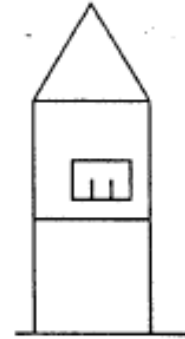
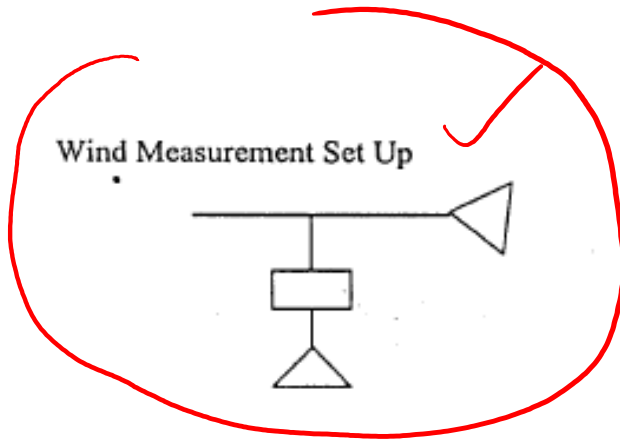


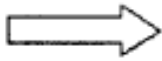
$$C \rightarrow \frac{\text{mass}}{\text{m}^3}$$

$$u \rightarrow \text{m/s}$$

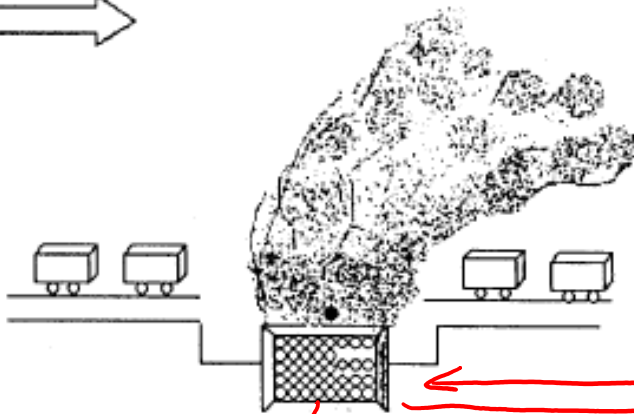
$$\sigma_y \& \sigma_z, \text{m}$$



Handy sampler set-up



C_0



Coal Wagon Tipping



Coal Storage

$$(C_1 - C_0) = \frac{Q}{\pi u \sigma_y \sigma_z}$$

↑
measurement

We estimate Q (mass/time)

Sulphuric Acid Plant: Emissions and Control

- $S + \frac{1}{2} O_2 \longrightarrow SO_2 + \text{Heat} (-127,700 \text{btu/lb mole})$
- $SO_2 + \frac{1}{2} O_2 \longleftrightarrow SO_3 + \text{Heat} (-41,400 \text{btu/lb mole})$

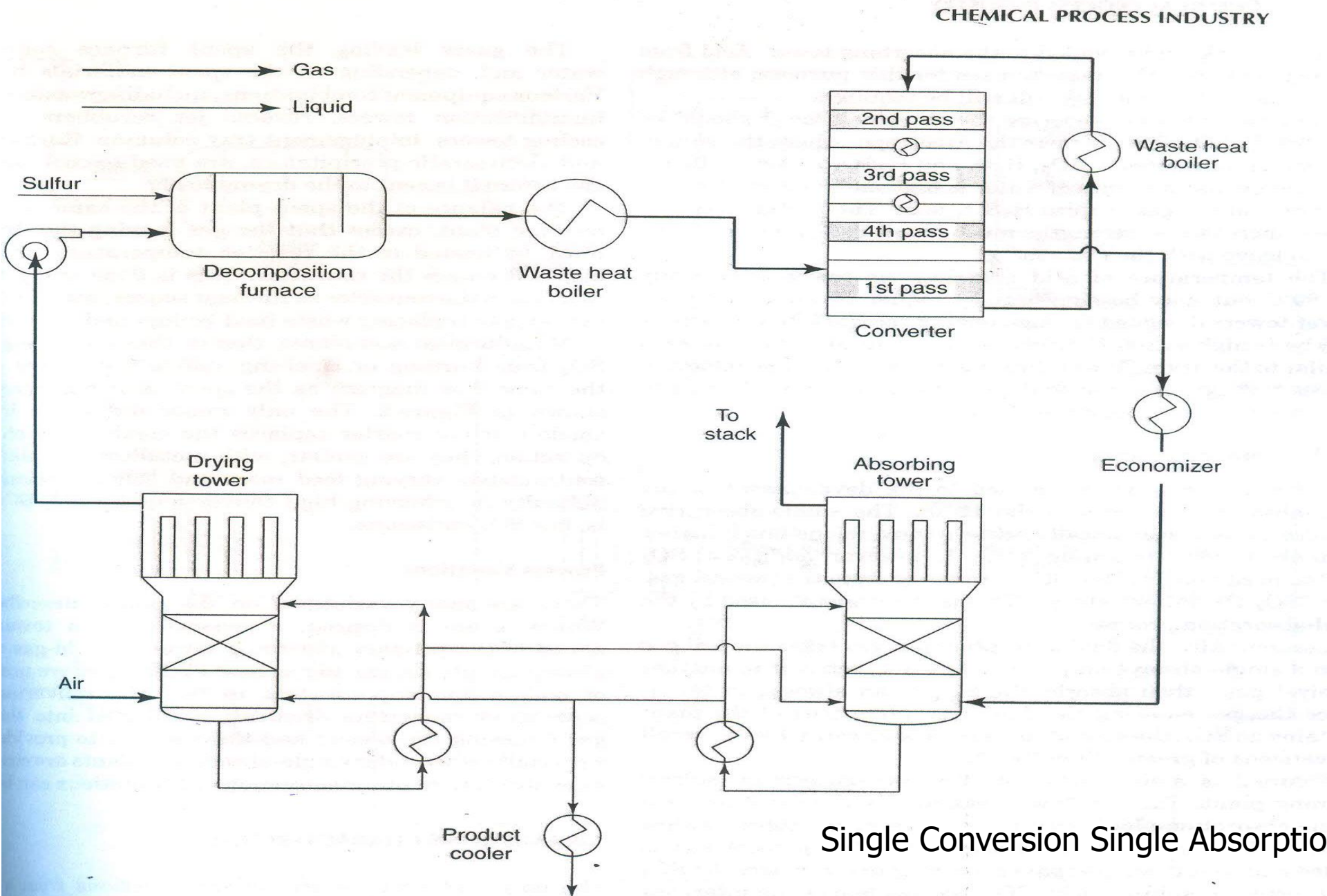
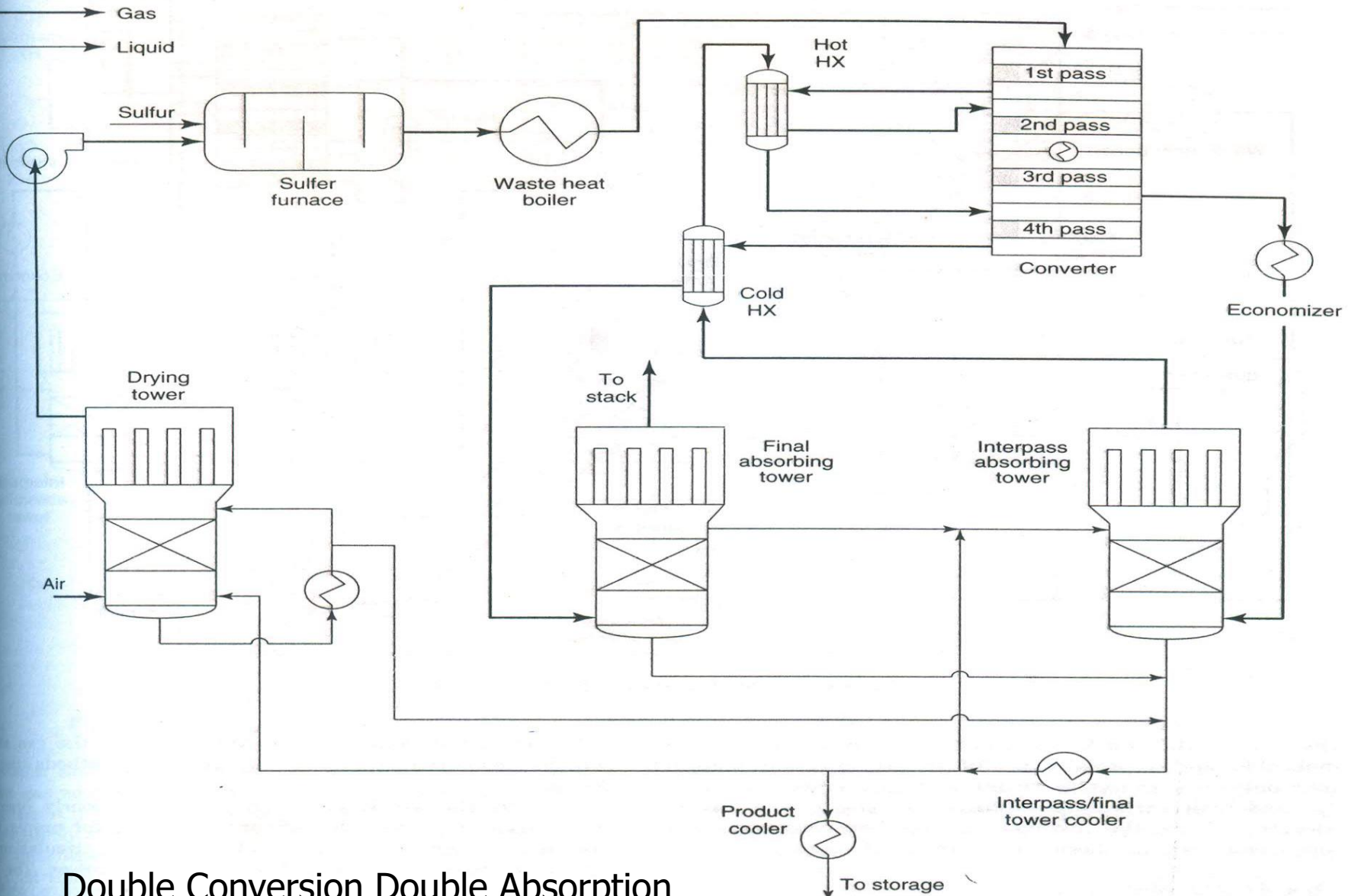
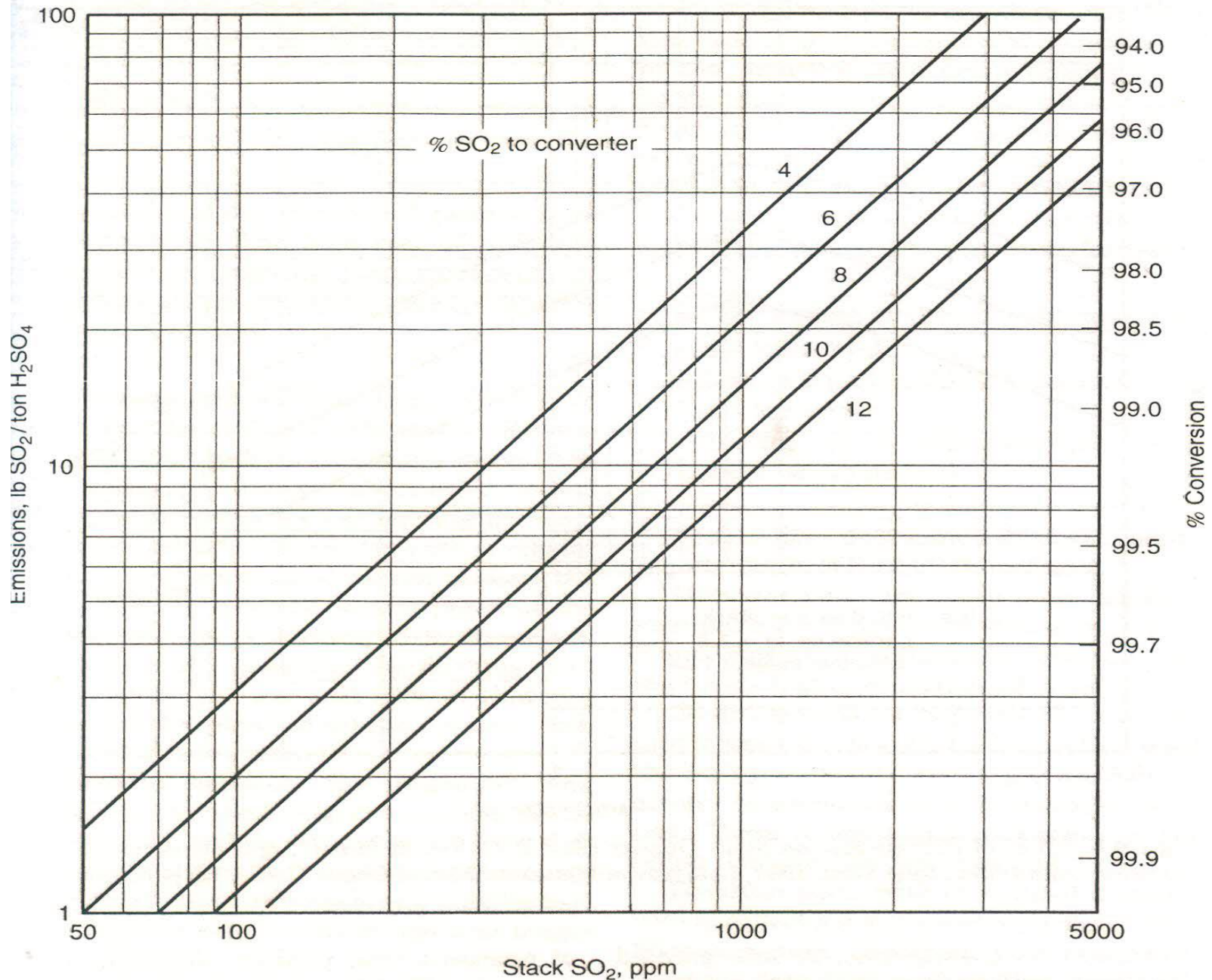


Figure 1. Typical Single-Absorption Sulfur Burning Acid Plant.



Double Conversion Double Absorption



4-316 Diacid Conversion and Mass Emissions Versus Inlet and Exit Sulfur Dioxide Concentration

SO₂

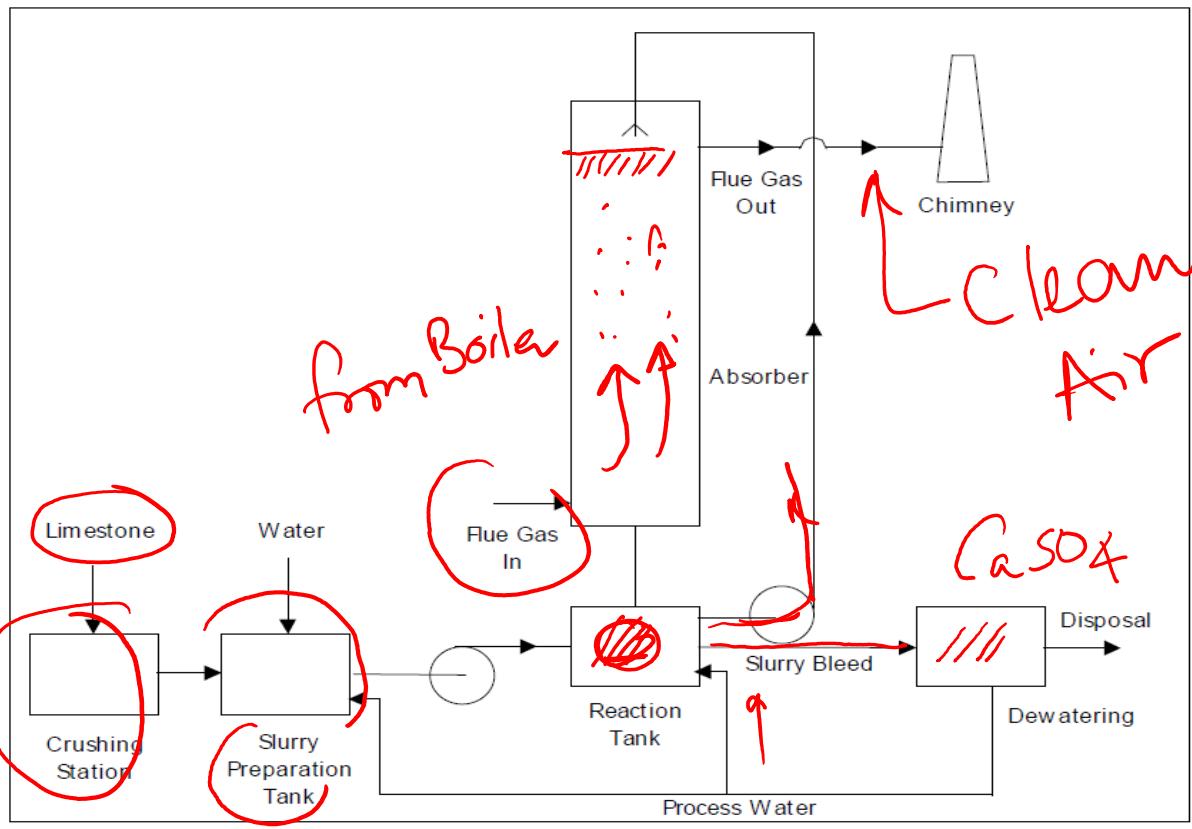
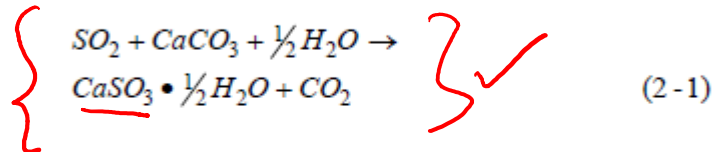
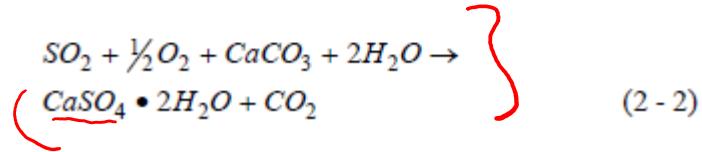


Figure 2-2. Baseline wet FGD system.

The overall reactions in the absorber and in the reaction tank can be summarized by:



and



SO₂ is removed by sorption and Reaction. Reaction is completed and crystallization occurs in reaction tank

FGD Sea
Lime stone, Lime, MgO, water

The dissolution and crystallization reactions in the reaction tank are, to a large extent, controlled by the pH of the liquid, which is a function of limestone stoichiometry (number of mols of Ca added per mol of SO_2 removed). Both pH and limestone stoichiometry are preset parameters for the operation of an absorber. Normally, the required stoichiometry of a limestone wet FGD system varies from 1.01 to 1.1 moles of CaCO_3 per mole of SO_2 (1.01 to 1.05 for modern scrubbers) and pH is in the range 5.0 to 6.0. A gradual decrease in a preset operating value of pH indicates increased limestone consumption and triggers the fresh limestone feed. Spent sorbent from the reaction tank (slurry bleed) is dewatered and

Mist eliminators are provided on top of the absorbing tower to reduce mist carry over to the atmosphere via chimney and to reduce corrosion of ducting and fans.

Seawater Process

The seawater process utilizes the natural alkalinity of seawater to neutralize SO_2 . The chemistry of the process is similar to the LSFO chemistry except that the limestone comes completely dissolved with the seawater and that the chemistry does not involve any dissolution or precipitation of solids. Seawater is available in large amounts at the power plant as cooling medium in the condensers. It is used as a sorbent downstream of the condensers for the purpose of FGD. Seawater is alkaline by nature, and has a large neutralizing capacity with respect to SO_2 .

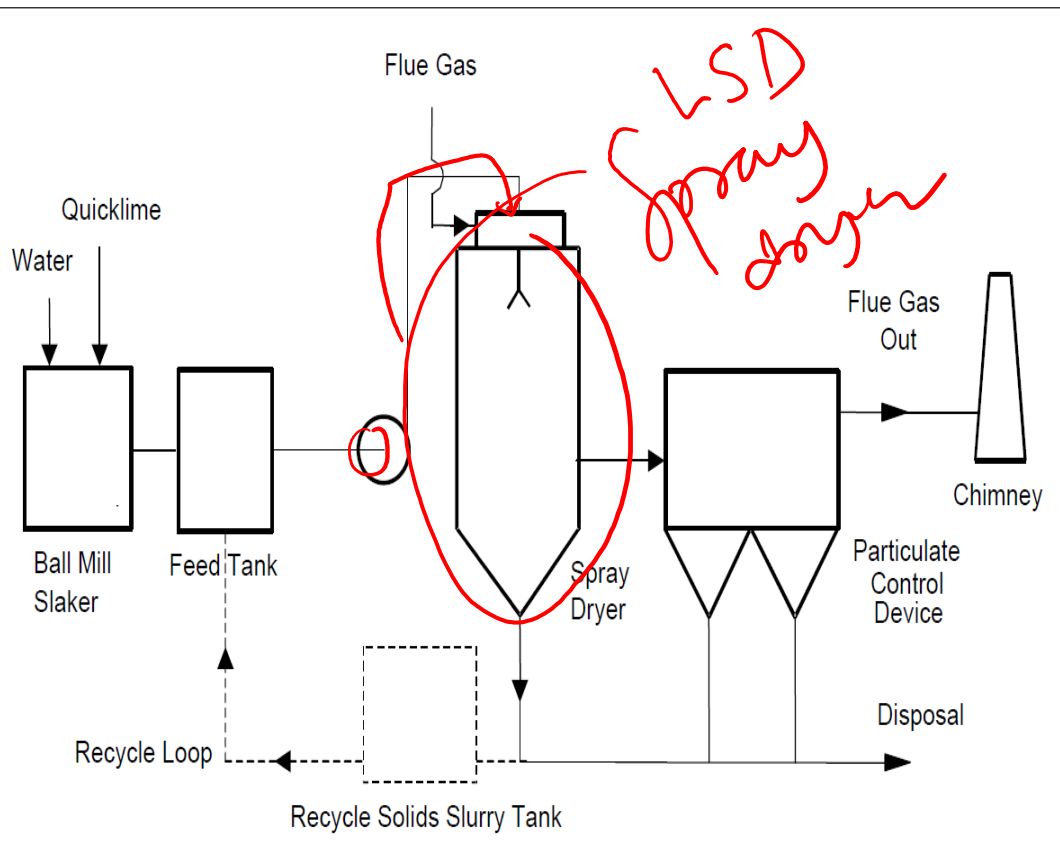
The absorption of SO_2 takes place in an absorber, where seawater and flue gas are brought into close contact in a counter-current flow. The scrubber effluent flows to the treatment plant where it is air-sparged to oxidize absorbed SO_2 into sulfate before discharge.¹⁵ The sulfate is completely dissolved in seawater, so as a result there is no waste product to dispose of. Sulfate is a natural ingredient in seawater, and typically there is only a slight increase of sulfate in the discharge. This increase is within variations naturally occurring in seawater. The difference from the background level normally is not detectable within even a short distance from the point of discharge.

Alkaline

Dry FGD Technologies

In these technologies, SO₂-containing flue gas contacts alkaline (most often lime) sorbent. As a result, dry waste is produced with handling properties similar to fly ash. The sorbent can be delivered to flue gas in an aqueous slurry form [*lime spray drying process (LSD)*] or as a dry powder [*duct sorbent injection process (DSI), furnace*]

sorbent injection process (FSI), and circulating fluidized bed process (CFB)]. The LSD and the CFB require dedicated absorber vessels for sorbent to react with SO₂, while in DSI and FSI new hardware requirements are limited to sorbent delivery equipment. In dry processes, sorbent recirculation may be used to increase its utilization. All dry FGD processes discussed here are once-through (i.e., non-regenerable) and, in general, limited to SO₂ removals below those attainable with wet once-through FGD.



Lime Spray Drying

LSD for the control of SO₂ emissions is used for sources that burn low- to medium-sulfur coal, with occasional applications for coals with higher sulfur content. Some issues that limit the use of spray dryers with high-sulfur coals include the potential impact of chloride contained in the coal on the spray dryer performance, and the ability of the existing particulate control device to handle the increased loading and achieve the required efficiency.

Spray dryer

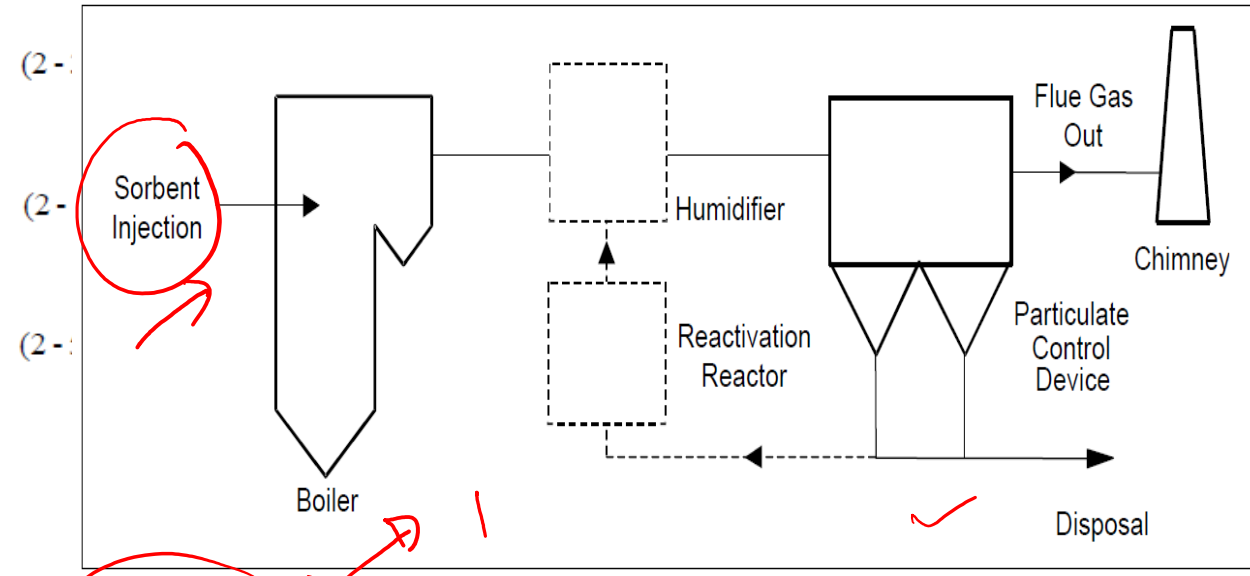
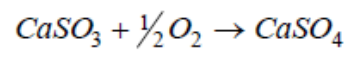
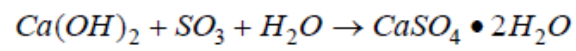
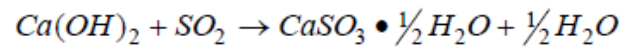
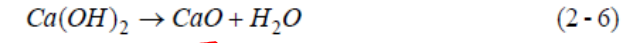


Figure 2-5. Schematic of FSI.

Furnace Sorbent Injection

In the FSI, a dry sorbent is injected directly into the furnace in the optimum temperature region above the flame.²⁰ FSI is shown schematically in Figure 2-5. As a result of the high temperature (approximately 1000 °C), sorbent particles (most often calcium hydroxide, but sometimes calcium carbonate) decompose and become porous solids with high surface systems,²¹ according to the reaction below:



SO₂ in the flue gas reacts with the nascent CaO as given below:

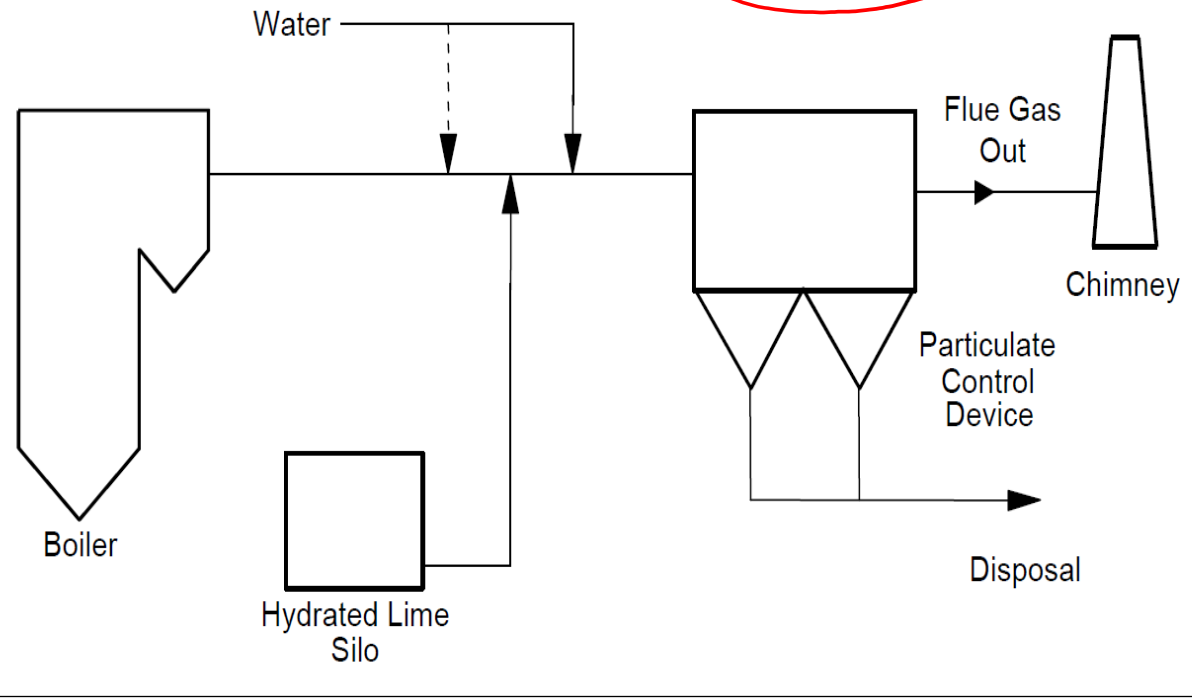
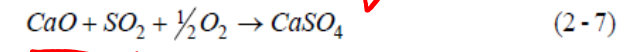
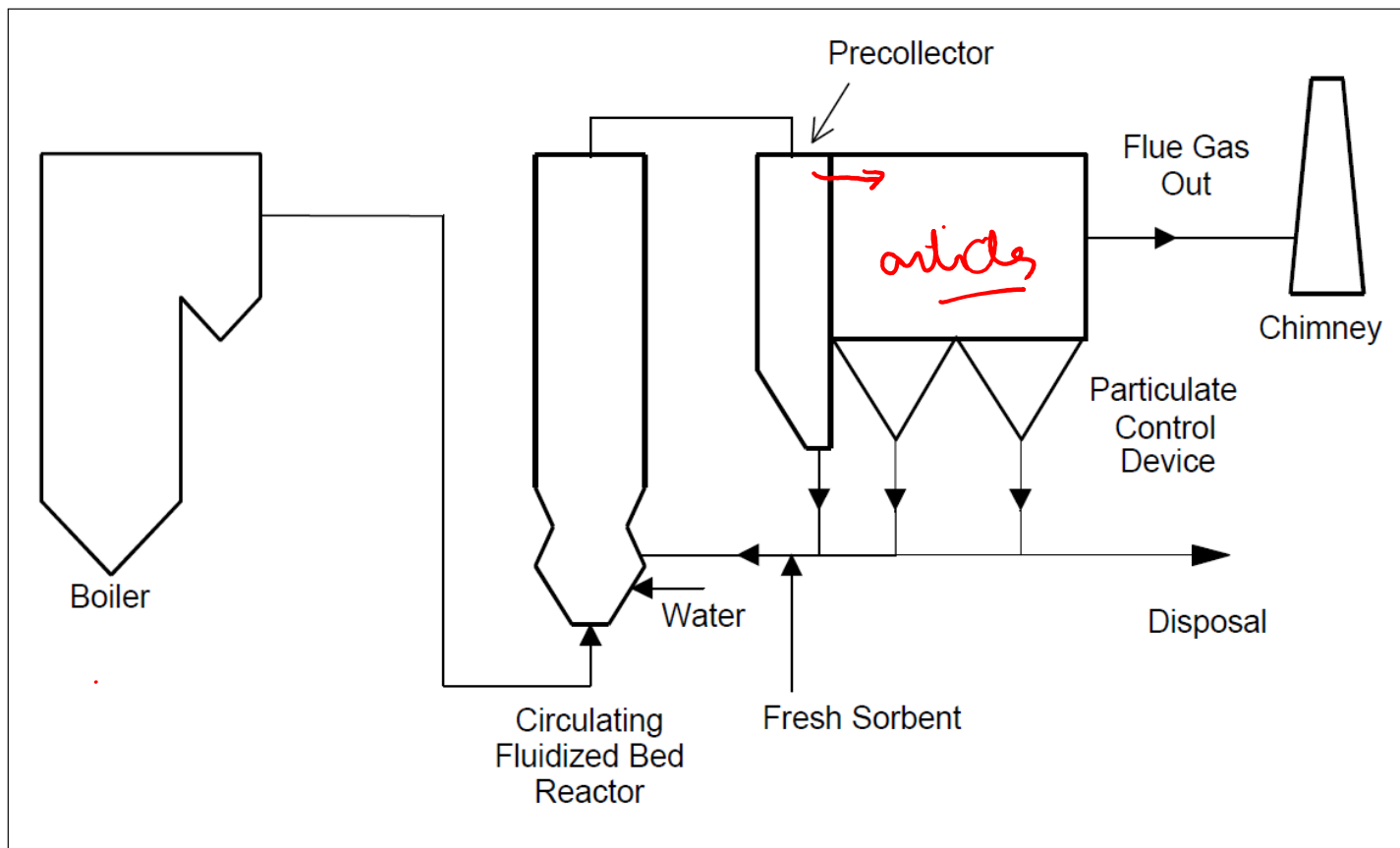


Figure 2-4. Schematic of DSL.

- Circulatory Fluidized bed SO₂ control
- <https://www.youtube.com/watch?v=EB0r6A5VxFU>



Circulating Fluidized Bed

In CFB, dry sorbent [most often $\text{Ca}(\text{OH})_2$] is contacted with a humidified flue gas in a circulating fluidized bed. CFB is shown schematically in Figure 2-6. The fluidized bed is formed as a result of flue gas flowing upward through a bed of sorbent solids. The CFB provides a long contact time between the sorbent and flue gas because sorbent passes through the bed several times. The flue gas laden with reaction products then flows to a particulate control device. Some of the particulate control device's catch is recirculated into the bed to increase the utilization of sorbent, while the remaining fraction is sent to disposal.

The CFB is characterized by good SO_2 mass transfer conditions from the gas to the solid phase. This is achieved as a result of intimate mixing of the solids with the gas as well as a high slip velocity between the two phases. An additional benefit of the fluidized bed is continuous abrasion of sorbent particles, resulting in the exposure of fresh, unreacted alkali.²²