 - Premix
 - Raw Gas (Nozzle Mix)
 - Combination Oil and Gas
 - **Low NO_x Burners**



- The addition of a tertiary air register reduces the amount of nitrogen oxides in the flue gas
- This type also can be operated with less excess air than the previous types mentioned

OTHER NO_x REDUCTION METHODS

- “Pre-combustion” controls – minimize NO_x formation by modifying the combustion process
 - Low Excess Air (LEA)
 - Off-Stoichiometric Combustion (external staging)
 - Low NO_x Burners (internal staging)
 - Flue Gas Recirculation (dilution)
 - Water (Steam) Injection (dilution)
- “Post-combustion” controls – chemically reduce flue gas NO_x to N₂
 - Selective Catalytic Reduction (SCR)
 - Non-selective Catalytic Reduction (NSCR)
 - Selective Non-Catalytic Reduction (SNCR)

FLAME ZONE NO_x REDUCTION

- Reduce peak temperature
 - Use a fuel rich primary flame zone (stage combustion)
 - Increase rate of flame cooling (reduced air preheat & firing rate)
 - Decrease adiabatic flame temperature by dilution (water injection / FGR)
- Reduce fuel gas residence time
 - Change shape of flame zone
 - Use a fuel rich primary flame zone
 - Increase rate of flame cooling
 - Decrease adiabatic flame temperature by dilution
- Reduce O₂ concentration
 - Decrease excess air (LEA)
 - Maintain controlled fuel / air mixing

NO_x REDUCTION SELECTION

Table 2. Use this chart to screen potential NO_x control technologies

Technique	Description	Advantages	Disadvantages	Impacts to Consider	Applicability	NO _x Reduction
Low Excess Air (LEA)	Reduces oxygen availability	Easy operational modification	Low NO _x reduction potential	High carbon monoxide emissions; Flame length; Flame stability	All fuels	1 – 15%
Off Stoichiometric Combustion (OS) a. Burners-out-of-service (BOOS) b. Overfire Air (OFA) c. Air Lances	Staged combustion, creating fuel-rich and fuel-lean zones	Low operating cost; No capital equipment required for BOOS	a. Typically requires higher air flow to control carbon monoxide; b. Relatively high capital cost; c. Moderate capital cost	Flame length; Forced-draft fan capacity; Burner header pressure	All fuels; Multiple burner devices	30 – 60%
Low-NO _x Burners (LNB)	Provides internal staged combustion, thus reducing peak flame temperatures and oxygen availability	Low operating cost; Compatible with FGR as a combination technology to maximize NO _x reduction	Moderately high capital cost; Applicability depends on combustion device and fuels, design characteristics, waste streams, etc.	Forced-draft fan capacity; Flame length; Design compatibility; Turndown flame stability	All fuels	30 – 50%
Flue Gas Recirculation (FGR)	Up to 20 – 30% of the flue gas is recirculated and mixed with the combustion air, thus decreasing peak flame temperatures	High NO _x reduction potential for natural gas and low-nitrogen fuels	Moderately high capital cost; Moderately high operating cost; Affects heat transfer and system pressures	Forced-draft fan capacity; Furnace pressure; Burner pressure drop; Turndown flame stability	Gas fuels and low-nitrogen fuels	40 – 80%
Water/Steam Injection (WSI)	Injection of steam or water at the burner, which decreases flame temperature	Moderate capital cost; NO _x reductions similar to FGR	Efficiency penalty due to additional water vapor loss and fan power requirements for increased mass flow	Flame stability; Efficiency penalty	Gas fuels and low-nitrogen fuels	40 – 70%
Reduced Air Preheat (RAPH)	Air preheater modification to reduce preheat, thereby reducing flame temperature	High NO _x reduction potential	Significant efficiency loss (1% per 40 °F)	Forced-draft fan capacity; Efficiency penalty	Gas fuels and low-nitrogen fuels	25 – 65%
Selective Catalytic Reduction (SCR)	Catalyst located in flue gas stream (usually upstream of air heater) promotes reaction of ammonia with NO _x	High NO _x removal	Very high capital cost; High operating cost; Extensive ductwork to and from reactor required; Large volume reactor must be sited; Increased pressure drop may require induced-draft fan or larger forced-draft fan; Reduced efficiency; Ammonia sulfate removal equipment for air heater required; Water treatment of air heater wash required	Space requirements; Ammonia slip; Hazardous waste disposal	Gas fuels and low-sulfur liquid and solid fuels	70 – 90%
Selective Noncatalytic Reduction (SNCR) – Urea Injection	Injection of urea into furnace to react with NO _x to form nitrogen and water	Low capital cost; Relatively simple system; Moderate NO _x removal; Nontoxic chemical; Typically low energy injection sufficient	Temperature dependent; Design must consider boiler operating conditions and design; NO _x reduction may decrease at lower loads	Furnace geometry and residence time; Temperature profile	All fuels	25 – 50%
Selective Noncatalytic Reduction (SNCR) – Ammonia Injection (Thermal DeNO _x)	Injection of ammonia into furnace to react with NO _x to form nitrogen and water	Low operating cost; Moderate NO _x removal	Moderately high capital cost; Ammonia handling, storage, vaporization, and injection systems	Furnace geometry and residence time; Temperature profile	All fuels	25 – 50%

From Chemical Engineering Progress – January 1994

AIR PREHEATERS

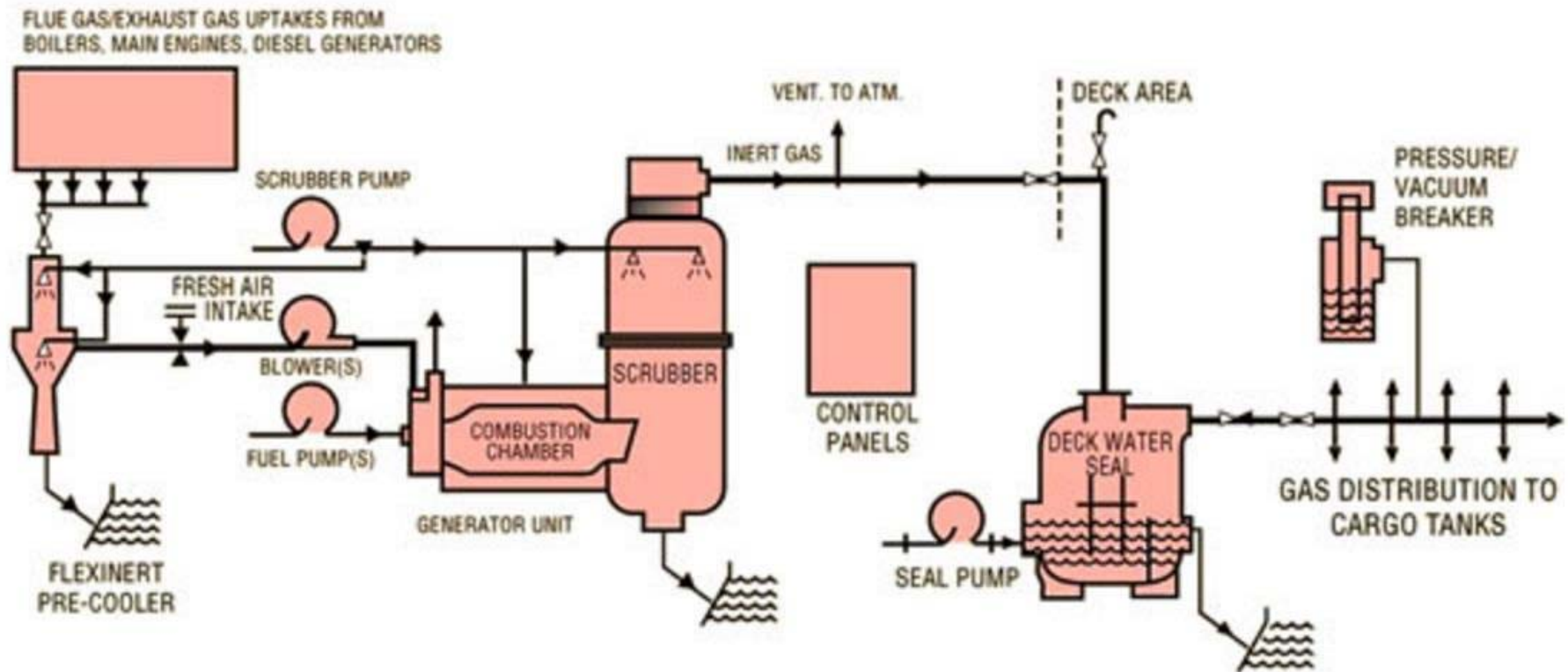


- Used to preheat the combustion air which is then routed to the burners
 - Used when exhaust temperatures of combustion systems are high (up to a flue gas temperature of 400° C)
 - This high exhaust temperature will allow the preheated combustion air to reach up to 300° C
 - This allows for the heat in a system to be recirculated and reduces losses to the atmosphere

INERT GAS GENERATOR

- Used on board marine product tankers
- Consist of a gas producer and a scrubbing system
 - Atmospheric air is burned using diesel and the exhaust is collected
 - Resulting exhaust contains less than 5% oxygen ("inert gas")
 - This gas is then routed to the cargo tanks to prevent explosion of flammable cargo
 - Gas consists mainly of CO₂

INERT GAS GENERATOR

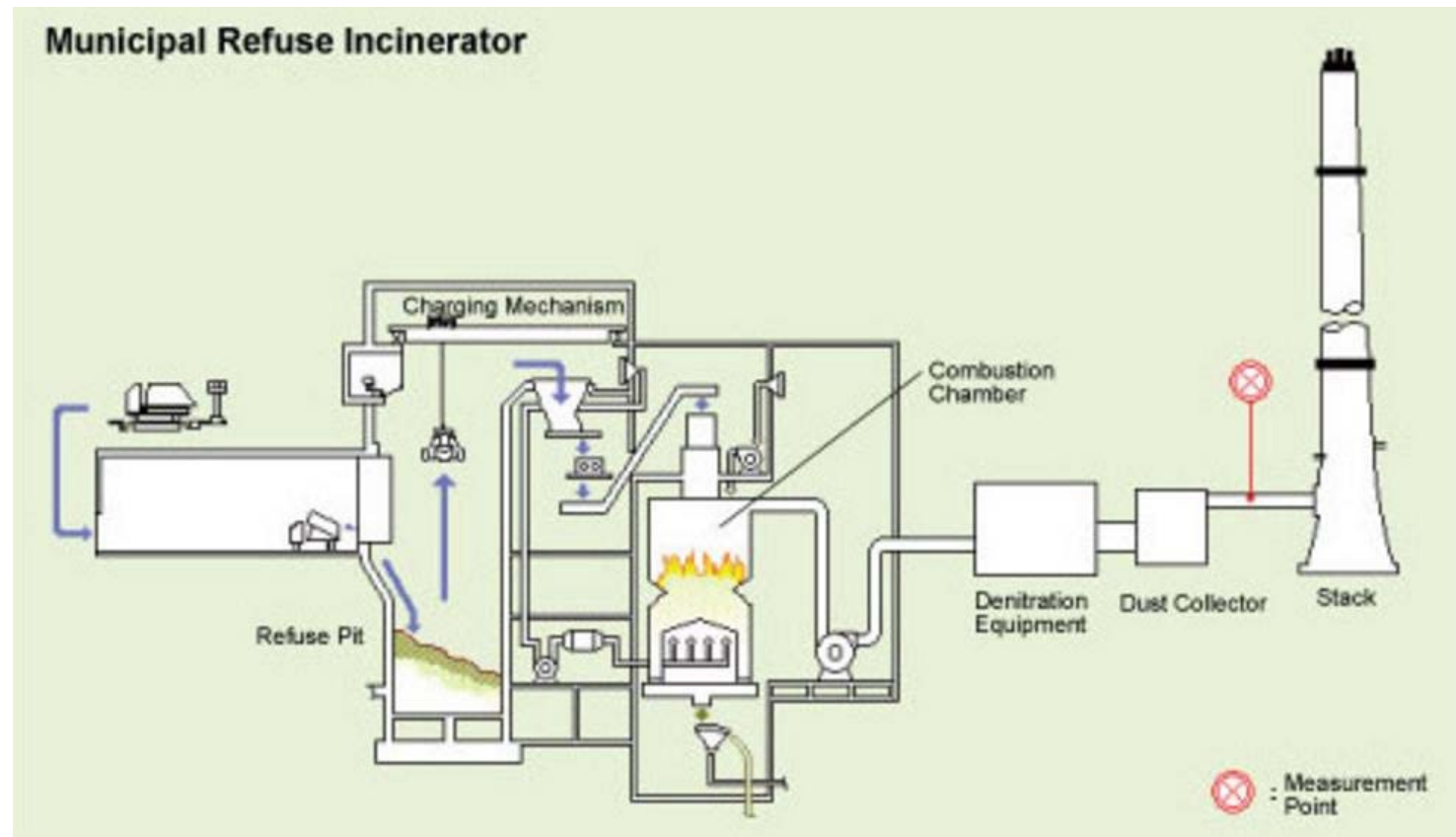


INCINERATORS

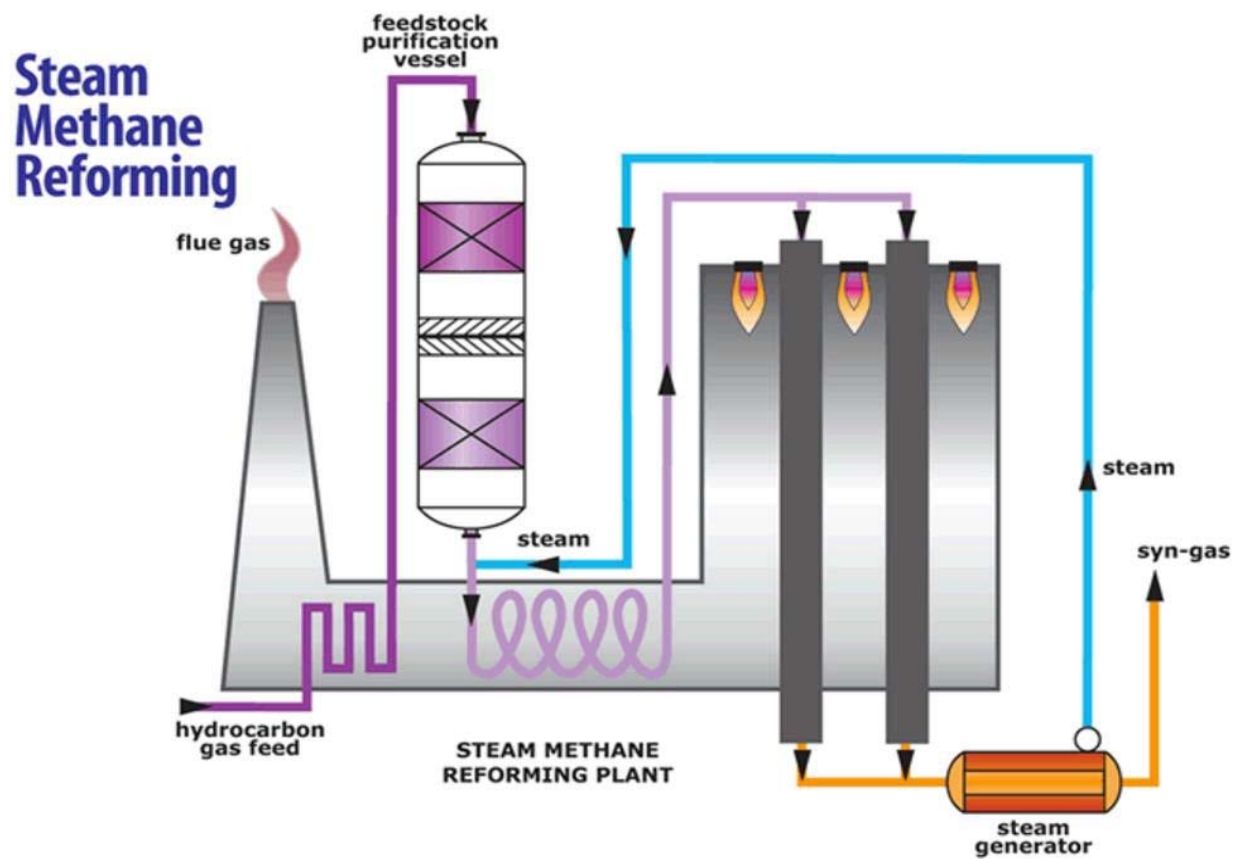
- Utilized for solid waste disposal when other means of disposal are impractical
 - Handles a wide variety of wastes, including the ability to consume refuse of high moisture content (garbage or food wastes)
 - Due to increasing stringency of air pollution codes, must include air pollution control systems
 - Rapid burning is required to increase efficiency (disposal capacity per square foot of floor area)



INCINERATOR



EXAMPLE FURNACE APPLICATION



REFERENCE MATERIALS



- *Engineering Data Book*. Tulsa, Okla. (6526 E. 60th St., Tulsa 74145): Gas Processors Suppliers Association, 1987. Print.