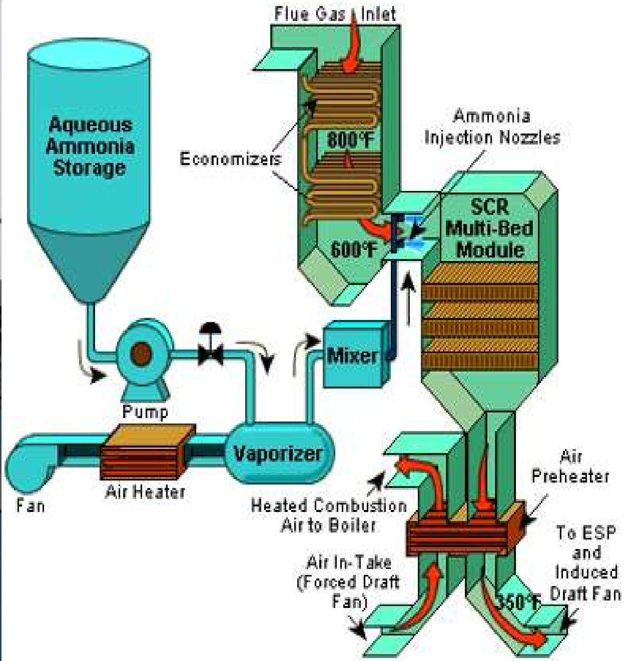
Curtailment of Sox & NOx in Thermal Power plants

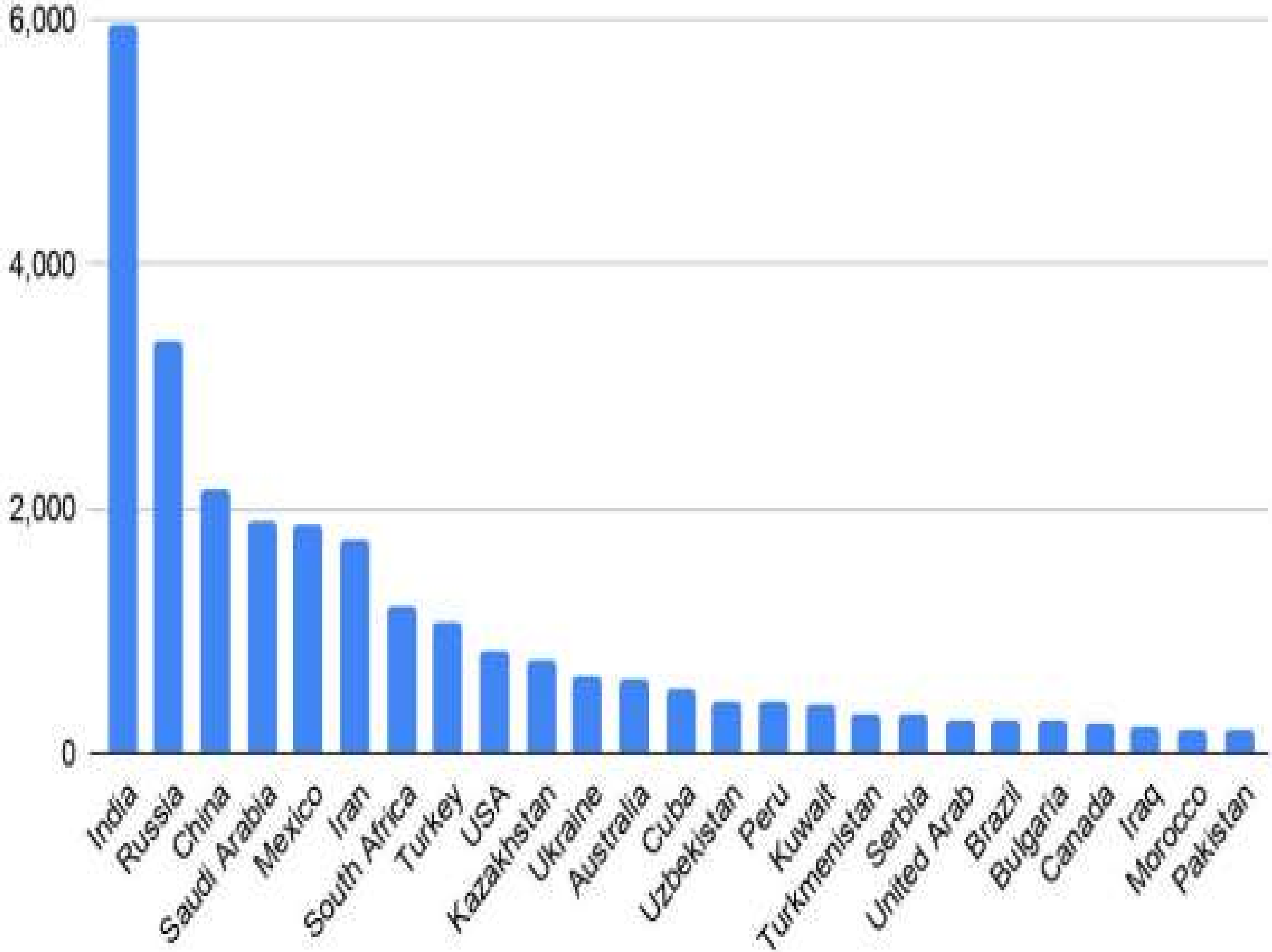
A thorough update on the adopted measures, ground realities and progress so far
Dated: 17/08/2022



Contents

Top 25 emitter countries of anthropogenic SO2 in 2019

SO2 emissions in k Tons (yr 2019)



Center for Research on Energy and Clean Air & Greenpeace India. India: 5953 k Tons , Russia: 3362, China 2156

New environmental norms (limits notified as on Dece 2015)

Description	SO_2		NO_x	SPM	Mercury (Hg)	Sp water consumption
	mg/Nm3					m3/MWh
Installation Period	Units < 500 MW	Units > 500 MW				
Before 31/12/2003	600	200	600	100	0.03	3.5
01/01/04 to 31/12/16			**300**	50		
From 01/01/2017	100		100	30		**2.5**

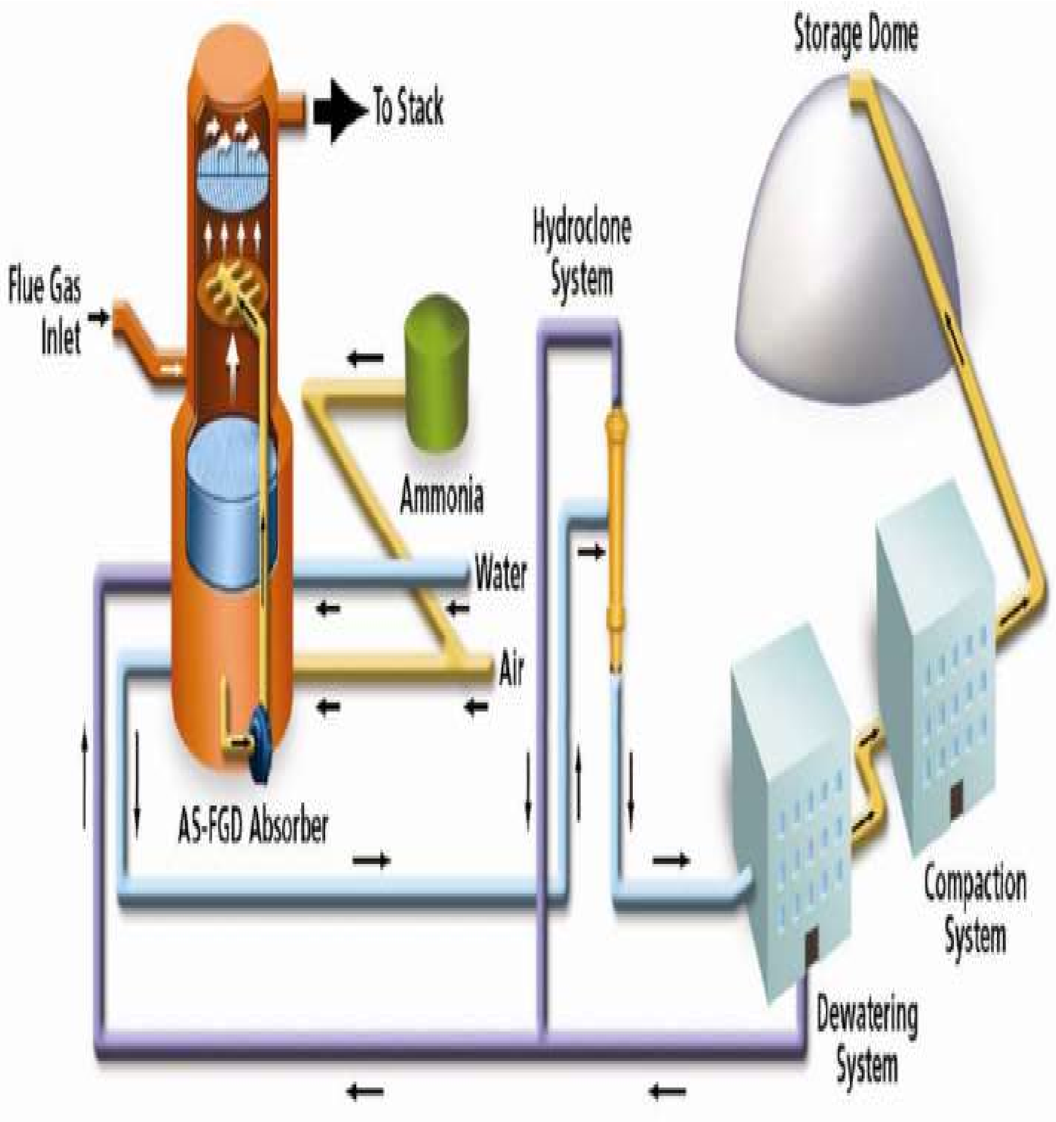
Water norms:

- All plants with once through cycle (OTC) shall install Cooling Tower (CT) and achieve specific water consumption of 3.5m3/ MWh within 2 years of notification.
- All existing CT based plants shall reduce specific water consumption up-to-maximum of 3.5m3/MWh within a period of 2 years.
- New plants to be installed after 01/01/2017 shall have to meet specific water consumption of **2.5 m3/MWh** & **achieve zero water balance**.

Types of FGD Process

i. Ammonia based Desulphurization System
ii. Sea water FGD system
iii. Circulating Dry Scrubber Technology
iv. Dry Sorbent Injection (DSI) system
v. Wet Flue Gas Desulphurization System

Ammonia FGD

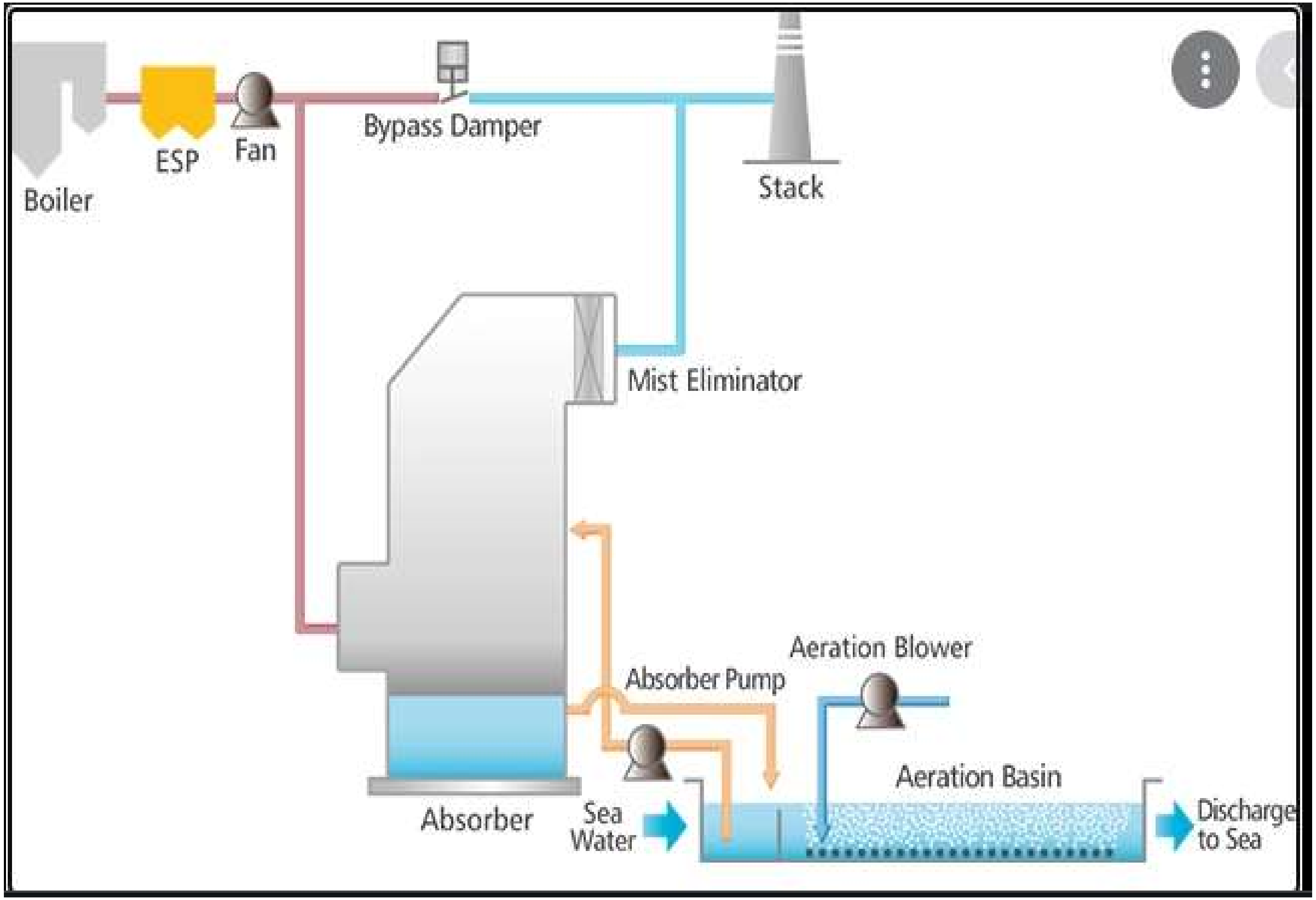


(1) $SO_2 + 2NH3 + H_2O \rightarrow (NH_4)2SO_3$

(2) $(NH_4)2SO_3 + ½O_2 \rightarrow (NH_4)2SO_4$

- NH3, fg, oxidizing air and process water enter an absorber containing multiple levels of spray nozzles.
- The nozzles generate fine droplets of NH3 -containing reagent to ensure intimate contact of reagent with incoming fg.
- The SO_2 in the flue gas stream reacts with NH3 in the upper half of the vessel to produce **ammonium sulfite.**
- The bottom of the absorber vessel serves as an **oxidation tank** where air oxidizes the ammonium sulfite to ammonium sulfate.
- The resulting ammonium sulfate solution is pumped back to the spray nozzle headers at multiple levels in the absorber.
- Prior to the scrubbed fg exiting the top of the absorber, it passes through a demister that coalesces any entrained liquid droplets and captures fine particulates.

Sea water FGD

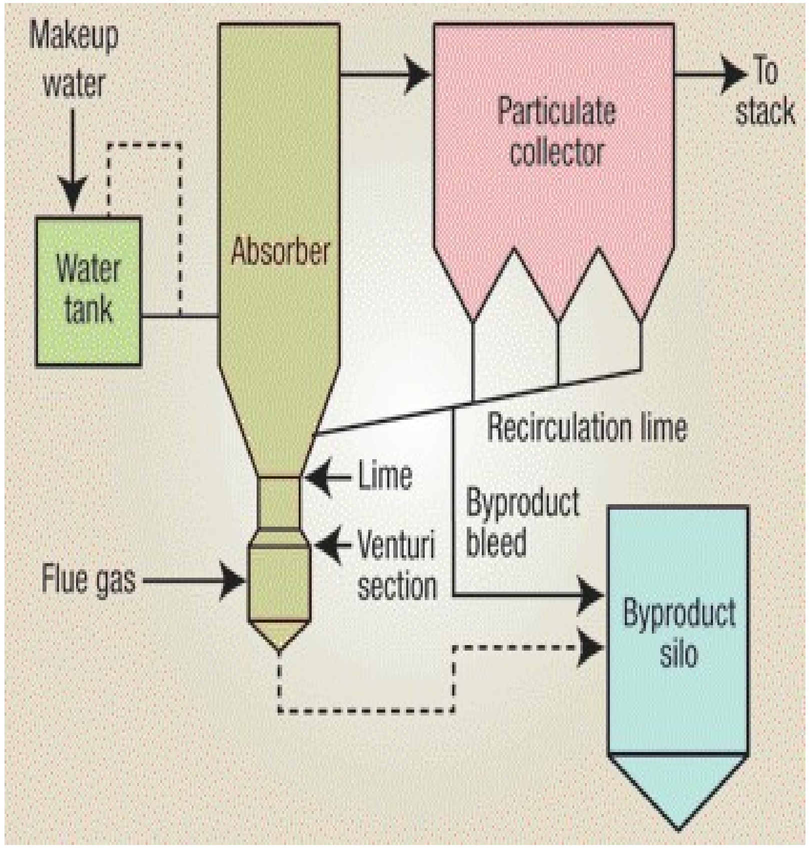


- Absorber
- Absorber Spray pumps
- Mist eliminator
- Oxidation basin or Aeration basin
- Oxidation air blower
- Oxidation Air distribution system
- Wet stack

$CaHCO3 + NaHCO3 + SO2 = Na2SO3 + CaSO3 + H2O + CO2$

$Na2SO3 + CaSO3 + O2 = Na2SO4 + CaSOO4$

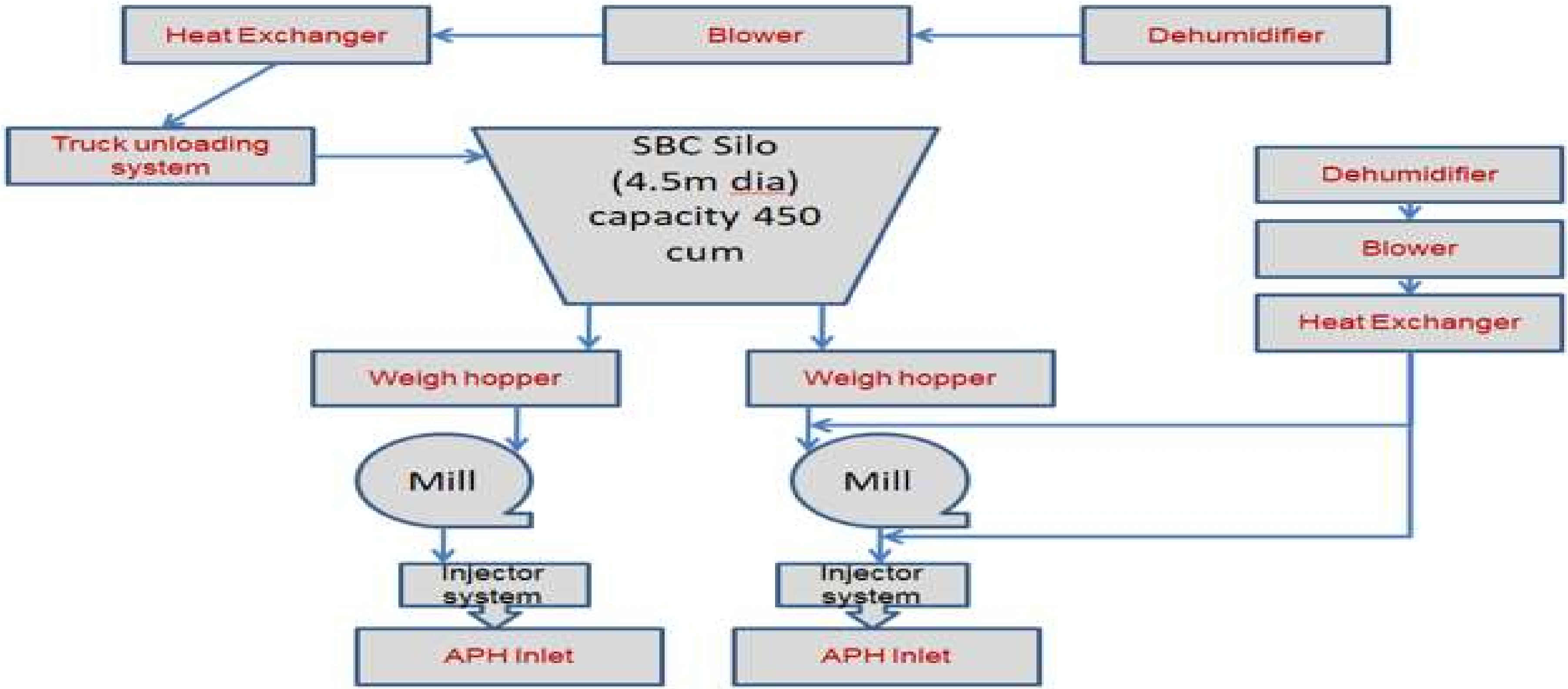
Circulating Dry Scrubber (CDS) technology (Semi dry type).



CDS: Circulating Dry Scrubber

- Flue gas passes through parallel venturies mixing with **hydrated lime**, water and **recycled solids** to create a fluidized bed where the reaction of the calcium with the SO_2 and SO_3 to form CaSO3 and CaSO4 takes place.
- **Reagent is added as a dry powder** into the absorber to allow for adequate mixing with the flue gas.
- **Water is injected** independently into the absorber, **cooling the flue gas to a specified temperature** range above the saturation temperature.
- The flue gas, containing CaSO3 and CaSO4 and fly ash, then travels to the ESP, where solids are captured and removed from the system.
- Large quantities of solids are recycled back to the absorber for use in the fluidized bed.

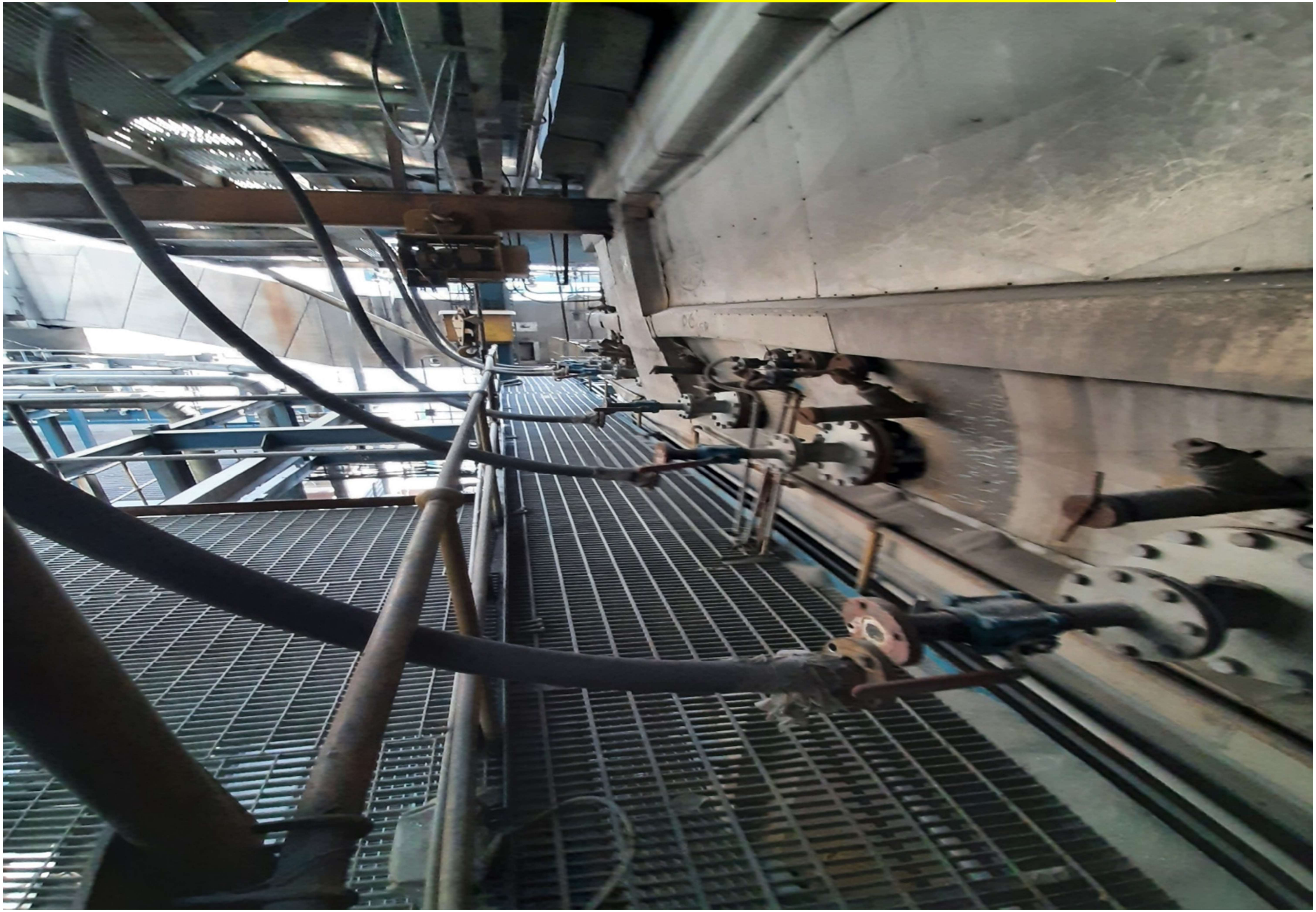
Dry Sorbent Injection System schematic Diagram



Sorbent : Sodium Bicarbonate: $2NaHCO_3 + SO_2 + 1/2\ O_2 = Na_2SO_4 + 2CO_2 + H_2O$

Sorbent: Sodium Carbonate: $Na_2CO_3 + SO_2 + 1/2\ O_2 = Na_2SO_4 + CO_2$

Sodium Bicarbonate (is injected in 2nd pass before APH)



Technology Selection

Factors considered:

1: Sulphur Content in Coal.

2: SO_2 removal Efficiency requirement of particular plant.

3: Availability of Reagent (if any).

4: Disposal and handling of By-product.

5: Locational/Geographical factors of the plant.

6: Plant life.

7: Space requirement for FGD facility.

Design Basis

The Flue Gas Handling System is designed to handle 100% of the boiler effluent flue gas & is based on the following:

- Flue gas flow at FGD inlet
- Flue gas temp at FGD inlet
- Type of coal used.
- Sulphur content in coal
- SO2 content at inlet (mg/Nm3)
- SO2 removal efficiency desired/ SO2 emissions (mg/Nm3)

Maximum gas flow rate – per absorber (Nm3 /h)	3,400,000
Power plant size (MW)	up to 1,000
Fuel	Coal, lignite, oil, HFO, industrial processes
Maximum SO2 content at inlet (mg/Nm3)	15,000
SO2 Removal rate with GGH (%)	98
SO2 Emissions (mg/Nm3)	30
Load range (% MCR)	20 - 100
Seawater temperature inlet to absorber (°C)	4 - 45
Alkalinity – minimum (mmol/l)	1.2
pH Seawater inlet (minimum)	7.7

Gypsum by-product

The purity of the Gypsum by-product of a typical FGD system:

- Gypsum purity of 90 % minimum
- Moisture content of 10 % maximum
- Chloride content 100 ppm maximum

for the specified range of specified coal(s) and design limestone.

Basic chemistry of FGD system

Sulphur di oxide (SO_2) + **Limestone (CaCO3)** → **Gypsum (CaSO4.2H2O)**

Chemical reaction

$CaCO_3$ (Limestone) + H_2O = $Ca(OH)_2 + CO_2$

$Ca(OH)_2 + SO_2 = CaSO_3 + H_2O$

$CaSO_3 + 3H_2O + \frac{1}{2} O_2 = CaSO_4.2H_2O$(Gypsum)$+ H_2O$

Overall

$$SO_2 + CaCO_3 + 2H_2O + 1/2\, O2 = CaSO_4.2H_2O + CO_2$$

Lime stone based Wet Flue Gas Desulphurization System

Overall System Description

1. Flue Gas handling system
2. Limestone handling system
3. Reagent preparation & Reagent feed system
4. Absorber, Reaction tank, Mist eliminator system, Recycle Spray System, Forced Oxidation System, Aux storage system.
5. Primary & Secondary Dewatering System
6. Gypsum handling system
7. Filtrate water system

Flue Gas Handling System

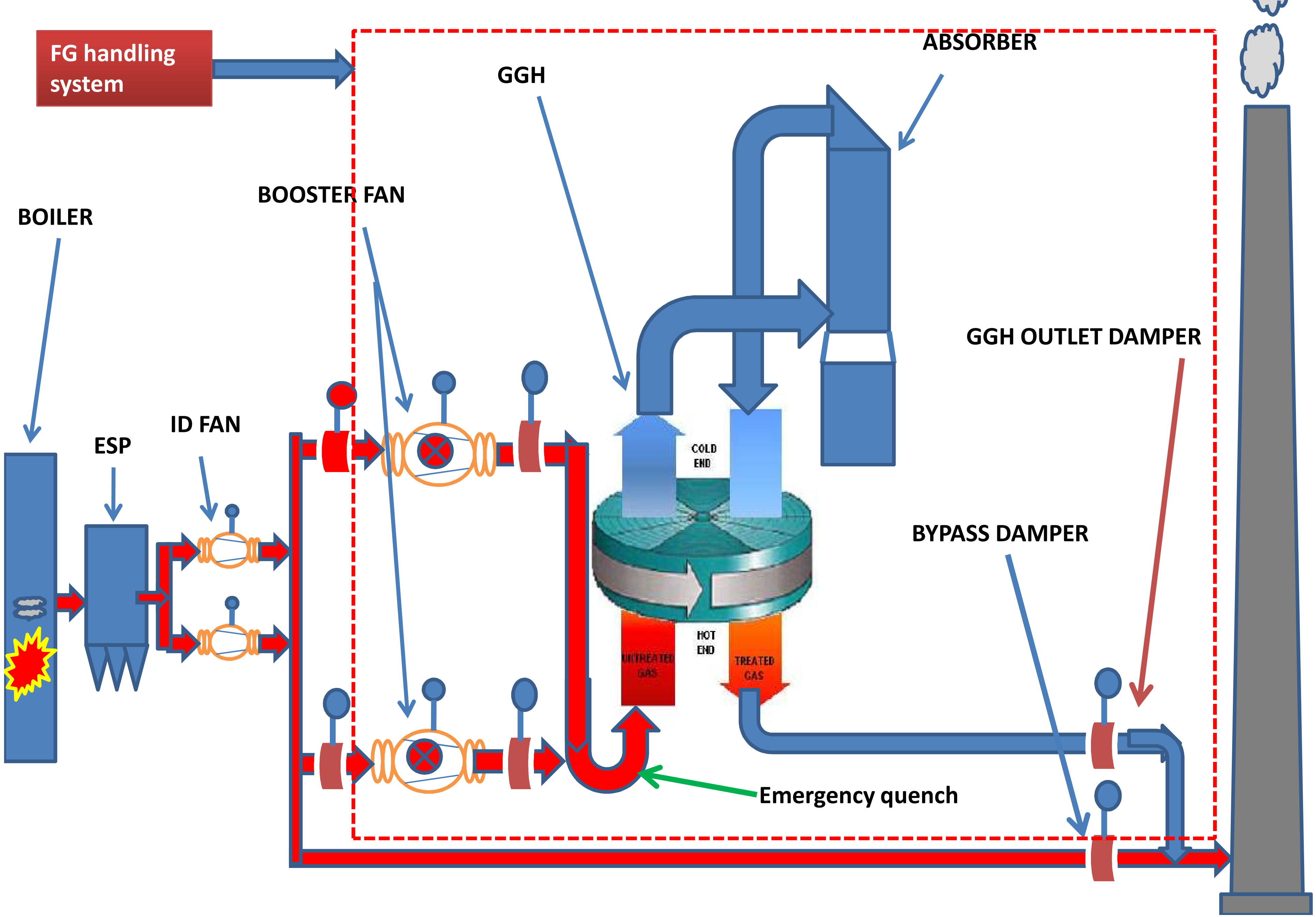
FUNCTION:

- It carries the untreated flue gases laden with SO_2 to the absorber for treatment and then to the stack for distribution into the atmosphere.

- Monitoring equipment to be provided for measurement of the
- SO_2 contained in the flue gas entering the WFGD system
- SO2 level leaving the WFGD system.

This information determines the SO_2 removal efficiency.

Flue Gas Handling System



Why Booster fans ?

- The addition of the ductwork, GGH and WFGD system equipment into the flue gas path imposes a higher draft demand on the existing ID fans beyond that for which they were originally designed.

- To satisfy increased demand, the existing ID fans are supplemented with Booster Fans to provide the additional motive force for driving the flue gas through the WFGD equipment into the existing stack.

GGH: Gas to Gas Heater
WFGD: Wet Flue Gas Desulphurization

Limestone Handling System

The purpose:

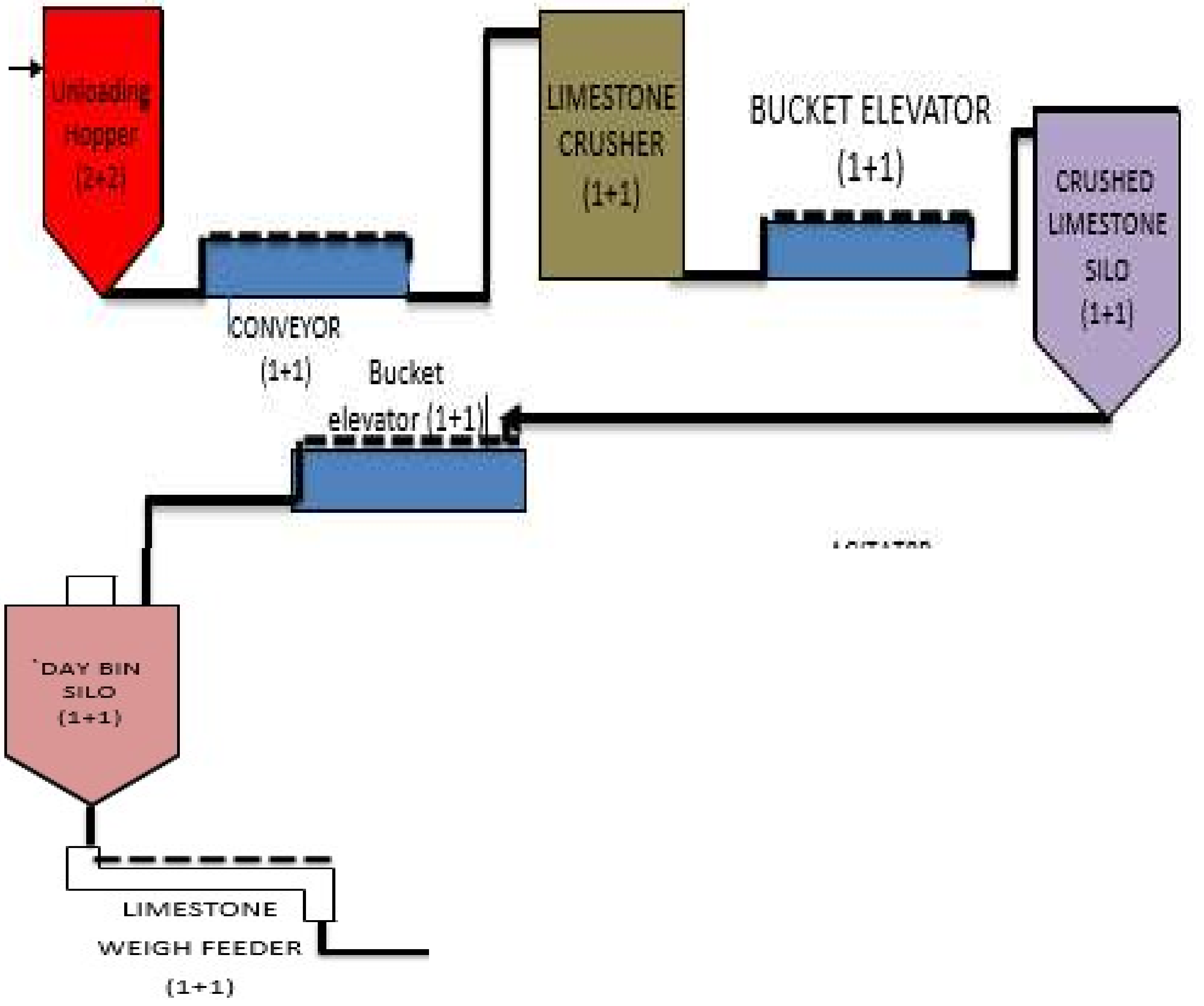
- To transport the limestone from delivery trucks to the unloading hoppers through a limestone crushing system.
- To store the limestone in Silo and deliver the same for the reagent preparation process.

Equipment in Limestone Handling System

Equipment:

- Unloading hopper
- Belt Conveyor
- Belt Feeders
- Limestone crusher
- Bucket elevator (transfers limestone from crusher to Silo)
- Crushed lime stone silo
- Bucket elevator (transfers crushed limestone from to Day Silo)
- Screw Conveyor
- Belt weighers
- Magnetic Separators
- Metal Detectors
- Rod gates
- Rack & Pinion gates

Flow Diagram of Limestone handling system



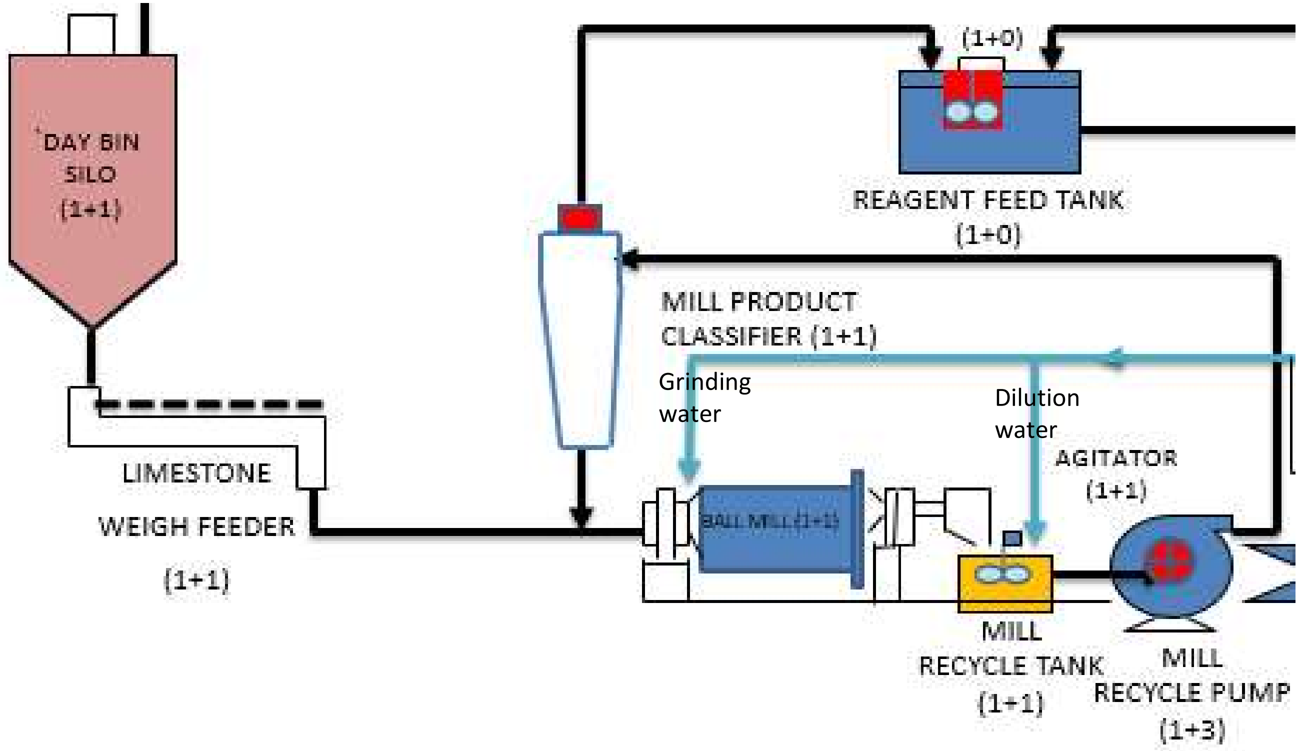
Reagent Preparation System

Function:

- ❖ The production of Limestone slurry by crushing limestone stored in the Limestone Silo and mixing it with water.
- ❖ Limestone slurry is used in the absorber.

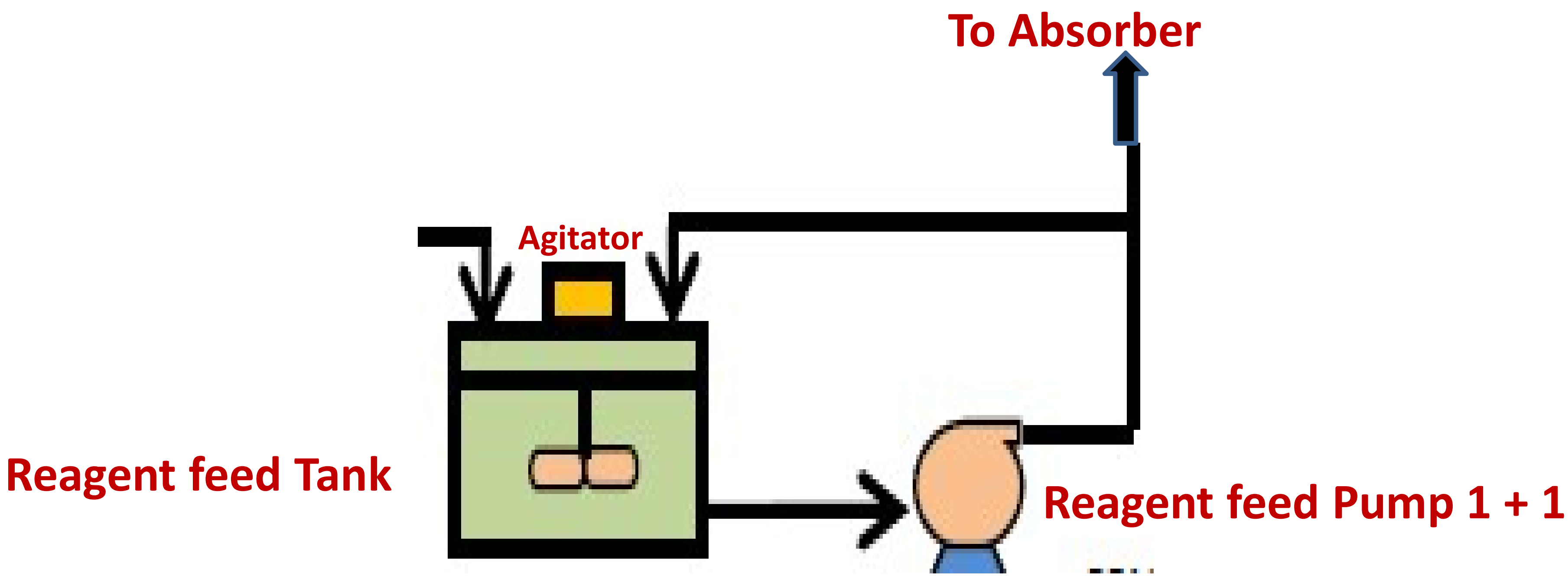
- The size of the limestone feed is reduced to a fine powder so as to increase the surface area of the limestone and this increases the reactivity of the reagent.
- Thus limestone is used more efficiently and use less limestone for a given amount of SO_2 removed.
- **Mixing of the limestone with water forms the reagent slurry of desired density** which neutralizes the SO_2 absorbed in the absorber.

Reagent Preparation System



- Lime stone, makeup water and mill product classifier underflow are fed to the inlet chute of the ball mill.
- Slurry of pulverized limestone overflows the ball mill & leaves through the gravity discharge chute.
- The product output passes 90 % through 325 mesh (44 micron) screen.

Reagent Feed System



The Reagent Feed Tank : Allows the efficient operation of the Reagent Preparation System while providing makeup of reagent slurry to maintain the required slurry chemistry.

Top-mounted Reagent Feed Tank Agitator:

Maintains the reagent slurry in suspension by circulation & agitation. It keeps the reagent slurry from settling to the bottom of the Reagent Feed Tank when the limestone (calcium carbonate) concentration is as high as 30% (total suspended solids).

Reagent Feed Pump (1 +1) : Continuously circulates the reagent through the reagent feed loop back to the tank. Delivers reagent slurry to the Absorber, as and when needed to maintain the Absorber process chemistry.

Absorber including Reaction tank, Mist Eliminator Wash System, Recycle spray system & Forced Oxidation System

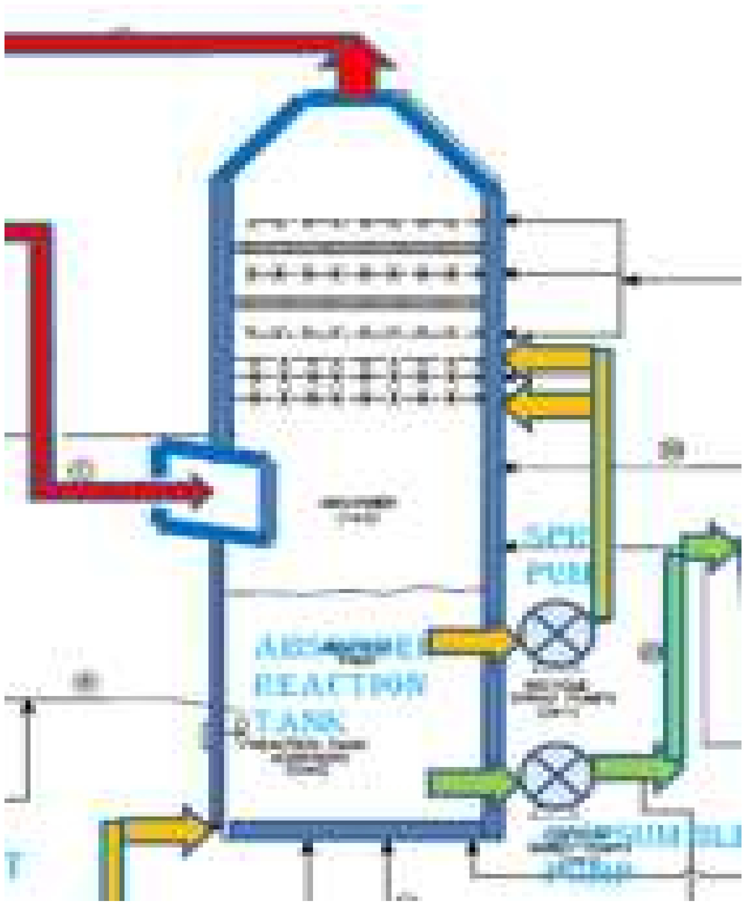
What is Absorber? General Terminology

Absorber:

- It is the vessel where SO2 is removed from the fg.

Absorber Open Spray Tower: (Also referred to as scrubber, wet scrubber, open spray tower)

- The upper part of the Absorber vessel where the slurry is sprayed, and the SO2 is absorbed and neutralized.



Recycle tank :

It is **the lower part of the Absorber vessel where slurry is held** and where some of the chemical processes take place.

- **Functions:**

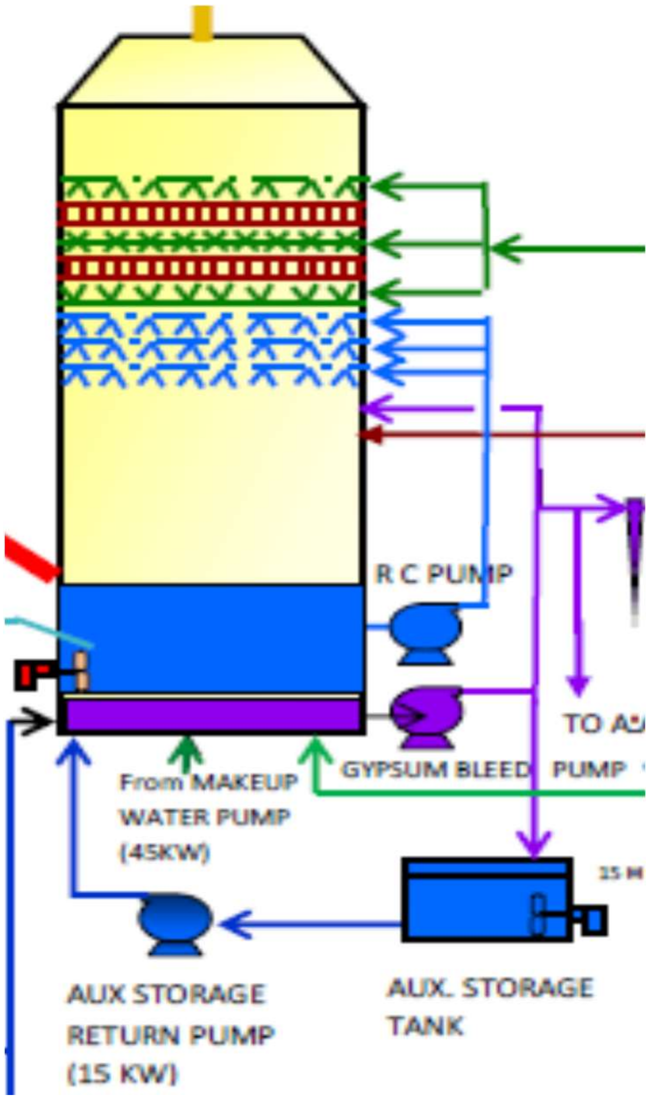
To provide adequate **retention time for oxidation of Calcium sulfite to calcium sulphate (Gypsum), limestone dissolution reactions** & to promote gypsum crystal growth.

Recycle spray system

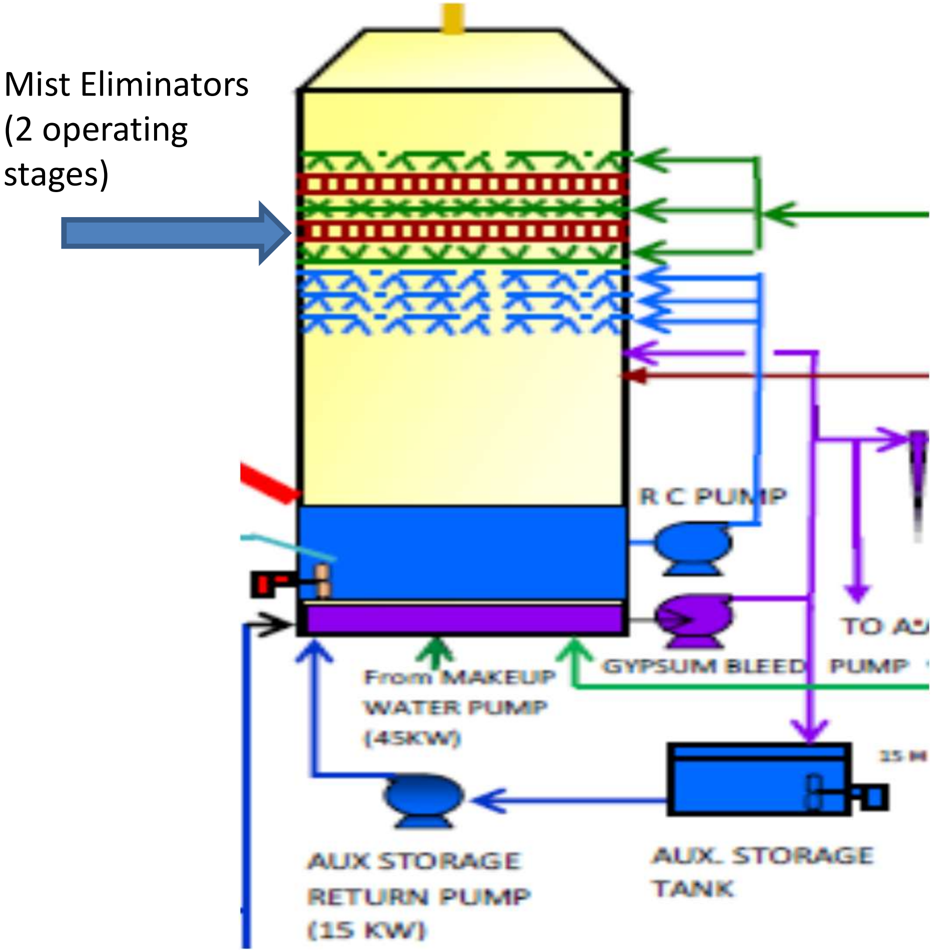
- It brings the fg and the slurry into contact so that the SO2 removal reaction can take place.

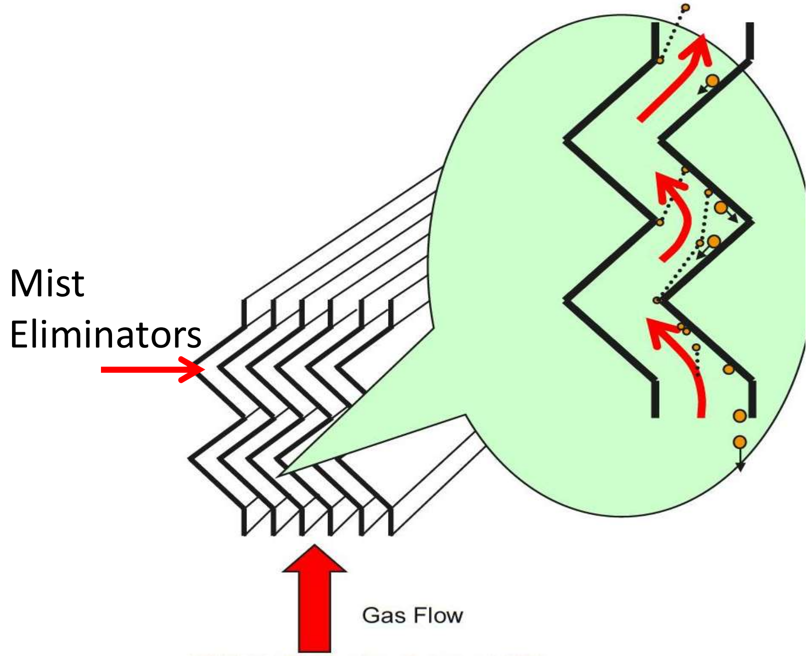
- The slurry is distributed evenly around the tower by the Spray Nozzles designed to achieve proper atomization of the recycle slurry into a spray of fine droplets. This spray cools the flue gases and absorbs the SO2 from the gases.

- **Absorber Reaction Tank**: Provides a reservoir for the reaction tank slurry.



Mist Eliminator system

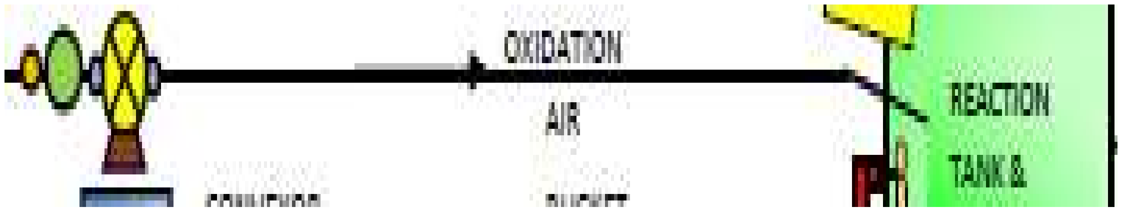




Removes entrained droplets from treated flue gas before the gas exits the absorber module, **preventing pluggage of ductwork due to carryover of slurry**. Thus clean saturated gas exits the absorber.

Forced Oxidation System

- The Oxidation fans supply the compressed air to lances submerged in the Absorber Reaction Tank for the oxidation reaction.
- The oxidation air is quenched with adequate amount of raw water to avoid nozzle plugging.
- The Oxygen in air reacts with $CaSO_3$ and oxidizes it to $CaSO_4$.
- **Some of the $CaSO_3$ produced in the absorber is naturally oxidized to CaSO4**. **If left to natural oxidation, however, the combination of $CaSO_3$ and $CaSO_4$ forms a precipitate sludge with water.** Since the desired byproduct is gypsum (calcium sulfate dehydrate), the sulfite form of the product must be converted to Sulphate.
- The most economical way to remove the sulfite form is to oxidize the sulfite to its sulfate form.

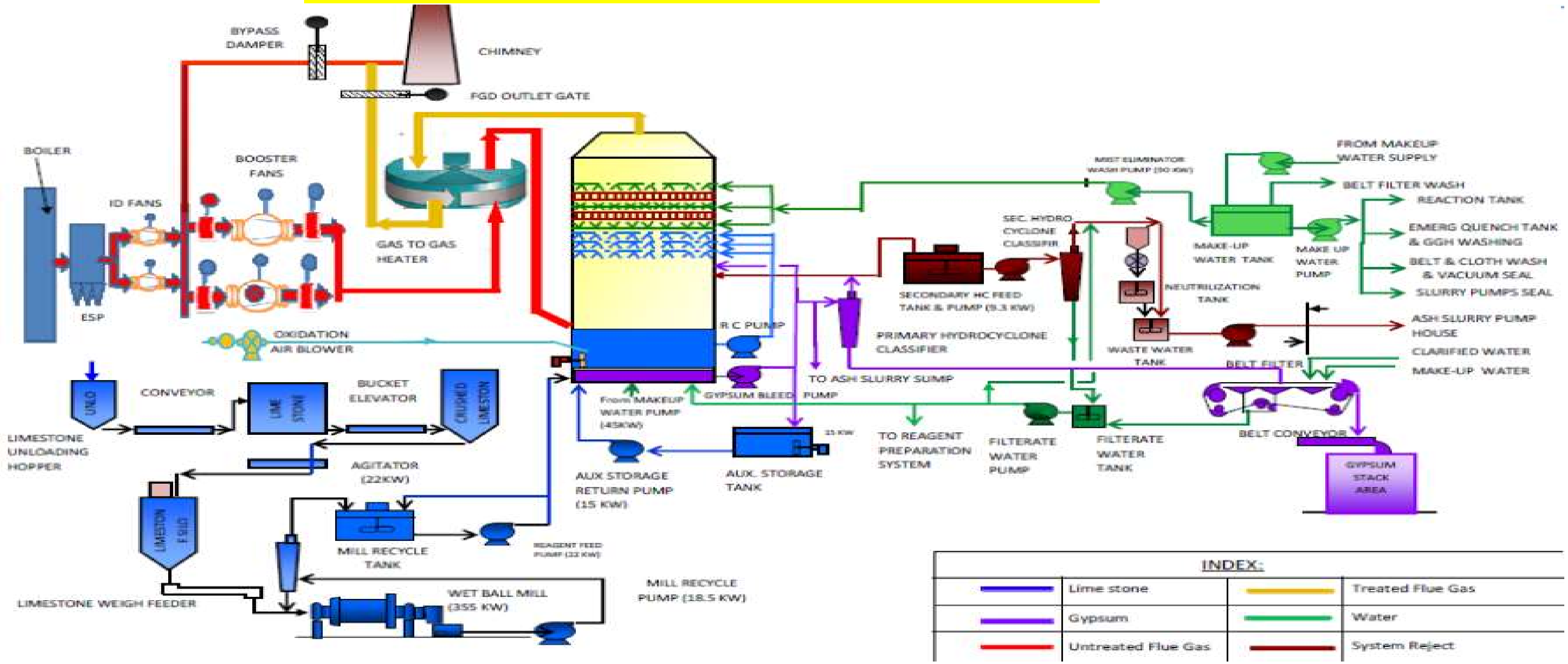


$CaCO_3$ (Limestone) + $H_2O = Ca(OH)_2 + CO_2$

$Ca(OH)_2 + SO_2 = CaSO_3 + H_2O$

$CaSO_3 + 3H_2O + 1/2O_2 = CaSO_4.2H_2O$(Gypsum)$+ H_2O$

Primary Dewatering System



Function:

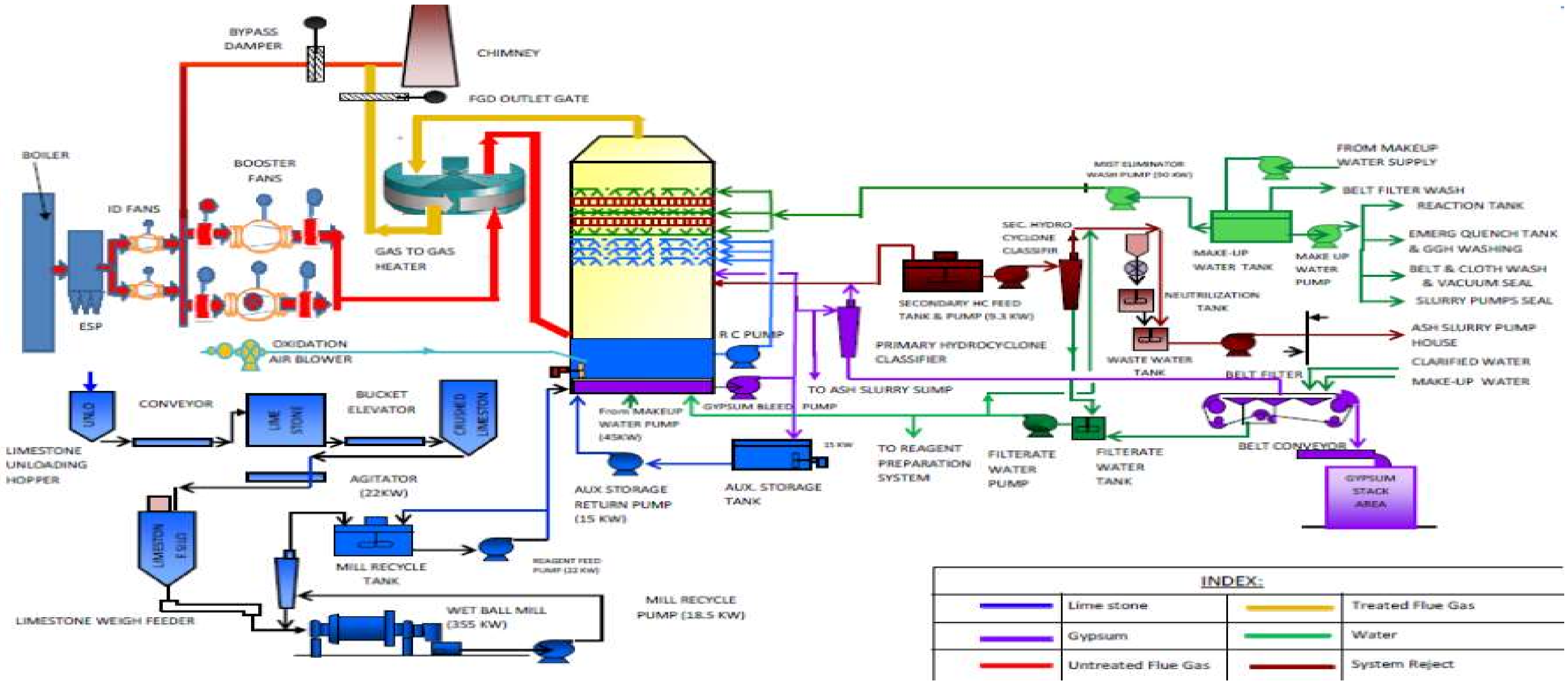
❖ The Primary HC Classifier receives slurry from the Absorber Reaction Tank via Gypsum Bleed Pumps.

❖ The underflow of the Primary HC Classifier is sent to the Vacuum Belt Filter (Sec Dewatering System) for further processing. A recirculation loop is continued when Vacuum Belt Filters are not ready to feed or reaction tank density is not ready to dewatering gypsum slurry.

❖ The Overflow from the Primary HC Classifier containing slurry with less solids is returned to the Reaction Tank or sent to the Secondary HC Feed Tank.

HC Classifier: Hydro-cyclone Classifier

Secondary Dewatering System



1. Delivers the gypsum slurry to the Belt Filters so as to produce a Gypsum cake by dewatering.
2. Convey the Gypsum cake to the Gypsum Handling System.

The filtrate produced during the dewatering process is delivered to the Filtrate Water Tanks.

Flow Diagram of Gypsum Handling System

Purpose:

To transport the gypsum cake from the Vacuum Belt Filter (Sec Dewatering Belt Filter) to the Gypsum Stack Area.

Equipments:

Belt Conveyor - 1

Belt Conveyor - 2

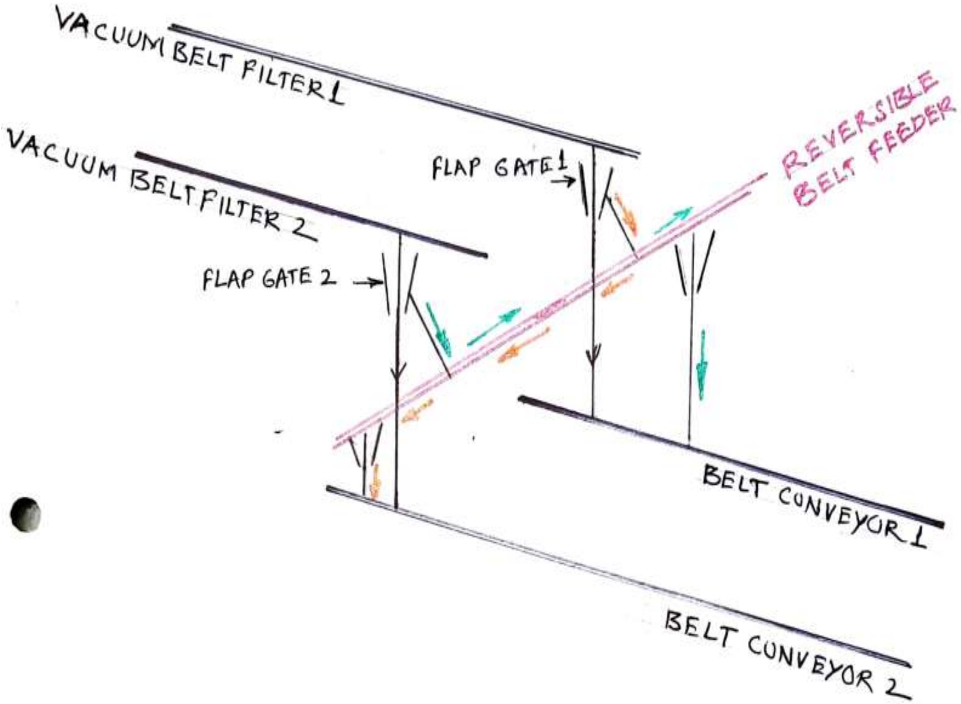
Reversible Belt Feeder

Travelling Tripper -1

Travelling Tripper – 2

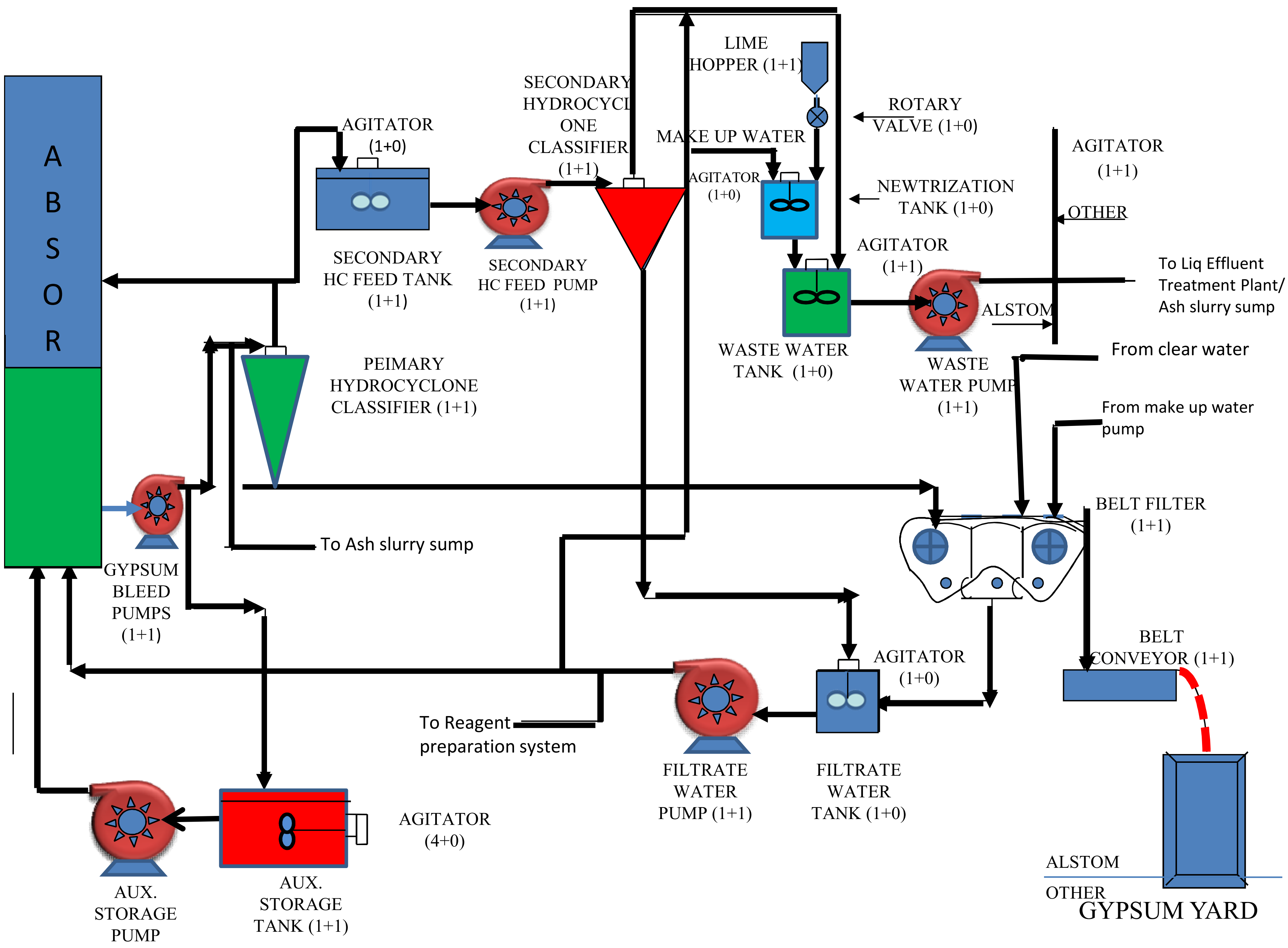
Flap Gate-1 &2

Gypsum stack area



The Belt Filter removes the remaining moisture from the gypsum slurry before the gypsum is transferred to the Gypsum Handling System.

There are (1+1) Belt Filters supplied. Each Belt Filter has a dedicated vacuum system and a dedicated cake wash system. The gypsum slurry flows by gravity from the Primary Dewatering System to the Secondary Dewatering System.



ABSOR
AGITATOR (1+0)
SECONDARY HC FEED TANK (1+1)
SECONDARY HC FEED PUMP (1+1)
SECONDARY HYDROCYCL ONE CLASSIFIER (1+1)
LIME HOPPER (1+1)
ROTARY VALVE (1+0)
MAKE UP WATER
AGITATOR (1+0)
NEWTRIZATION TANK (1+0)
AGITATOR (1+1)
OTHER
AGITATOR (1+1)
To Liq Effluent Treatment Plant/ Ash slurry sump
ALSTOM
WASTE WATER TANK (1+0)
WASTE WATER PUMP (1+1)
From clear water
From make up water pump
PEIMARY HYDROCYCLONE CLASSIFIER (1+1)
To Ash slurry sump
GYPSUM BLEED PUMPS (1+1)
BELT FILTER (1+1)
BELT CONVEYOR (1+1)
AGITATOR (1+0)
To Reagent preparation system
FILTRATE WATER PUMP (1+1)
FILTRATE WATER TANK (1+0)
AGITATOR (4+0)
AUX. STORAGE PUMP
AUX. STORAGE TANK (1+1)
ALSTOM
OTHER
GYPSUM YARD

NOx reduction techniques

Primary Methods

1. Low NOx Burner

- Are designed to control fuel and air mixing at each burner in order to create more branched & larger flame.
- The initial fuel combustion occurs in a **fuel-rich**, **oxygen deficient zone** while the PA required for transport of fuel from Mill to furnace remains same.
- This delays the air / fuel mixing process & hence leads to partial combustion of coal.
- With insufficient oxygen available in primary combustion zone, most of the O_2 is consumed by carbon and hydrogen, leaving less available to form NO_x.
- Hydrocarbons created during coal combustion react with already formed NOx to turn it into molecular nitrogen (N_2).
- **But there is a trade-off between low NOx emissions and high boiler efficiency. Reduced combustion efficiency leads to an increase in CO emissions.**

2. Furnace Air staging

By using OFA systems, the availability of oxygen near the burner area is controlled to minimize NOx formation.

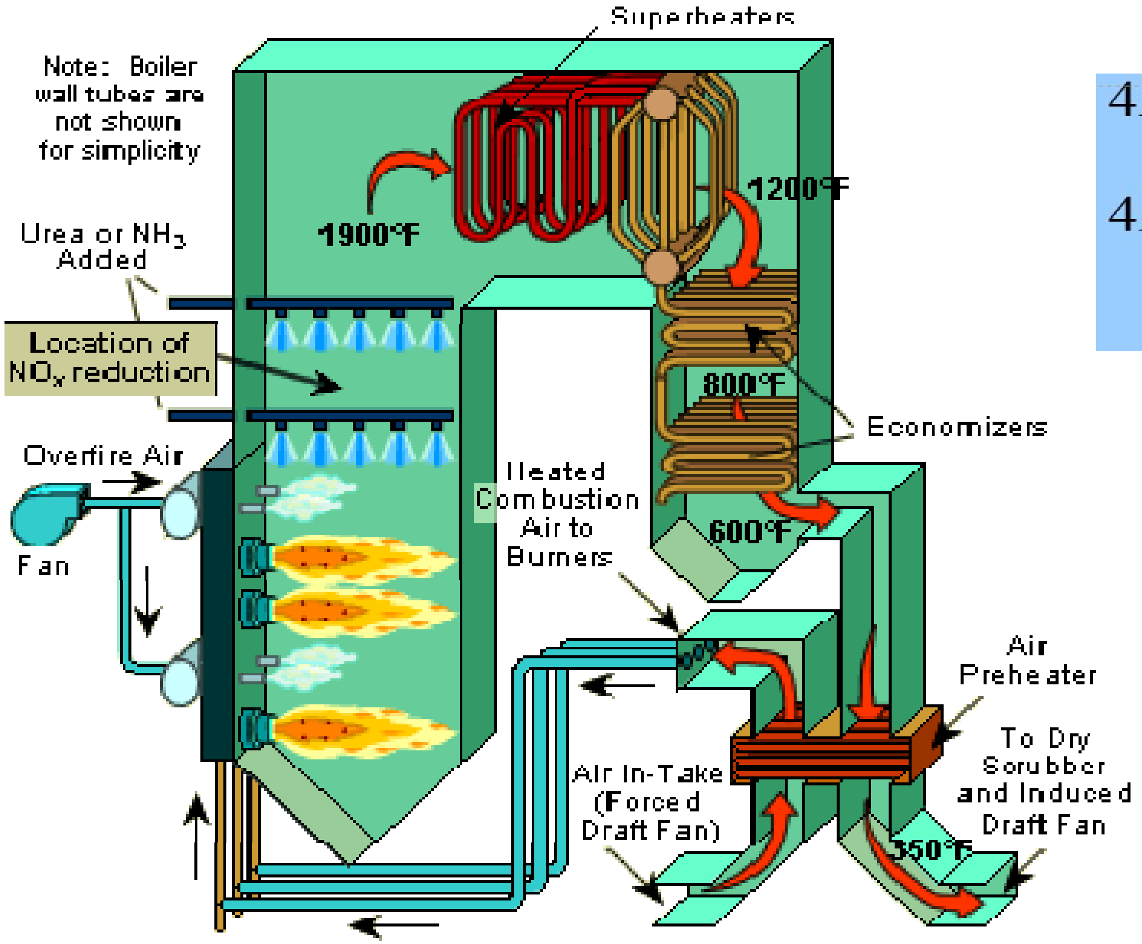
- ❖ Initially, 70-80 % of the oxygen is provided near burners, leading to partial combustion of the fuel.
- ❖ The remaining oxygen is injected through OFA nozzles above the burner where combustion is completed.

The relatively low temperature of the secondary stage limits the production of NOx.
OFA technology **can reduce NOx formation by 20-45 %.**

Post Combustion techniques/ Secondary Methods

Selective Non-Catalytic Reduction (SNCR)

Figure 6. Example SNCR System for NO_x Control in a Boiler



$$4NH_3 + 4NO + O_2 \rightarrow 4N_2 + 6H_2O$$

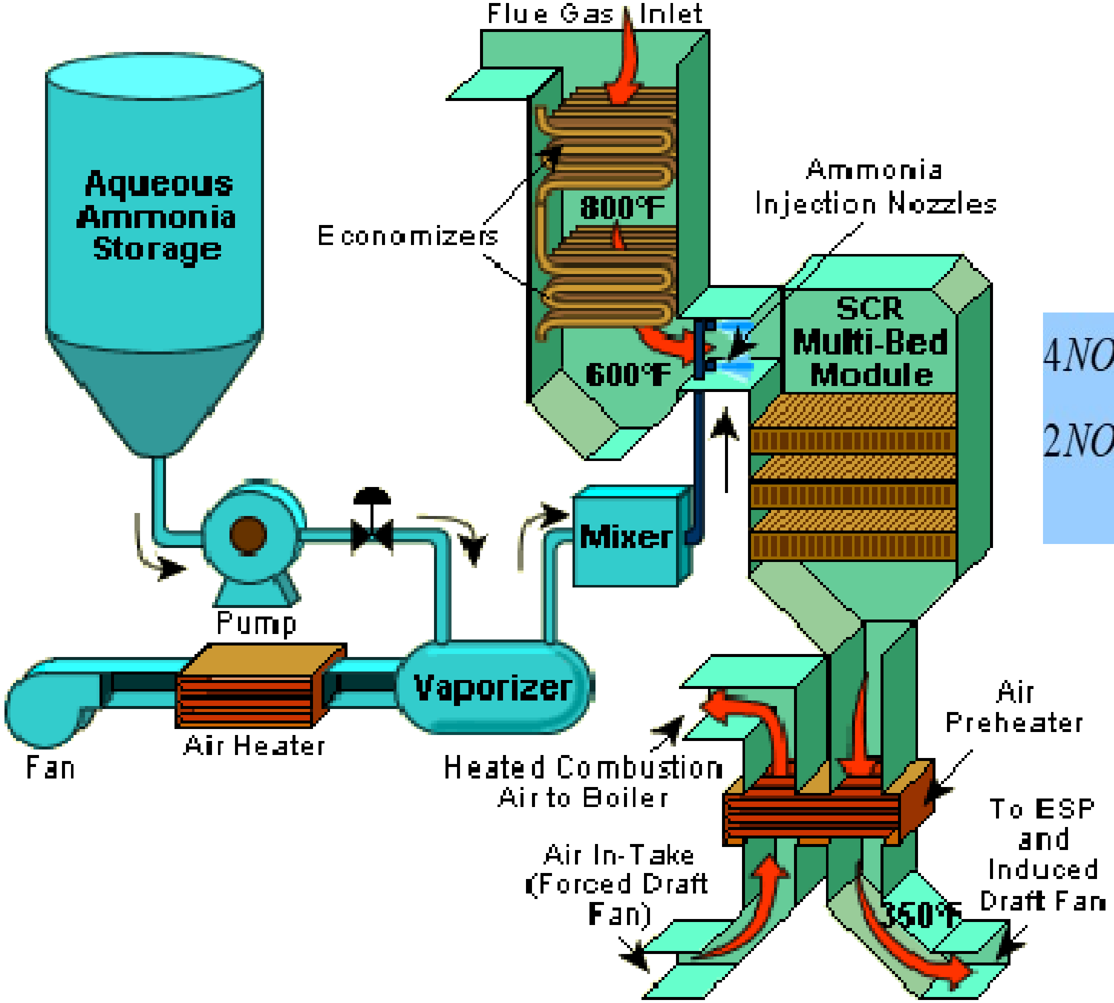
$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

Above 1000 °C

Post Combustion techniques/ Secondary Methods

Selective Catalytic Reduction (SCR)

Figure 7. Example SCR System for NO_x Control in a Boiler



$$4NO + 4NH_3 + O_2 \xrightarrow{TiO_2 \text{ or } V_2O_5 \text{ supported catalyst}} 4N_2 + 6H_2O$$

$$2NO_2 + 4NH_3 + O_2 \xrightarrow{TiO_2 \text{ or } V_2O_5 \text{ supported catalyst}} 3N_2 + 6H_2O$$

Temperature ~ 300 - 400 ºC

Thanks

Any question?

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