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SULPHURIC ACID MAKING PLANT

0. INTRODUCTION

The sulphuric acid has many and important uses and so it is considered one of the more important chemical products.

Its main use is the production of fertilizers (phosphatic fertilizers and ammonium sulphate) and in the petroleum refining; but is also largely used in other industries as explosives, metallurgical industry, detergents, paints and pigments, rayon and cellulose films, textiles and in many other chemical processes where a strong acid in water solution is required.

It is marketed in different grades and strengths : from the so-called acid chamber (65% acid concentration) to the higher concentrated acids as the 98% sulphuric acid or oleum (fuming acid). In the majority of cases, sulphuric acid is sold directly by the producer to the consumer; the bulk of the acid is sold in tank-cars or tank-wagon lots with a steadily growing emphasis on truck deliveries. Acid sales in carboys or steel drums are very much the exception, being this method generally considered uneconomical and highly expensive.

For this reason, the production plants are located in the vicinity of the major consumers.

The cost of the product is largely dependent on the cost of the main raw material (sulphur) provided that the utilization of the waste heat generated by the process is maximized. For the selected technology the required personnel is not numerous and the type of machinery and equipment involved in the plant is not too sophisticated for both the operation and maintenance.

1. PRODUCT DEFINITION

The process plant described hereinafter has a production capacity of 30 t/d of 98% sulphuric acid having standard characteristics as follows :

. temperature	50°C
. colour	colourless and free from suspended and or insoluble matter
. purity	98% H_2SO_4 ± 0.5
. iron	not more than 0.02%
. arsenic	not more than 0.002%
. sulphur dioxide	not more than 0.01%

Using demineralized water in the process it will be also possible to produce acid of battery grade, that is:

. purity	98% H_2SO_4 ± 0.5
. iron	not more than 0.005%

2. TECHNOLOGY REVIEW

The production of sulphuric acid consists schematically of the following phases :

- production of sulphur dioxide
- oxidation of the sulphur dioxide to sulphur trioxide by the atmospheric oxygen
- absorption of the sulphur trioxide in water

The production technology is different depending on how the oxidation phase is carried out; the available processes are two : the chamber process and the contact (or catalytic) process.
In the first process the of sulphur dioxide is not directly oxidized to sulphuric acid by oxygen contained in the air, but an intermediate compound involving nitrogen oxides is formed and the reaction is really a cyclic process involving the alternate formation and decomposition of the intermediate compound.
On the contrary, in the contact process the oxidation of the sulphur dioxide is directly carried out by the oxygen of the air : this reaction, which is very slow at ambient temperature, can develop at high rate at 400°C and using vanadium-pentoxide as catalyst.
The concentration of the acid produced in the chamber process is 65% (52° Bé), while in the contact process it is 98%.
The contact process, due to its more simplicity, is

largely preferred when using elemental sulphur as raw material especially for plant of small capacity as in the present case.

There are many technology suppliers for such kind of process in the world, but not all of them are suitable to supply plants of limited capacity as in our case; Chemadex (Poland), Garbato (Italy), Lurgi (Germany) and Mechim (Belgium) can anyway be considered, among others, as service of technology.

3. DESCRIPTION OF THE PRODUCTION PLANT

3.1 SCHEMATIC PROCESS DESCRIPTION

A schematic flow diagram of the sulfuric acid making plant based on the contact process is shown in fig. 3.1. As first step, the sulfur, which must be stored in bulk for safety reasons, is melted, heating it, by means of steam, to approximately 115°C. Impurities of the sulfur are for the most part settled in the melting basin and the rest is removed trough a precoat filter; the clean sulfur is then stored in a tank from which it is pumped to the combustion chamber together with dry air; at the exit of the combustion chamber the sulfur is completely oxidized to SO_2.

The gases from the combustion chamber (8 ÷ 11 % SO_2 according to the process) are then cooled down to the temperature required by the conversion (about 400°C).

The released heat is used to produce steam which (except a small part that is used for the sulfur melting) is available as energy source at battery limits.

The conversion of SO_2 to SO_3 is accomplished in a multistage converter , filled with vanadium-pentoxide. The conversion reaction is strongly exothermic and therefore control of temperature at an optimum value is necessary to obtain sulfuric acid on the most economical basis. To obtain this temperature control the catalyst is distributed in layers, and heating surfaces are interposed between them, so that the heat is removed in a stepwise manner.

Cooling between the passes is achieved in many ways (internal or external heat exchangers, air or boiler water as cooling fluid, etc.) and this makes the main difference in the design of the conversion towers offered by the various technology suppliers; the final exchanger is however the boiler feed water preheater (economizer). The economical conversion yield is 98% approximately.

To reach an higher yield a second conversion (and absorption) step would be required; the increase in

sulfur efficiency would be 1.5% against an increase of 25% of the investment cost.
After the economizer the 98% SO_3 gases are introduced in the absorption stage in which the sulfur trioxide is absorbed directly into concentrated sulfuric acid; the absorber is ususally a packed tower where the concentrated acid descends over the packing countercurrent with the rising gas stream. A recirculation system provides the proper dilution of the concentrated acid, its cooling for removing the heat generated by the absorption, its recirculation to the tower or its delivery to the product tank.

3.2 LIST OF MAIN MACHINERY AND EQUIPMENT

Sulfur melting system

- Melting tank
- Liquid sulfur transferring and filtering system
- Liquid sulfur storage tank
- Metering pump for burner feeding

Sulfur combustion

- Air blower
- Air drying tower
- Burner
- Waste Heat boiler

Conversion

- Multistage contact converter, filled with vanadium-pentoxide
- Interstage gas coolers
- Economizer

Absorption stage

- Packed tower for gas absorption
- Gas stack
- Recirculation tank and pump
- Acid coolers
- Acid storage tank
- Loading arms

Start-up auxiliaries

- Gasoil storage tank
- Auxiliary burner for gasoil combustion
- Heat exchanger (flue gas from gasoil combustion/dry air)
- Auxiliary stack

Utilities

- Cooling tower system
- Water treating plant for producing process water and boiler make-up water
- Steam condensate recovery system
- Boiler feed water deaerator and pumping system
- Compressed air system
- Electric transformer

3.3 COST OF EQUIPMENT AND MACHINERY

The cost of equipment and machinery of a plant producing 30 tons of 98% sulfuric acid per day including the items listed in the para. 3.2, the bulk materials, spare parts and engineering, is estimated (1988) at 1,900,000 U.S. $, F.O.B. European port.

3.4 ERECTION COSTS (ex-Europe)

The erection costs, including the erection of all process, equipment, piping, electric systems, instrumentation, water system, fire fighting system and all other utilities, can be estimated in the range of 400,000 US $ (1988).

3.5 LAY-OUT AND CIVIL WORKS

The total area required amounts to 6,200 sq.mt, of which :

1,250 sq.mt (80% covered) for process plant and H_2SO_4 storage tank
1,300 sq.mt (50% covered)for utilities
1,400 sq.mt (80% covered)for store of raw sulfur and H_2SO_4 containers

Other facilities and buildings (as workshop, warehouse, offices, canteen, etc.) are not considered in this profile, their design depending mainly on the general context in which the project is to be carried out.

Process plants and utility plants are normally designed for outdoor installations, with the only protection given by a roofing of corrugated sheet iron sustained by steel trusses and columns; steel structures must be lined with acid resistant paints; the same type of roofing is also applicable to the store of H_2SO_4 plastic containers.

Foundations shall be in reinforced concrete; in the process plant area foundations and floor are lined with acid resistant bricks bound with acid resistant cement. The H_2SO_4 tanks (in the present case at least 2 x 250 cu.mt, De = 7 m) are placed on supporting walls, 1.2 m high, to facilitate the inspection of the tank bottoms; the two tanks must be installed inside a basin of a volume equal to the content of the tanks; the basin walls, the supporting walls and the floor must be lined with antiacid bricks bound with antiacid cement.
The raw sulfur (crushed sulfur) storage building is devided in two sections, each covering an area of 18 x 24 m approximately.
The construction of this store is in reinforced concrete up to a height of 3.1 m about and in structural steel from this level to a total height of 6 m. So the two sections of the store have columns, floor and walls (on three sides) up to 3.1 mt in reinforced concrete, designed to resist to the sulfur heap thrust; the height of the heap is 2.3 mt; the sulfur specific weight is 1.3 ton/cu.mt.
Above the heap an antifire spray system must be installed, controlled from outside. The roof in corrugated steel iron will project forward for 3 mt along the front wall; concrete steel columns and trusses must be protected with acid resistant paints.
The capacity of each store section will be 1.000 ton approximately, 2.000 ton as total. The loading and unloading of the sulfur will be done by the front wall, which is open, by a loading shovel.

4. REQUIREMENTS AND COSTS OF RAW MATERIALS, CONSUMMABLES AND UTILITIES

The main raw material, is sulfur; a complete list of raw materials, consummables and utilities is as follow:

- sulfur	340 Kg/ton of 100% H_2SO_4
- filtering aid (diatomite)	1.5 Kg/ton of 100% H_2SO_4
- cooling water (make up)	2.7 m^3/ton of 100% H_2SO_4

- boiler water (make up)	54 Kg/ton of 100% H_2SO_4
- electric power for the process	71.7 KWh/ton of 100% H_2SO_4
- electric power for utilities	30 KWh/ton of 100% H_2SO_4
- process water	166 Kg/ton of 100% H_2SO_4

Notes :

- The sulfur consumption is based on the following specification of the mineral :

. commercial form		granular
. sulfur	minimum	99.2% (dry basis)
. carbon	maximum	0.1%
. ash	"	0.1%
. arsenic	"	0.25 ppm
. selecium	"	1 ppm
. tellerium	"	1 ppm
. moisture	"	1%
. solid suspension and contamination	"	0.8% on 50 micron screen

- The cooling water consumption is referred to a cooling tower system with a range of 10°C and a make up equal to 5% of the recirculation flowrate.

- The make up of the b.f.w. is supposed equal to the 3% of the boiler production.

- The power consumption of utilities is approximate, being dependent on local conditions.

In calculating operating costs, a credit from the net production of 1.200 Kg of steam at 17 bar for each ton of 100% sulfuric acid must be taken into account.
About the present and future price of sulfur the actual picture is as follows.

There has been in the last twenty years a strong upwards trend in the real price of sulfur; there has been also a close correlation between the sulfur prices and production and traded volumes. Since the demand is expected to increase in the near future, the trend would not change. Present price on international market (F.O.B. price) is 140 ÷ to 150 $/t; the price forecast at the end of the nineties is likely 180 $/t (in terms of dollars 1988).

5. MAINTENANCE COSTS

The annual maintenance cost, including spare parts, at full production can be assumed as 4% of the machinery and equipment cost.

6. MAN POWER REQUIREMENTS

The sulfuric acid together with auxiliary units plant operates continuously; so the operating personnel, for the most part, shall work on three shifts per day; so the production organization will include :

- Production manager	1
- Process engineer	1
- Sulfur store and melting section's operators	2
- Chemist	1
- Product dispatching and store	1
- Shift foreman	1 x 4
- Sulfur combustion and conversion section's operator	1 x 4
- Drying and absorption section's operator	1 x 4
- Utility section's operator	1 x 4
- Analysts	1 x 4
Total	6 + (5 x 4) = 26

7. PREPRODUCTION PERIOD AND COSTS

7.1 CONSTRUCTION PERIOD

Thirty months must be allowed for the implementation of the project, from contract signature to start-up of commercial production.

7.2 PRE-PRODUCTION COSTS

. Project administration : approx 90 m/m
. Consultant fee : 200,000 US $
. Training : 50,000 US $
. Commissioning : 2% of the total investment cost

8. PRODUCTION PROGRAMME

Considering an availability of all the materials of direct and indirect manpower, of all ininterrupted energy supplies in the required quantities, the max plant production can be reached at the end of the second year of production.

9. ENVIRONMENTAL MAJOR ASPECTS

Sulfur dioxide, sulfur trioxide and sulfuric acid are normally present in small concentrations in the tail gas of any well-designed and well-operated contact type sulphuric acid plant. Sulfur dioxide is by far the most common hazardous gas which is vented into the atmosphere, and it can be dangerous to both human being and nature. Tall stacks represent by far the most common method of disposing of the tail gases of sulfuric acid plants. The height of a stack necessary to get proper dispersion of the gases into the atmosphere will depend on the local meteorological conditions and on the surroundings of the plant; formulas are available to calculate the required height of stacks; however stacks 40 ÷ 60 m in height have proved satisfactory where no unusual terrain or ambient conditions exist.

10. ACID PRICE

Present price of 100% acid, F.O.B. European port, is around 60÷70 $/t. The trend shows a relative stability of this price due to the availability of the so-called smelter acid.

FIG. 3.1 PROCESS BLOCK DIAGRAM