Lecture 16

Sulphuric acid

1. Introduction

More sulphuric acid is produced than any other chemical in the world. The output of sulphuric acid at base metal smelters today represents about 20% of all acid production. Most of its uses are actually indirect in that the sulphuric acid is used as a reagent rather than an ingredient. The largest single sulphuric acid consumer by far is the fertiliser industry. Sulphuric acid is used with phosphate rock in the manufacture of phosphate fertilisers. Smaller amounts are used in the production of ammonium and potassium sulphate. Substantial quantities are used as an acidic dehydrating agent in organic chemical and petrochemical processes, as well as in oil refining. In the metal processing industry, sulphuric acid is used for pickling and descaling steel; for the extraction of copper, uranium and vanadium from ores; and in non-ferrous metal purification and plating. In the inorganic chemical industry, it is used most notably in the production of titanium dioxide.

Certain wood pulping processes for paper also require sulphuric acid, as do some textile and fibres processes (such as rayon and cellulose manufacture) and leather tanning. Other end uses for sulphuric acid include: effluent/water treatment, plasticisers, dyestuffs, explosives, silicate for toothpaste, adhesives, rubbers, edible oils, lubricants and the manufacture of food acids such as citric acid and lactic acid. Probably the largest use of sulphuric acid in which this chemical becomes incorporated into the final product is in organic sulphonation processes, particularly for the production of detergents. Many pharmaceuticals are also made by sulphonation processes.

2. Production of Sulphuric acid

2.1 Raw Material Preparation including Storage and Handling

Sulphur storage and handling

Liquid sulphur is a product of the desulphurisation of natural gas and crude oil by the Claus- Process, with the cleaning of coal flue gas as a second source. The third way is the melting of natural solid sulphur (Frash-process) but this is not in frequent use because there are many difficulties in removing the contaminants. The following is a typical analysis of molten sulphur (quality: bright yellow):-

Ash max. 0.015% weight

Carbon max. 0.02% weight

Hydrogen sulphide ca. 1-2mg.kg-1

Sulphur dioxide 0mg.kg-1

Arsenic max. 1mg.kg-1

Mercury max. 1mg.kg-1

Water max. 0.05% weight

Liquid sulphur is transported in ships, railcars and trucks made of mild steel. Special equipment is used for all loading and unloading facilities. Liquid sulphur is stored in insulated and steam heated mild steel tanks. The tank is is equipped with submerged fill lines to avoid static charges and reduce agitation in the tank. The ventilation of the tanks is conventionally free. A further fact is less de-gasing of hydrogen sulphide and sulphur dioxide. All pipes and pumps are insulated and steam heated. The normal temperature level of the storage and handling is about 125-145°C.

2.2 Material Processing

2.2.1 Conversion of SO_2 into SO_3

The design and operation of sulphuric acid plants are focused on the following gas phase chemical equilibrium reaction with a catalyst:-

$$SO_2 + \frac{1}{2}O_2 \longleftrightarrow SO_3\ ;\ \ \Delta H = -99\ kJ.mol^{-1}$$

This reaction is characterised by the conversion rate, which is defined as follows:-

conversion rate =100 (%)

Both thermodynamic and stoichiometric considerations are taken into account in maximizing the formation of SO3. The Lechatelier-Braun Principle is usually taken into account in deciding how to optimise the equilibrium. This states that when an equilibration system is subjected to stress, the system will tend to adjust itself in such a way that part of the stress is relieved.

For SO2/SO3 systems, the following methods are available to maximise the formation of SO3:-

– Removal of heat – a decrease in temperature will favour the formation of SO3 since this is an exothermic process

– Increased oxygen concentration

– Removal of SO3 (as in the case of the double absorption process)

– Raised system pressure

– Selection of the catalyst to reduce the working temperature (equilibrium)

– Increased reaction time

Optimum overall system behaviour requires a balance between reaction velocity and equilibrium.

However, this optimum also depends on the SO2 concentration in the raw gas and on its variability with time. Consequently, each process is more or less specific for a particular SO2 source.

2.2.2 Absorption of SO_3

Sulphuric acid is obtained from the absorption of SO_3 and water into H_2SO_4 (with a concentration
of at least 98%).

The efficiency of the absorption step is related to:-

– The H_2SO_4 concentration of the absorbing liquid (98.5-99.5%)

– The range of temperature of the liquid (normally 70°C-120°C)

– The technique of the distribution of acid

– The raw gas humidity (mist passes the absorption equipment)

– The mist filter

– The temperature of incoming gas

– The co-current or counter-current character of the gas stream in the absorbing liquid

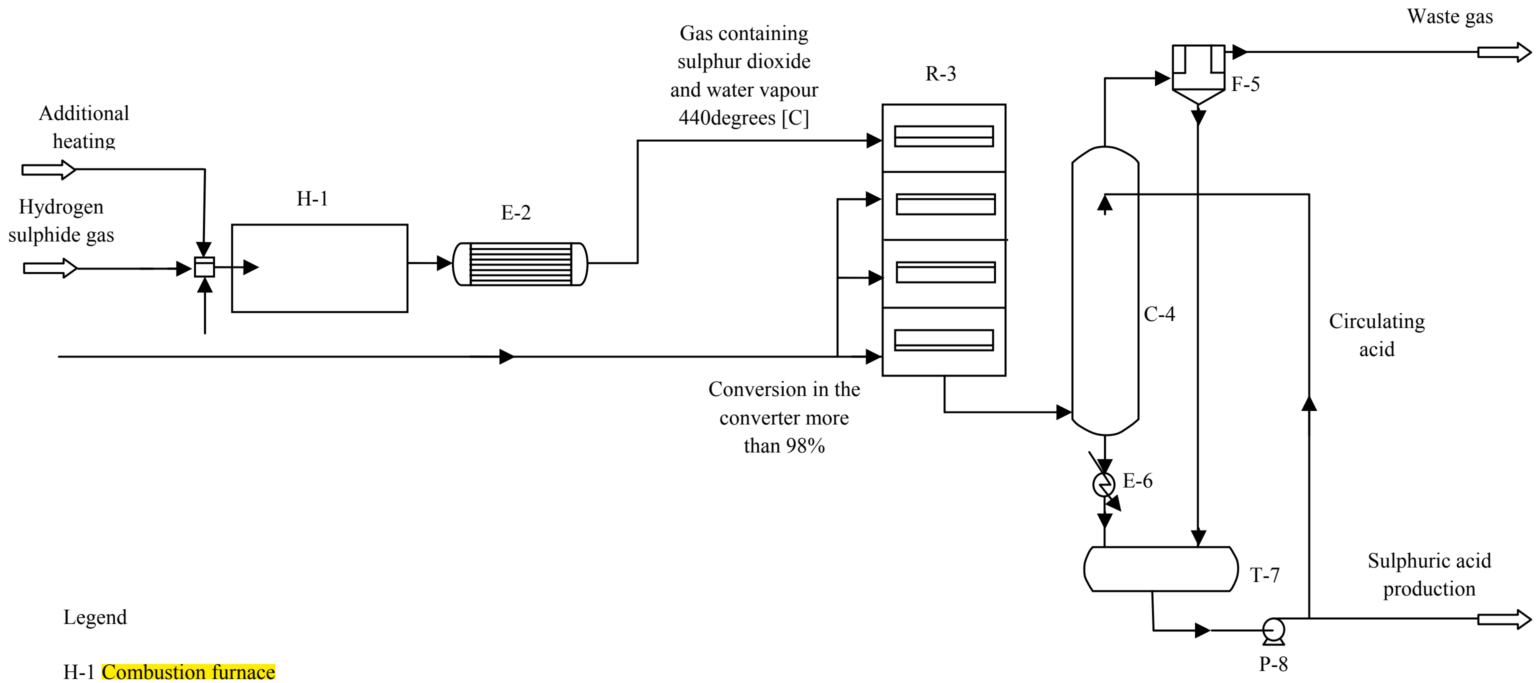
SO_3 emissions depend on:-

– The temperature of gas leaving absorption

– The construction and operation of the final absorber

– The device for separating H_2SO_4 aerosols

– The acid mist formed upstream of the absorber through the presence of water vapour



Legend

H-1 Combustion furnace
E-2 Waste heat boiler
R-3 Converter
C-4 Condensation
F -5 Filter
E-6 Cooler
T-7 Intermediate tank
P-8 Circulating pump

A typical sulphuric acid production Plant