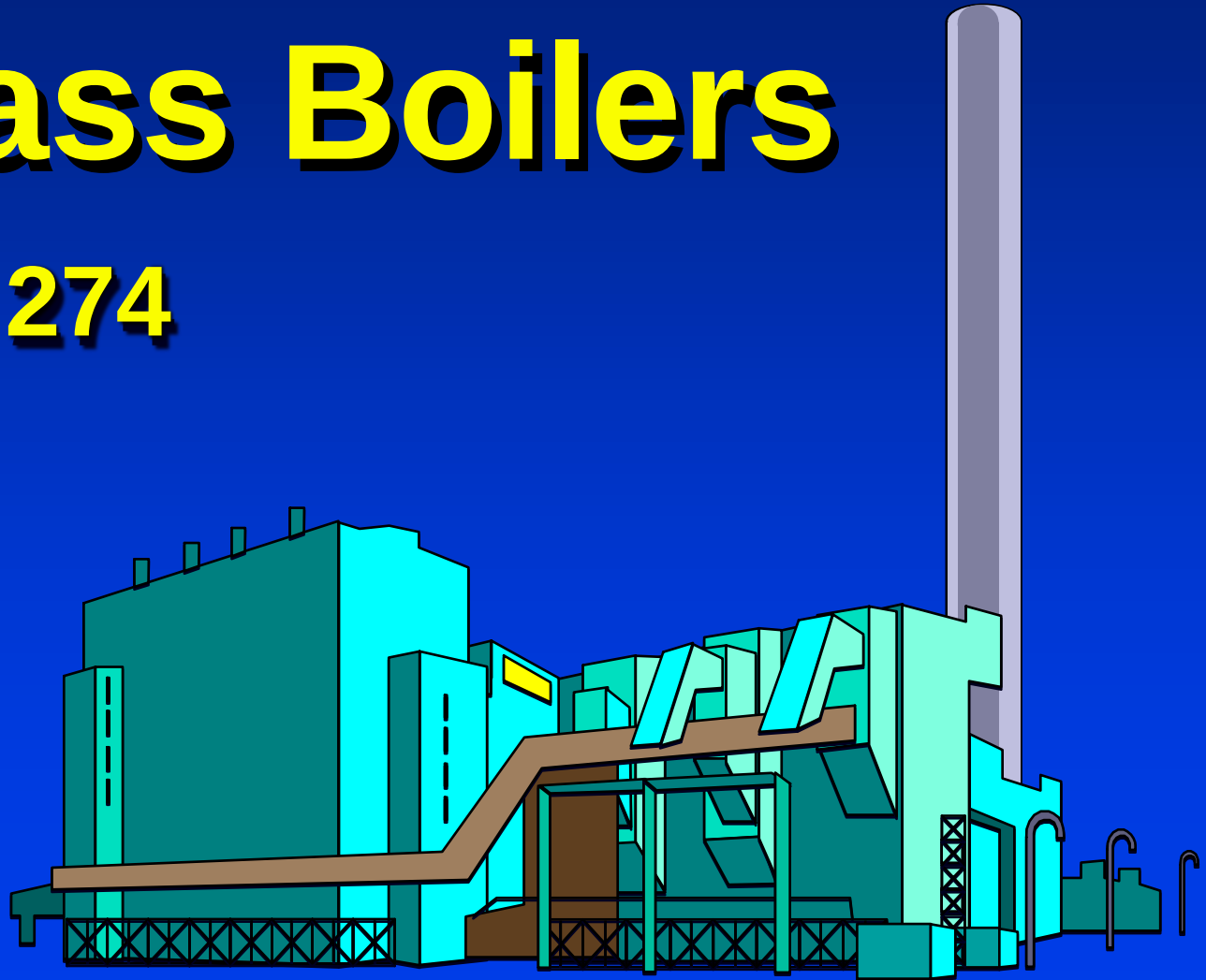




California Environmental Protection Agency

# Biomass Boilers

Course # 274



# Course Overview

- ◆ Air Pollution **Why**

- ◆ Boiler Uses **What**

- ◆ Boiler Theory and Operation

- ◆ Air Pollution Formation

- ◆ Air Pollution Control Devices

- ◆ Boiler Regulations **How**

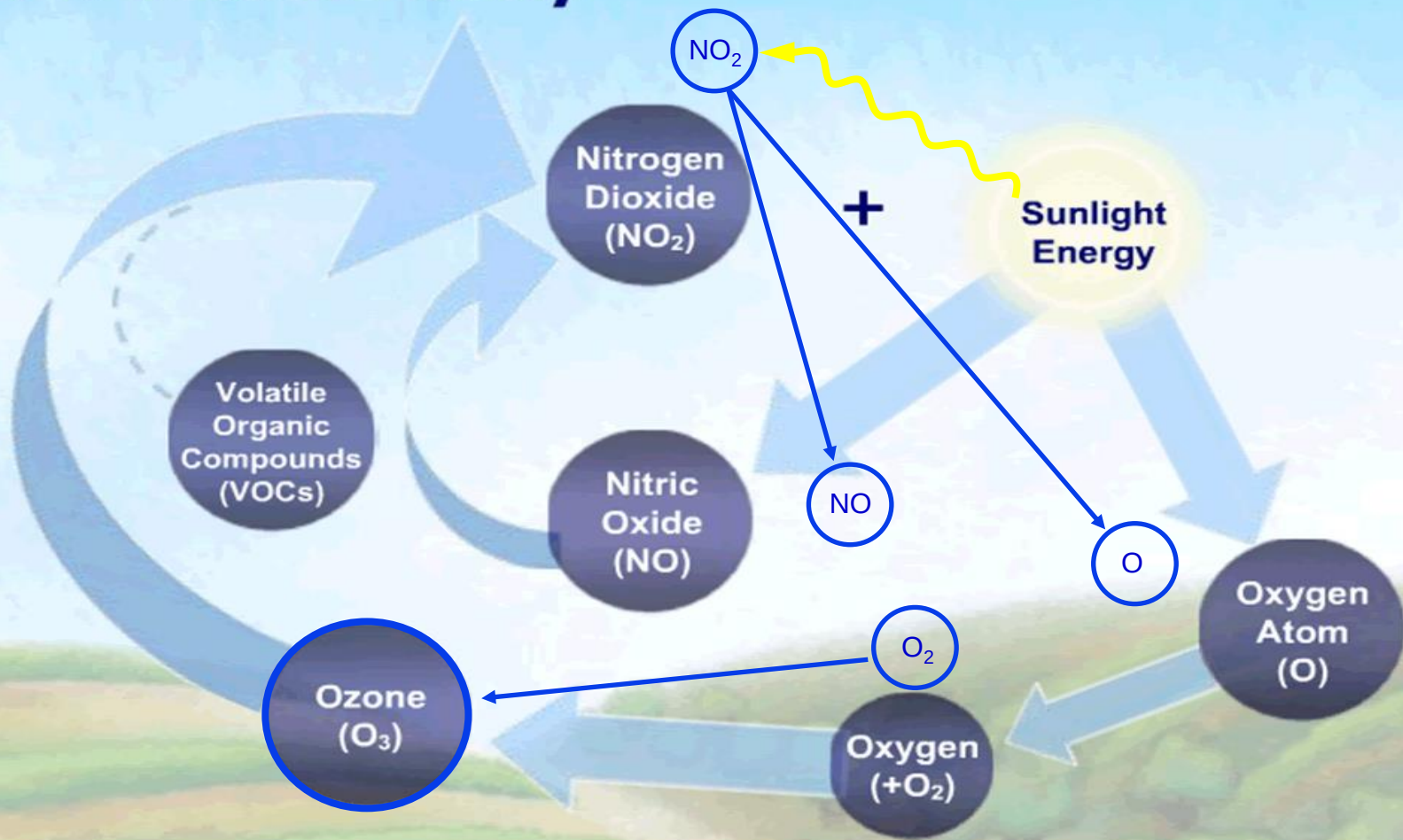
- ◆ Typical Permit Conditions

- ◆ Inspection Procedures





# Ozone Photochemistry



# Uses of Boilers

- ◆ **Electrical generation**      High Pressure (1,800 -3,800 psi)
- ◆ **Space heating**      Low Pressure (150 – 1,600 psi)
- ◆ **Food preparation**
- ◆ **Commercial laundries**
- ◆ **Pulp & paper industry**
- ◆ **Petroleum industry**
- ◆ **Chemical industry**



**Small  
Firetube  
Boiler**





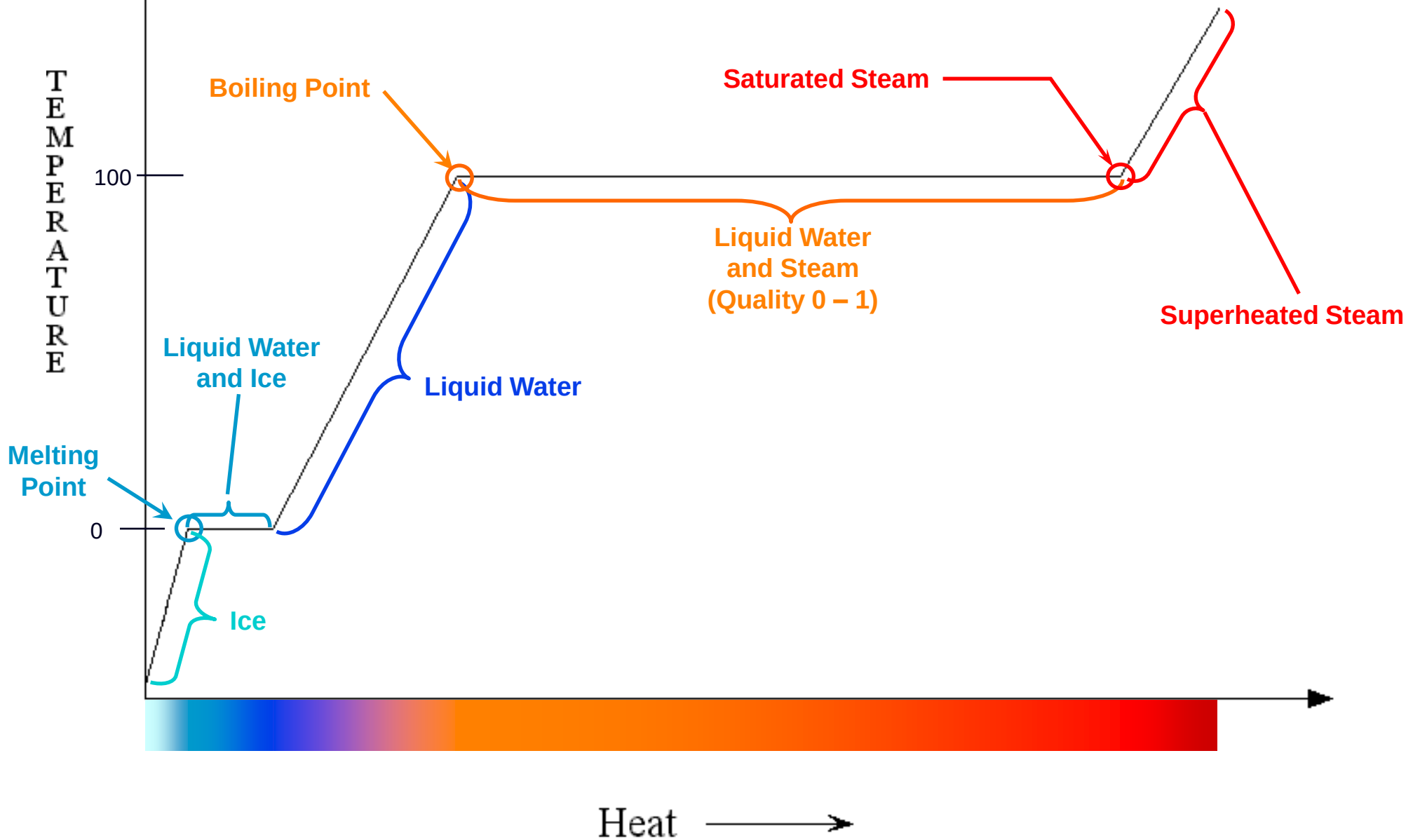
**Industrial  
Boiler**



# **Biomass Utility Boiler**



# Phase Changes of Water





# Hot Numbers

- ◆ **British Thermal Unit (BTU)**

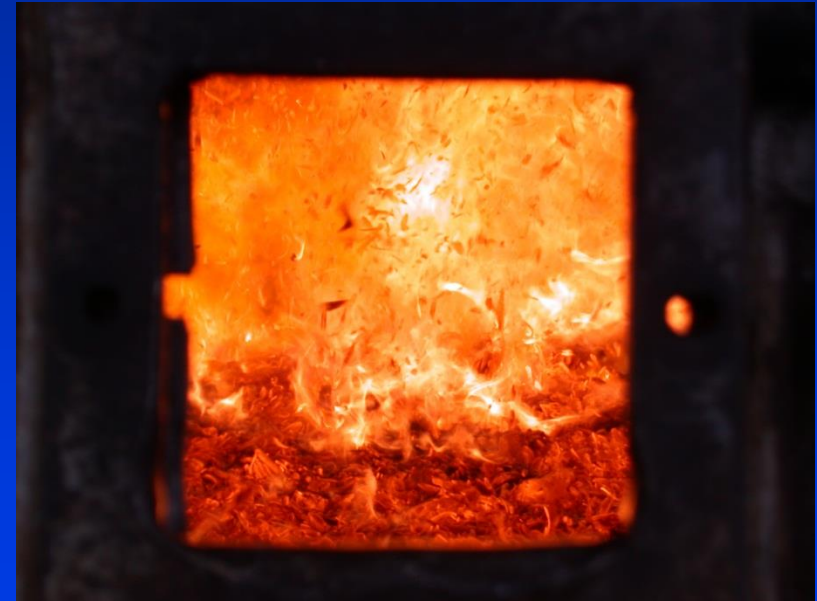
- ◆ 1 BTU the amount of energy needed to heat one pound of water one degree Fahrenheit or  $\approx$  energy given off by burning one wooden match

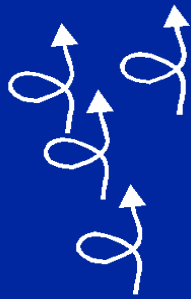
- ◆ **Lower Heating Value (LHV)**

- ◆ Heating value of a fuel not counting heat needed to vaporize water

- ◆ **Higher Heating Value (HHV)**

- ◆ Heating value of a fuel including heat needed to vaporize water





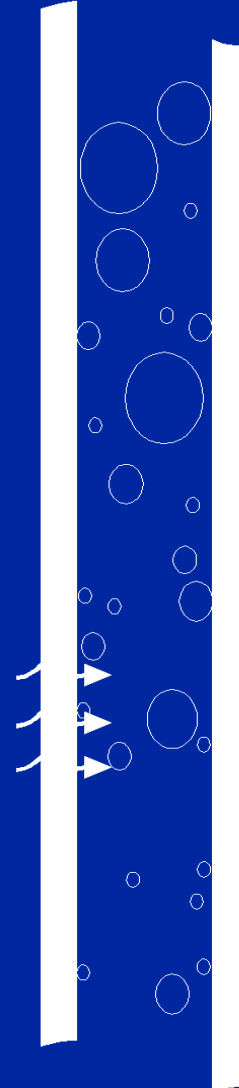
**CONVECTION**  
HOT GASES  
TRANSFER HEAT  
TO THE TUBE

**RADIATION**



HEAT TRANSFER  
THRU SPACE

**CONDUCTION**  
HEAT TRANSFER  
THRU THE  
METAL TUBE  
WALL



# Heat Transfer Methods





**Boilers &  
Opacity**



**What Opacity is This?**





# **Boiler Ratings**

**Millions of BTU/hr**  
**Boiler HP**  
**Pounds of Steam/hr**  
**Megawatts**  
**Tons per day**



COMBUSTION ENGINEERING, INC.

NEW



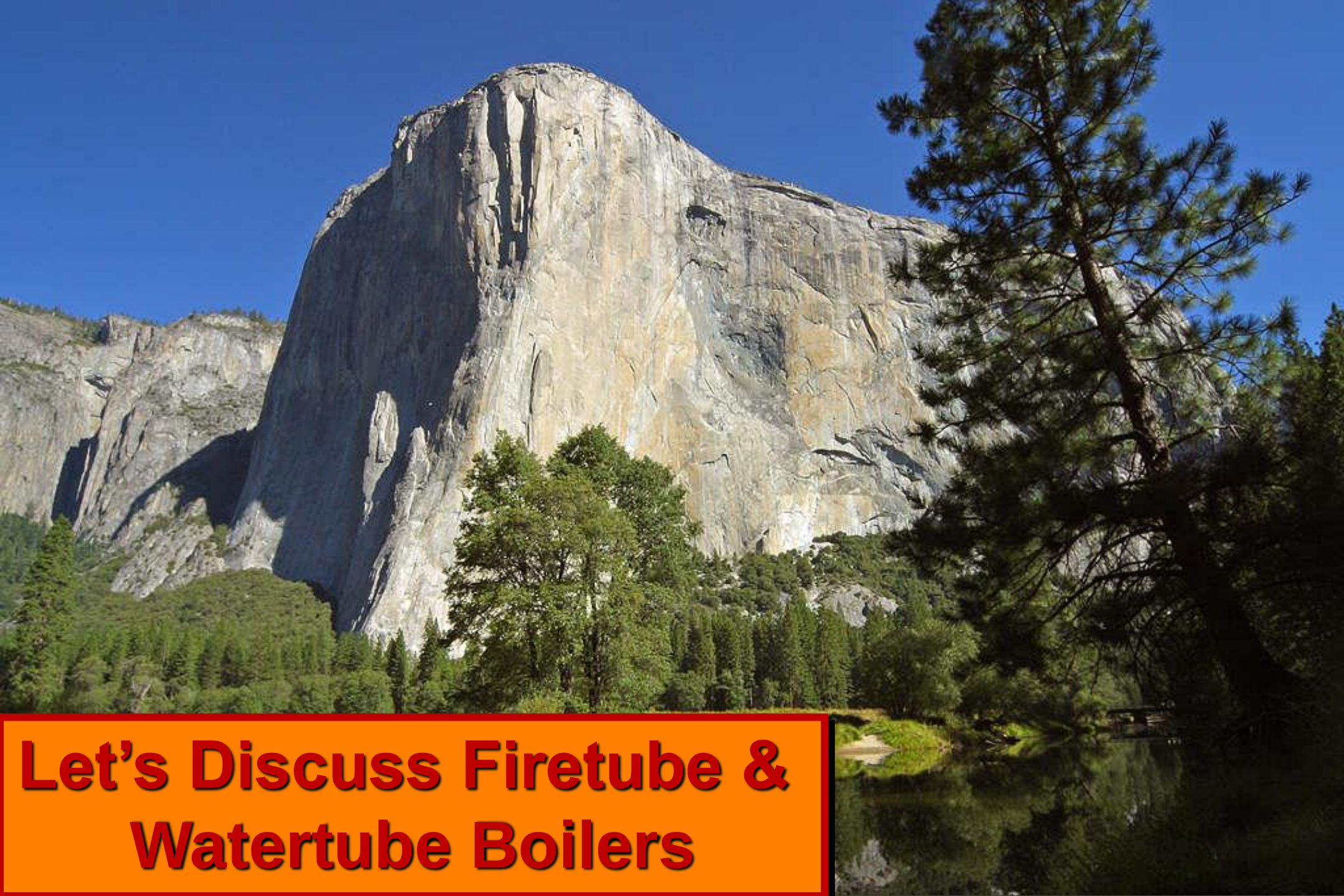
YORK

# C-E STEAM GENERATOR

|                         |                  |              |            |             |         |
|-------------------------|------------------|--------------|------------|-------------|---------|
| RATED STEAMING CAPACITY | 1,540,000 LB/HR  | MAX PRESSURE | 2300 PSI   | SUPERHEATER | 955°F   |
| REHEATER CAPACITY       | 1,452,500 LB/HR  | MAX PRESSURE | 650 PSI    | TEMPERATURE | 865°F   |
| HEATING SURFACES        | SQ. FT. : BOILER | WATER WALLS  | 32,980     | ECONOMIZER  | 115,000 |
| BUILT TO A S M E        |                  | RULES        |            |             |         |
| CONTRACT NO.            | 6468             | MFR'S NO.    | 20942      | TYPE        | RRP     |
|                         |                  |              | YEAR BUILT | 1970        |         |

Typical Boiler Rating





**Let's Discuss Firetube &  
Watertube Boilers**



EXHAUST  
GASES

# Fire-Tube Boiler

STEAM TO PROCESS

STACK

STEAM DRUM

HEAT  
EXCHANGE  
TUBES

BOILING WATER

PARTITION  
PLATE

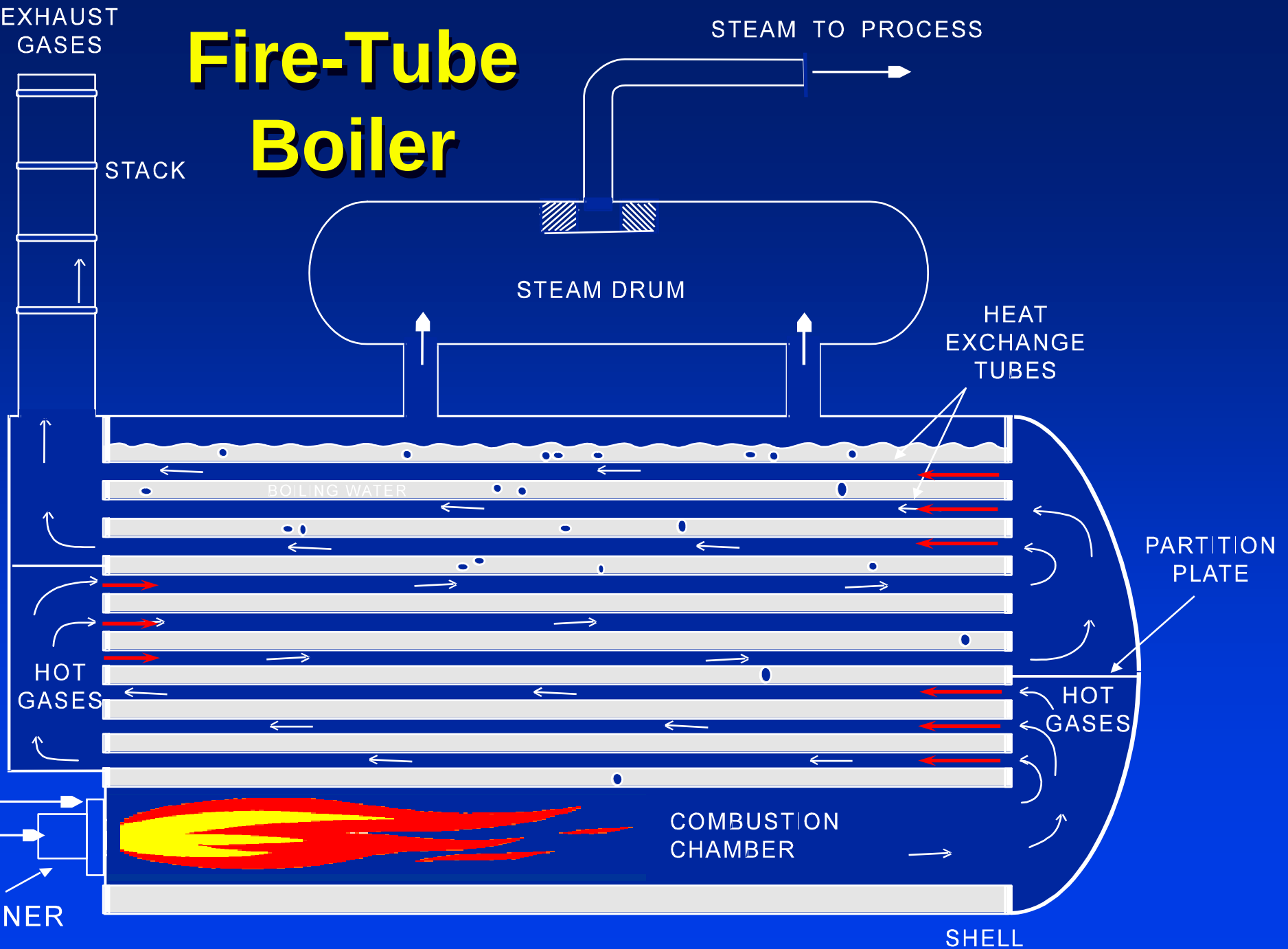
HOT  
GASES

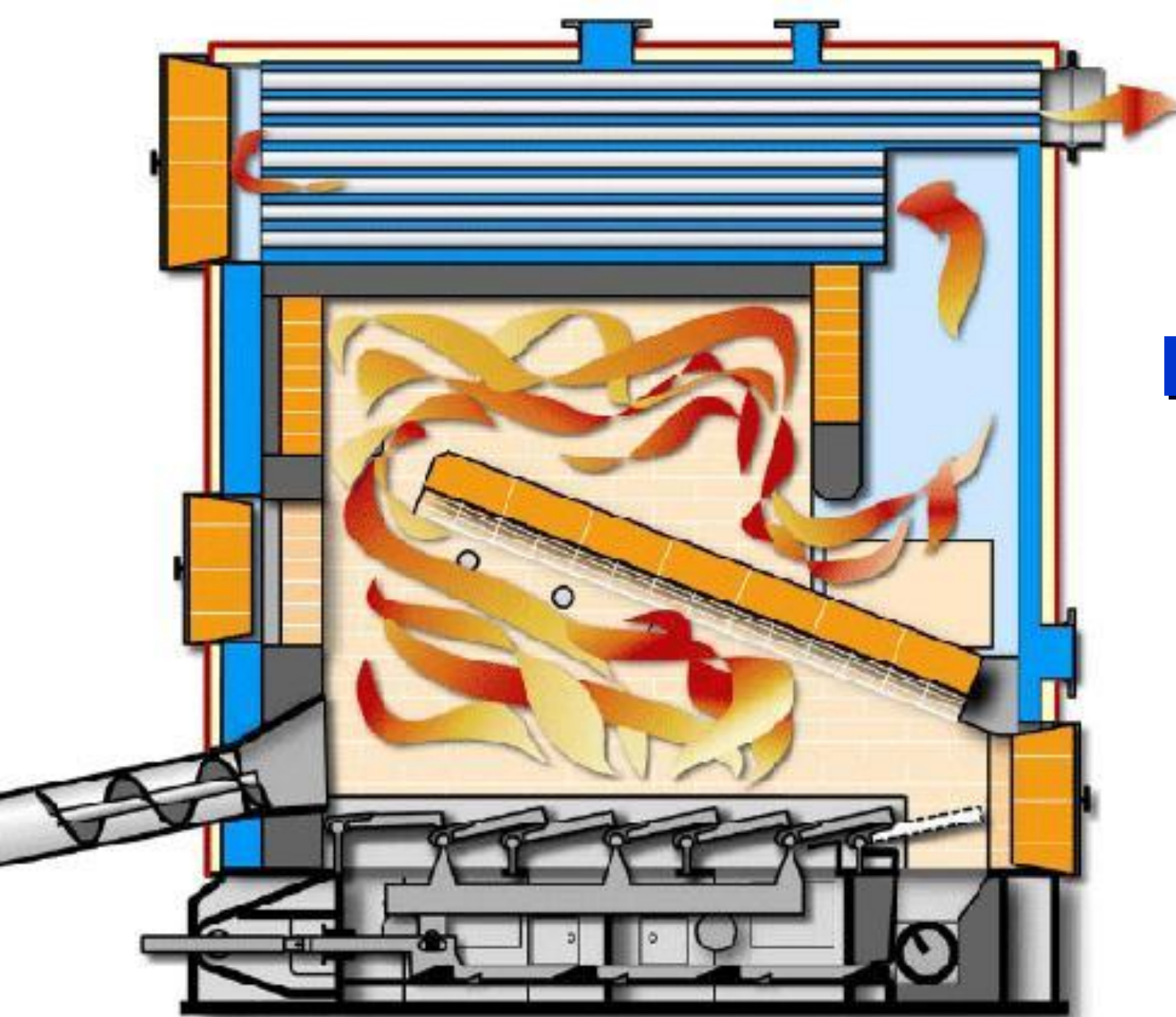
HOT  
GASES

AIR  
FUEL  
BURNER

COMBUSTION  
CHAMBER

SHELL

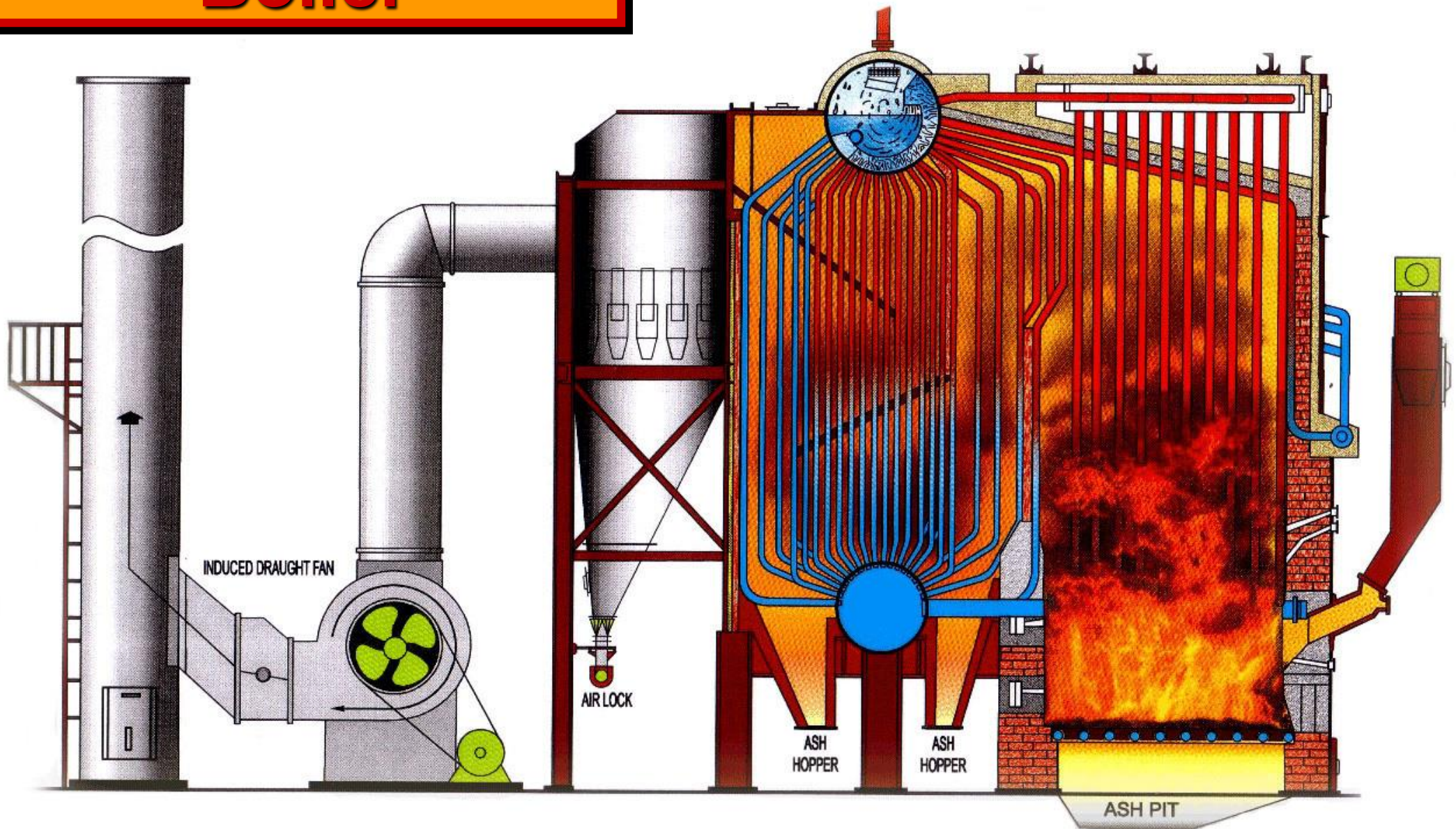




**Fire-Tube  
Boiler**



# Water-Tube Boiler







**Hybrid Boiler**





**Fire Wall**





**Boiler Tubes**

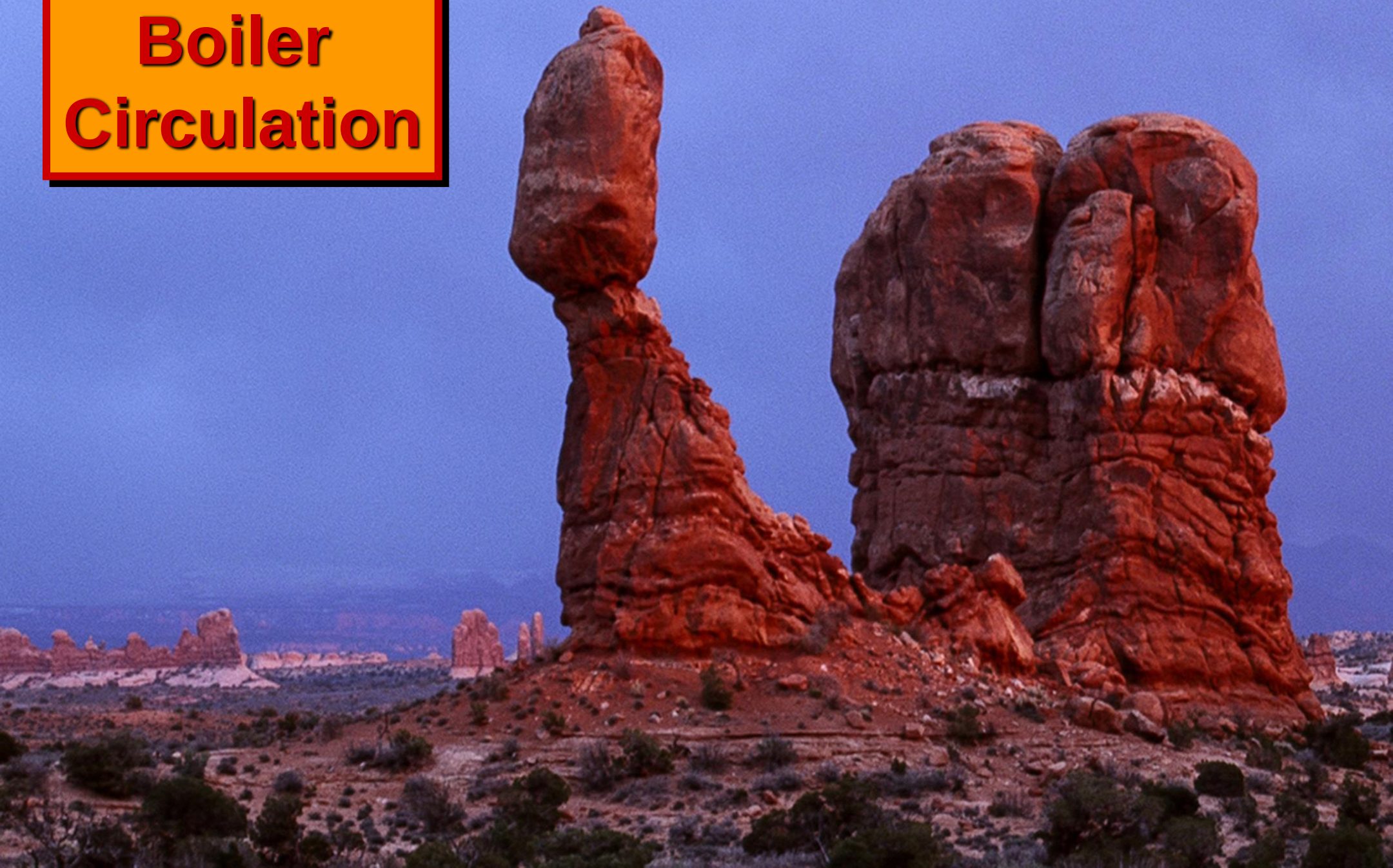




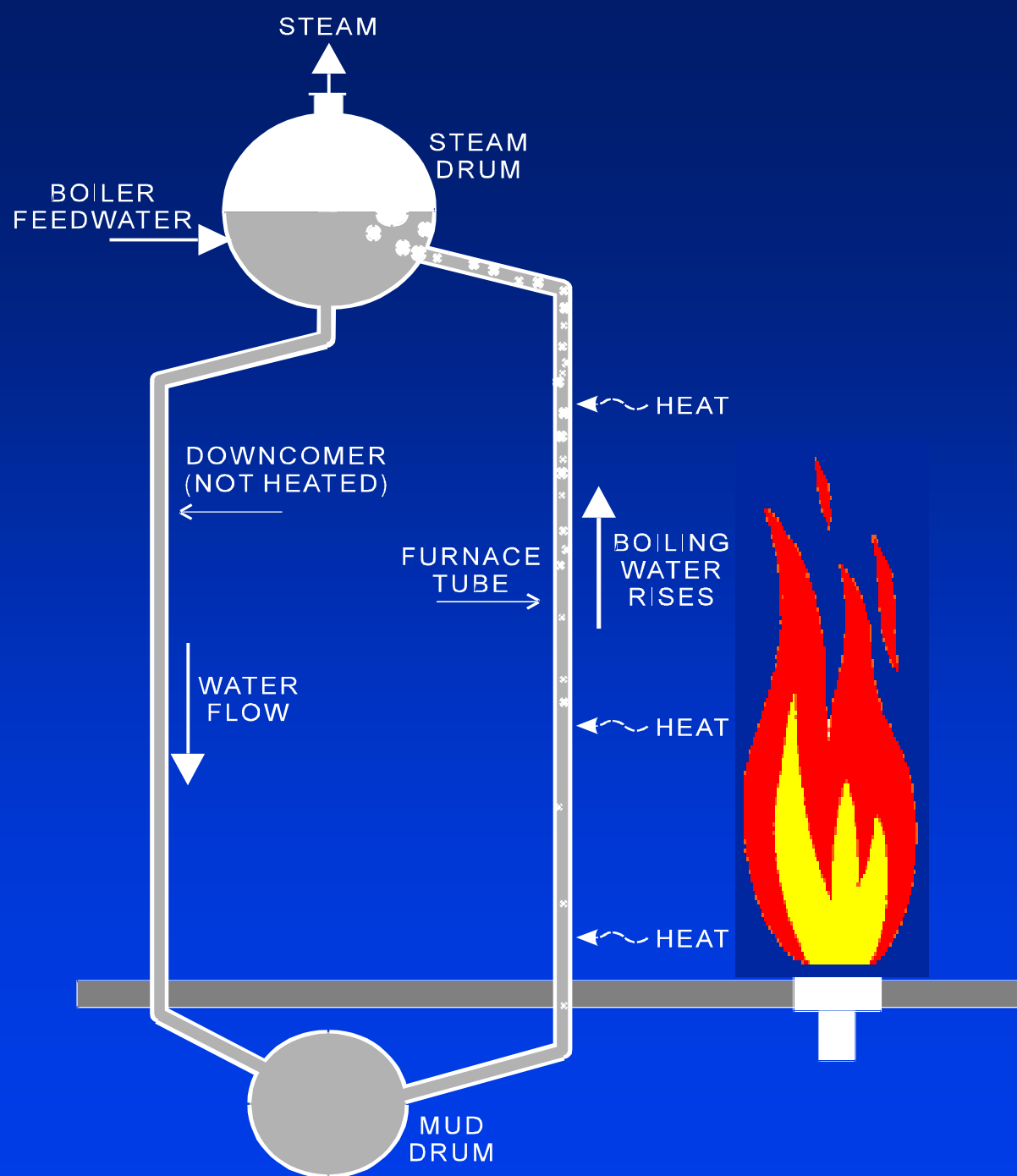
**Boiler Tubes with Fins**



# **Boiler Circulation**

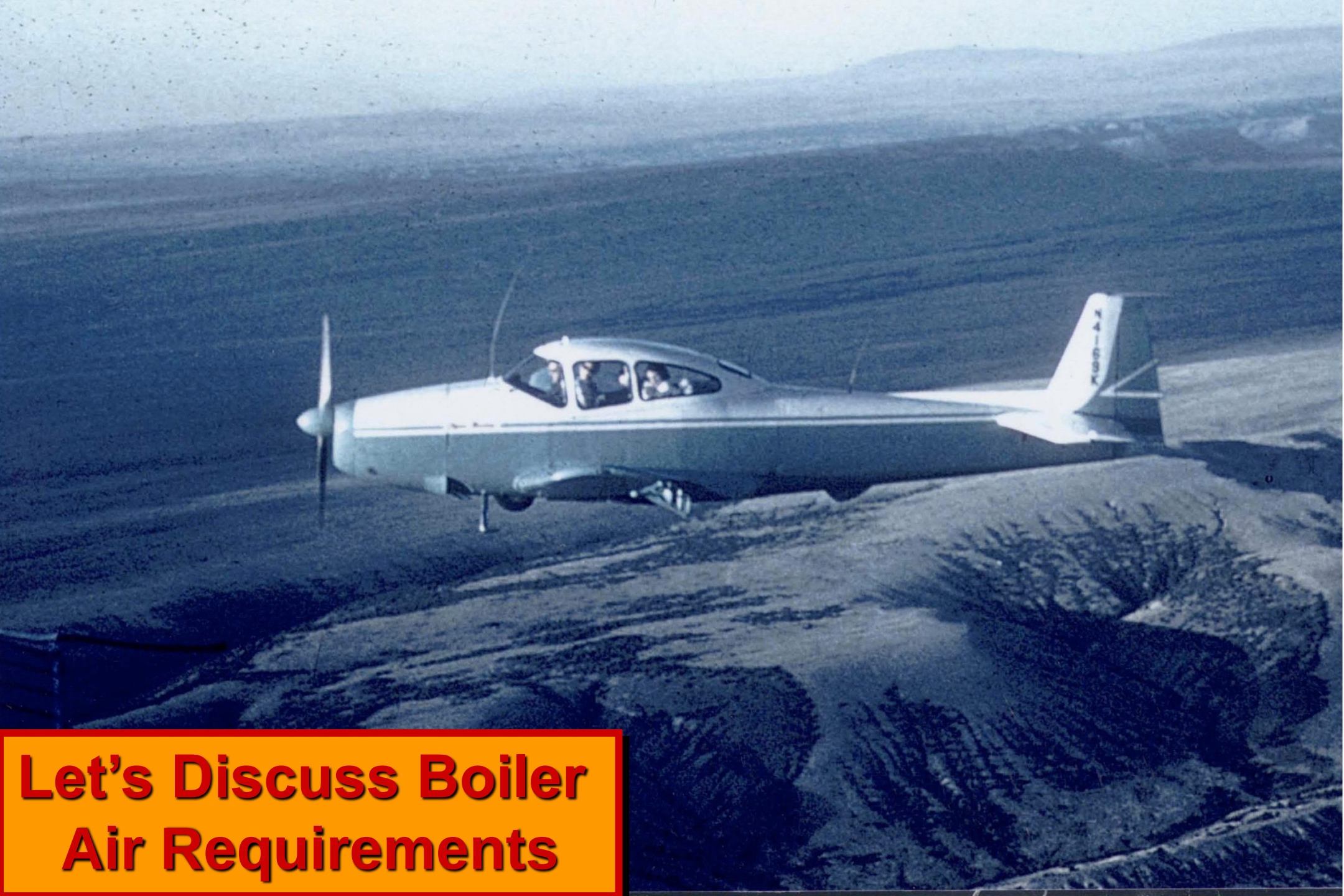






# Water to Steam Circulation Loop





**Let's Discuss Boiler  
Air Requirements**



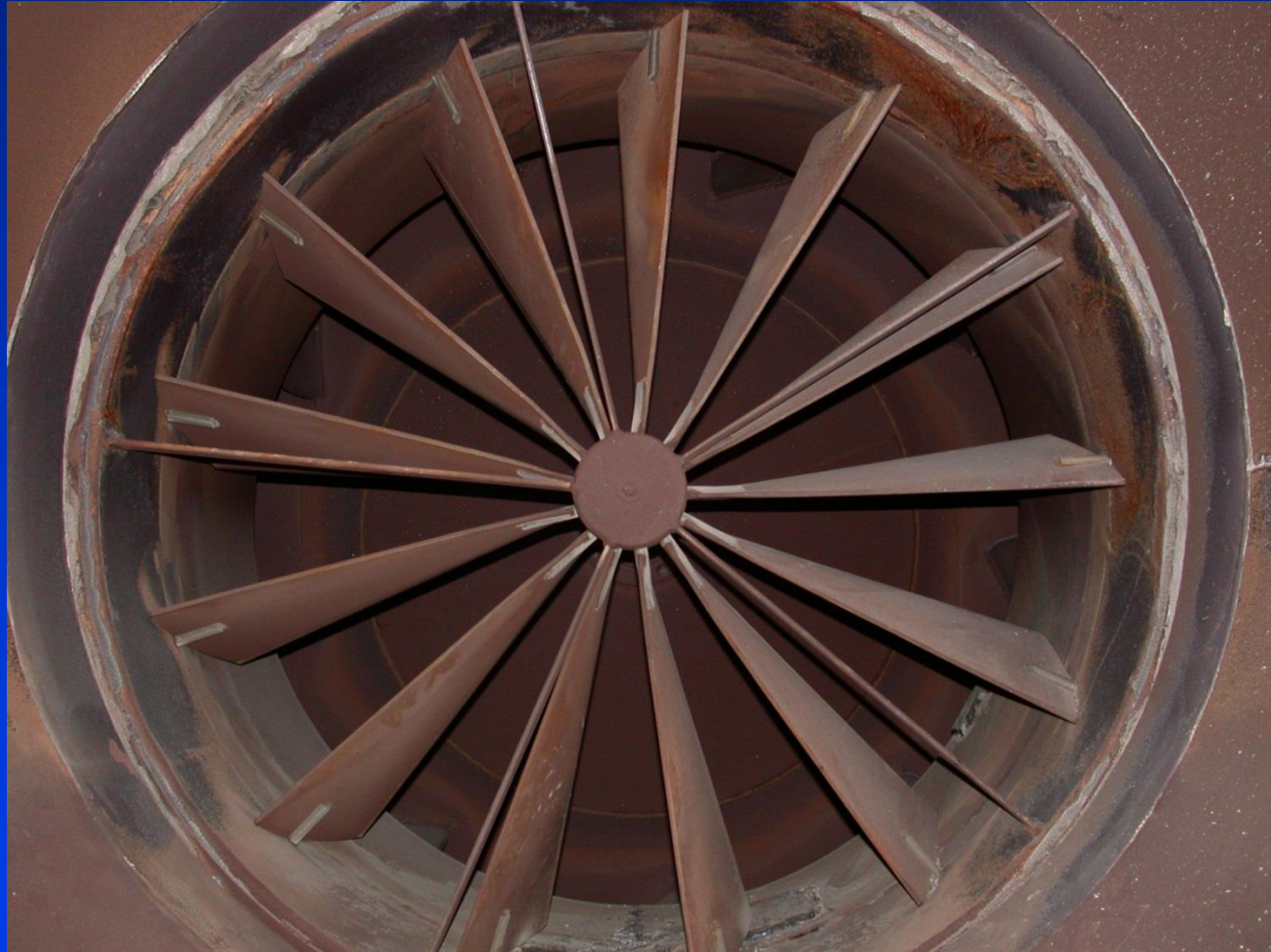
# Boiler Air Requirements

- ◆ **Draft**

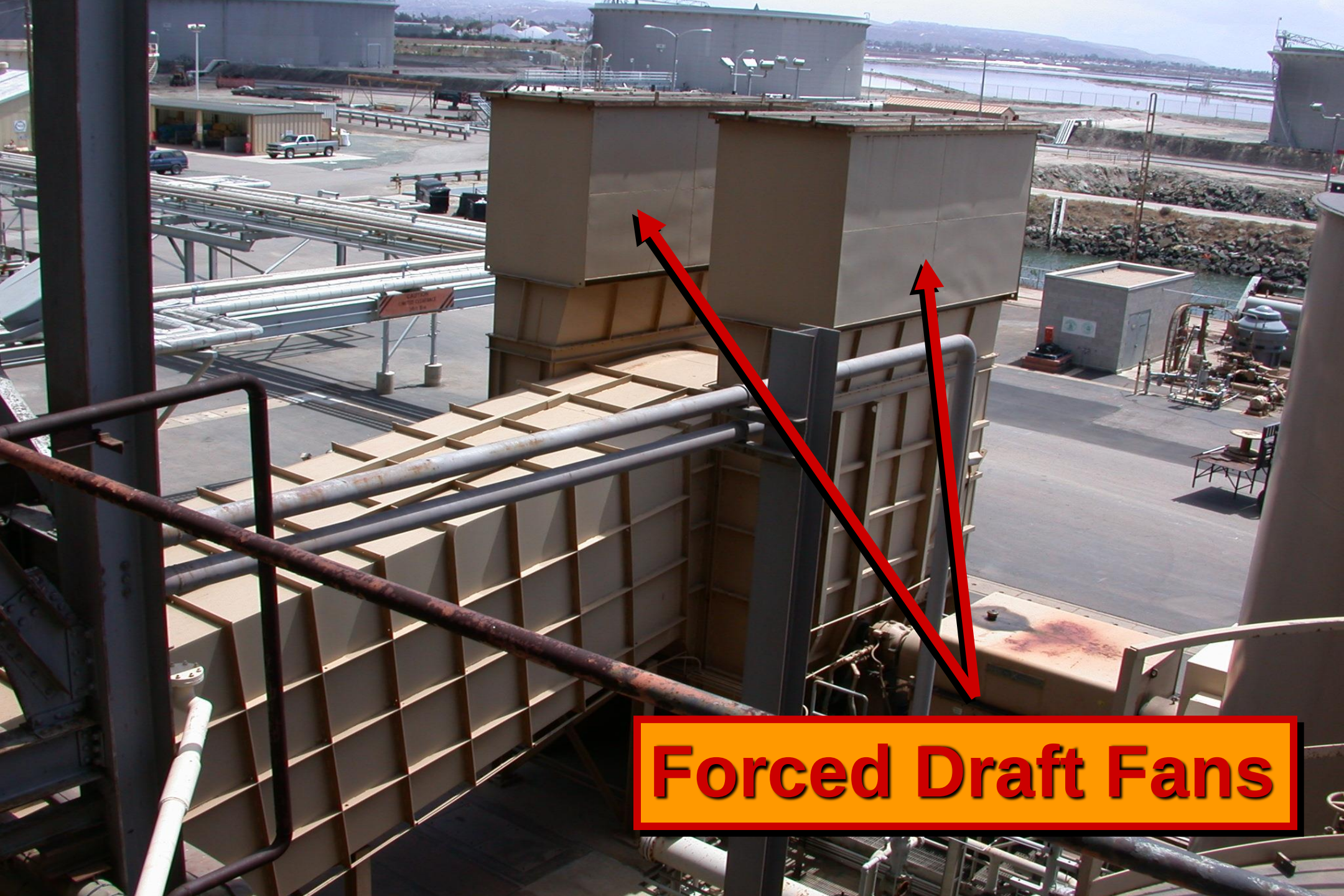
- ◆ **Natural**
- ◆ **Forced**
- ◆ **Induced**

- ◆ **Combustion air**

- ◆ **Primary**
- ◆ **Secondary**
- ◆ **Excess**







**Forced Draft Fans**



# Induced Draft Fans

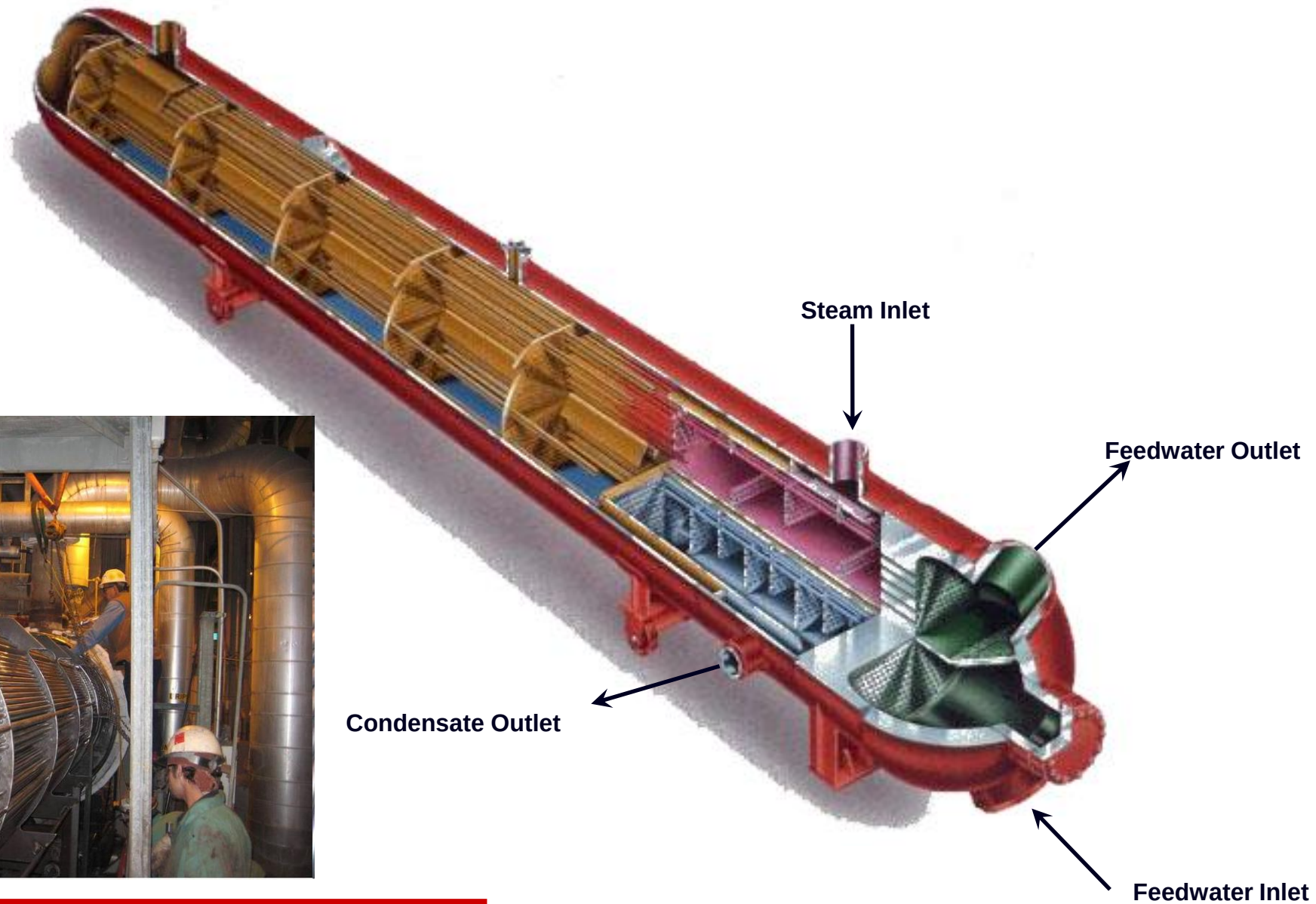






**Let's Discuss Economizers,  
Feedwater Heaters & Air-Preheaters**





**Feedwater Heater**

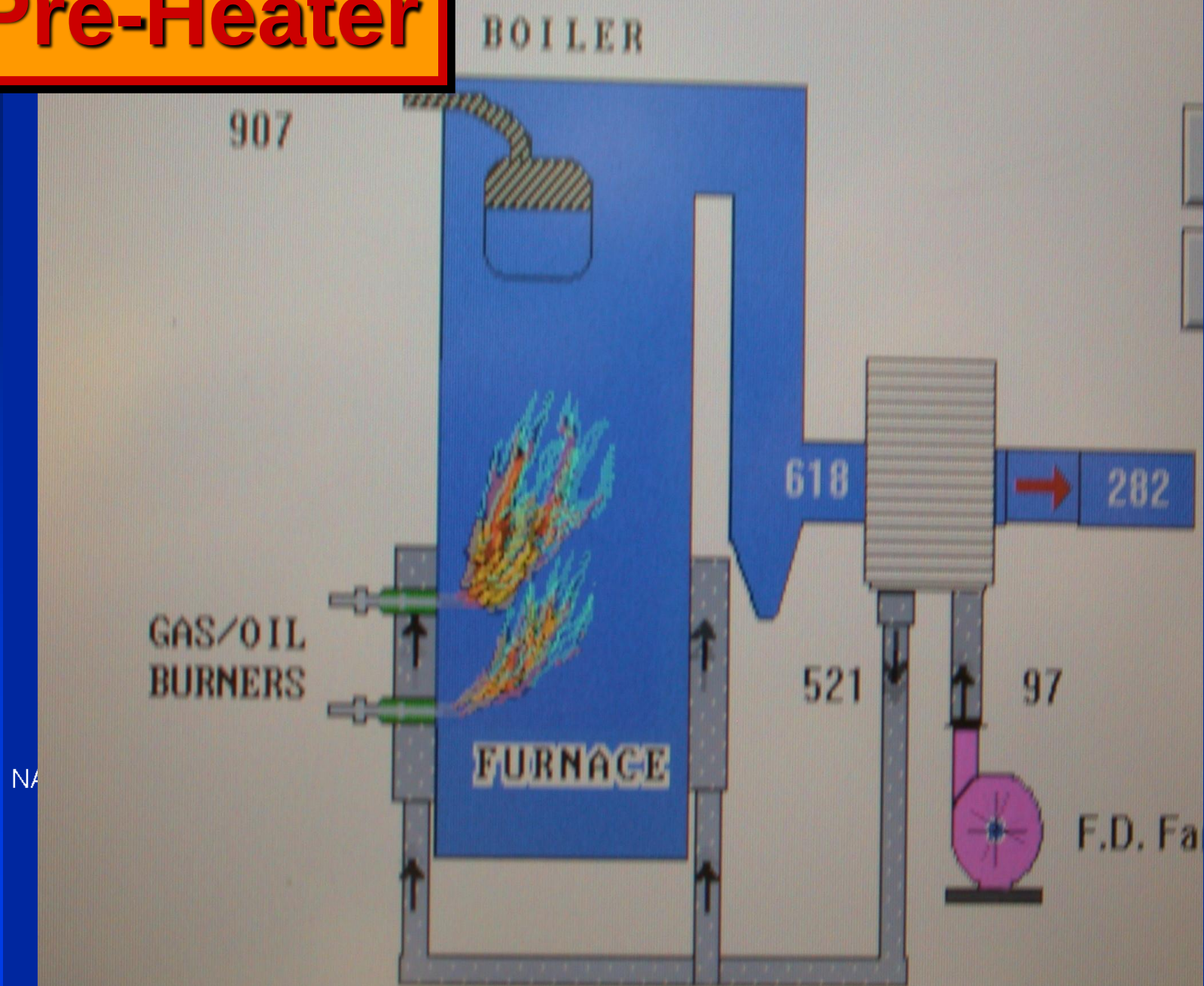


# Economizer – H<sub>2</sub>O Inside Tubes





# Air Pre-Heater



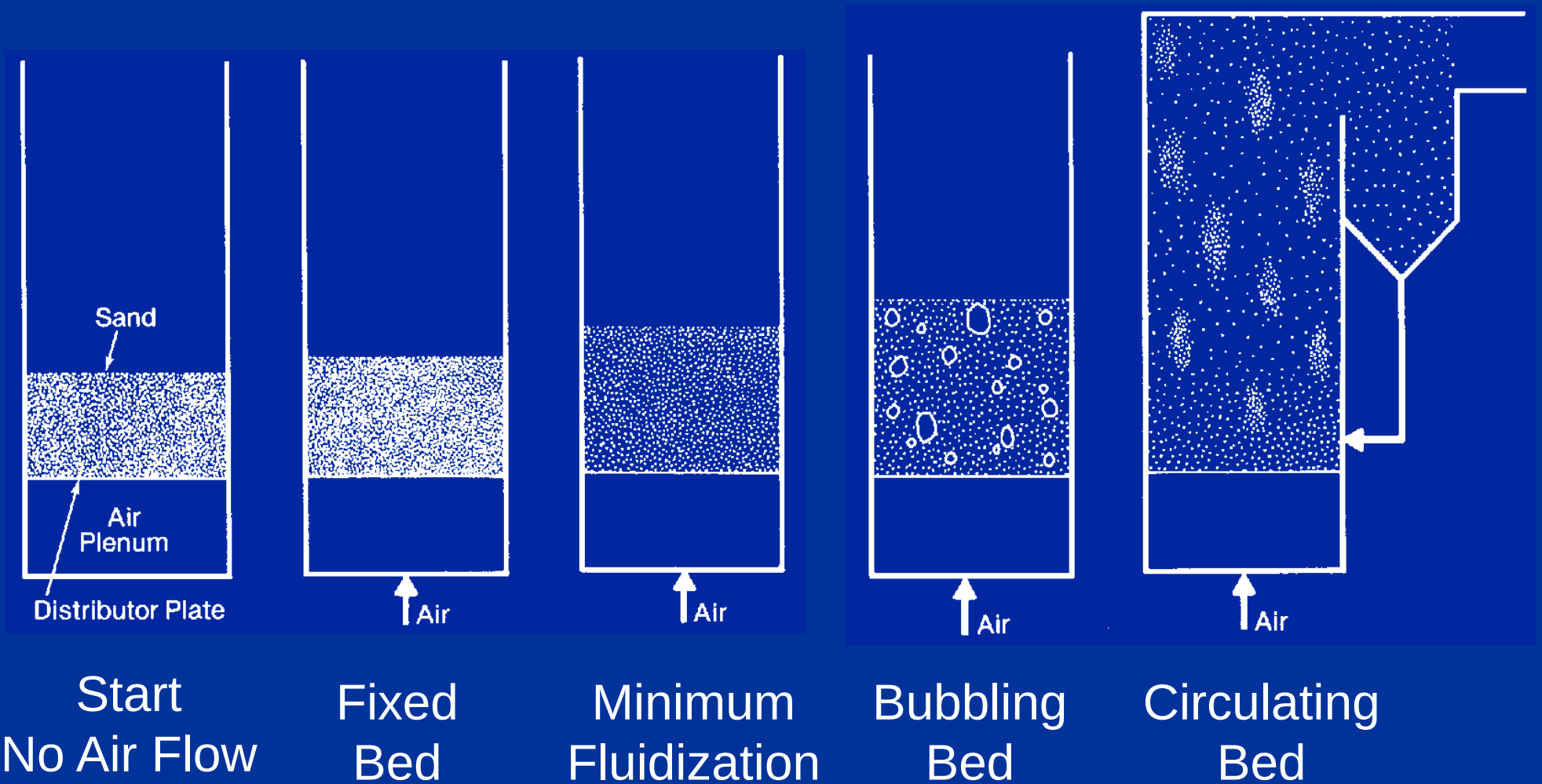




**Let's Discuss Fluidized  
Bed Boilers**

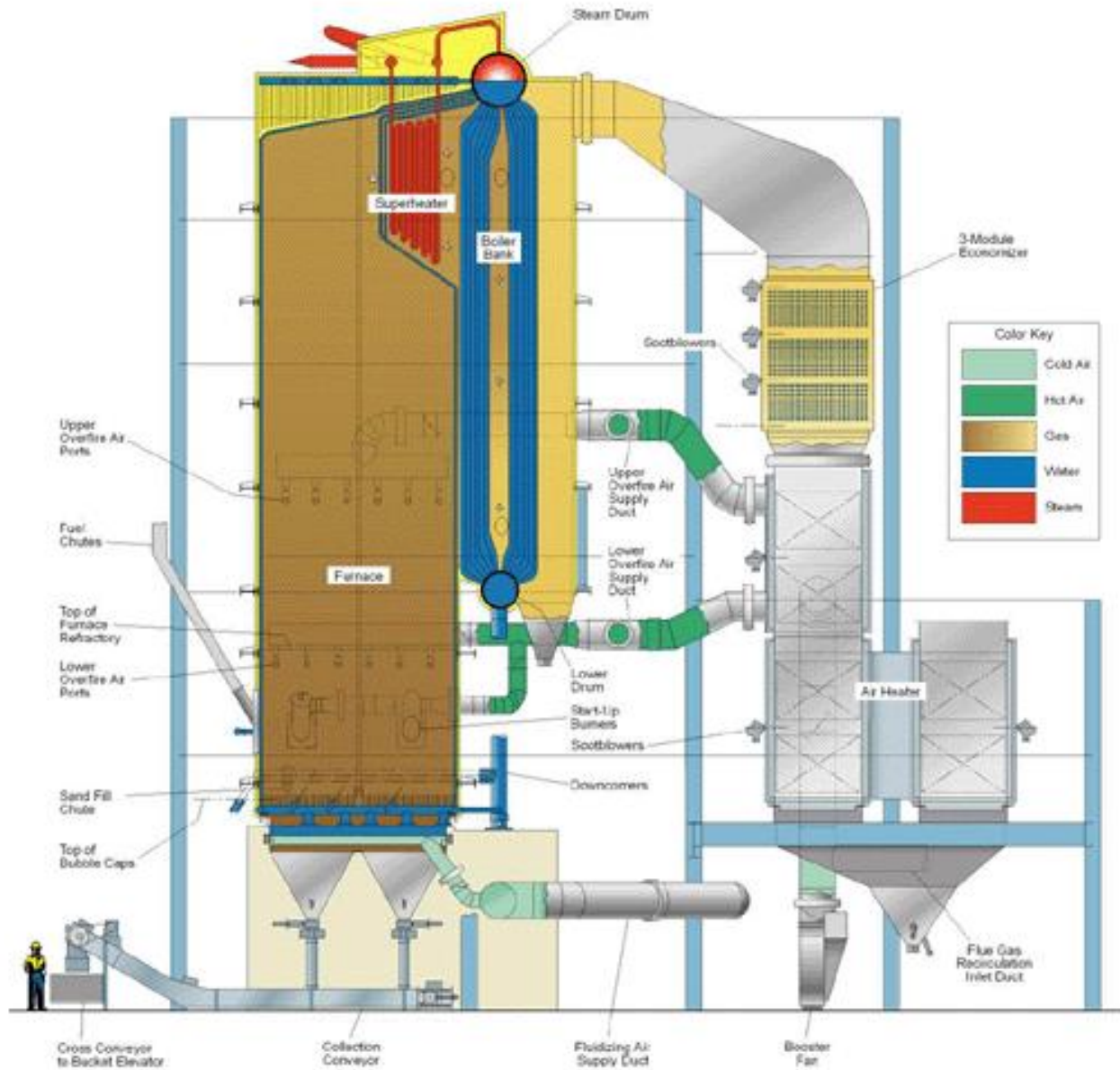


# Fluidized Bed Modes





## BFB Bottom Supported



# Bubbling Fluidized Bed (BFB)

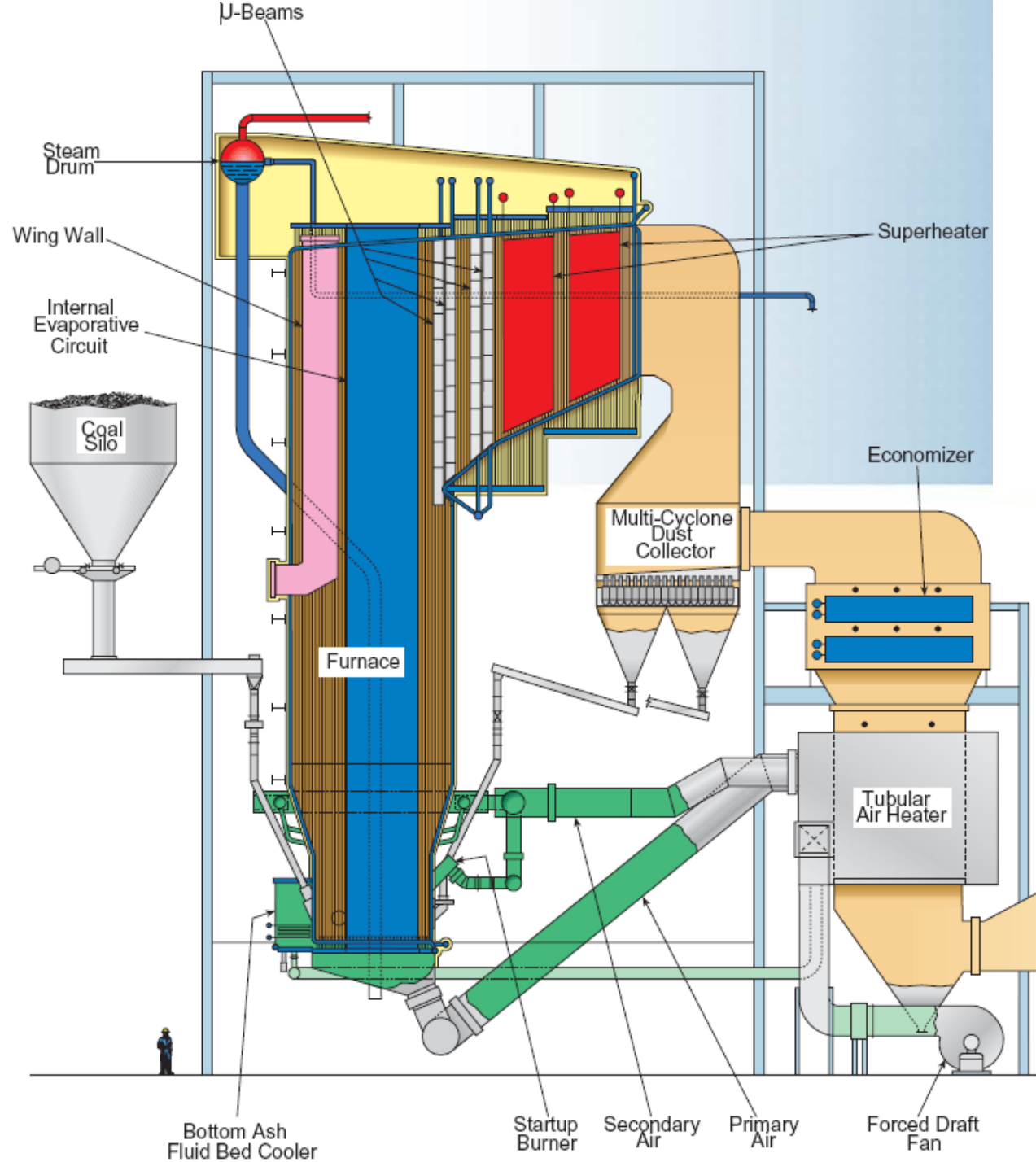




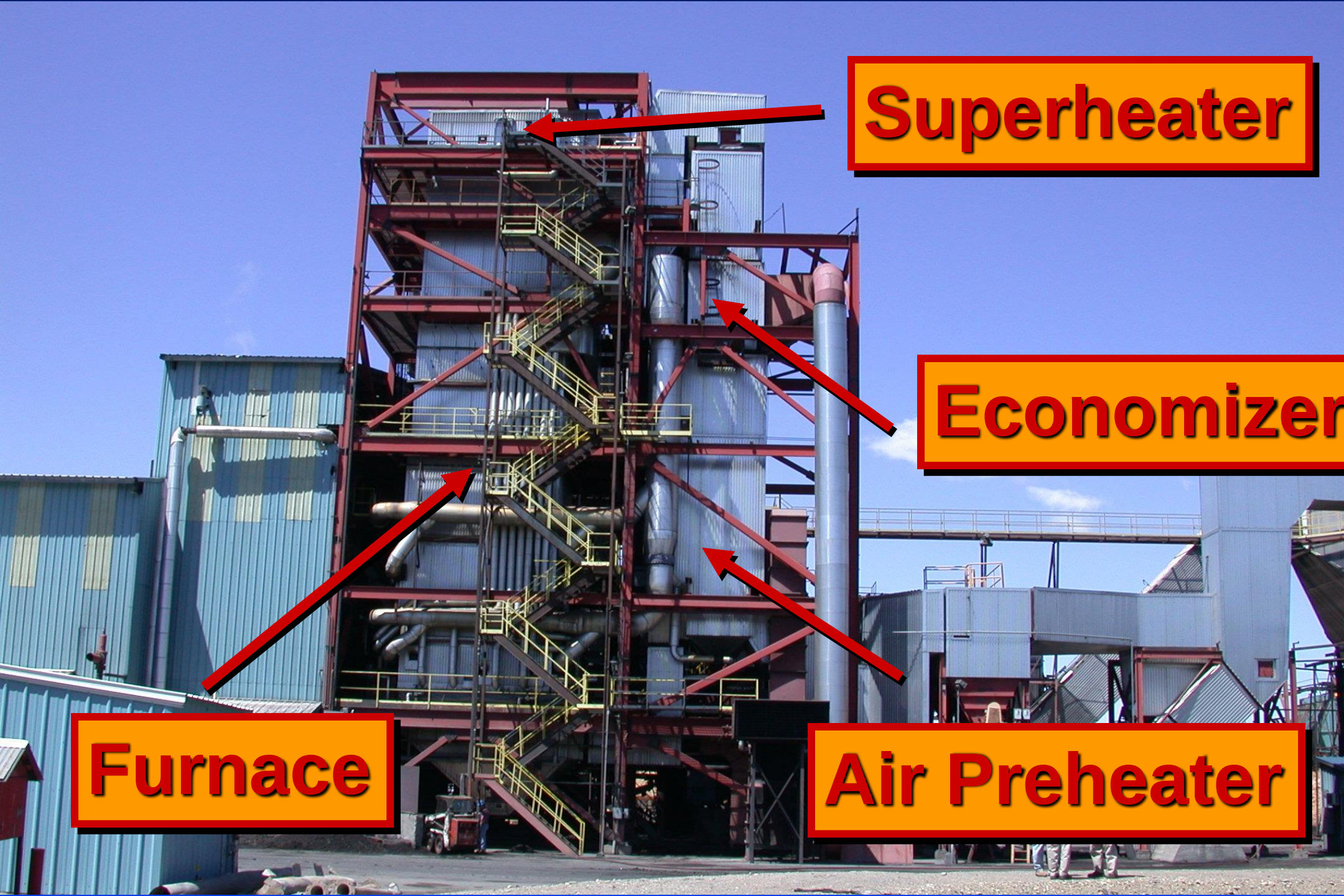
**Circulating Fluidized Bed (CFB) Boilers**



# Circulating Fluidized Bed Boiler







**Superheater**

**Economizer**

**Furnace**

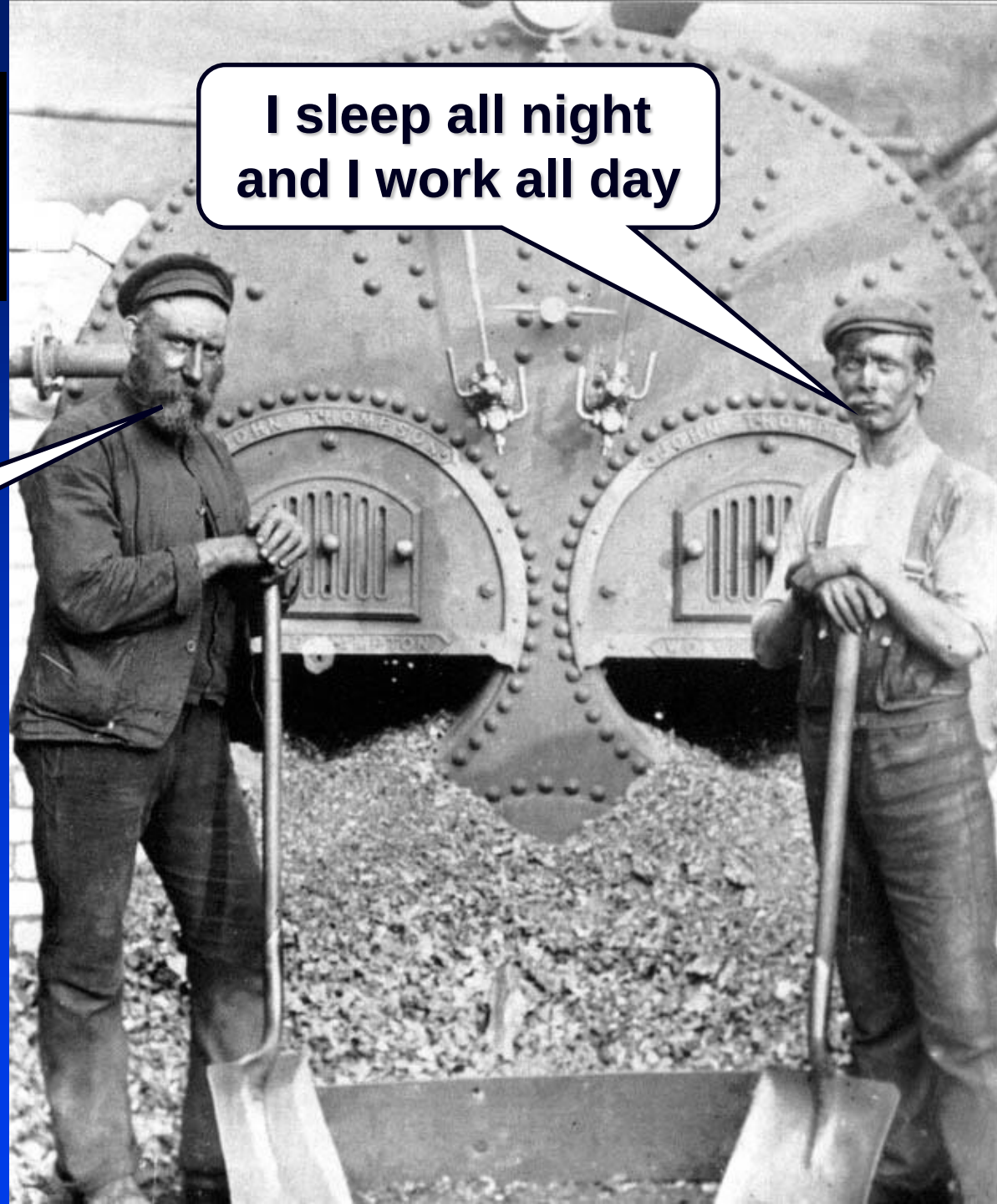
**Air Preheater**



# Let's Discuss Stoker Boilers

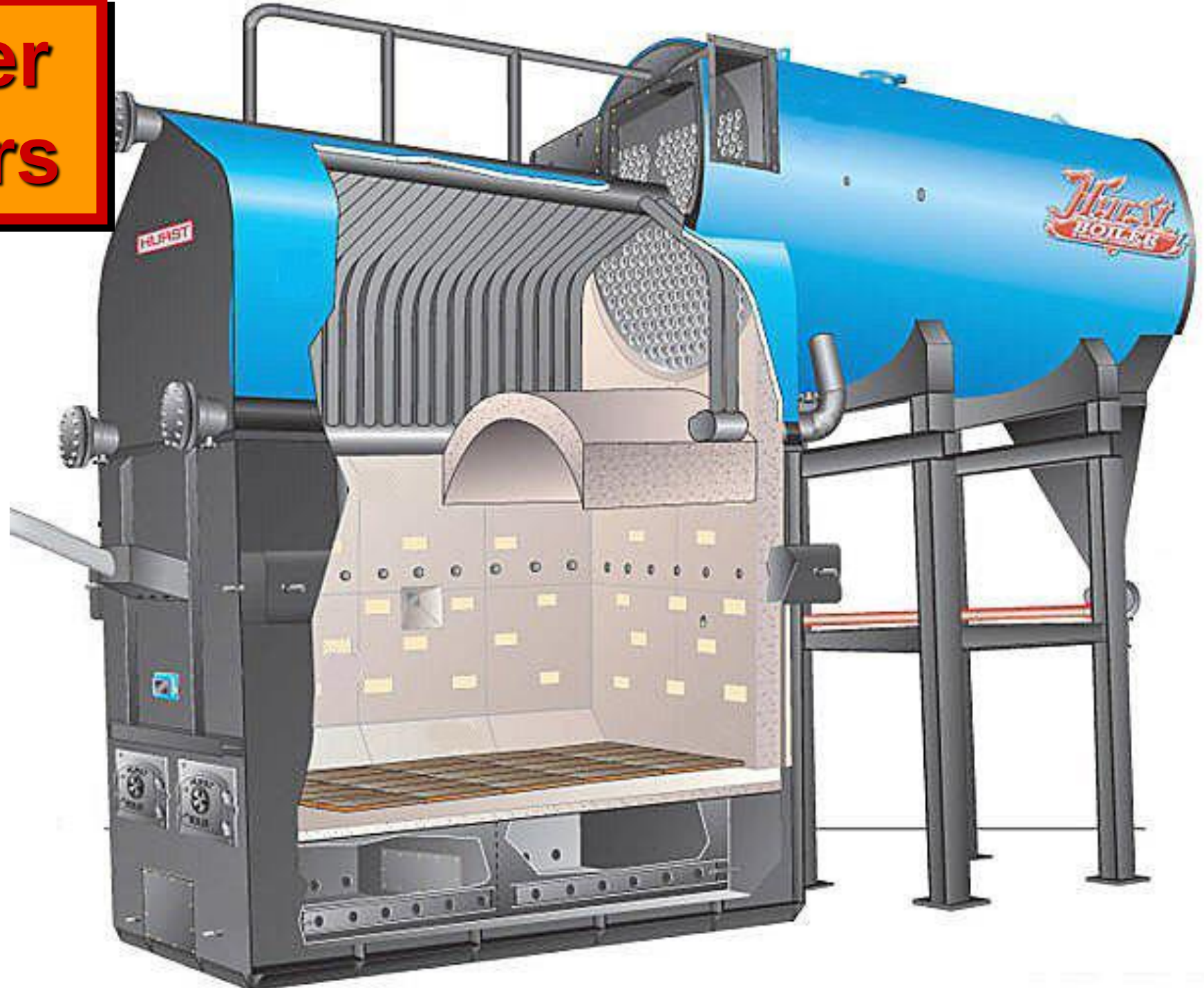
I'm a STOKER  
jack and I'm Ok

I sleep all night  
and I work all day





# Stoker Boilers





# Stoker Boilers





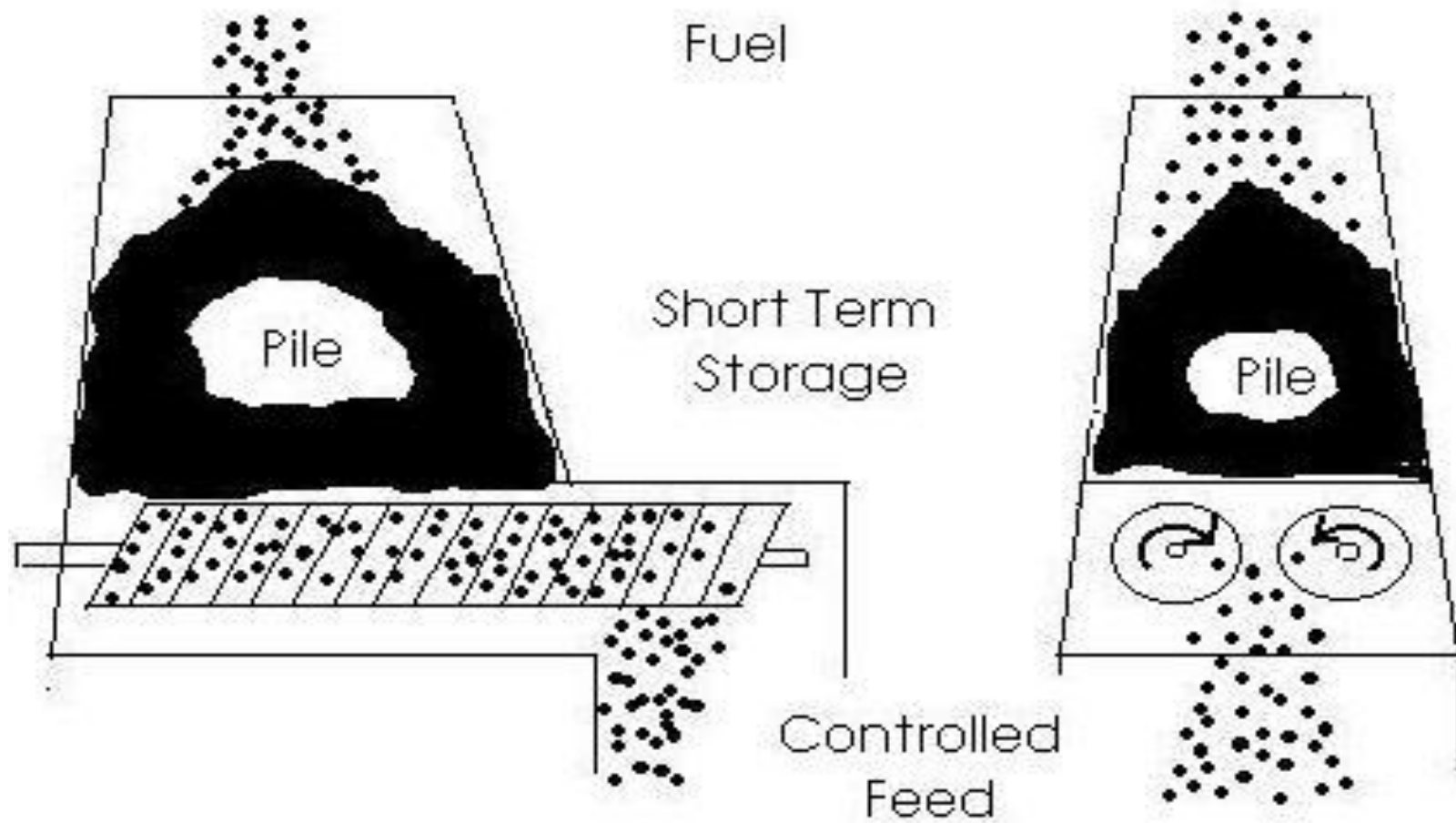
# ***Combustion Using a Stoker Boiler***

- ♦ **“Stoker” involves combustion on a grate**
- ♦ **Fuel Distribution Onto the Grate**
- ♦ **Undergrate or Underfire Air**
- ♦ **Overfire Air**
- ♦ **Three Steps of Biomass Combustion**
  - ♦ **Step 1 - Drying**
  - ♦ **Step 2 - Gasification and Volatile burnout**
  - ♦ **Step 3 - Char Burnout (Step #3) on the grate**



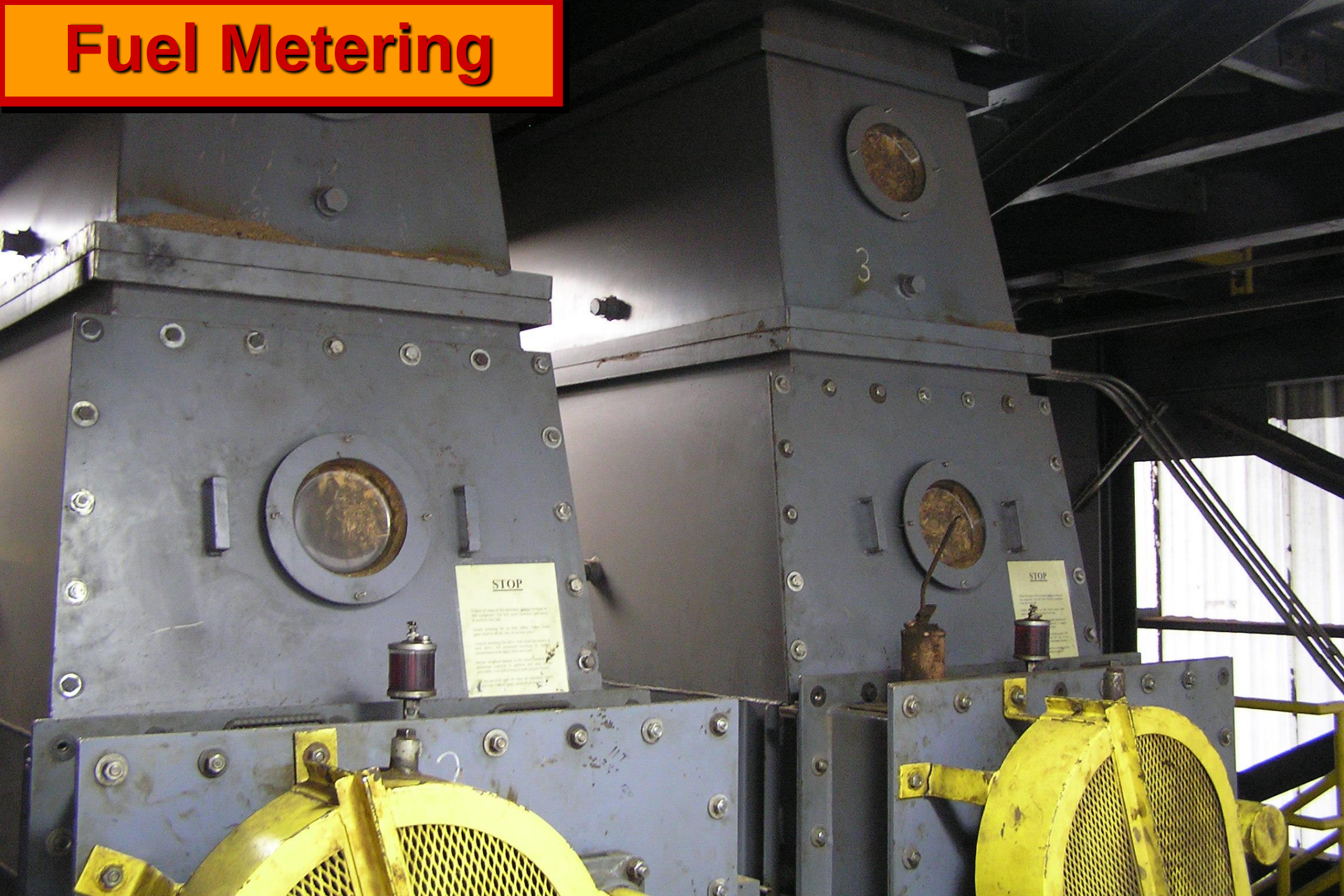


# Fuel Metering



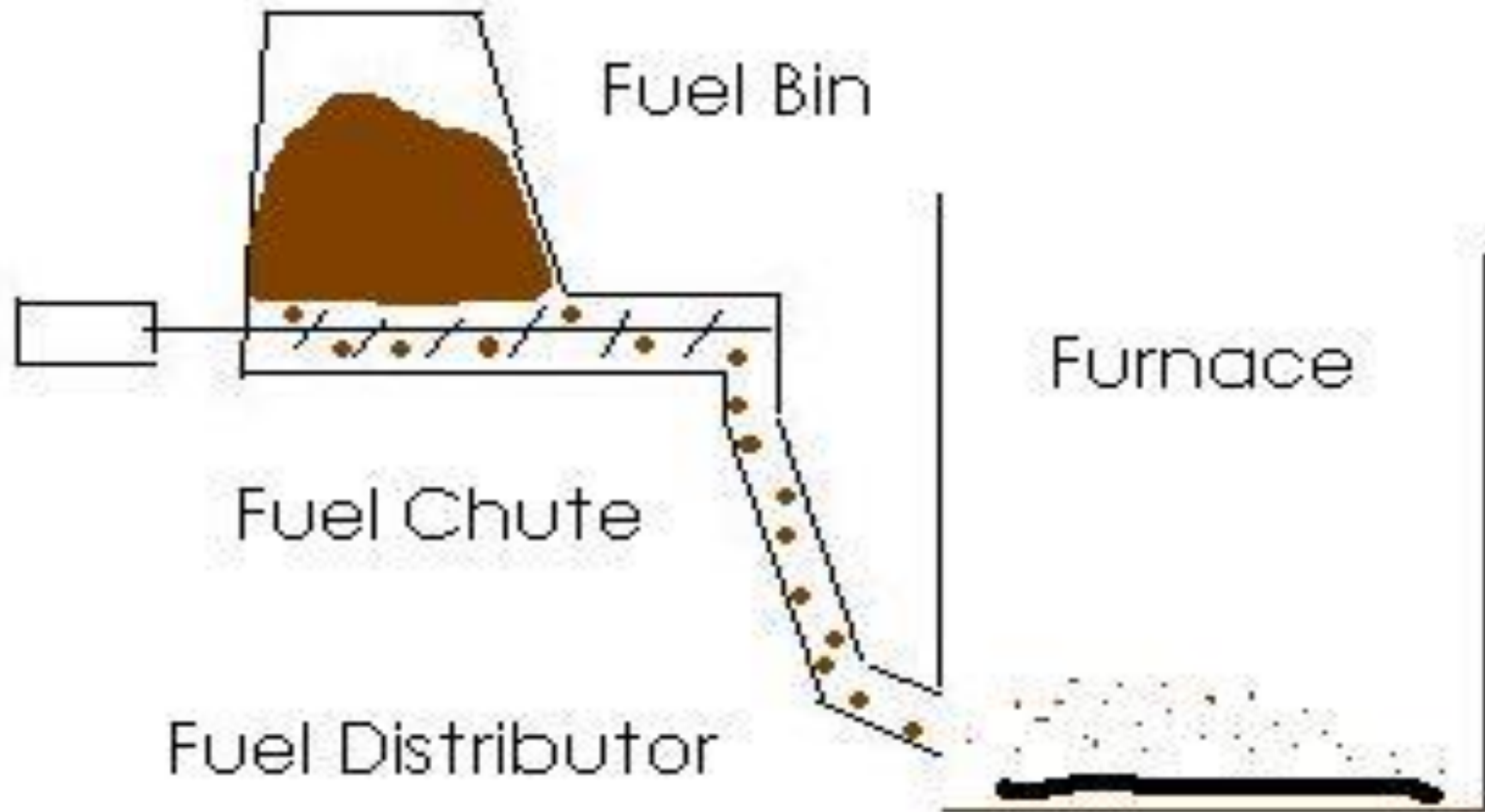


# Fuel Metering



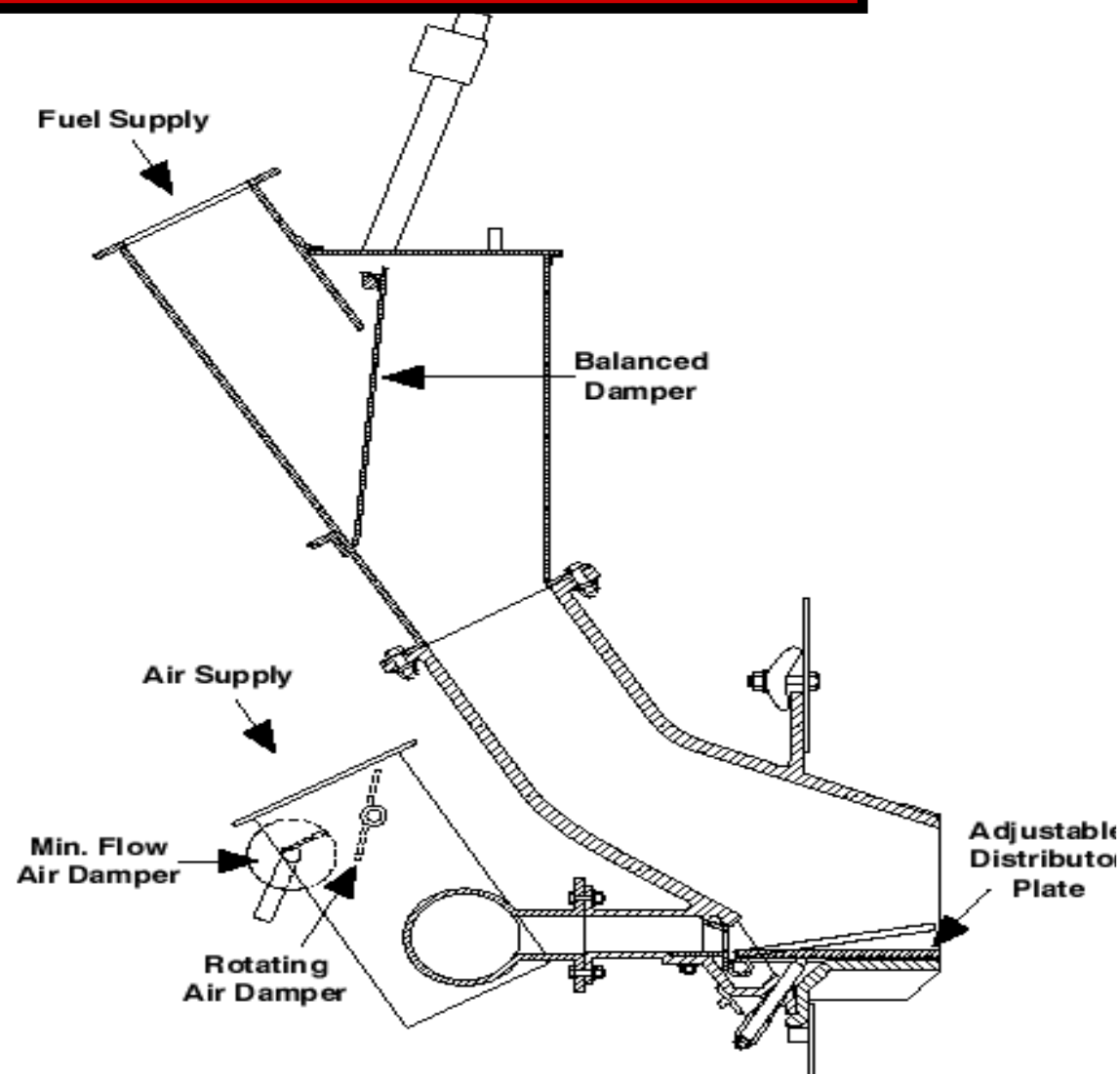


# Fuel Chute and Simple Distribution





# Pneumatic Distribution



**Detroit Air Swept Fuel Distributor  
Model AD**

# Pneumatic Distribution

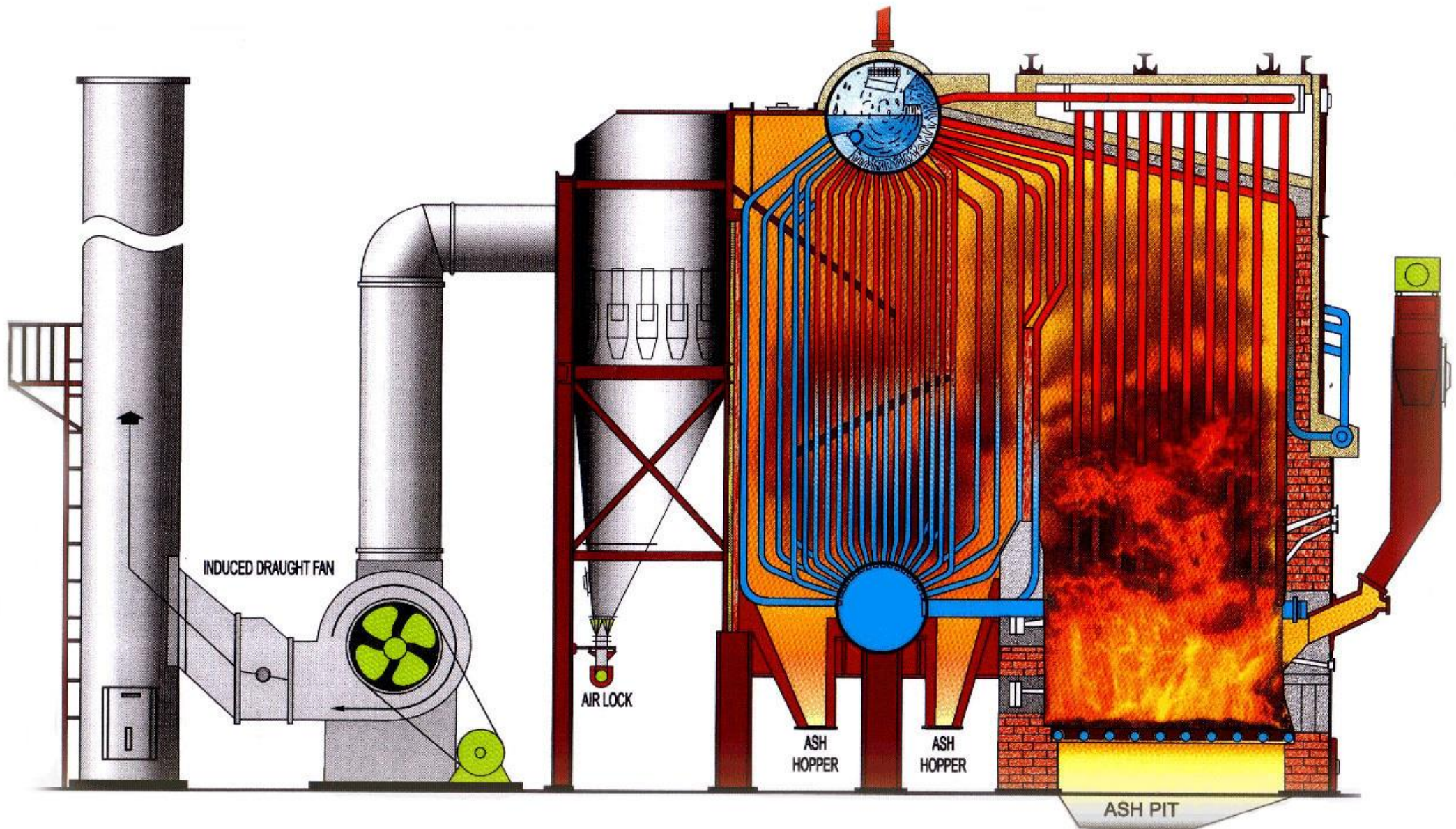




# Classified by Grate Designs

- ◆ Fixed Grate (Pinhole)
- ◆ Vibrating Grate
- ◆ Watercooled Hydrograte
- ◆ Reciprocating Grate
- ◆ Kablitz Grate
- ◆ Traveling Grate

# Fixed Grate

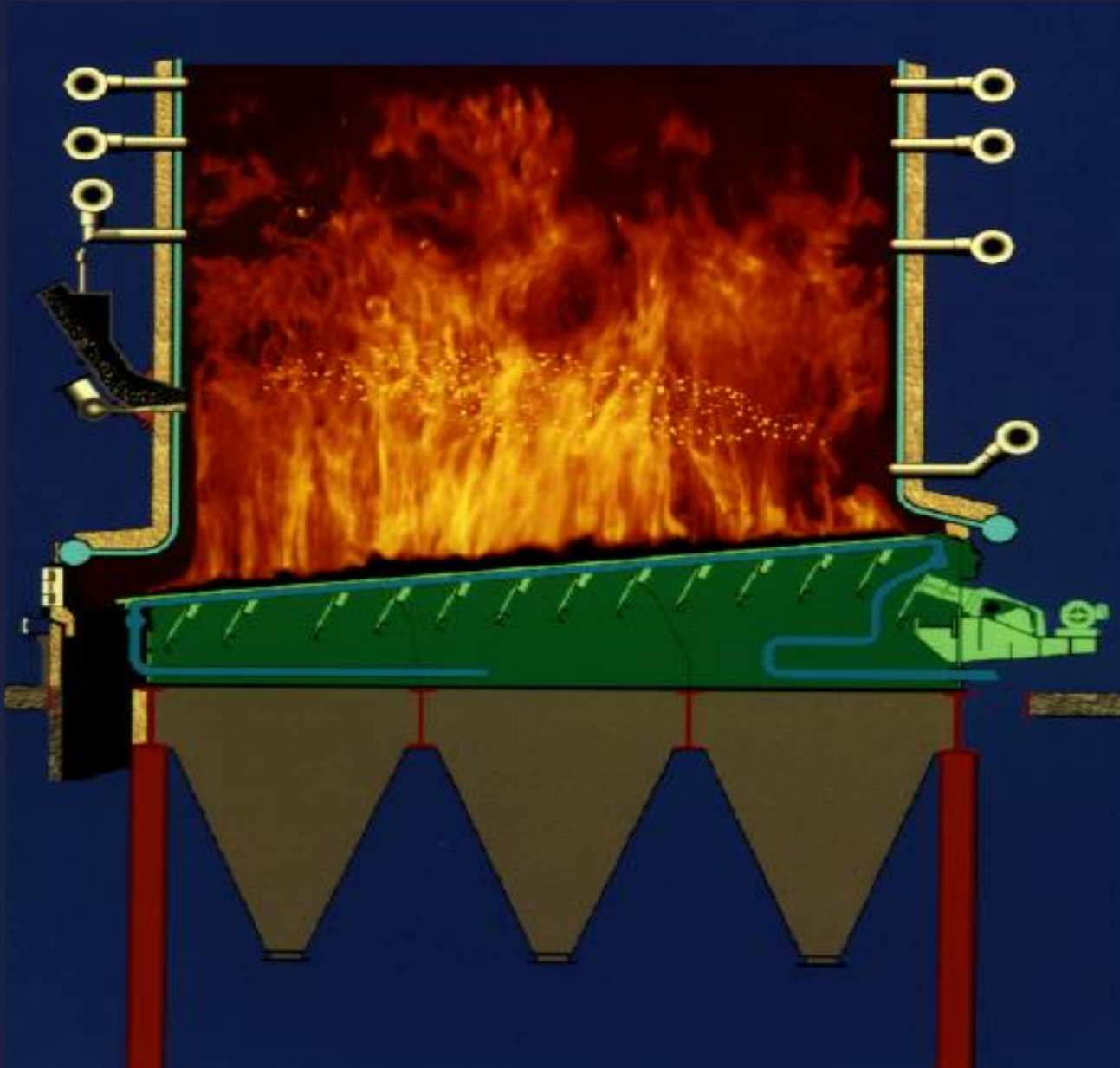




# Vibrating Grate

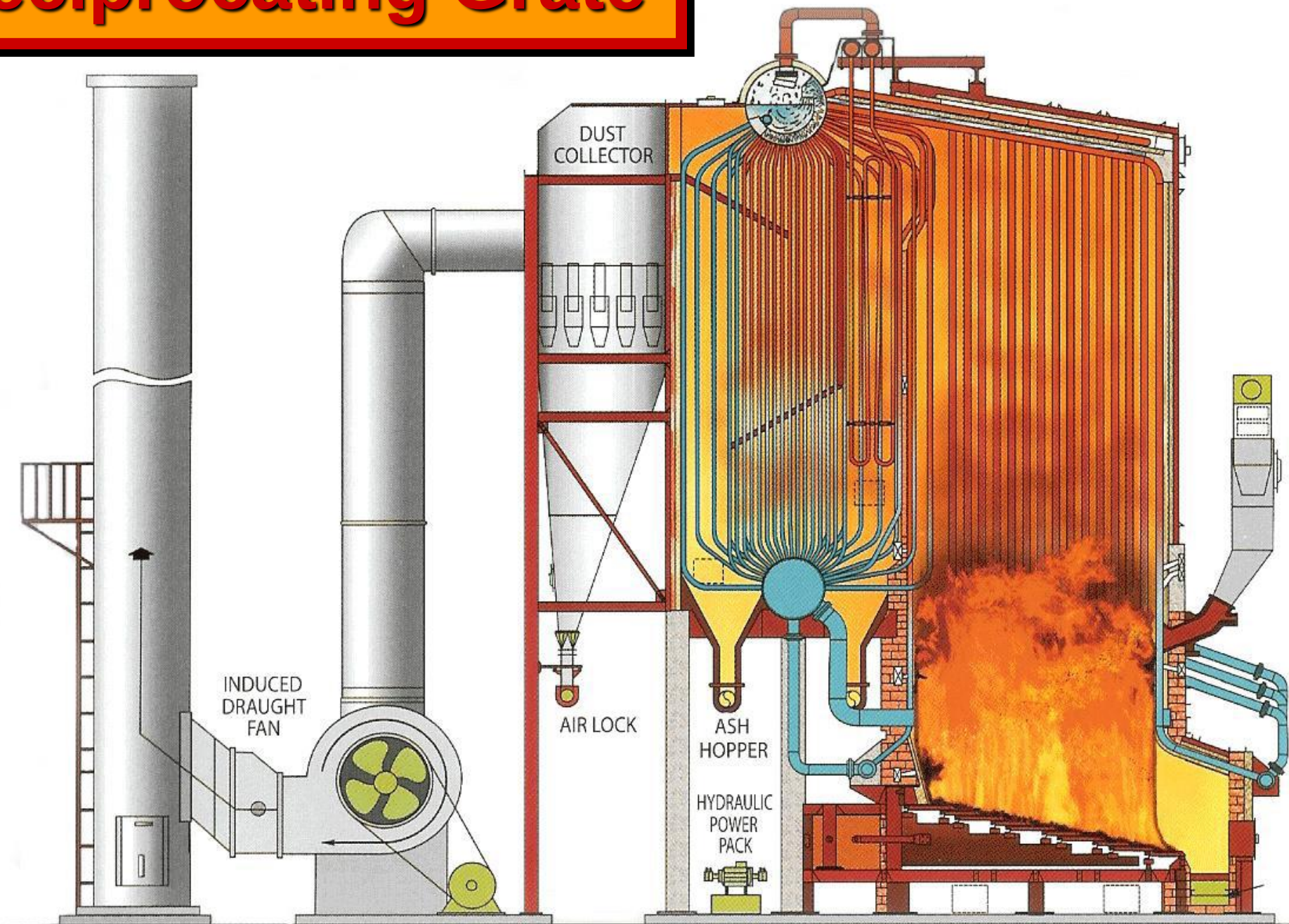


# ***Watercooled Hydrograte***





# Reciprocating Grate



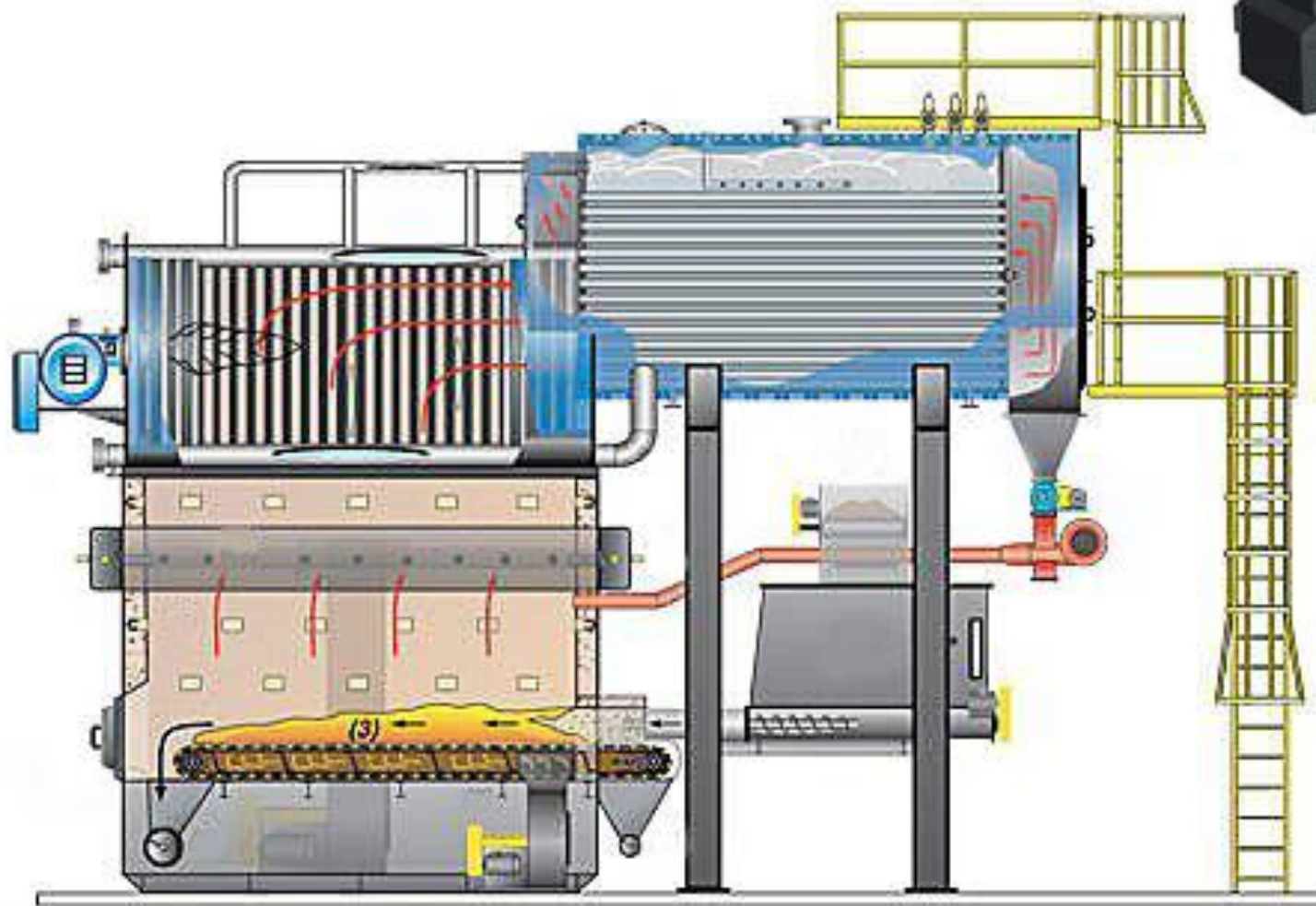


# Kablitz Grate





# Traveling Grate



# Traveling Grate

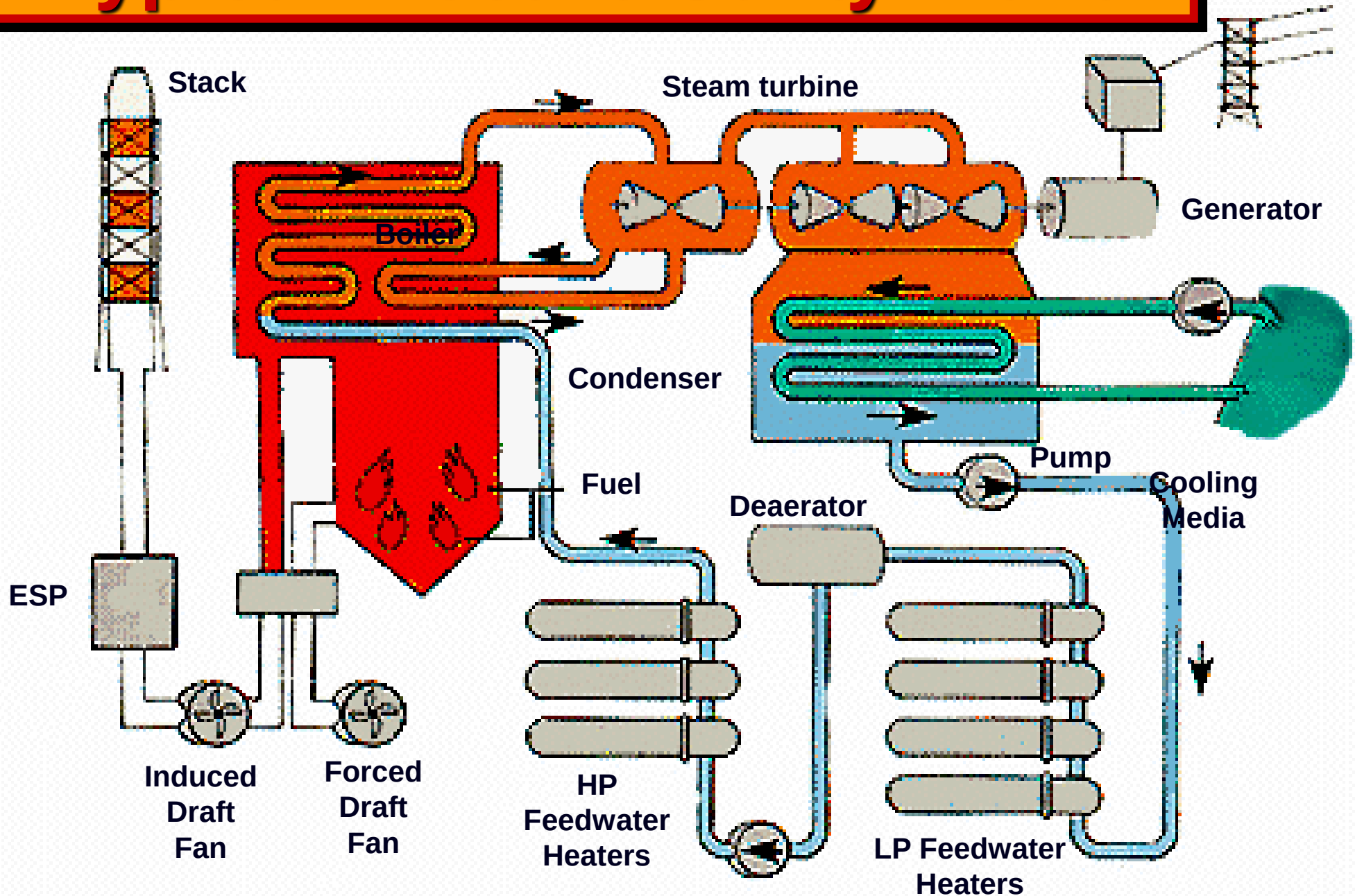




# Let's Discuss Power Generation



# Typical Electric Utility Plant

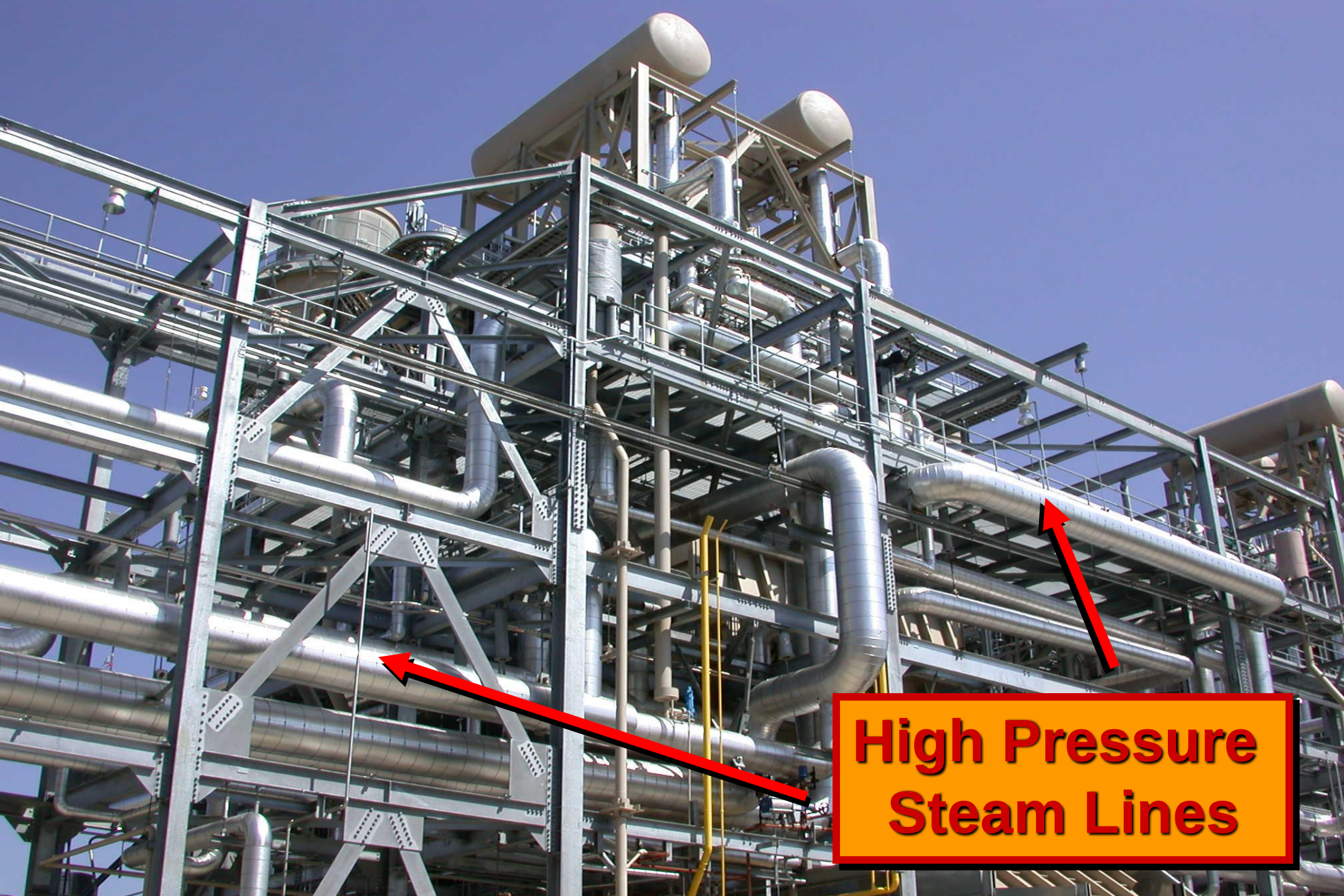




# High Pressure Steam Risers







**High Pressure  
Steam Lines**



# Steam Turbine

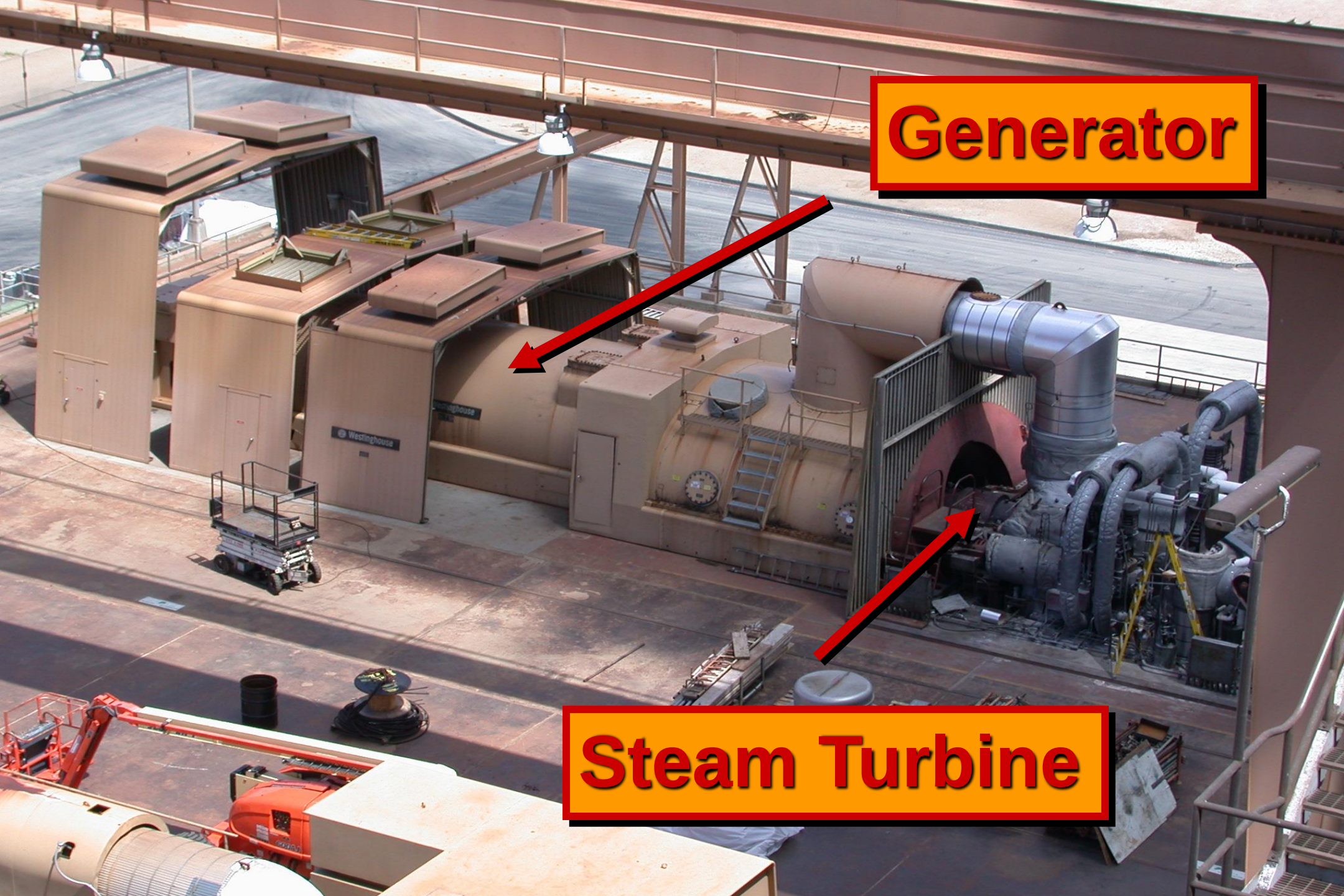




# Steam Turbine







**Generator**

The image shows a massive industrial machine, a generator, with a tan-colored metal casing. It is situated in a large industrial facility with a high ceiling and steel beams. To the right of the generator is a complex assembly of pipes, valves, and machinery, which is the steam turbine. A red arrow points from the 'Generator' label to the tan casing. Another red arrow points from the 'Steam Turbine' label to the complex machinery on the right. The floor is made of large concrete slabs, and there are various tools and equipment scattered around, including a small cart and a red crane arm in the foreground.

**Steam Turbine**





**Cooling Towers**



# Typical Control Room







2,600 MW

2 – 750 MW boilers

4 – Gas turbines and  
2 steam turbines in a  
2 to 1 arrangement

**Moss Landing**



# Let's Discuss Biomass







**Waste Wood**



**Almond Shells**



**Walnut Shells**



**Orchard Trimmings**



**Urban Wood Waste**



**Corn Stover**



**Forest Debris**

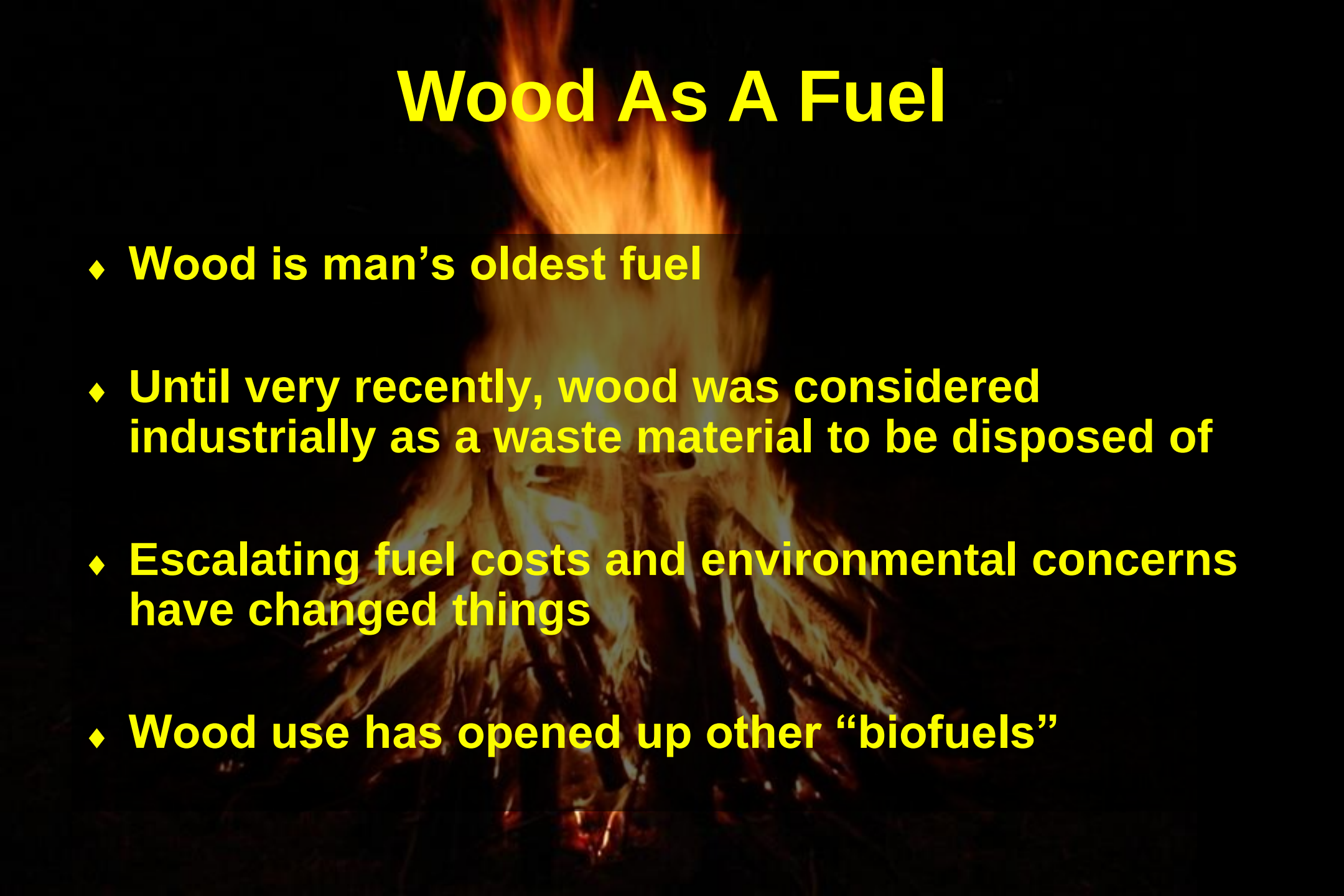


**Rice Hulls**

**Biomass Fuels**



# Wood As A Fuel



- ♦ Wood is man's oldest fuel
- ♦ Until very recently, wood was considered industrially as a waste material to be disposed of
- ♦ Escalating fuel costs and environmental concerns have changed things
- ♦ Wood use has opened up other “biofuels”



# ***History***

- ♦ 200,000 to 300,000 years - Controlled Use of Fire
- ♦ 10,000 to 20,000 years – Domesticated (living area)
- ♦ 800 years ago - First wood fuel shortages
- ♦ 400 years ago - Coal use in Europe
- ♦ 250 years ago - Industrial Revolution
- ♦ 150 years ago - Oil use
- ♦ 130 years ago - Natural gas use and electrification
- ♦ 70 years ago - Industrial wood-firing
- ♦ 50 years ago - Air pollutant investigations
- ♦ 20 years - Biofuels and “space age” investigations



- 
- ♦ **Wood differs from conventional fossil fuels**
    - ♦ Physical structure
    - ♦ Chemical structure
    - ♦ Moisture content
    - ♦ “It’s alive” when harvested
  - ♦ **Therefore it burns and must be burnt differently**
  - ♦ **Commercially viable for other uses**
  - ♦ **Relatively scarce resource**
  - ♦ **Development of “urban wood wastes”**



# Wood Fuel Physical Characteristics

- ♦ **Xylem interior “white wood”**
  - ♦ Board lumber
  - ♦ Chips
- ♦ **Cambium layer**
  - ♦ new growth
  - ♦ source of nutrients
- ♦ **Bark**





# Wood Fuel Physical Characteristics

- ♦ Debarking removes the Cambium layer and bark
- ♦ Yard wastes
- ♦ Processed through a hammermill (“hog”) for size reduction
- ♦ White wood
  - ♦ Sawdust
  - ♦ Sanderdust
  - ♦ Chip fines
- ♦ Other - plywood trim





# Waste Wood at Lumber Mill





**Mixed Fuel**



**Pallets, Urban Wood Waste, Tree Trimmings**



**Rice Hull Silo**





# Wood Fuel Variability

- ♦ Random reclaim operations will result in significant variations in fuel quality
- ♦ Emphasizes the importance of good fuel management and blending
- ♦ Selective fuel purchasing is also very important
- ♦ But ... generally, you burn what you got



# Fuel Quality

- ♦ **Poor combustion performance and high CO**
- ♦ **Small wood particles**
  - ♦ **Not handled well in the feed and distribution systems**
  - ♦ **Rapidly entrained with insufficient time to complete the 3-Step combustion process within the furnace**
- ♦ **High moisture content**
  - ♦ **Tends to pile on the grate**
  - ♦ **Causes “thick-bed” grate conditions**
  - ♦ **Disrupts undergrate airflow**



# Fuel Preparation

- ◆ Screening
- ◆ Metal Removal
- ◆ Drying
- ◆ Deicing
- ◆ Sizing
- ◆ Blending





# Wood Fuel Sizing

- ♦ **“Overs” (> 3 inches) => Plug fuel chutes**
  - ♦ Screen out
  - ♦ Mill to a smaller size
- ♦ **“Fines” (<1/4 in) => Not completely burned**
  - ♦ Segregate
  - ♦ Blend up to 20% with larger materials



# Wood Fuel Screening







**Tub Grinder for  
Gross Size  
Reduction**



# Hammermill for Fine Size Reduction





# Wood Fuel Drying

- ♦ **Part of another wood processing operation**
  - ♦ **Kiln dried trim**
  - ♦ **Dried planer shavings**
  - ♦ **Sanderdust**
- ♦ **MC > 65% requires some type of drying or blending with drier fuel**
- ♦ **MC < 15% is potentially explosive**



# Fuel Blending





# Importance of Blending

- ◆ Control moisture content
- ◆ Improve fines burnout
- ◆ Implement by:
  - ◆ Gross mixing using a front-end loader
  - ◆ Separate fuel bins feeding a common feed system





# **Wood Fuel Characteristics - Moisture Content**

- ♦ **Water needed for life**
- ♦ **Present in the cell structure and on surface**
- ♦ **Moisture content varies with**
  - ♦ **Species**
  - ♦ **Location**
  - ♦ **Season**
  - ♦ **Handling practices**
- ♦ **Nature levels of 30% to 65%+**
- ♦ **Kiln dried to less than 10%**



# Effect of Moisture

- ♦ **Decreases combustion temperatures**
- ♦ **Leads to incomplete combustion and the generation of higher levels of CO and ash C**
- ♦ **Decreases boiler efficiency**
- ♦ **Leads to more fuel use, higher energy costs and increased air pollutants**



# Wood Fuel Characteristics - Volatility

- ♦ 70% to 80% of dry wood is “volatile” hydrocarbons
- ♦ Released from the wood structure at relatively low temperatures (500 F)
- ♦ Volatiles burn “in suspension” away from the wood particles
- ♦ Balance is “fixed carbon” or “char”



# Wood Chemistry

## Hydrocarbons

|                      |                                            |
|----------------------|--------------------------------------------|
| ♦ Methane            | $\text{CH}_4$                              |
| ♦ Ethane             | $\text{C}_2\text{H}_6$                     |
| ♦ Propane            | $\text{C}_3\text{H}_8$                     |
| ♦ Complex Fuels      | $\text{C}_x\text{H}_y$                     |
| ♦ More Complex Fuels | $\text{C}_x\text{H}_y\text{S}_z\text{N}_a$ |

# Wood Species

| Parameter     | Pine    | Redwood | Hemlock | Fir     |
|---------------|---------|---------|---------|---------|
| C (%wt,dry)   | 50.3    | 53.5    | 50.4    | 52.3    |
| H (%wt,dry)   | 6.2     | 5.9     | 5.8     | 6.3     |
| O (%wt,dry)   | 43.1    | 40.3    | 41.4    | 40.5    |
| N (%wt,dry)   | 0.04    | 0.10    | 0.10    | 0.10    |
| S (%wt,dry)   | < 0.1   | < 0.1   | < 0.1   | < 0.1   |
| Ash (%wt,dry) | 0.3     | 0.2     | 2.2     | 0.8     |
| Moisture (%)  | 30 - 60 | 30 - 60 | 30 - 60 | 30 - 60 |
| Btu/lb        | 9,153   | 9,220   | 8,620   | 9,058   |



# **3-Step Combustion Process**

## **Step #1 - Drying**

- ♦ **Fresh wood particles absorb heat by convection and radiation from the ongoing combustion processes**
- ♦ **Initially, the heat energy evaporates the water in the cells and on the surface**
- ♦ **The evaporated water vapor diffuses away and mixes with the combustion products**

# **3-Step Combustion Process**

## **Step #2 – Devolatilization**

- ♦ **The wood fuel particles continue to absorb heat**
- ♦ **The energy absorbed releases the volatile combustibles**
- ♦ **The volatiles diffuse away, mix with air (oxygen), and burn**
- ♦ **The energy released radiates back and helps to sustain combustion**



# **3-Step Combustion Process**

## **Step #3 - Char Burnout**

- ♦ **The char remains after the volatiles have been released**
- ♦ **Char is primarily pure carbon and requires:**
  - ♦ **An extended time period to burn**
  - ♦ **Air (oxygen) transported to it**
- ♦ **Inert ash remains after the char burnout**





# Ash

- ◆ Intrinsic ash (potassium) can combine with alumina and silica to form a relatively low melting point temperature ash (1600 to 1800 F)
- ◆ Potassium also volatilizes at low temperatures (1500 F) and reacts with ash in the boiler flue gas stream contributing to fouling problems
- ◆ Ash accumulation causes
  - ◆ Airflow problems
  - ◆ High draft levels and fan horsepower
  - ◆ Reduced superheat temperatures
  - ◆ Boiler shutdowns



**Ash  
Loadout**



# Ash Loadout







**Let's Discuss  
Emissions  
& Controls**



# Emissions From Boilers

**Fuel  
+  
Air  
(N<sub>2</sub>, O<sub>2</sub>)**



- ♦ H<sub>2</sub>O
- ♦ CO<sub>2</sub>
- ♦ CO
- ♦ NO<sub>x</sub>
- ♦ HC
- ♦ SO<sub>x</sub>
- ♦ PM
- ♦ Cl-

# Emissions Control Methods

- ◆ **Boiler design**
- ◆ **Proper maintenance**
- ◆ **Operating conditions**
- ◆ **Fuel types**
- ◆ **Combustion modifications**
- ◆ **Exhaust treatment**





# Control of Gaseous Emissions

- ♦ Low-NO<sub>x</sub> burners
- ♦ OFA
- ♦ Ammonia injection (SNCR)
- ♦ Catalysts (SCR)
- ♦ RSCR
- ♦ FGR



# Combustion Considerations

- ◆ Time
- ◆ Temperature
- ◆ Turbulence
- ◆ Oxygen
- ◆ Nitrogen

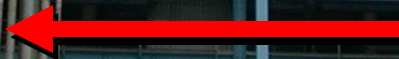




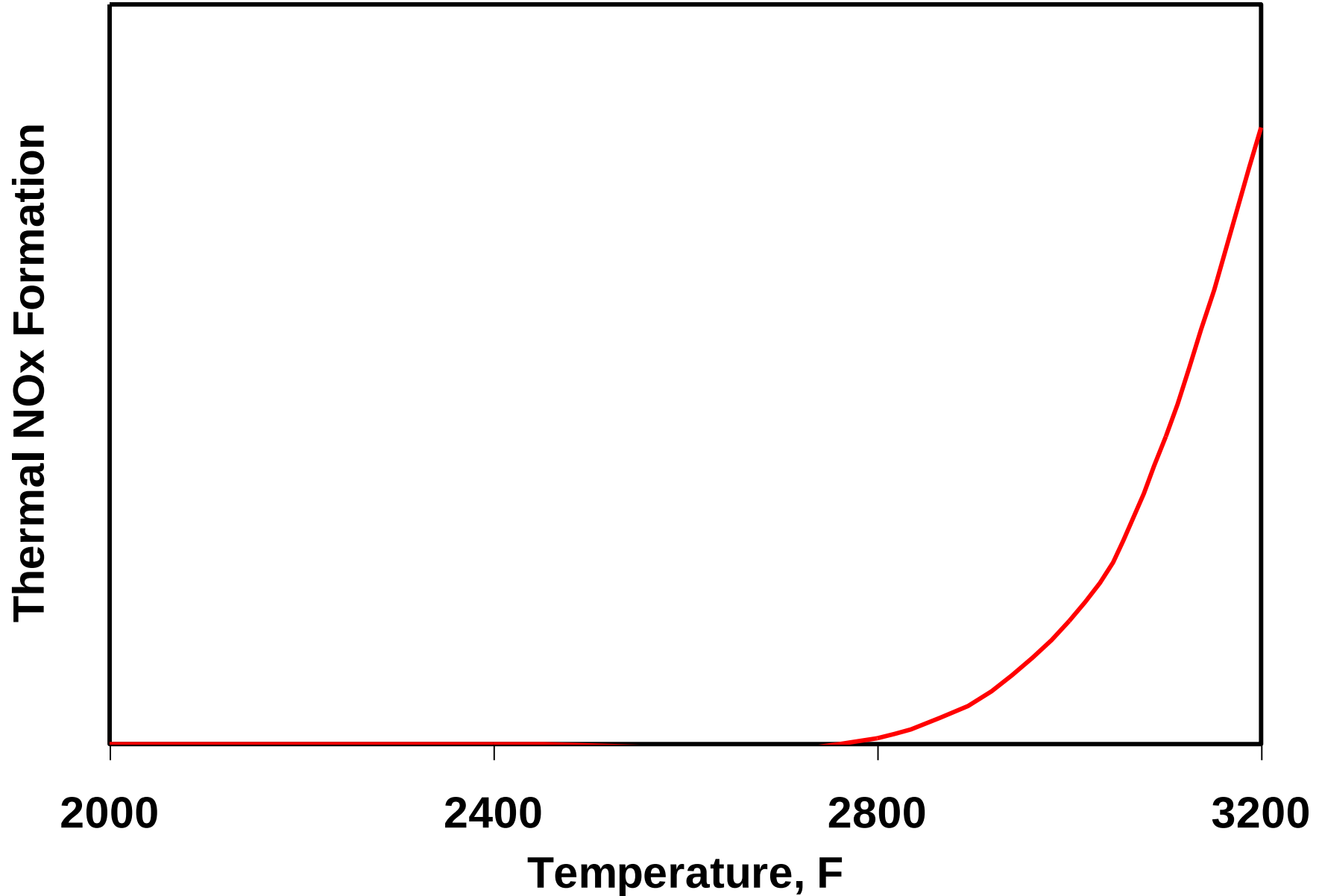


- ◆ Thermal NO<sub>x</sub>
- ◆ Fuel-bound NO<sub>x</sub>
- ◆ Prompt NO<sub>x</sub>

**NO<sub>x</sub> Creation**

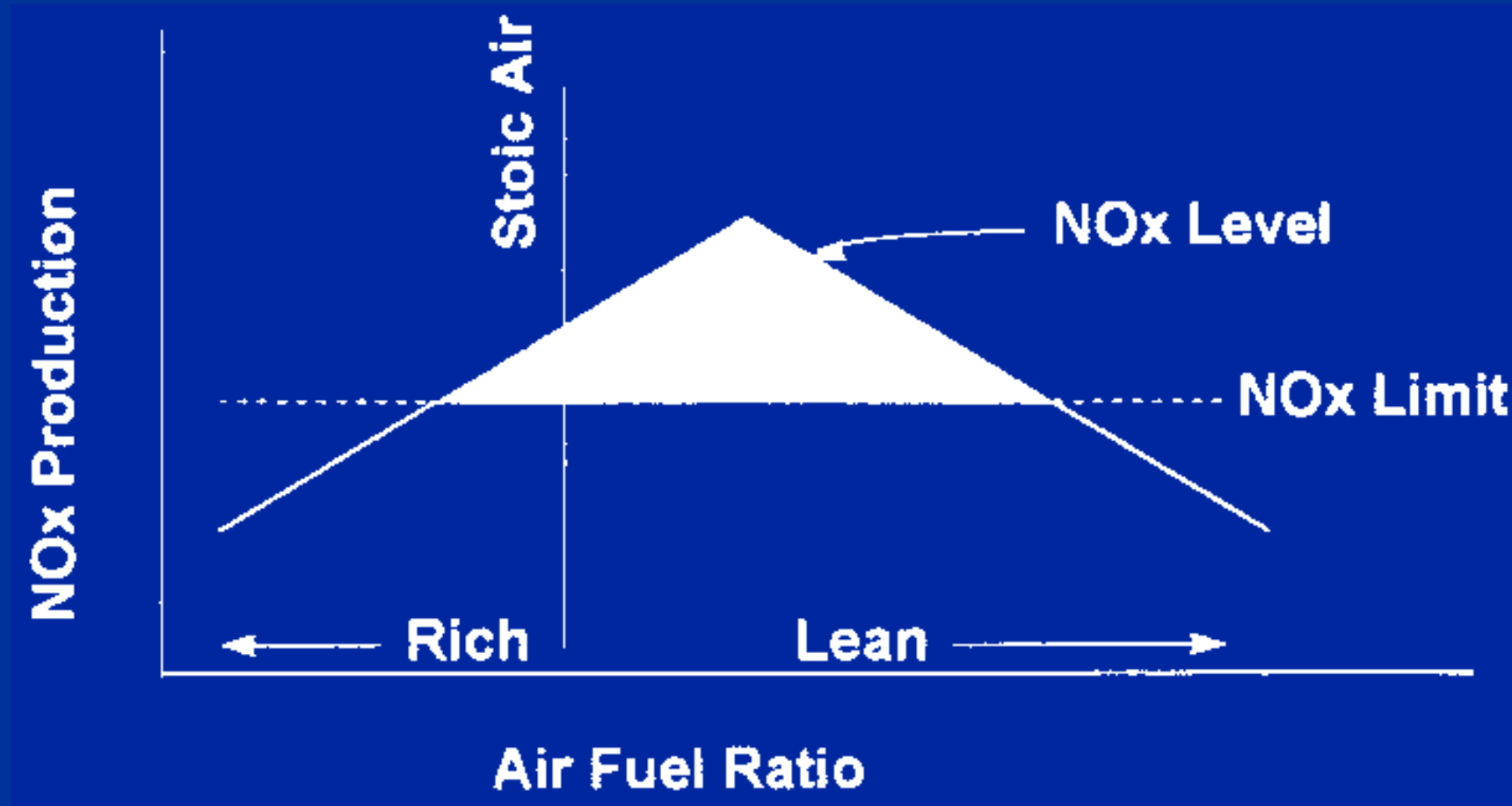


# Thermal NOx vs. Temperature





# NOx Production vs. Air/Fuel Ratio



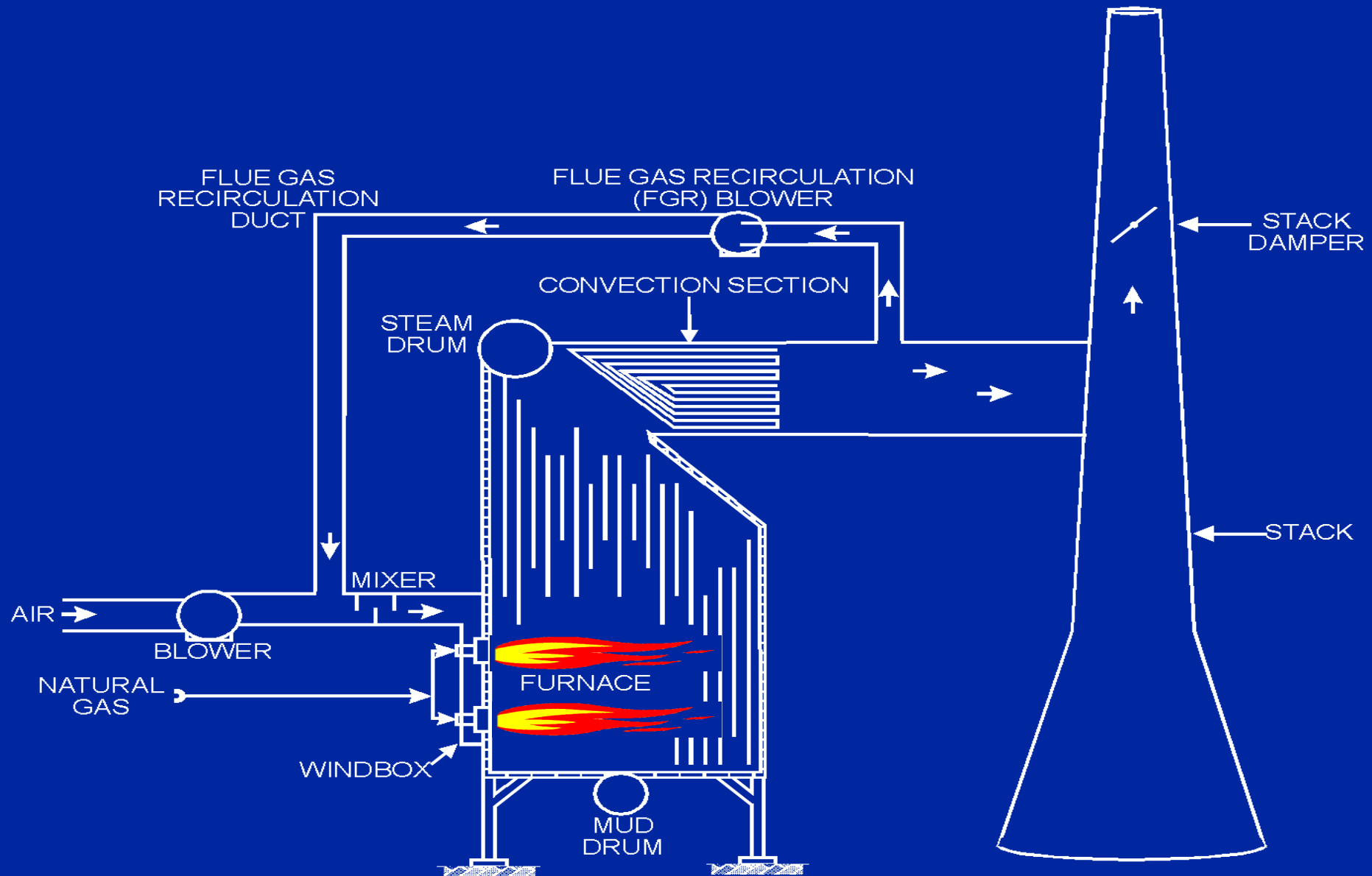


# Let's Discuss FGR

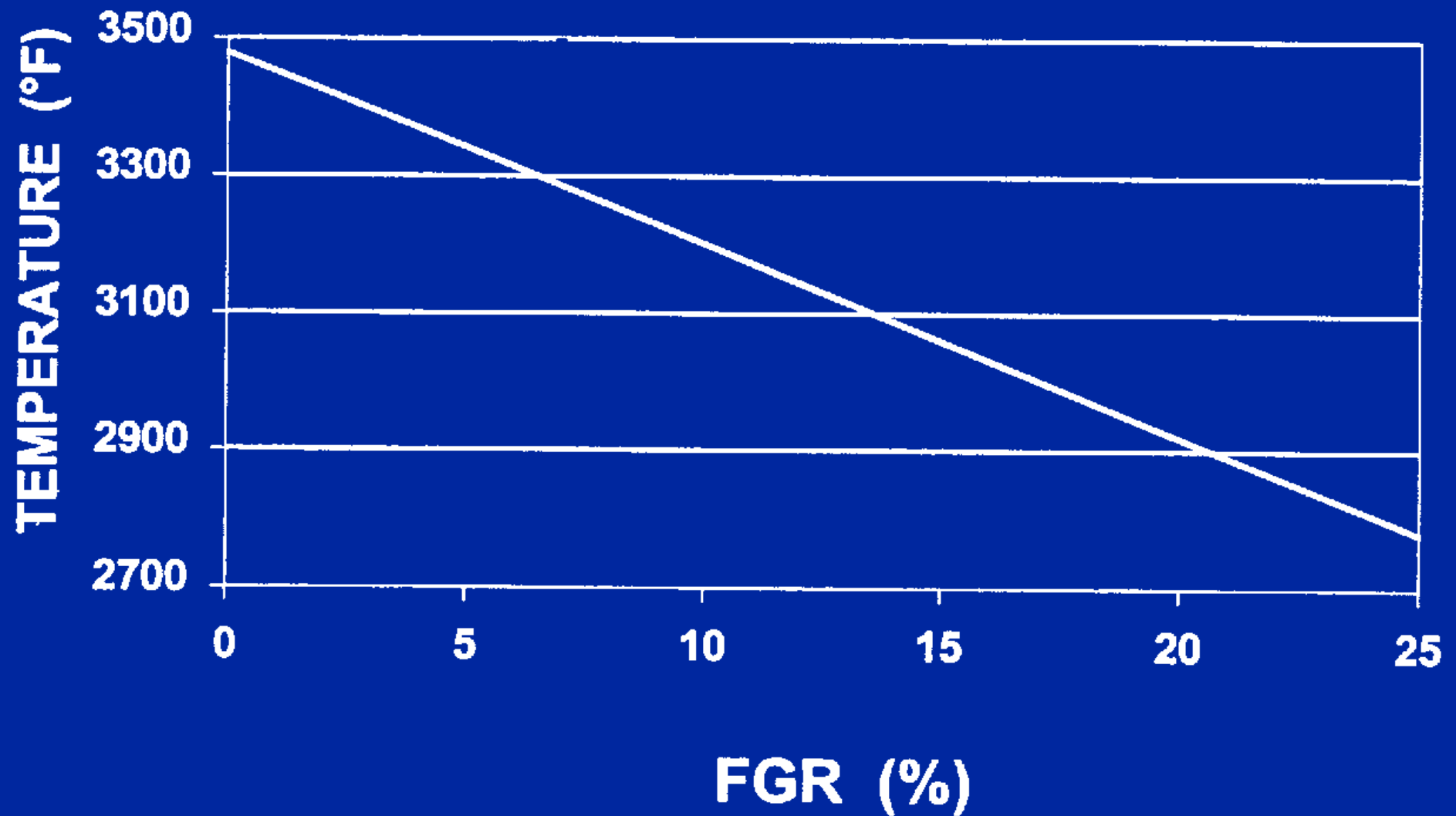




# Flue Gas Recirculation (FGR)



# Flame Temperature vs. FGR



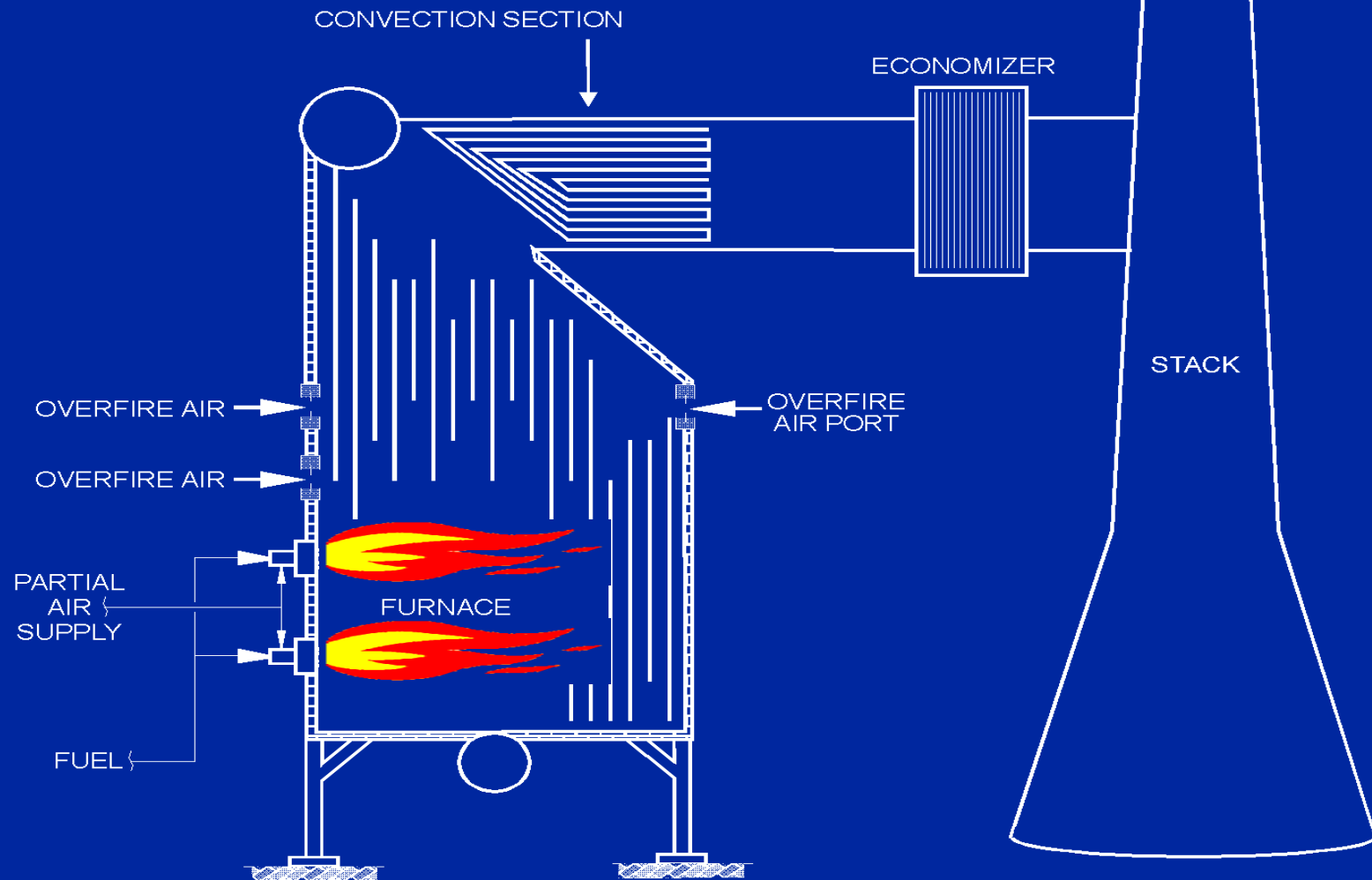


A photograph of a winter forest. In the foreground, two large, reddish-brown tree trunks (likely redwoods) stand prominently. The background is filled with numerous evergreen trees heavily laden with snow. The ground is also covered in a thick layer of snow. A wooden fence is visible in the distance at the bottom of the frame.

**Let's Discuss  
Staged Combustion**



# Staged Combustion with Overfire Air





# Let's Discuss SCR, SNCR and RSCR



# ***What is SCR?***

SCR  
↓  
Selective Catalytic Reduction

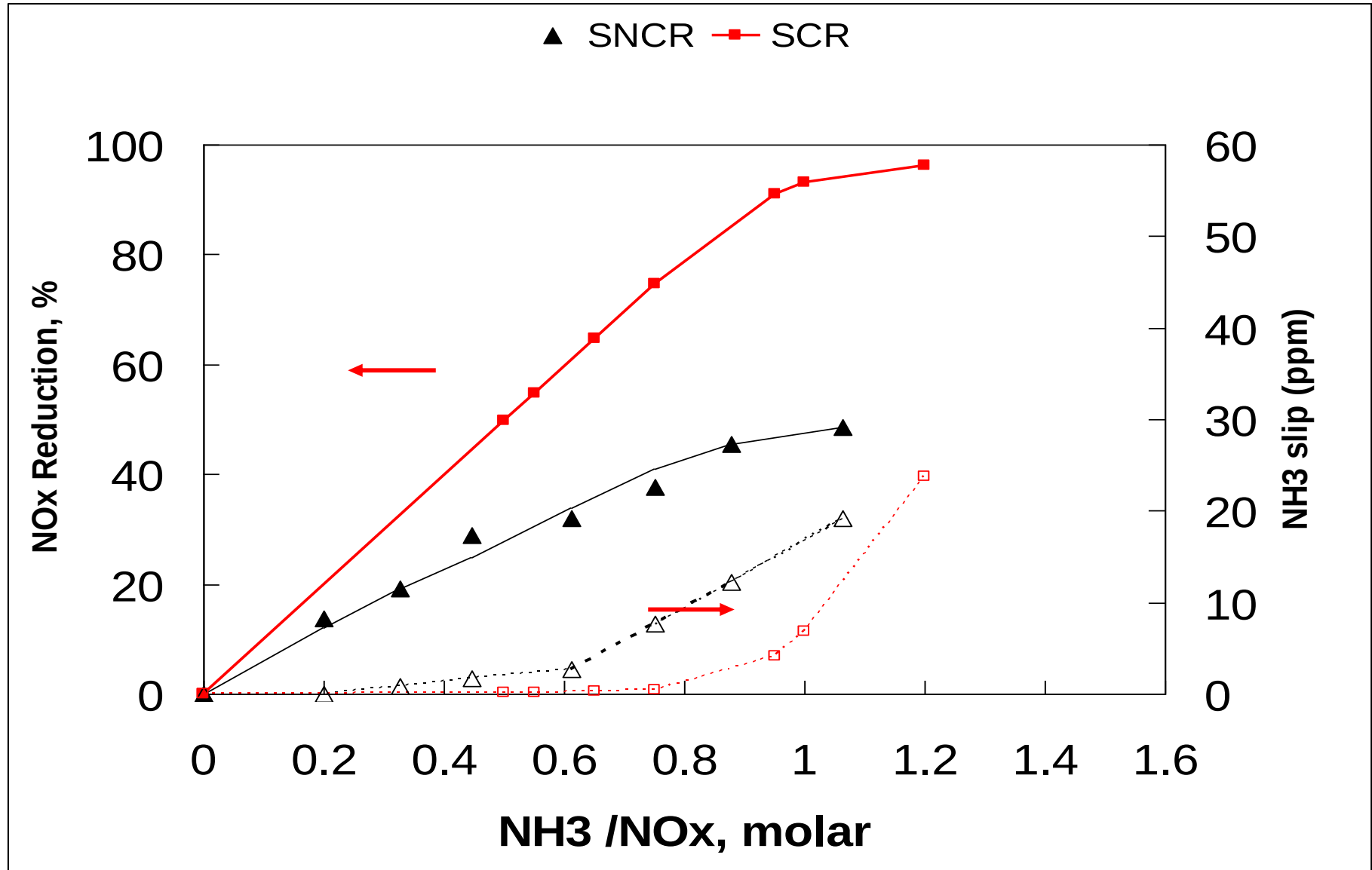
( This means that  $\text{NO}_x$  will selectively react with  $\text{NH}_3$  in the presence of Oxygen, similar to SNCR but a catalyst is needed to help the reaction which takes place at a lower temperature than SNCR)



# ***SCR Application***



# ***SNCR vs. SCR***





# ***Where is SCR Used***

- **Widespread Use**
  - Coal and Gas Fired Utility Boilers
  - Gas Turbine Electric Generators (Simple and Combined Cycle)
- **More Recently**
  - Refinery Combustion Systems
  - Smaller Industrial Boilers (Gas, Biomass Fired)

# SCR @ Typical Utility Boiler



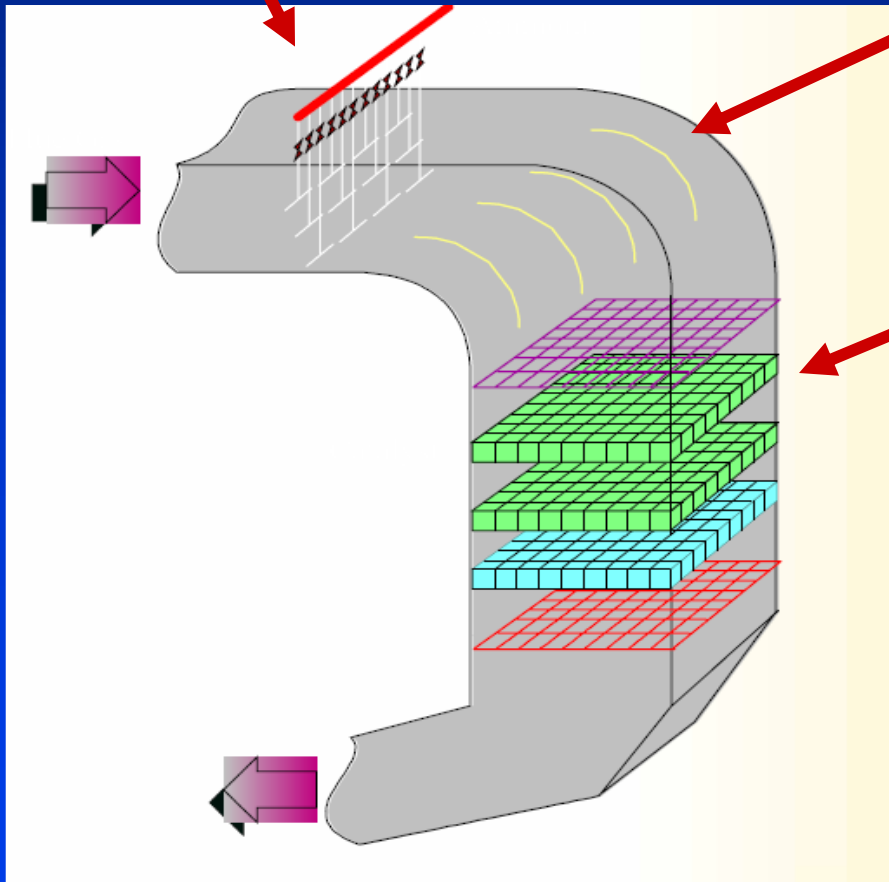


# SCR

NH<sub>3</sub> Injection:  
(Uniform NH<sub>3</sub>/NO<sub>x</sub> Critical)

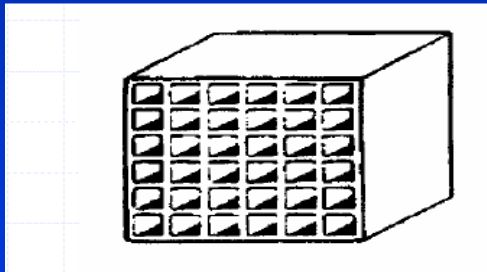
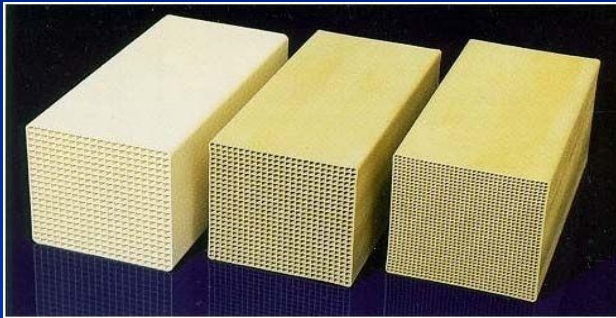
Turning Vanes to give  
uniform Velocity across the  
Catalyst

Catalyst  
Layer(s)

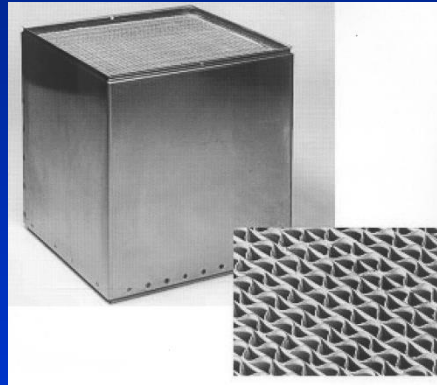


# SCR Catalyst Types

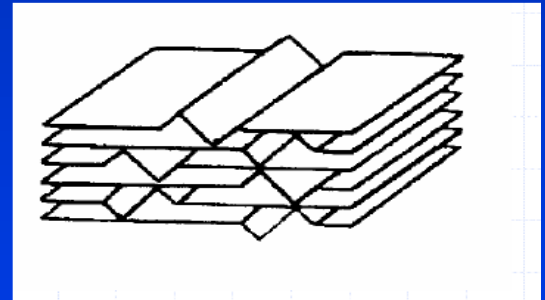
Extruded Ceramic  
Honeycomb



Corrugated  
(Haldor-Topsoe)



Plate



## Composition

- Vanadium Pentoxide ( $V_2O_5$ )
- Titanium Dioxide ( $TiO_2$ )
- Molybdenum
- Tungsten





**SCR Catalyst &  
 $\text{NH}_3$  Tubes**



# SCR Catalyst





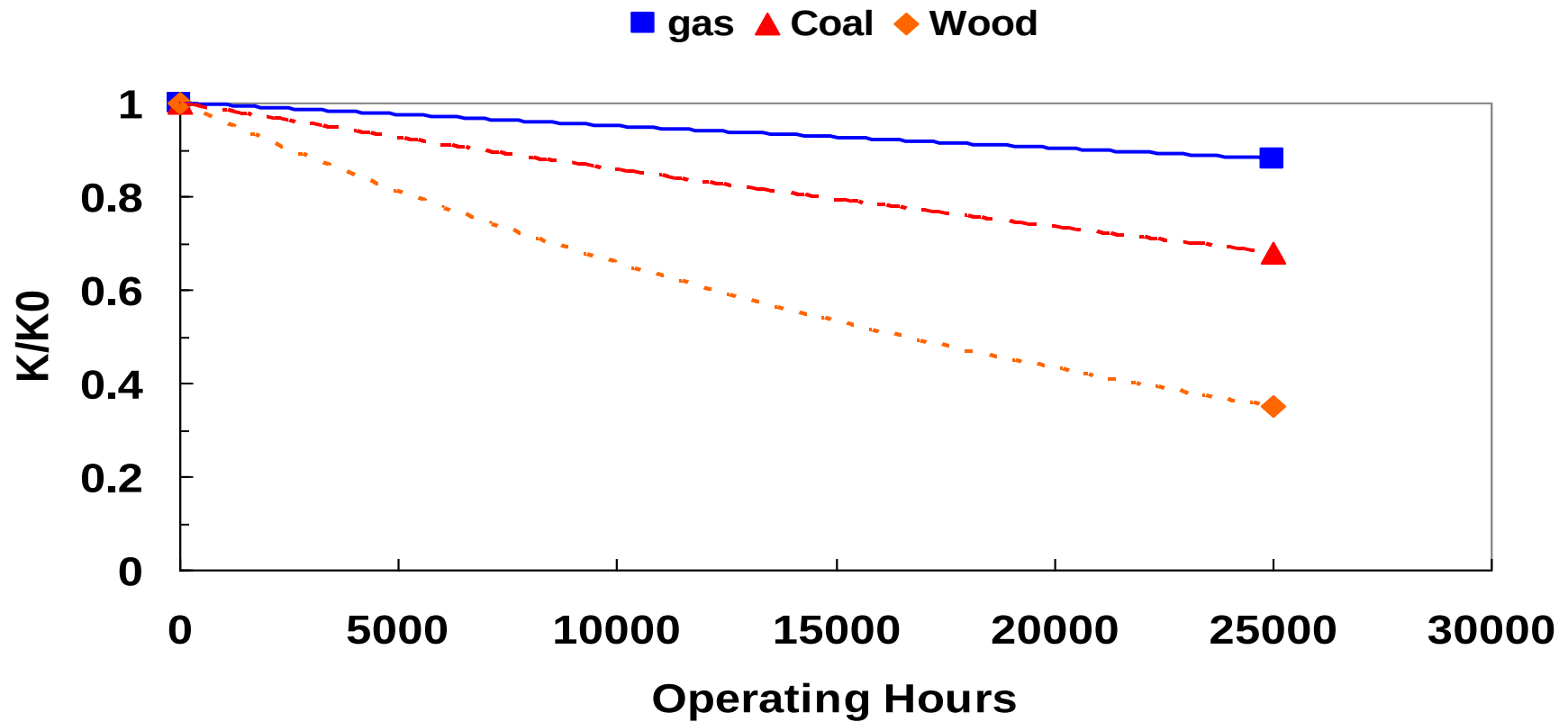
# ***Catalyst Degrades With Time***

## Reason for Degradation Fuel Dependent

- ☛ Bituminous Coal-Arsenic Poisoning
- ☛ Other Coal- Calcium sulfate blinding
- ☛ Potassium & Chlorine Poisoning



# *Typical Catalyst Deactivation Rates*





# ***Ammonia Injection Grid***

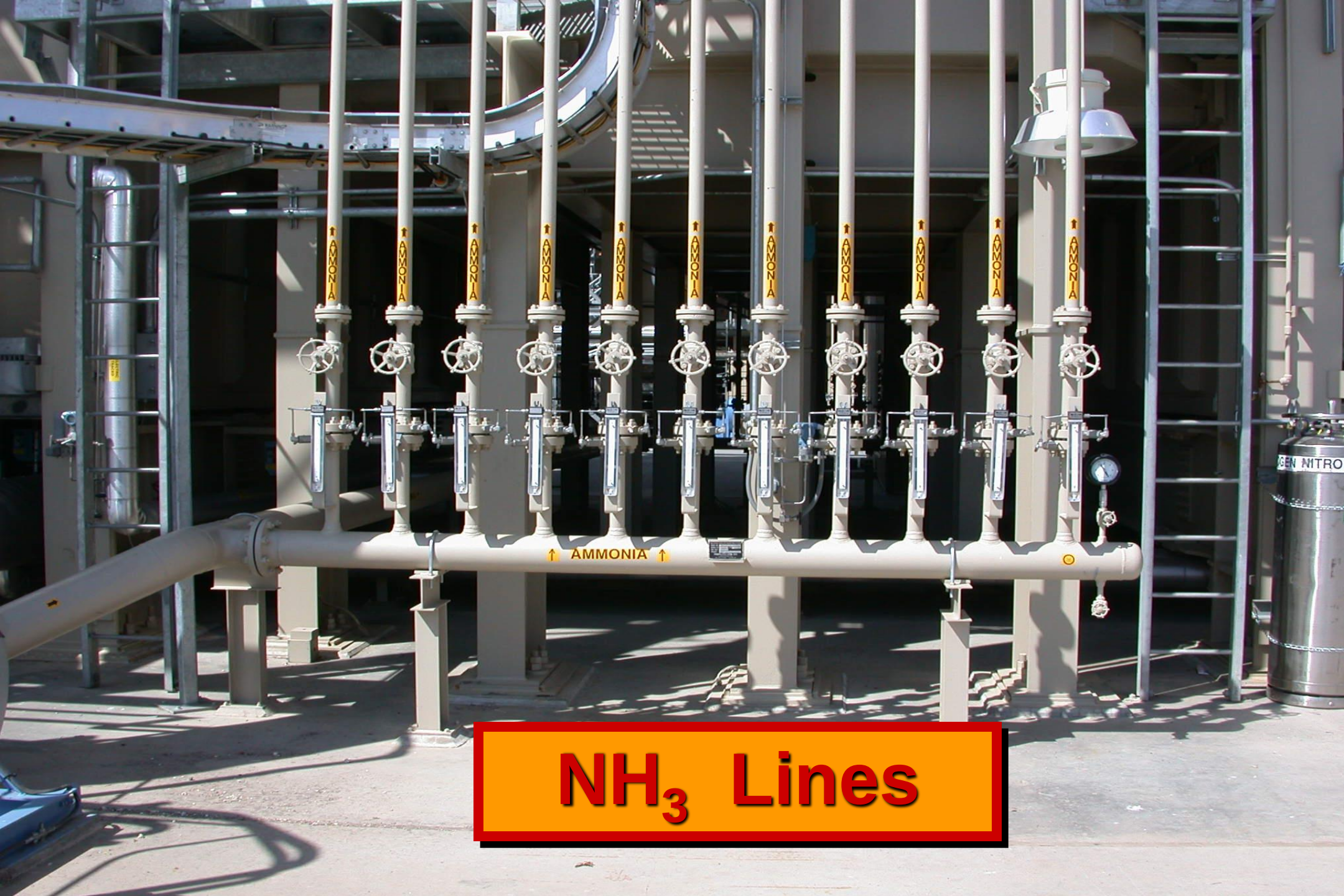




A large industrial facility, likely a power plant or refinery, featuring a complex network of pipes, valves, and structural steel. A group of workers wearing hard hats is gathered in the foreground, looking towards the structure. A red arrow points from a text box to a specific section of the piping.

# SCR & NH<sub>3</sub> Tubes





**NH<sub>3</sub> Lines**





***Small Boiler  
with SCR***





**Utility Boiler with SCR**

# ***SNCR vs SCR***

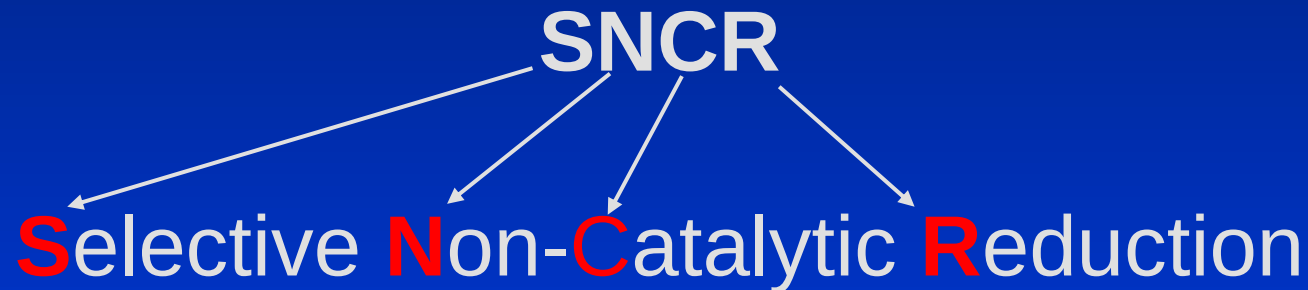
|                            | SNCR            | SCR                     |
|----------------------------|-----------------|-------------------------|
| <b>NOx Reductiuon</b>      | <b>20-50%</b>   | <b>50-95%</b>           |
| <b>Hardware</b>            | <b>Simple</b>   | <b>More Complex</b>     |
| <b>Capital Cost</b>        | <b>Low (1)</b>  | <b>High (5-10)</b>      |
| <b>Reagent Utilization</b> | <b>Typ. 30%</b> | <b>Almost 100%</b>      |
| <b>O&amp;M</b>             | <b>Reagent</b>  | <b>Reagent/Catalyst</b> |
| <b>Designability</b>       | <b>Poor</b>     | <b>Good</b>             |
| <b>NH3 slip</b>            | <b>5-20 ppm</b> | <b>&lt;10 ppm</b>       |





**Let's Discuss Particulate & NH<sub>3</sub>  
Controls**

# ***What is SNCR?***



(Means that a chemical will selectively react with  $\text{NO}_x$  in the presence of Oxygen)

- Ammonia ( $\text{NH}_3$ )

Urea (  $\text{NH}_2\text{CONH}_2$ )





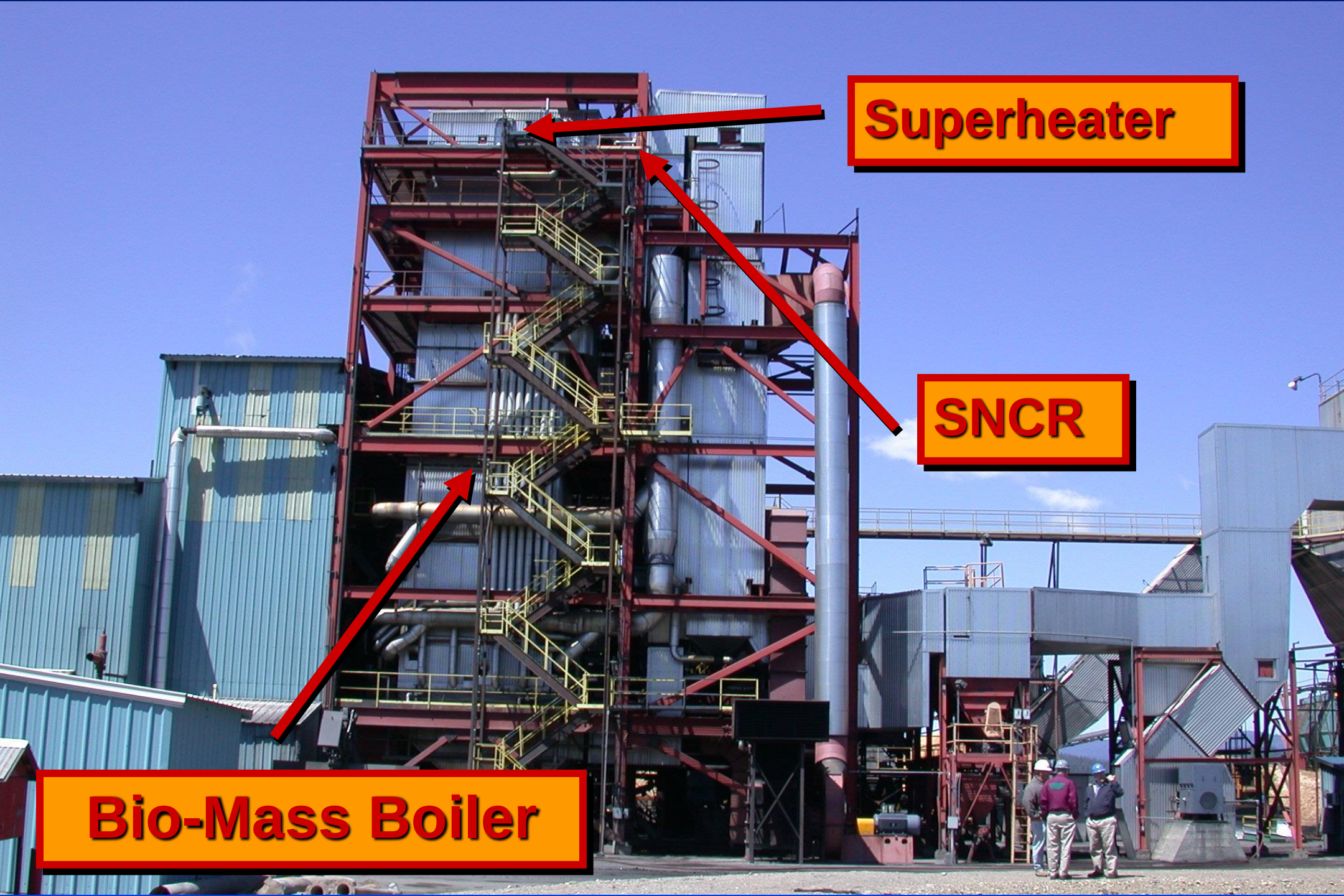
**Circulating Fluidized Bed Boiler  
w/SNCR**



# ***SNCR @ Bio-Mass Plant***







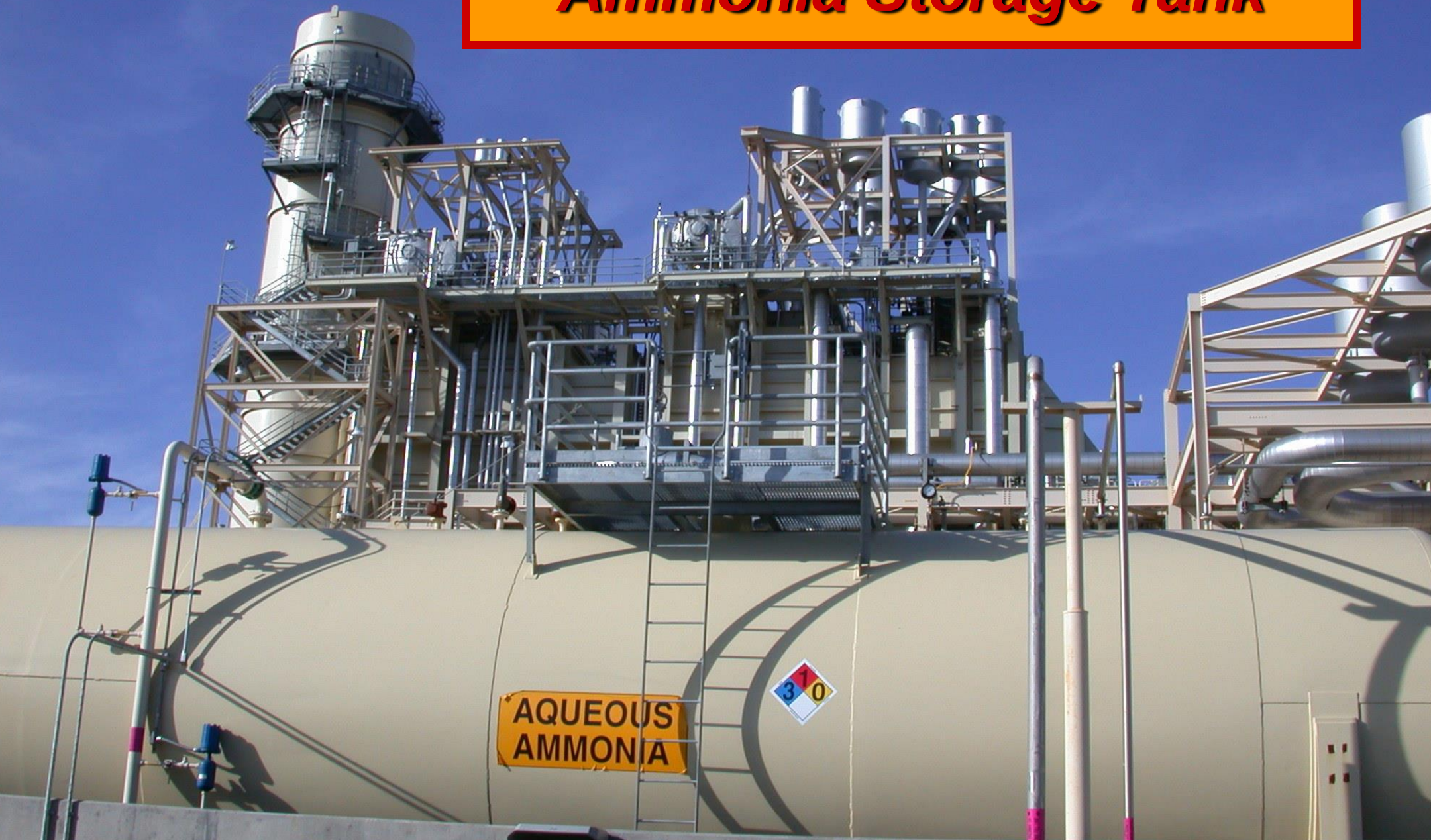
**Superheater**

**SNCR**

**Bio-Mass Boiler**



# ***Ammonia Storage Tank***





# ***Anhydrous Ammonia Storage Tank***



# ***Ammonia vs. Urea***

| Parameter         | Ammonia                                                                 | Urea                                                       |
|-------------------|-------------------------------------------------------------------------|------------------------------------------------------------|
| Form              | High Vapor Pressure Liquid<br>Ammonia/Water Solution                    | Liquid Solution                                            |
| Safety            | Anhydrous/29.4% Aqueous- safety iss<br>19% Aqueous- fewer Safety Issues | No Safety Issues                                           |
| Storage           | Anhydrous-Pressure Vessel<br>Aqueous- Atmospheric Pressure              | Atmospheric Pressure<br>Crystallization at Low Temperature |
| Injectors         | Needs Carrier Gas                                                       | Atomizers( Pressure or Twin Fluid)                         |
| Temperature       | Peak Removal @ 1750 F                                                   | Peak Removal @ 1850 F<br>Large Dilute Drops Shield Urea    |
| System Complexity | Relatively Simple                                                       | Relatively Simple                                          |

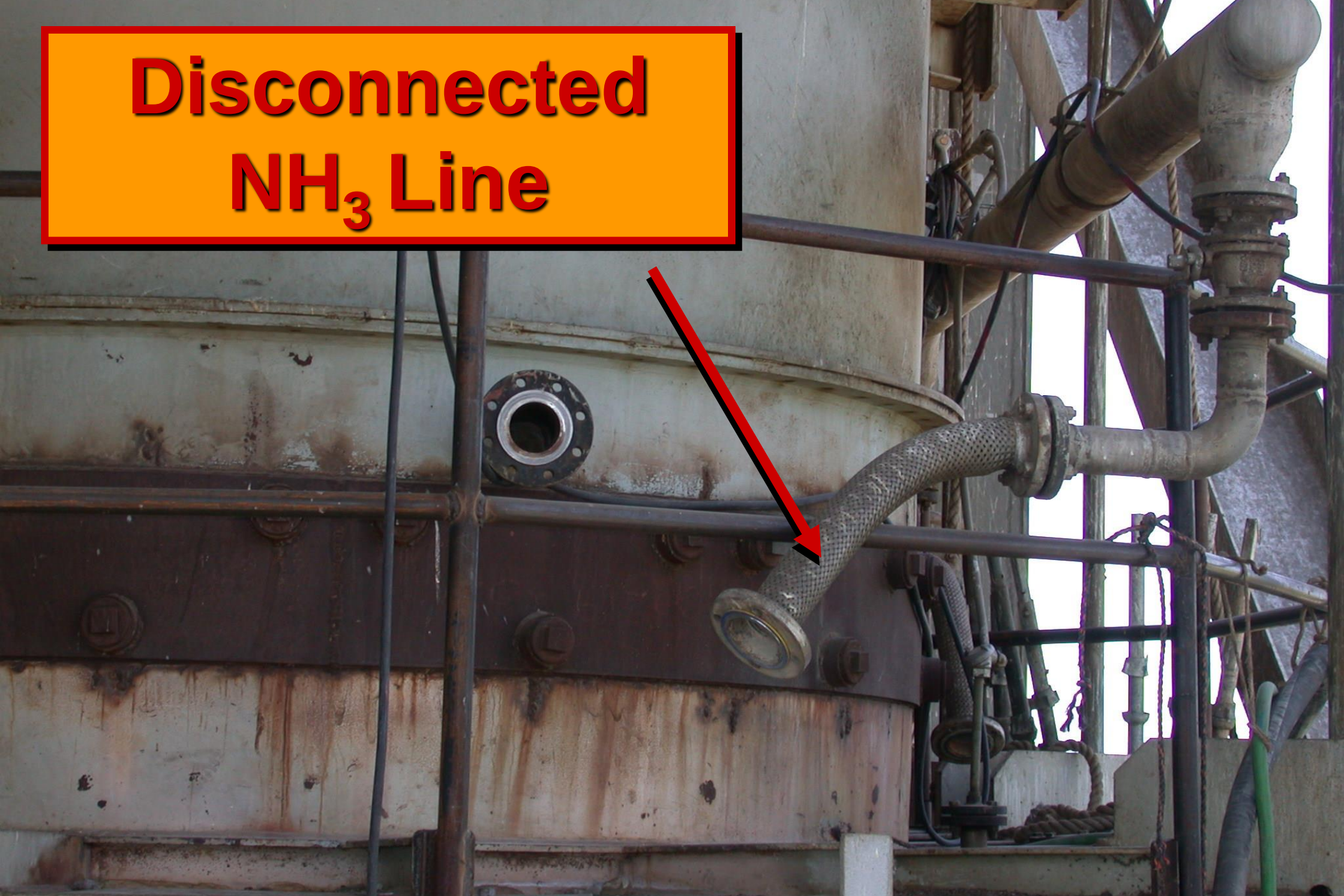




**Bio-Mass Boiler**



# Disconnected NH<sub>3</sub> Line





# ***Balance-of-Plant Impacts***

- ♦ **NH<sub>3</sub> Slip**
- ♦ **SO<sub>3</sub>/NH<sub>3</sub> Reactions (APH Deposition)**
- ♦ **HCl/NH<sub>3</sub> Reactions (Plume Visibility)**
- ♦ **Ash/NH<sub>3</sub> Absorption (Ash Sales, General Nuisance)**
- ♦ **N<sub>2</sub>O Emissions**

# ***What is RSCR?***

**RSCR**



```
graph TD; RSCR --> Regenerative; RSCR --> Selective; RSCR --> Catalytic; RSCR --> Reduction;
```

**Regenerative Selective Catalytic Reduction**

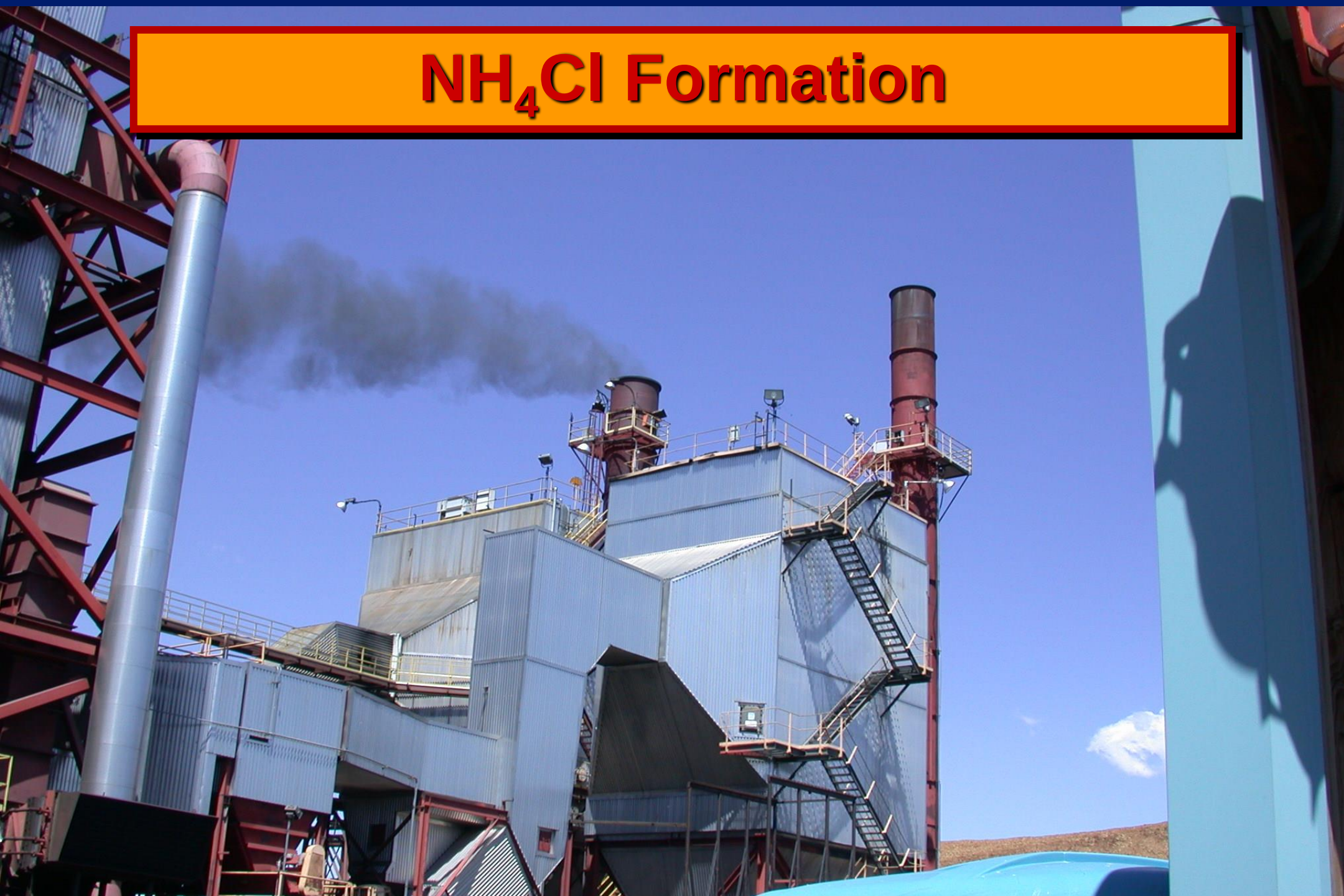
( This means that  $\text{NO}_x$  will selectively react with  $\text{NH}_3$  in the presence of Oxygen, similar to SCR with a catalyst to help the reaction and two thermal transfer beds)



## ***Ammonia Slip***

- ♦  $\text{NH}_3 + \text{OH} \Rightarrow \text{NH}_2 + \text{H}_2\text{O}$
- ♦  $\text{NH}_2 + \text{NO} \Rightarrow \text{N}_2 + \text{H}_2\text{O}$
- ♦  $2\text{NH}_3 + \text{OH} + \text{NO} \Rightarrow 2\text{H}_2\text{O} + \text{N}_2 + \text{NH}_3$
- ♦ 10 to 25 ppm  $\text{NH}_3$  Slip
- ♦ Could be higher
- ♦ Always have Some  $\text{NH}_3$  slip

# $\text{NH}_4\text{Cl}$ Formation





## ***NH<sub>4</sub>Cl Formation***

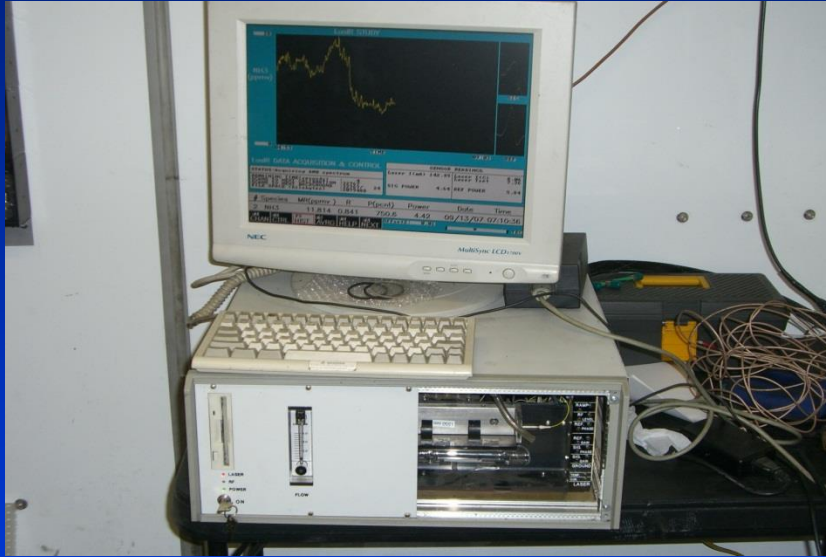
- ◆ Function of the concentrations of NH<sub>3</sub> and HCl
- ◆ Concentrations decrease as air is mixed into the plume
- ◆ Lower concentrations => less NH<sub>4</sub>Cl formed
- ◆ Therefore: air dilution is good

## ***What Can Be Done??***

- ♦ Minimize (eliminate Cl) in fuel
- ♦ Install acid gas controls
- ♦ Minimize  $\text{NH}_3$  slip  $\leq$  monitor
- ♦ High stack gas temperatures
- ♦ High ambient air temperatures (winter time a problem??)
- ♦ Promote rapid gas/air mixing ??
- ♦ Install high gas temperature concentric stack annulus ??

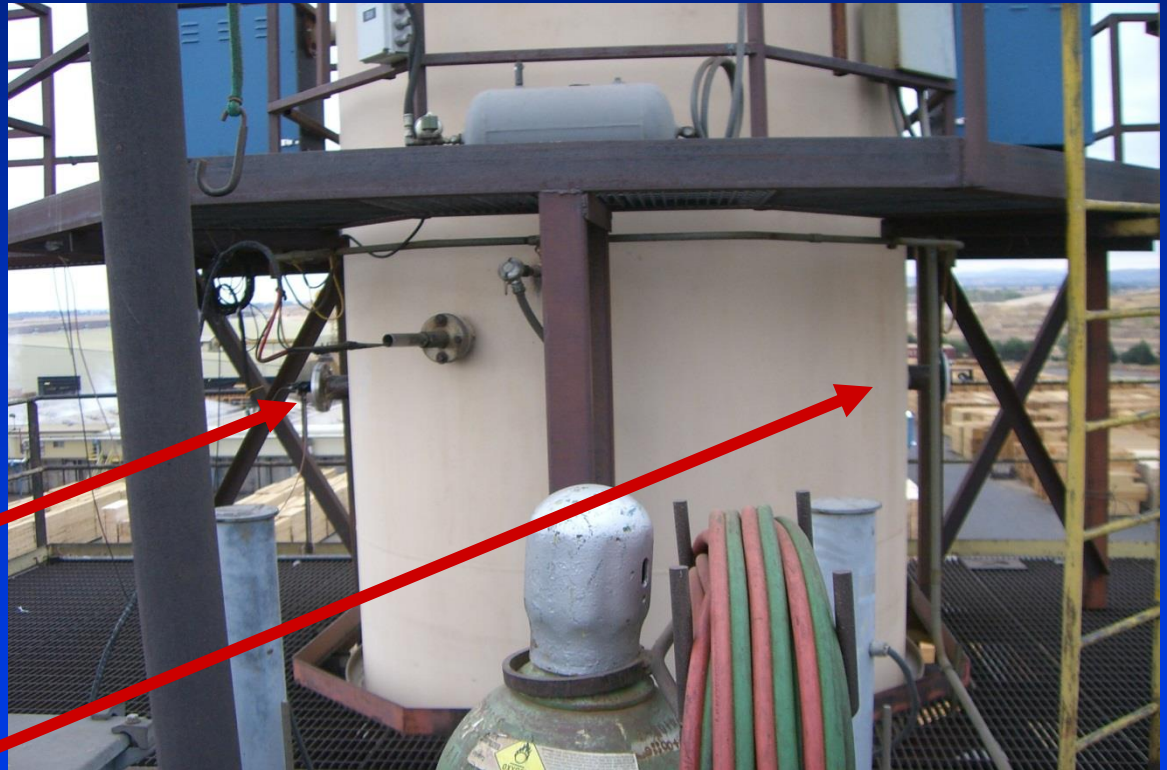


# Continuous $\text{NH}_3$ Analyzer



Laser &  
Detector

Retro  
Reflector



# Comparison of NOx Reduction Technologies

| Technology                                   | Approx. Reduction | Approx. lbs/MMBTU | Approx. ppmv @ 3% O2 |
|----------------------------------------------|-------------------|-------------------|----------------------|
| Standard burners                             | Base case         | 0.14              | 120                  |
| Low NOx burners                              | 60%               | 0.06              | 45                   |
| Ultra Low NOx burners – 1 <sup>st</sup> gen. | 80%               | 0.03              | 25 - 30              |
| Ultra Low NOx burners – 2 <sup>nd</sup> gen. | 95%               | 0.007             | 6 - 9                |
| FGR                                          | 55%               | 0.025             | 20                   |
| Compu- NOx w/ FGR                            | 90%               | 0.015             | 15 - 20              |
| SNCR                                         | 80%               | 0.033 - 0.085     | 27 - 70              |
| Catalytic Scrubbing                          | 70%               | 0.017 - 0.044     | 14 - 36              |
| SCR                                          | 90 – 95%          | 0.006 - 0.015     | 5 - 12               |



# **Let's Discuss PM Control**





# ***What is Particulate Matter??***

- ♦ It is what the test measurement says it is
- ♦ Meaning:
  - ♦ Solid particles that are captured on a filter
  - ♦ Condensable matter collected in a set of impingers
- ♦ What eventually condenses in the atmosphere is also considered as particulate matter along with “solid” particulate in the gas stream





**PM**



**Circulating  
Fluidized Bed  
Boiler**

***Sources of PM***



## ***Sources of “Particulate Matter”***

- ♦ **Ash in the fuel**
  - ♦ **Silica and Alumina** - generally large particles that are retained or collected in the boiler/precipitator
  - ♦ **Intrinsic ash** - generates the small particles that are more troublesome to control
  - ♦ **Alkalis** - potassium, sodium and calcium
- ♦ **Condensables (HCl, SO<sub>3</sub>, NH<sub>4</sub>Cl)** which are also considered as “particulates”

# Control of Particulate Emissions

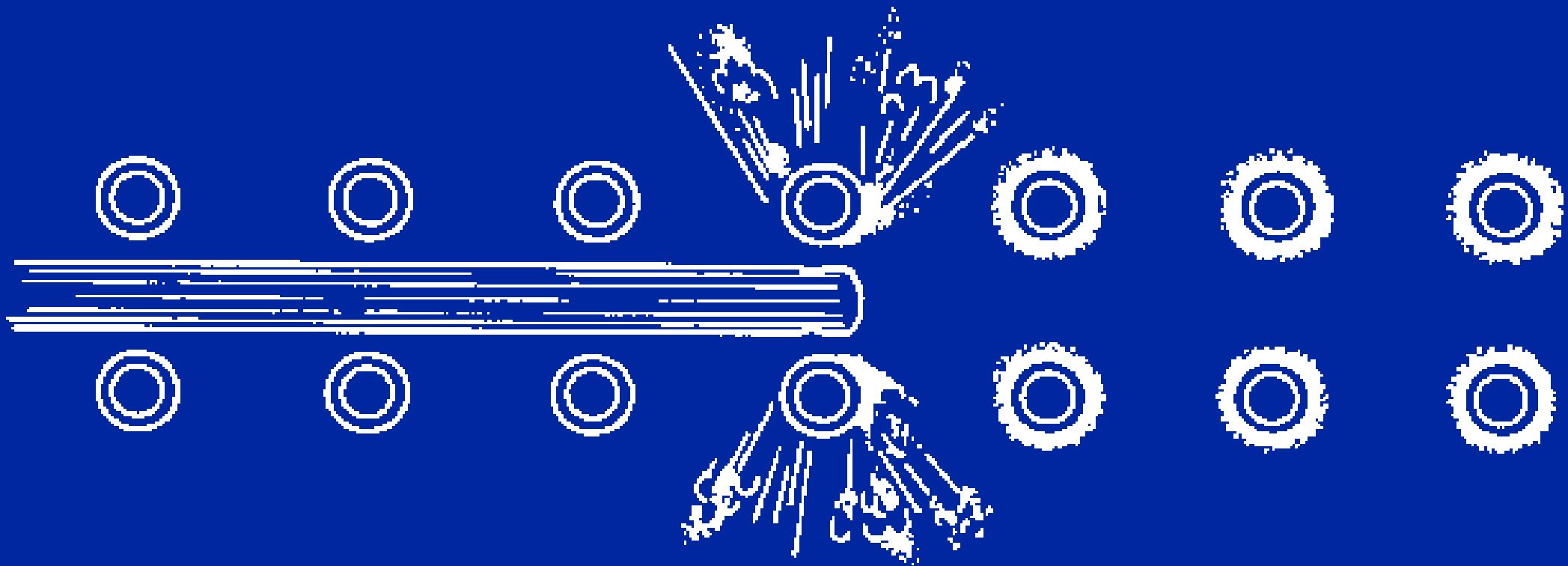
- ◆ Settling chambers
- ◆ Cyclones
- ◆ Baghouses
- ◆ ESPs
- ◆ Scrubbers



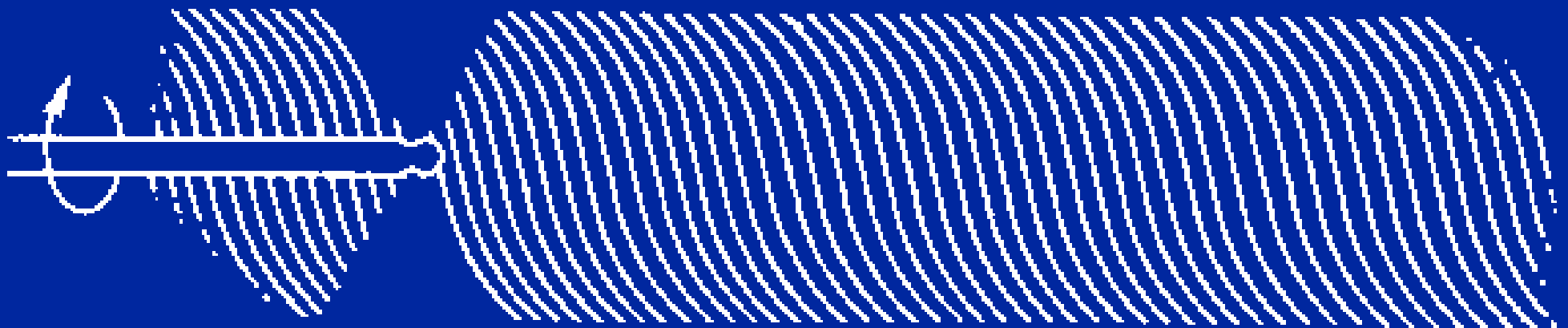


# Water Spray



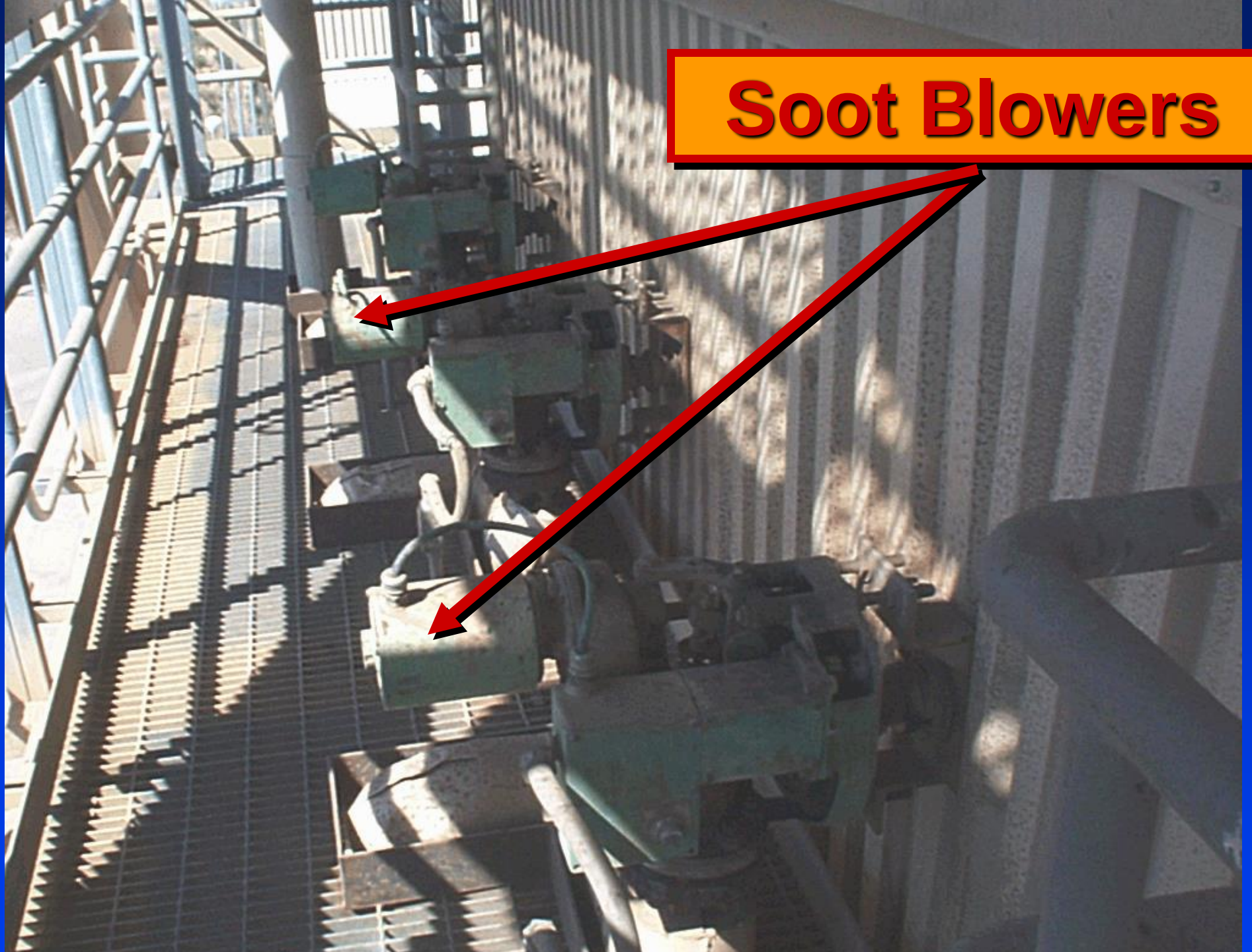


## Soot Blowing





# Soot Blowers





A large, yellow, conical industrial cyclone separator stands prominently in the foreground of a lumber mill. It has a long, curved yellow discharge chute on the left and a tall, grey, corrugated metal exhaust stack on the right. The structure is supported by a yellow metal frame with ladders and walkways. In the background, there's a dry, hilly landscape with a rocky outcrop. A parking lot with several vehicles, including a red and white truck, is visible. To the right, there are stacks of lumber and a red metal structure. In the distance, more hills and a small town are visible under a clear blue sky.

**Cyclone**





# Multi- Cyclone





**Baghouse**



**ESP**







**Regulatory  
Requirements**



# Regulatory Requirements

- ◆ Federal, state, and local requirements
- ◆ Boiler specific limits
- ◆ Permit requirements
- ◆ Monitoring requirements
- ◆ Visible emission limits
- ◆ Nuisance regulations
- ◆ Breakdowns & variances



# **Boiler Regulations**

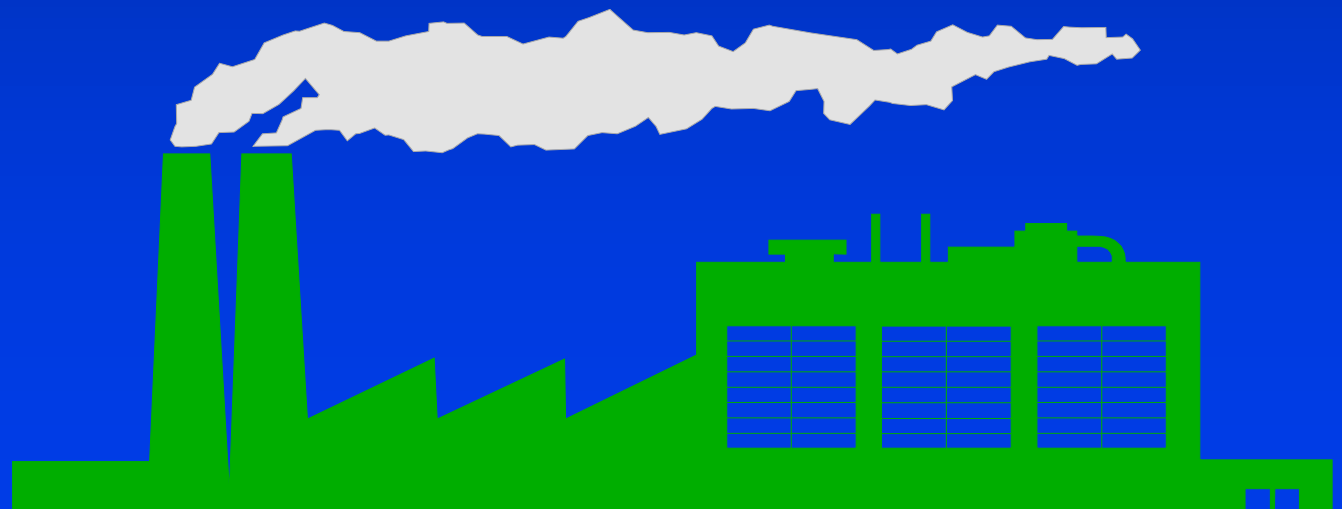
- ♦ **NSPS 40 CFR Part 60 Subpart D, Da, Db, Dc, Ea**
- ♦ **Acid Rain Provisions (Parts 72,73,74,75, 76, 77, 78)**
- ♦ **RCRA 40 CFR Parts 264 & 266**
- ♦ **State Regulations including VE**
- ♦ **SIP Requirements**
- ♦ **Local Regulations**
- ♦ **MACT DDDDD & JJJJJJ**





# Boiler Emission Limits

- ◆ NOx, SO2, particulate, and opacity values for boilers are based on applicable subpart, heat input, date built or modified, and fuel used
- ◆ States and districts may have more stringent limits



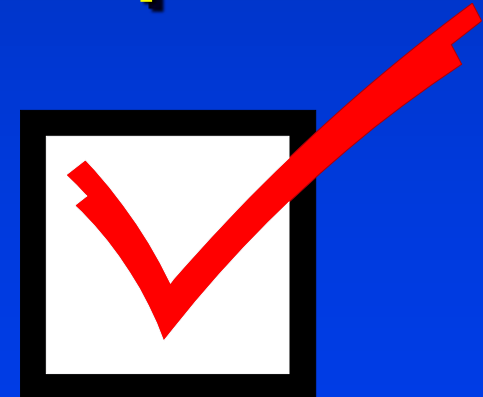
# BACT

| Type of Control                             | NOx Limits         |
|---------------------------------------------|--------------------|
| Natural Gas Fired with SCR & Low NOx Burner | 0.010<br>lb/MMBTU  |
| Natural Gas Fired Units (< 60 MMBTU/hr)     | 0.035<br>lb/MMBTU  |
| Biomass Fuel Fired Boilers (Large), SNCR    | 0.10<br>lb/MMBTU   |
| Municipal Solid Waste                       | 110 ppmv<br>@7% O2 |



# Permit Condition Categories

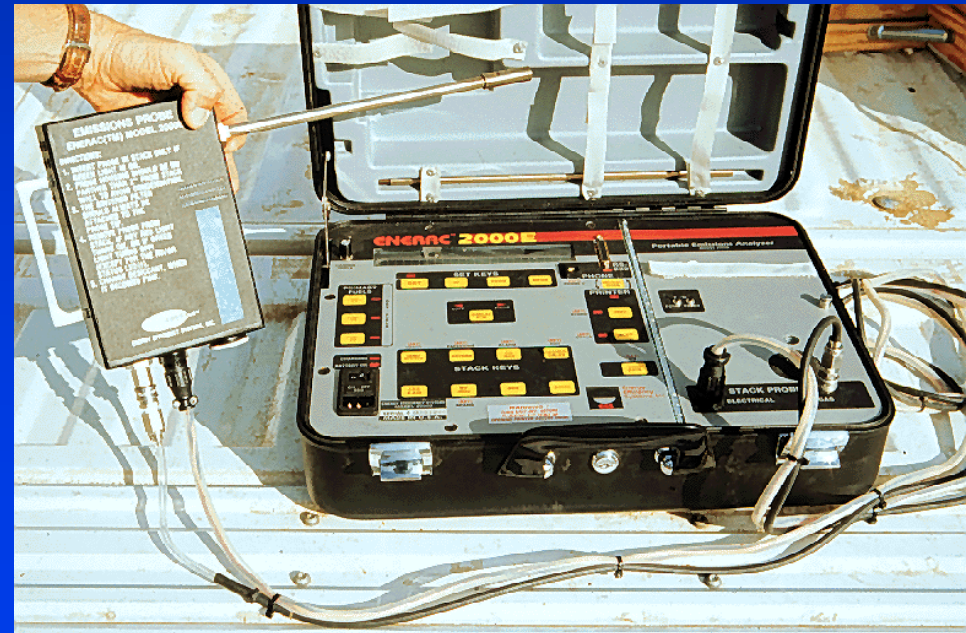
1. Emissions Limitations
2. Equipment Requirements
3. Operating Conditions
4. Monitoring and Recording Requirements
5. Compliance Testing
6. General Requirements



# Alternative Monitoring

- ◆ Portable analyzer monitoring of NO<sub>x</sub>, CO, O<sub>2</sub>
- ◆ Determination of FGR rate
- ◆ Burner mechanical adjustments
- ◆ O<sub>2</sub> Trim concentration
- ◆ FGR valve(s) setting

**Portable Combustion  
Analyzer**







# **Boiler Inspections**

# Points of Inspection

- ◆ Capture
- ◆ Transport
- ◆ Air mover
- ◆ Control device
- ◆ Instrumentation
- ◆ Subsystem
- ◆ Records





# Pre-Inspection



- ◆ Prepare inspection form
- ◆ File review
- ◆ Regulation review
- ◆ Equipment check
- ◆ Pre-entry & entry
- ◆ Pre-inspection meeting
- ◆ Permit check

# Reasons for Inspections

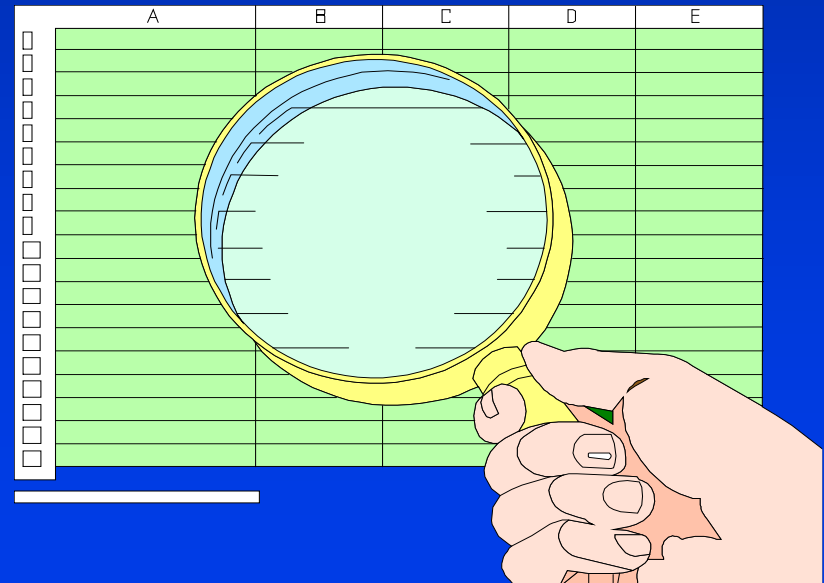
- ◆ **Compliance determination**
- ◆ **Complaint investigation**
- ◆ **Source plan approval**
- ◆ **Review or renewal of permits**
- ◆ **Special studies**





# Inspection

- ♦ Visible emission evaluation
- ♦ General upkeep & maintenance
- ♦ Monitoring instruments & records
- ♦ Fuel type and quality
- ♦ Maintenance records
- ♦ Operational records
- ♦ Source tests





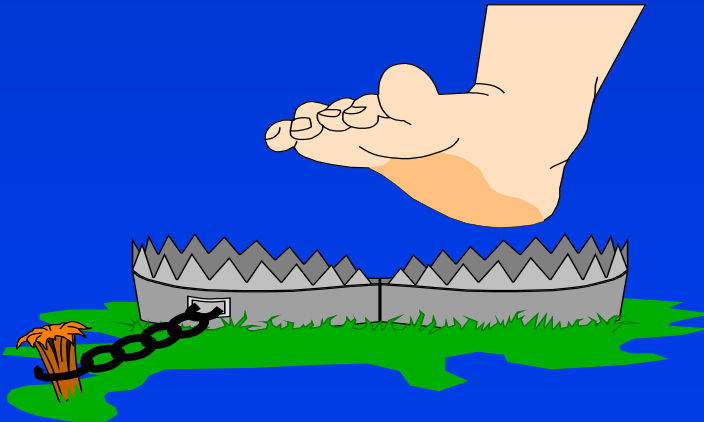
# Plant Safety





# Inspector Safety

- ♦ Proper equipment
- ♦ Plant warnings
- ♦ Heat
- ♦ High pressure steam
- ♦ Electrical hazards
- ♦ Noise
- ♦ Moving parts
- ♦ Inhalation hazards
- ♦ Hazardous materials
- ♦ Machine disintegration
- ♦ Fires
- ♦ Other hazards & traps





**Plant Safety**





**Plant Hazards**



**Confined  
Space**







**DANGER**  
**CONFINED SPACE**  
ENTER BY PERMIT ONLY

**Confined  
Space**

**DANGER**  
**CONFINED SPACE**  
POSSIBLE NITROGEN  
ATMOSPHERE  
ADEQUATE MECHANICAL  
VENTILATION REQUIRED



**DANGER**

**CONTAINS ASBESTOS FIBERS**

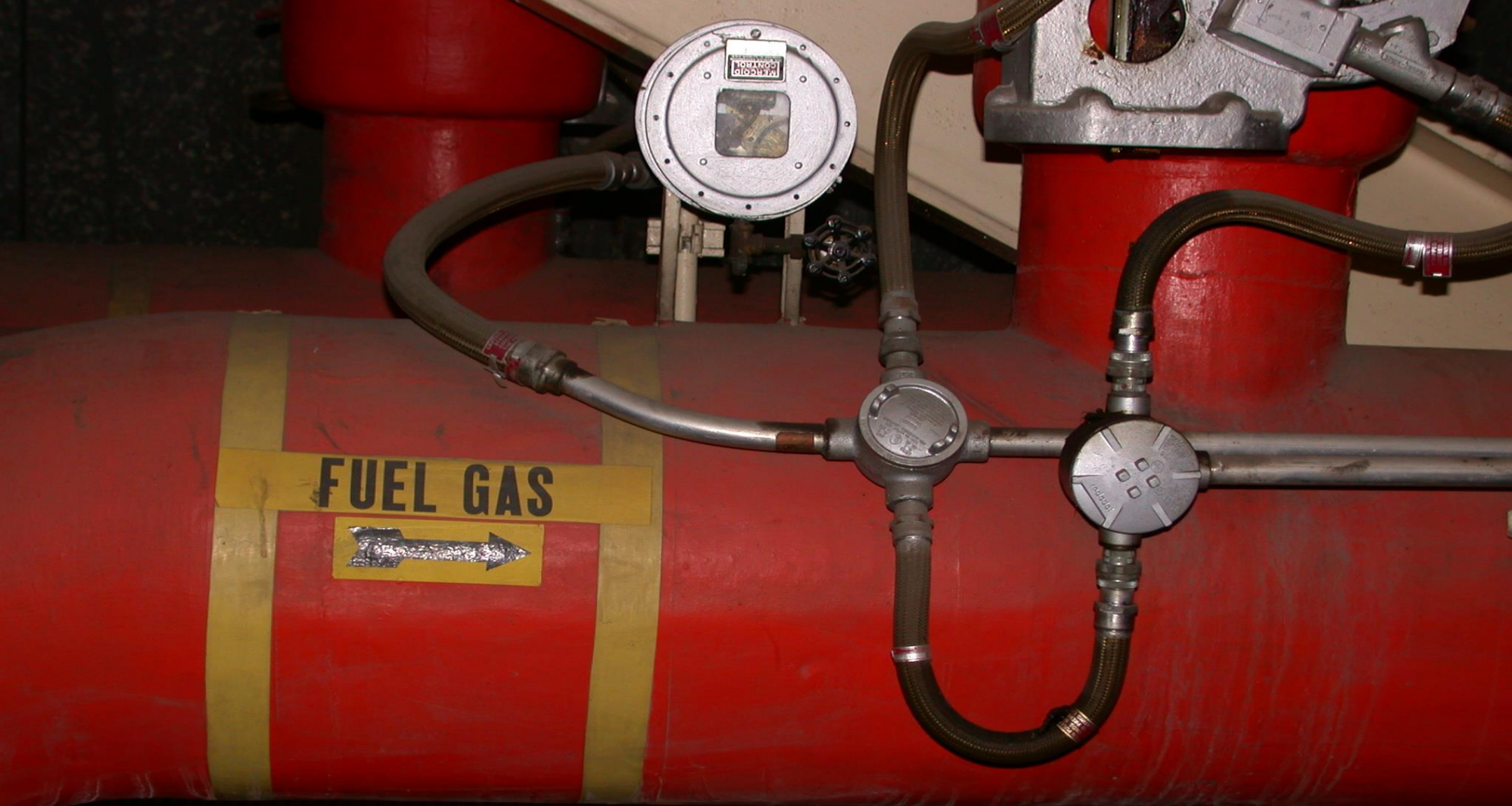
**AVOID CREATING DUST**

**CANCER AND LUNG DISEASE HAZARD**

**AVOID BREATHING AIRBORNE ASBESTOS**

62-1397 (5/88)





**HP Gas Lines**



A photograph showing a significant rupture in a wall, likely made of drywall or plaster. The hole is irregular and jagged, revealing a dark, hollow interior. A bright, intense light source, possibly a flashlight, is directed at the hole from the right, creating a strong glare and illuminating the edges of the damage. The surrounding wall surface is a light, off-white color with some visible texture and minor discoloration. In the bottom left corner, there is a red rectangular box with a black border containing the text "Ruptured Steam Line" in a bold, black, sans-serif font.

**Ruptured  
Steam Line**





The image shows an industrial setting with large, insulated pipes and a motor. The pipes are wrapped in grey insulation and have a pinkish-purple outer layer. A motor is visible in the background, emitting a bright orange glow. The scene is dimly lit, with the primary light source being the motor's glow.

**Steam  
Exhaust**



**Access**







**Access**

# Thank You!

