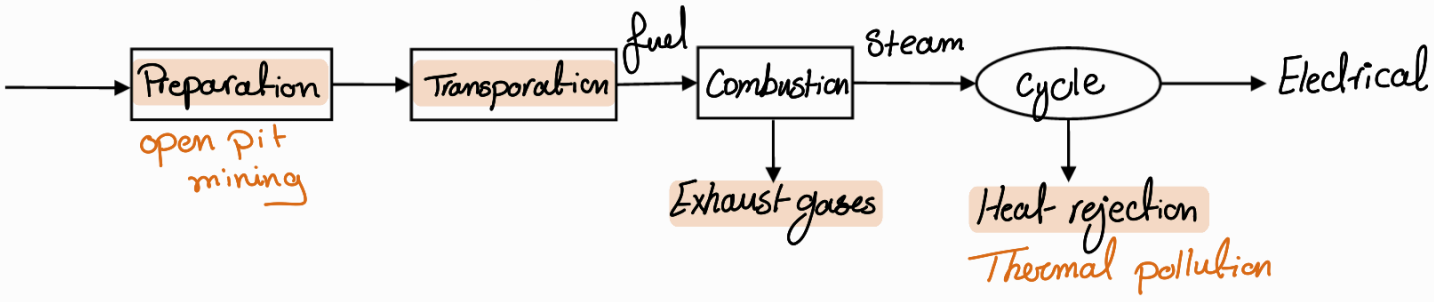
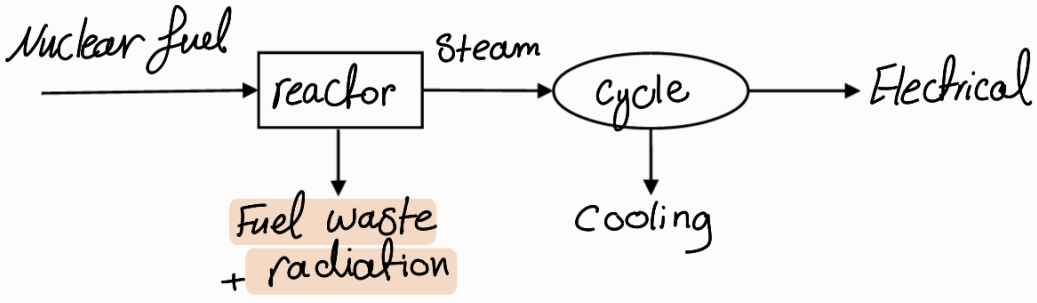
Chapter 5: Energy Conversion

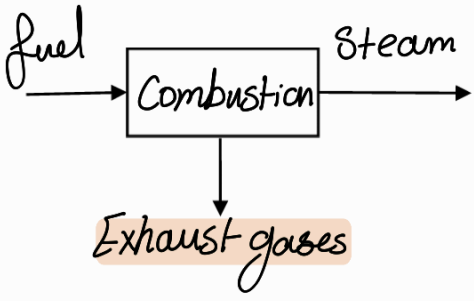
- Steam power plant pollution sources



- Nuclear power plant pollution sources



- Gas turbine pollution sources



: Pollution sources

Power generation pollution

- Gaseous: SO_x, NO_x, CO, CO_2, + particle
  Aldehydes and hydrocarbons.
- Thermal
- Nuclear radiation and waste

Gaseous

▷ SO_x gas ⟹ Slide 10 for details

- SO_2 and SO_3
- Toxic and cause irritation to mucus membrane so it harms people
- Causes acid rain: $SO_3 + H_2O \longrightarrow H_2SO_4$ which harms vegetation (It has acidity lower than PH = 5.6)

▷ CO_2 gas

- Green house gas

Allows short wave sun radiation → Absorbs and bounces long wave radiation → Prevent earth cooling → EarthT increases

▷ CO gas ⟹ Slide 13 for details

- Colorless odorless gas that results from incomplete combustion
- CO sources: Automobile
  Industrial processes
  Residential processes
- CO effects: Harmful for humans
  1. Reduces O_2 delivery to tissues and organs
  2. Impair visual perception
  3. Can be life threatining

▷ NO_x gas

- NO, NO_2 and other minor nitrogen oxides
- Combustion product
- NO_x sources: Automobile
  Industrial processes
  Residential processes

- NO_x effects: 1. Causes health problems
  2. Creates Smog
  3. Acid rain
  4. Reduces visibility in urban area

□ Smog — CFC: Chloro Fluro carbons

- Smoke and fog ← NO_2
- Composed from: NO_x, SO_x, O_3, Smoke, particulates and other less visible pollutants (CO, CFC and radioactive sources) + Photochemical oxidation + Sunlight

□ Particulates PM

- Effects: 1. Harmful to humans (Breathing problems)
  2. Environmental (Visibility impairement, atmospheric deposition, Aesthetic damage and blanket- Sun radiation)
- Sources: •Inclustrial processes
  •Transportation
  •Residential
  •Dust from roads, construction and agricult-ural emissions

Air pollution Standards

1. Emission rate standard (Concentration of pollutants emitted)
2. Ambient concentration Standard (Concentration of pollutants at ground level)

▷ SO_2 control by: → 90% reduction H / 70% ~ L

1. Burning low sulfur fuel → Expensive
2. Reducing sulfur content- of fuel before combustion → Costly

$CaCO_3$ / $MgCO_3$

3. Removing SO_2 from product gases : • By adding additives to fuel
(Slide 29) • By fluidized bed combustion
$CaO + SO_2 + \frac{1}{2}O_2 \rightarrow CaSO_4$ • Flue gas scrubbing

☐ Flue gas scrubbing : Scrubbing the flue gases
1. Wet Scrubbing (FGD)
2. Dry Scrubbing

○ Wet- Scrubbing

FGD reaction

$$CaCO_3 + SO_2 + \frac{1}{2}O_2 \longrightarrow CaSO_4 + CO_2$$

Thrown away or re used to produce H_2SO_4

Flue gas → Fly ash removal device → SO_2 absorber

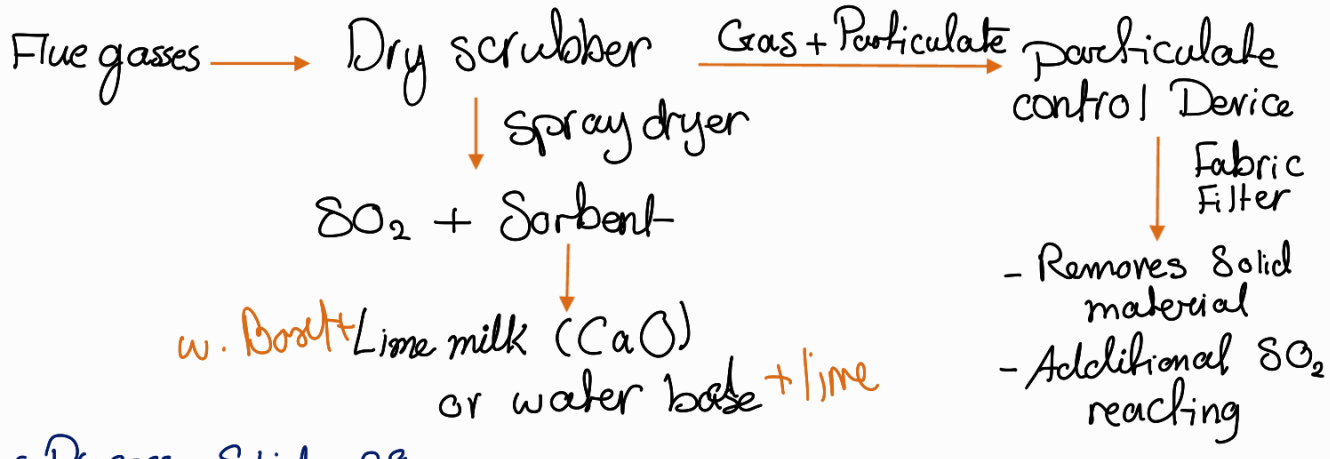
Fly ash removal device:
- Electrostatic percipitator
- Wet Scrubber
  - spray towers (Slide 36)
  - Venturis
  - Plate towers
  - mobile packed beds

Spray towers / Venturis / Plate towers:
- vertical or Horizontal
- Cocurrent
- Counter current
- cross current-

SO_2 absorber → Saturated with water → Highly Corrosive gases

Corrosion minimizing:
1. reheating gases above dew point-
2. Choosing construction materials and design

- Dry scrubbing
  - Dry injection or spray drying



For Process : Slide 38

▷ NO_x Control

* Thermal NO : NO resulting from combustion air
  → Higher flame temperature produces larger amounts of NO
  → Flame temperature is influenced by :
    1. Rate of furnace cooling
    2. Combustion air temperature
    3. Excess air
* Fuel NO_x
  → NO_x from fuel which is a function of nitrogen in fuel

* NO_x control method
  1. Flue gas recycling
  2. Two stage combustion & off stochiometric firing
  3. Increasing the cooling rate

* Control techniques
  1. Low- excess air firing
  2. Staged combustion
  3. Flue gas recirculation
  4. Low NO_x burners
  5. Re-burning

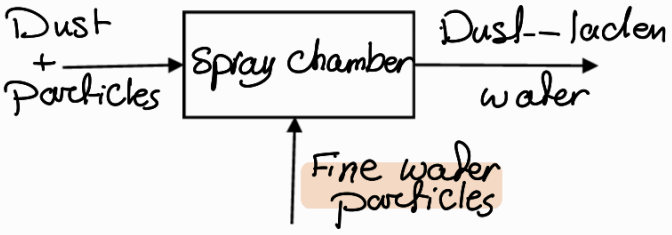
- Re-burning
  Taking a 10-20% of fuel and injected it to create a rich fuel in the reburn zone ⟶ reduces NO_x

- Two-Stage combustion or off-stochiometric firing: some of burners are operated fuel rich and others are air rich ⟶ reduces NO_x by a 5-6 factor

▷ Particulate control
- Effects: 1. Cause respiratory problems
  2. Eye irritation
  3. Enhance smog formation
- Types: Dust (100 μm) / Fume (0.03-0.3 μm) / Mist (0.5-3 μm) / Smoke (0.05-1 μm) / Spray (10-100 μm)
- Control methods
  1. Electrostatic precipitators
  2. Bag filters
  3. Scrubbers (wet)
  4. Mechanical dust-collection (cyclones)

- Cyclones Slide 54
  - Removes coarse particles
  - Separates particles from air by exploiting their inertia
  - Used before fine particles control devices
  - Advantages: 1. Simple design
    2. Small floor area
    3. low pressure drop
    4. High particle loading rates

- Wet scrubber
  - Washes dust and particles



- Electrostatic percipitators (EPS) Slide 61
  - Uses electrostatic charge to separate particles
  - Consists of wires and plates with high voltage difference

Grounded

- Bag filter Slide 65?
  - Used for: • Expensive material (high collect- efficiency needed)
    • Fine Sized particulate

Thermal pollution

- Thermal discharge index (TDI):

$$TDI = \frac{\text{Thermal power discharged to environment } MW_{th}}{\text{Electric power output } MW_e} = \frac{1 - \eta_{Th}}{\eta_{Th}}$$

- Heat is rejected by condenser cooling system and exhaust gases + heat losses in cycle

- Effects: Increases T of water bodies
  - Fresh water → Aquatic life is harmed
  - Salt water → Marine life is enhanced

- Limitations are on cooling systems → Cooling towers are used
- EPA standards are 2.8°C increase in temperature for once-through cooling system

Nuclear waste

- Radioactive waste: Number of radio isotopes which are unstable configurations of elements that decay, emitting ionizing radiation.
- Sources: 1. Nuclear fuel cycle: In All processes of nuclear fuel cycle, from front end to back end
  2. Medical and industrial wastes

- Front- end
  - Fuel preparation
  - Main by-product of enrichement is DU (U-238 & U-235) → Used in keels of yachts & anti-tank shells

- Back end
  - Spent fuel rods → Fission products (Sr-90 H.E β; Cs-137 H.E β; Sn-126 H.E γ) → in nuclear reactors
    Acitinicles &
    neutron emittors

  - Management: By destroying, diluting or isulating radio active element

1. Fuel reprocessing
   Waste fuel is temporarly stored then it is processed and used.
   Vitrification: Mixing high-level waste with sugar then Calcination (Slide 90, 91)
   (solidification)

2. Fuel Storing
   Stored for several years under water in cooling ponds to provide cooling and radiation protectio

3. Burials: Under the sea or under the ground

EPA limits

SO_2: Coal: $\frac{0.52}{10^6}\ \frac{kg}{KJ}$

Oil: $\frac{0.34}{10^6}\ \frac{kg}{KJ}$

In 1978 Standard 90% reduction for High Sulfur coal

NO_x: Coal: $\frac{0.3}{10^6}\ \frac{kg}{KJ}$

Oil: $\frac{0.13}{10^6}\ \frac{kg}{KJ}$

gas: $\frac{0.086}{10^6}\ \frac{kg}{KJ}$

70% reduction for low Sulfur coal

Particulates: Coal, gas, Oil } $0.043\ \frac{kg}{KJ}$