Design of Sulfuric acid Plant Producing 20 Thousand Tons Per Year

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Abstract

This graduation project presents a detailed study on the design and operation of a sulfuric acid plant with an annual capacity of 20000 tons. It covers the theoretical background of sulfuric acid, a vital industri- al chemical, emphasizing its properties, uses, and global significance. The project focuses on the Double Contact Double Absorption (DCDA) method, an efficient process that enhances production yield and re- duces emissions. The material balance and operational details of key components—the sulfur furnace, converter, and absorber—are explored. The sulfur furnace burns sulfur with air to generate sulfur dioxide (SO_2), which is further oxidized in the converter to form sulfur trioxide (SO_3) using a vanadium pentoxide (V_2O_5) catalyst at high temperatures. The SO_3 is then absorbed in the absorber to create oleum, which is diluted to produce sulfuric acid with nearly 98% purity. Comprehensive calculations and assessments are conducted for each unit to ensure optimal performance while complying with environmental standards.

Process Description

The main reactions involved in the manufacture of Sulfuric Acid from elemental Sulfur are Oxidation of sulfur-to-sulfur dioxide:

$$S + O_2 \longrightarrow SO_2$$

Further Oxidation of sulfur di oxide to sulfur tri oxide in presence of catalyst:

$$SO_2 + 1/2\ O_2 \longrightarrow SO_3$$

Reaction of sulfur trioxide with water to produce Sulfuric Acid:

$$SO_3 + H_2O \rightarrow H_2SO_4$$

Molten sulfur is transported by tanker and poured into a sulfur pit, where steam coils maintain its tempera- ture. It is then pumped into a sulfur burning furnace at a constant rate. Air, dried by a circulating sulfuric acid stream, is supplied to burn the sulfur, producing sulfur dioxide (SO_2) and heat, which is recovered in the Waste Heat Recovery Boiler. The gases pass through a multi-stage converter with a vanadium pentox- ide catalyst, where SO_2 is converted to sulfur trioxide (SO_3). After cooling via heat exchangers, oleum generator, and economizer, the SO_3 is absorbed in the Inter Pass Absorption Tower (IPAT). Any remaining SO_2 is reheated and passed through the final catalyst stage, with SO_3 absorbed in the Final Absorption Tower (FAT).

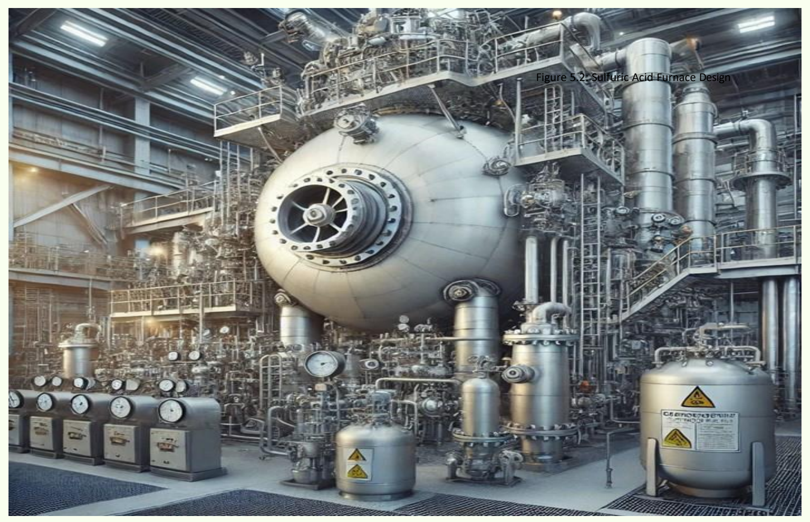


Figure 5.1: industrial sulfuric acid reactor

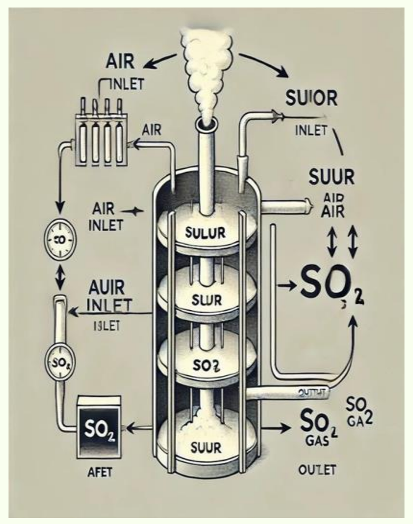
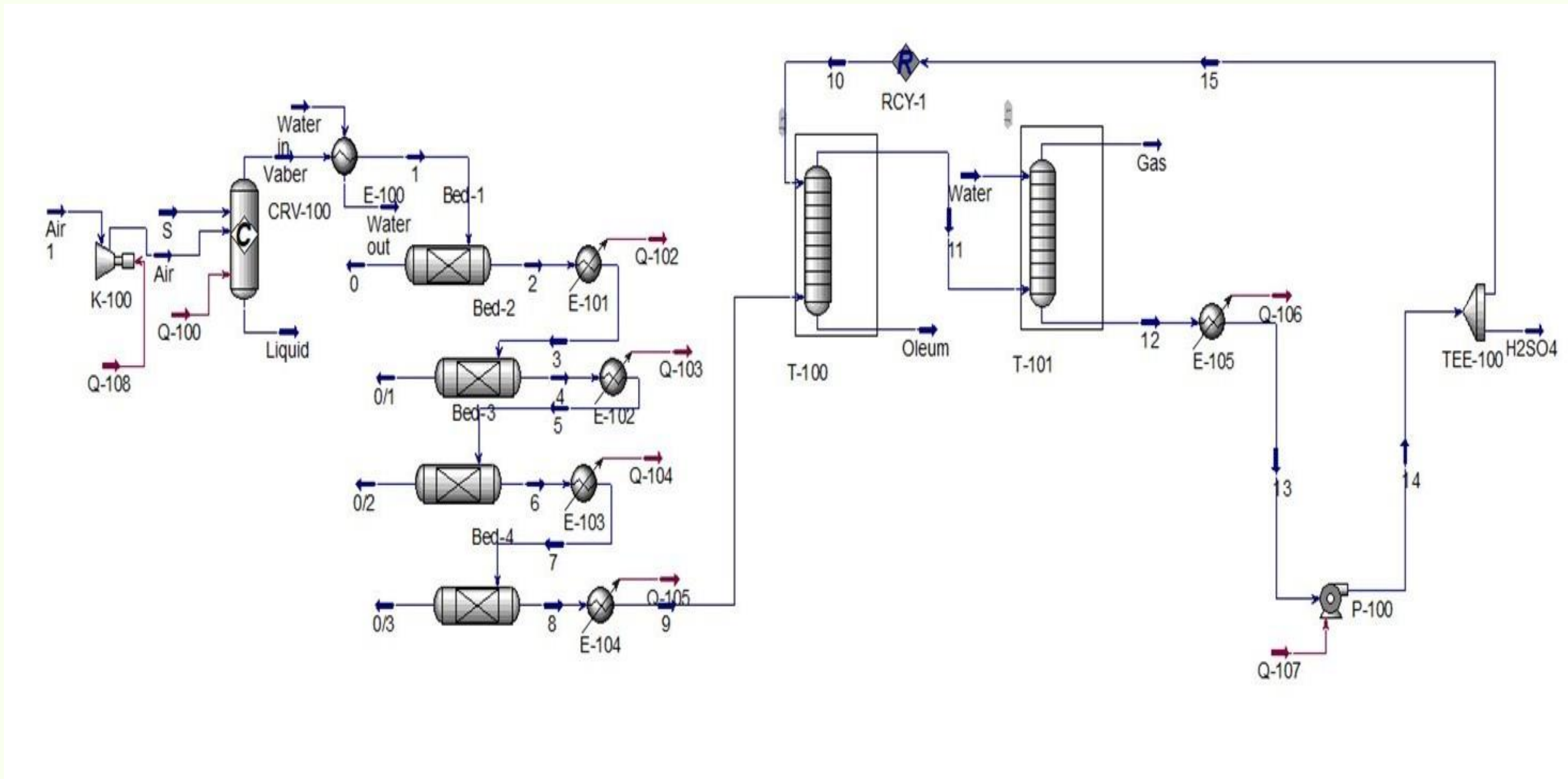


Figure 5.2: Sulfuric Acid Furnace Design



Cumulative cash flow diagram

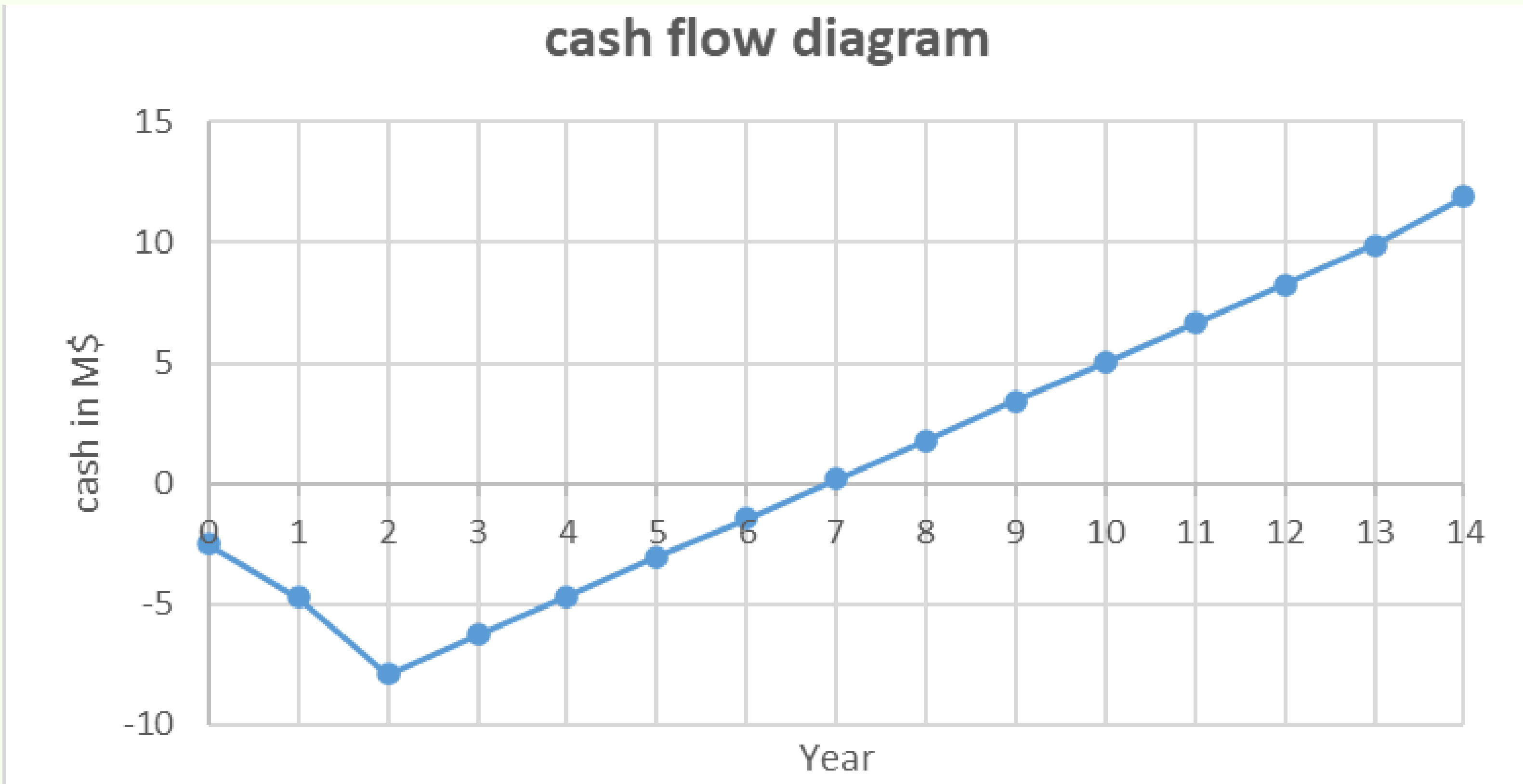


Table 6.4: Cost summary (values needed to calculate COM)

Cost summary (USD)	
Fixed capital Cost	1,176,428
Utility cost	207,289
Raw Material Cost	467,974
Operating Labor Cost	243,849

Annual utility cost

Unit type	Equipment Code	Cost in 2024 ($)
Cooler	E-101	9,560
	E-102	6,717
	E-103	526
	E-104	12,276
	E-105	3,102
Heat exchanger	E100	49,422
Pump	P-100	37
Reactor	CRV-100	41,065
Compressor	K-100	655,825
Total Capital Cost		778,533

Table 5.7: Shell and tube heat exchanger data summary

E-100			
Q (kw)	4322.8	Number of tubes	230
Shell pass	1	Tube arrangement	triangular
Tube pass	2	Tube pitch (mm)	39.7
Heat transfer Area(m---2)	94.75	Bundle dimeter (m)	0.7
Tube dimension		Shell dimeter (m)	0.737
d_o (mm)	31.75	Baffle spacing (m)	0.37
		Baffle cut	25%
d_i (mm)	38.33	Length (m)	7.32
U_t (m/s)	9.81	u_s (m/s)	0.053

Conclusion

In the material balance calculations, the sulfur furnace produced 3517.18 kg/h of sulfur dioxide (SO_2), which was converted to 4395.3 kg/h of sulfur trioxide (SO_3). The air input was 17833.3 kg/h, primarily consisting of nitrogen. The energy bal- ance revealed that the heat exchanger handled 4322.8 kW, with a reactor energy flow of -20543672 kJ/h, indicating high energy demands. The heat exchanger used 230 tubes and a 0.737-meter shell diameter. Economically, the plant's capital cost was around 4.42 million USD, with annual labor costs of 915,845 USD and total manufacturing costs of 4.16 million SAR. The project projected profitability after 12 years, aided by the efficient Double Contact Double Absorption (DCDA) meth- od, which optimized production, reduced emissions, and ensured environmental compliance. products directly from the ground petrol, while the e-fuel method uses reactors to produce renewable hydrocarbon.