SULFURIC ACID
AP-42 Section 5.17
Reference Number
2

CONTROL OF AIR POLLUTION
FROM
SULFURIC ACID PLANTS

ROUGH DRAFT

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ENVIRONMENTAL PROTECTION AGENCY
Durham, North Carolina
August, 1971

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INTRODUCTION

This document has been prepared to provide guidance to owners and operators of contact sulfuric acid production facilities and to State and local control agencies who will implement the standards of performance for new contact sulfuric acid plants. The standards were promulgated by the Administrator, Environmental Protection Agency, on November 15, 1971, and published in the Federal Register on the same date. The Administrator is authorized to develop and promulgate standards of performance for new stationary sources under Section 111 of the Clean Air Act (42 U.S.C. 1857 et seq) as amended by the Clean Air Amendments of 1970 (Public Law 91-604).

In 1970, an estimated 35,000,000 tons of sulfur dioxide (SO_2) were emitted to the atmosphere from stationary sources.[1] The bulk of this emission resulted from the combustion of coal and oil. The manufacture of sulfuric acid generated approximately 600,000 tons[1] of SO_2 in 1967 or about two percent of the stationary source total. About 31,000 tons of acid mist (H_2SO_4) were also emitted from contact plants in 1967 based on a national average emission estimate of 2.3 pounds per ton of 100 percent acid produced.[2]

Though emissions from sulfuric acid plants do not account for a large fraction of SO_2 on a nationwide basis, individual plants can be large point sources. Without control equipment a 650 ton-per-day (tpd) sulfuric acid plant can release as much as 2,300 pounds of SO_2 per hour and about 240 pounds per hour of acid mist. Emission data from several existing plants are provided in Atmospheric Emissions from Sulfuric Acid Manufacturing Processes.[3]

Sulfuric acid is one of the largest volume industrial chemicals produced in the United States. Production capacity totals approximately 38 million short tons and is accounted for by 250 plants. About 215, representing over 97 percent of the production capacity, are of the contact process type; the remainder are the older lead chamber process plants. United States sulfuric acid production in 1968 was 28.5 million short tons.[4] Production is expected to increase to 54 million and 88 million short tons by the years 1980 and 1990 respectively.[5]

Sulfuric acid is produced in a variety of concentrations and in four grades: commercial; electrolyte or high purity; textile (having low organic content); and chemically pure (C. P.) or reagent grade. Its chief uses are in the production of fertilizer, manufacture of chemicals, oil refining, pigment production, iron and steel processing, synthetic fiber production, and in metallurgical applications.

Most sulfuric acid is consumed near its point of manufacture, either by the producer or by nearby industries. Very little is shipped more than 300 miles.

About 68 percent of the contact process sulfuric acid in the United States is produced from elemental sulfur. The remaining acid is made from iron pyrites (4.5 percent); tail gas from smelters (9 percent); hydrogen sulfide; spent alkylation acid and acid sludge from petroleum refineries (18 1/2 percent).

Standards of performance apply only to contact-process sulfuric acid and oleum facilities that burn elemental sulfur, alkylation acid, hydrogen sulfide, organic sulfides, mercaptans, or acid sludge. They do not apply to metallurgical plants that use acid plants as SO_2 control systems, or to chamber process plants or acid concentrators. The metallurgical sulfuric acid processes will be treated at a later date when new source performance standards are established for the pertinent source categories.

For sulfuric acid manufacturing facilities and for all other categories of stationary sources for which performance standards are promulgated, either the Aministrator, Environmental Protection Agency, or the responsible State will provide preconstruction review. Where the State has been delegated authorization to implement and enforce the standards of performance promulgated under Section 111 of the Act, the Administrator will not provide preconstruction review. For sources to be located in States which have not been so delegated this authority, the Administrator will provide preconstruction review if requested by the owner or operator.

SUMMARY

Sulfuric acid production facilities can discharge sulfur dioxide as well as acid mist and nitrogen oxides. At this time, standards of performance are established only for sulfur dioxide, acid mist and for attendant visible emissions which are a function of acid mist. The latter pollutant is a "non-criteria pollutant" as defined by Section 111(d) of the Act requiring the establishment of State emission standards for existing sources.

The standards are:

SULFUR DIOXIDE

No more than 4.0 pounds of sulfur dioxide (SO_2) per ton of acid (100 percent H_2SO_4) produced or 2.0 kilograms SO_2 per metric ton.

ACID MIST

1. No more than 0.15 pound of acid mist (measured as H_2SO_4) per ton of acid (100 percent H_2SO_4) produced or 0.075 kilogram acid mist per metric ton.
2. No visible air pollutants shall be released to the atmosphere.

The standard allows about 0.3 of 1 percent of the feedstock sulfur to be released to the atmosphere as SO_2. For a typical plant, the standard is equivalent to an exit-gas concentration of 280 ppm SO_2.

Where rich SO_2 streams (greater than 8.0 percent sulfur dioxide) are processed, the equivalent concentration will be greater than 280 ppm.

Conversely, where weak SO_2 streams are handled, requisite concentrations will be less than 280 ppm. The range 180 to 350 ppm will cover most contact acid plants. The visible emission standard is compatible with the acid mist standard. If acid mist emissions are held at or below 0.15 pounds of H_2SO_4 per ton, there will be no visible emissions from the facility. This standard is equivalent to a concentration of 0.8 mg of sulfuric acid per standard cubic foot or 28 mg of sulfuric acid per normal cubic meter for the typical sulfur-burning system (8.0 percent SO_2 to converter). The volumetric equivalent concentration will vary from plant to plant depending on the inlet sulfur dioxide concentration.

The standard of performance applies only to contact sulfuric acid plants burning elemental sulfur, alkylation acid, hydrogen sulfide, organic sulfides and mercaptans, or acid sludge. It does not apply to metallurgical plants using pyrites or smelter gas, to chamber process plants, or acid concentrators.

These performance standards apply to any sulfuric acid production facility the construction or modification of which is commenced after August 17, 1971. Since construction of such facility requires 18 to 24 months, the first plants to be affected by the standard will not be operated until at least 1973.

It has been demonstrated that conventional sulfuric acid plants can be operated consistently at or below the SO_2 limits of the standards using the dual absorption contact process or the sodium sulfite system.

The first dual absorption process in the United States was put into operation in 1970 in New Jersey. Several have been operated successfully in Europe, some installed as early as 1964. The only sodium sulfite scrubbing system on an acid plant was put into service in 1971 also in New Jersey. In the latter process, SO_2 is thermally recovered from the scrubbing solution and fed back to the acid process.

The two above processes are cited because they find the widest application i.e., they convert would-be SO_2 pollution to increased acid production. There are other alkaline scrubbing processes which are capable of meeting the standard but they produce by-products which have limited marketability in many areas.

The acid mist standard can be achieved with fiber type mist eliminators and with tube and wire electrostatic precipitators. Where high concentrations of acid mist are encountered, either precipitators or high density, low velocity fiber mist eliminators will be required to meet the standard. Less efficient and less expensive fiber mist eliminators will suffice for those acid processes that generate relatively little acid mist.

States also will be required (1) to establish emission standards for sulfuric acid mist from all existing sulfuric acid production facilities and (2) to enforce such standards. The State standard need not be as stringent as the new source performance standard but must ~~consider~~ available ~~technology and must be sufficient to protect health and~~ welfare. A standard of ~~0.50 pounds of acid mist (as H_2SO_4) per ton~~ of acid (100 percent H_2SO_4) would be reasonable for existing sources although in some instances more stringent control might be required to protect health or welfare. This limit would require greater than 90 percent acid mist collection at most facilities. It would also be compatible with the better collection systems now in use at existing plants. In view of attendant costs of replacing existing collectors, many States may not deem it necessary to set the limit for existing facilities at the same level of the new source performance standard.

The standards are based on actual tests and take into consideration the fact that there are interferences which cause SO_2 and acid mist emissions to be greater during abnormal periods of operation. In fact, a total system designed to meet this standard at all times will operate at a lower SO_2 and acid mist level much of the time.

There are no indications that emissions of NO_x are of sufficient magnitude to warrant a standard. Limited analyses show exit concentrations of about 100 ppm NO_x under normal operation of spent acid plants. Practically no NO_x is produced by sulfur-burning plants.

Continuous SO_2 monitoring instrumentation is required to (1) provide a record of performance and (2) provide intelligence to plant operating personnel such that suitable corrections can be made when the system is shown to be out of adjustment. Operators will be required to maintain the monitoring equipment in calibration and to furnish records of SO_2 values to the Administrator of EPA or to the responsible State agency as requested.

Performance standards for all source categories will be reviewed from time to time. The limits may be revised depending upon new control technology which becomes available and is adequately demonstrated. Revisions could include the addition of limits for further pollutants as well as revisions in the present standards for SO_2, acid mist, and visible emissions.

The cost of SO_2 and acid mist control has been taken into consideration in setting these performance standards. The control cost includes 10 year amortization of the capital investment.

A 700-750 tons per day capacity dual absorption plant may cost 22 percent more than a conventional single absorption plant. The resultant SO_2 control cost is about 3 percent of the current list price of sulfuric acid.

The same capacity new single absorption plant with a sodium sulfite-bisulfite scrubbing process attached may cost 35 percent more than the conventional plant and the SO_2 control cost is about 5 1/2 percent of the sulfuric acid list price.

Acid mist control equipment is relatively less costly, representing from one to two percent of the capital investment of a 700-750 ton per day plant The control cost represents 0.1 to 0.7 percent of the current sulfuric acid list price depending on the type of equipment used.

Existing plants may use less expensive mist eliminators in some cases. The estimated installed cost of such a mist eliminator retrofitted to an existing plant producing 750 tons of acid per day is $44,000.

1.0 CONTACT SULFURIC ACID PRODUCTION

All contact processes incorporate three basic operations: (1) burning of sulfur or sulfur-bearing feedstocks to form SO_2; (2) catalytic oxidation of SO_2 to SO_3; and (3) absorption of SO_3 in a strong acid stream. The several variations in the process are due principally to differences in feedstocks. The least complicated systems are those that burn elemental sulfur. Where there are appreciable organics and moisture as in spent acid and acid sludge, additional operations are required to remove moisture and particulates prior to catalysis and absorption. The composition of feedstocks can affect the sulfur conversion ratio, the volume of exhaust gases and the character and rate of pollution releases.

1.1 Elemental Sulfur Burning Plants

Figure 1.1 is a schematic diagram of a contact sulfuric plant burning elemental sulfur. Sulfur is burned to form a gas mixture which is approximately eight percent sulfur dioxide, 13 percent oxygen, and 79 percent nitrogen. Combustion air is predried by passing it through a packed tower circulating 98 percent sulfuric acid. Air drying minimizes acid mist formation and resultant corrosion throughout the system.

Sulfur dioxide (SO_2) is oxidized to sulfur trioxide (SO_3) in the presence of a catalyst containing vanadium pentoxide. The temperature of the reacting gas mixture increases as the composition approaches equilibrium. Maximum conversion to SO_3 requires several conversion stages with intermediate gas cooling. The gas exiting the converter is cooled in an

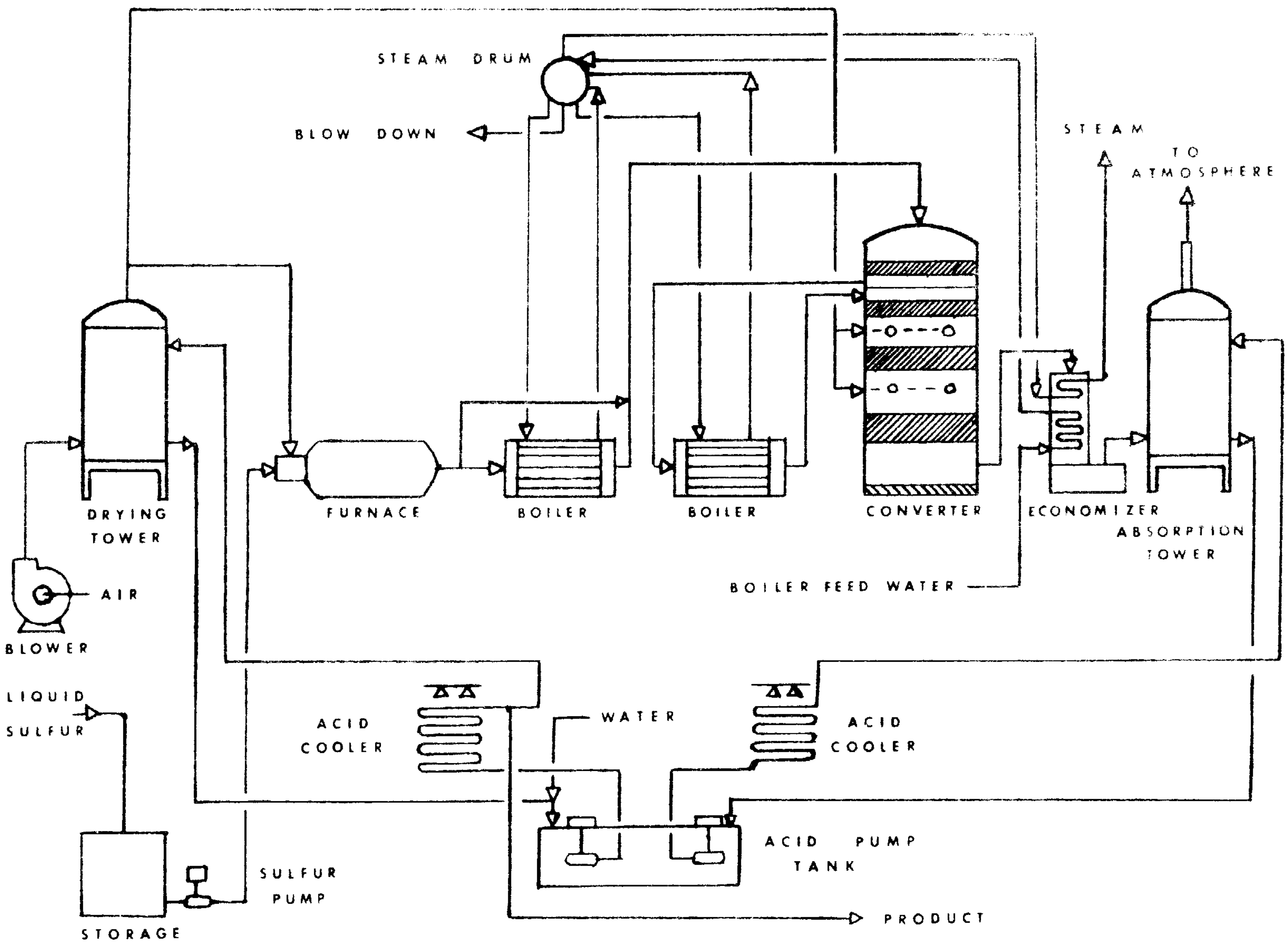


FIGURE 1.1 CONTACT-PROCESS SULFURIC ACID PLANT BURNING ELEMENTAL SULFUR

economizer to 450^{0} to 500^{0}F and SO_3 is absorbed in 98 percent sulfuric acid circulating in a packed tower. The acid content and temperature must be carefully controlled to prevent excessive SO_3 release.

If fuming sulfuric acid or oleum is produced, the SO_3 containing gases are first passed through an oleum tower which is fed with acid from the 98 percent absorption system. The gas stream from the oleum tower is passed through the 98 percent acid absorber for recovery of residual sulfur trioxide.

1.2 Spent Acid and Other By-Product Plants

Where spent acid, sludge, and similar feedstocks are employed, the processes are more elaborate and expensive than sulfur-burning plants due to the fact that the sulfur dioxide containing gas stream is contaminated. Gases must be cleaned if high-quality acid is to be produced. This requires additional gas cleaning and cooling equipment to remove dust, acid mist, and gaseous impurities, along with excessive amounts of water vapor. Purification equipment consists of cyclones, electrostatic dust and mist precipitators, plus scrubbers and gas-cooling towers in various combinations. Figure 1.2 shows one possible configuration of a spent acid plant. The balance of the process following the drying tower is essentially the same as an elemental sulfur-burning plant.

A few plants burning only hydrogen sulfide or hydrogen sulfide plus elemental sulfur use a simplified version of the above process. Wet gases from the combustion chamber and waste heat boiler are charged

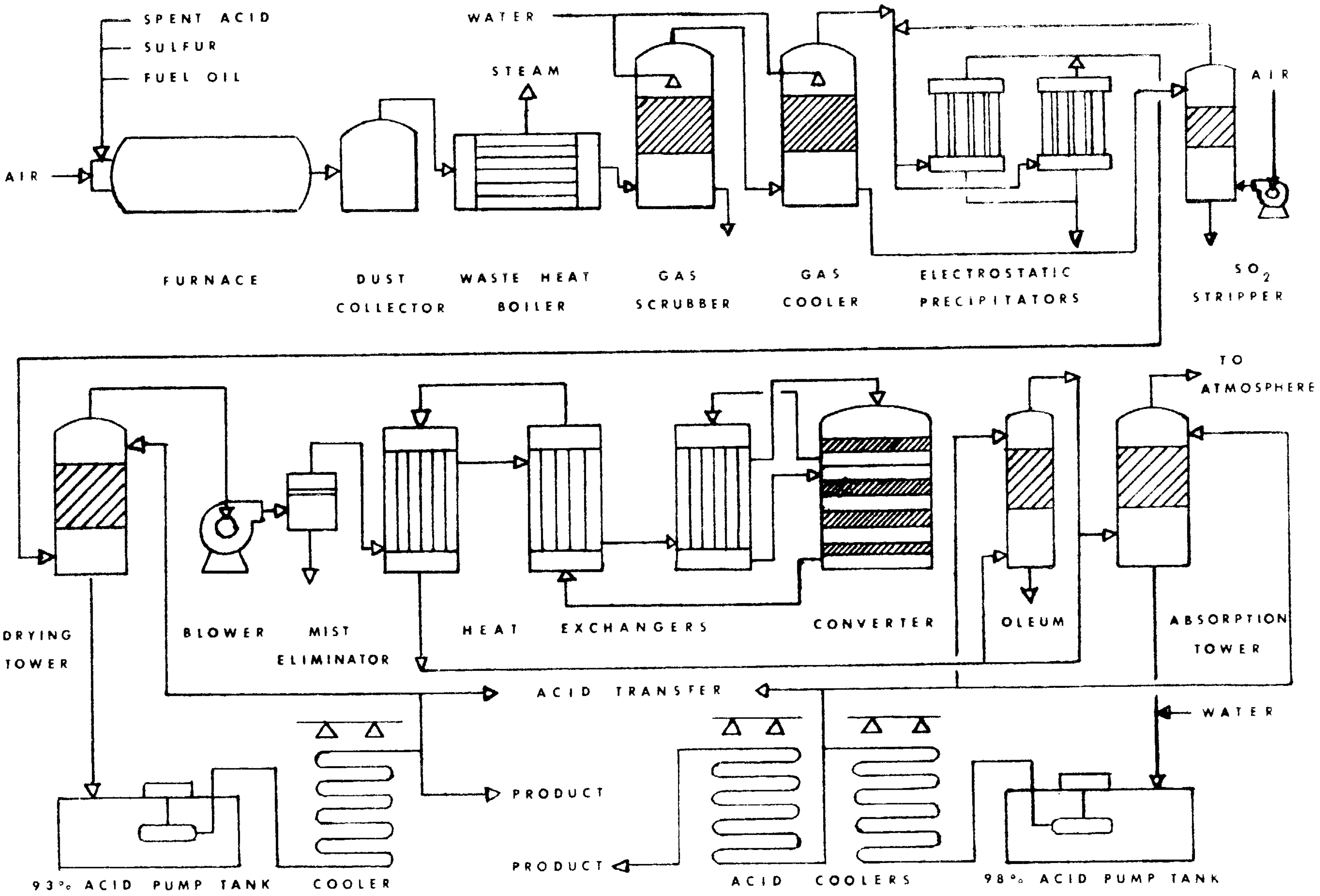


FIGURE 1.2 CONTACT-PROCESS SULFURIC ACID PLANT BURNING SPENT ACID

directly to the converter with no intermediate treatment. Gases from the converter flow to the absorber, through which 70 to 93 percent sulfuric acid is circulating. In such a "wet gas" plant much of the sulfur trioxide from the converter is in the form of acid mist which is not absorbed in the absorption tower. High efficiency mist collectors are utilized both to recover product and to prevent excessive air pollution.

2.0 EMISSIONS

2.1 Sulfur Dioxide

Mass SO_2 emissions vary inversely as a function of the sulfur conversion efficiency (i.e., fraction of SO_2 oxidized to SO_3). For sulfur burning plants, the inlet SO_2 concentration to the catalytic converters normally ranges between 7.5 and 8.5 percent but can be as high as 10.5 percent. Conversion efficiency depends upon the number of stages in the catalytic converter and to a lesser extent, on the amount of catalyst.

Most plants built prior to 1960 had only three catalyst stages and overall conversion efficiencies were approximately 95 to 96 percent. Sulfur burning plants built after 1960 generally had four stages and efficiencies normally ranged between 96 and 98 percent. Consequently, for three stage plants, SO_2 release ranges between 55 and 70 lb/ton and for four stage plants, between 26 and 55 lb/ton.

Spent acid plants followed the same design trend. Most three stage plants were built prior to 1960 and four stage plants were usually built after 1960. Typical SO_2 concentrations in the converter feed, conversion efficiencies, and resultant emissions for plants burning either H_2S or acid sludge primarily are given in Table 2.1. A three stage plant operating under adverse conditions may have SO_2 emissions as high as 6,000 ppm or 85 lb/ton.

TABLE 2.1

SULFUR DIOXIDE CONVERSION EFFICIENCIES AND EMISSIONS FOR THREE-AND FOUR-STAGE CONVERTERS

Feedstock	Sulfur	Hydrogen sulfide (with some other sulfur compounds)	Acid Sludge
SO_2 in converter Feed, % by volume	7.5 to 8.5	7	6 to 8
Three Stage Converter	95 to 96	94 to 96	94 to 96
Sulfur Conversion to SO_3 % by weight			
SO_2 Emissions, lb/ton 100% acid	50 to 80	50 to 90	50 to 85
SO_2 Emissions, ppm by volume	3,000 to 5,000	3,000 to 5,000	2,500 to 4,000
Four Stage Converter	96 to 98	95 to 98	95 to 98
Sulfur Conversion to SO_3, % by weight	96 to 98		
SO_2Emissions lb/ton 100% acid	25 to 65	50 to 85	30 to 105
SO_2 Emissions, ppm by volume	1,500 to 4,000	1,500 to 4,000	1,500 to 5,000

Exit SO_2 concentrations from contact plants vary as a function of the SO_2 content of dry gases fed to the converter. Where SO_2 strength is relatively low there is a significantly greater volume of gases handled per ton of acid produced.

A plant with 4.0 percent SO_2 in the dry gases to the converter will exhaust over two and one-half times the volume of a plant operating on a 10.0 percent SO_2 stream. i.e., 180,000 SCF/ton vs. 65,700 SCF/ton.

The relationship between mass emission rate, sulfur conversion and SO_2 exit concentrations has been plotted in Figure 2.1 for plants of various SO_2 strengths. The curve can be used for uncontrolled single absorption plants and for those plants equipped with tail gas removal systems or with the dual absorption process. It can be seen that the performance standard of 4.0 lb SO_2 per ton of acid requires 99.7 percent sulfur conversion (dual absorption) or equivalent SO_2 collection. At 98 percent conversion - optimum for most single absorption systems - exit SO_2 concentrations can vary from 900 to 2500 ppm as the inlet SO_2 content varies from 4.0 to 10.0 percent.

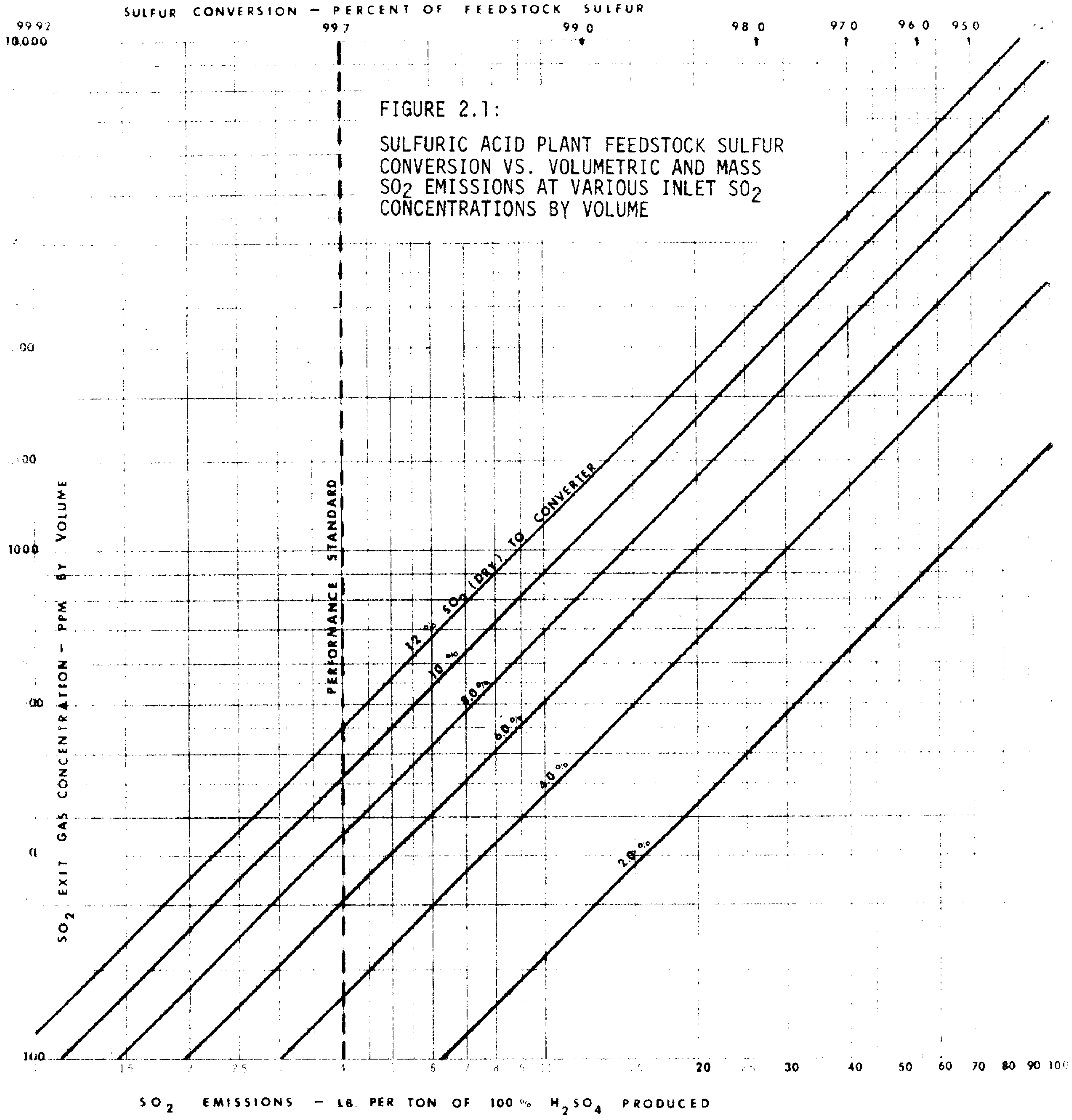


FIGURE 2.1:

SULFURIC ACID PLANT FEEDSTOCK SULFUR CONVERSION VS. VOLUMETRIC AND MASS SO_2 EMISSIONS AT VARIOUS INLET SO_2 CONCENTRATIONS BY VOLUME

2.2 Acid Mist

If significant sulfur trioxide (SO_3) is present in the stack gas as a result of poor absorber operation, it will combine with water vapor in the atmosphere to produce a visible acid mist. The only way to prevent this mist formation is through proper absorber operation.

The stack gas leaving the absorption tower always contains sulfuric acid vapor. This vapor is in equilibrium with the acid in the tower at its operating acid concentration and temperature. This vapor on cooling may condense in long ducts leading to the stack or in the stack itself. The condensed vapor is sometimes carried out of the stack as relatively large droplets which fall in the vicinity of the plant. Acid vapor may be reduced by operating the absorber at low temperatures, however this may hinder SO_3 absorption and increase acid mist emissions. The lowest absorber operating temperature must be determined to reduce acid vapor emissions while maintaining good absorber operation.

Acid mist is formed at any point in the system where the temperature falls below the SO_3 dew point and the water vapor is present in the gas to react with the SO_3. Once formed, this mist is extremely stable and much of it passes through the absorber. The quantity and particle size distribution of acid mist are functions of the sulfur feedstock and strength of the acid produced.

In bright elemental sulfur burning plants, dry sulfur is burned in dry air and hence there is little water vapor available for mist formation. However, when dark or contaminated sulfur is burned, the hydrocarbon impurities burn to produce water vapor. This in turn combines with SO_3 to form acid mist as the gas cools in the economizer or absorption tower.

In oleum producing plants, greater quantities and a much finer mist is produced. From 85 to 95 weight percent of the particles are less than 2 microns in diameter as compared to about 30 percent less than 2 microns for 98 percent acid production.[6] Acid mist emissions prior to control equipment ranges between 0.4 to 4 lb/ton for sulfur burning contact plants producing no oleum to about 1 to 10 lb/ton for spent acid burning plants producing oleum,[7] based on an 8 percent SO_2 feed to the converter.

Spent acid plants characteristically form acid mist in the early stages of the process. This requires mist removal prior to drying and oxidation as well as from the tail gas after absorption.

"Wet Gas" plants burning hydrogen sulfide deliberately form acid mist by not drying the process gas. Much of this mist is recovered as product acid with gas cooling equipment and high efficiency mist eliminators or electrostatic precipitators.[8]

For a given mass emission rate, acid mist concentrations vary as a function of the exhaust gas volume and thus the SO_2 control of the gases fed to the converter. In Figure 2.2 a relationship has been developed between mass emission rates and concentrations over a range of SO_2 strengths. The curves can be used with any gas stream before or after mist eliminators provided there is no dilution.

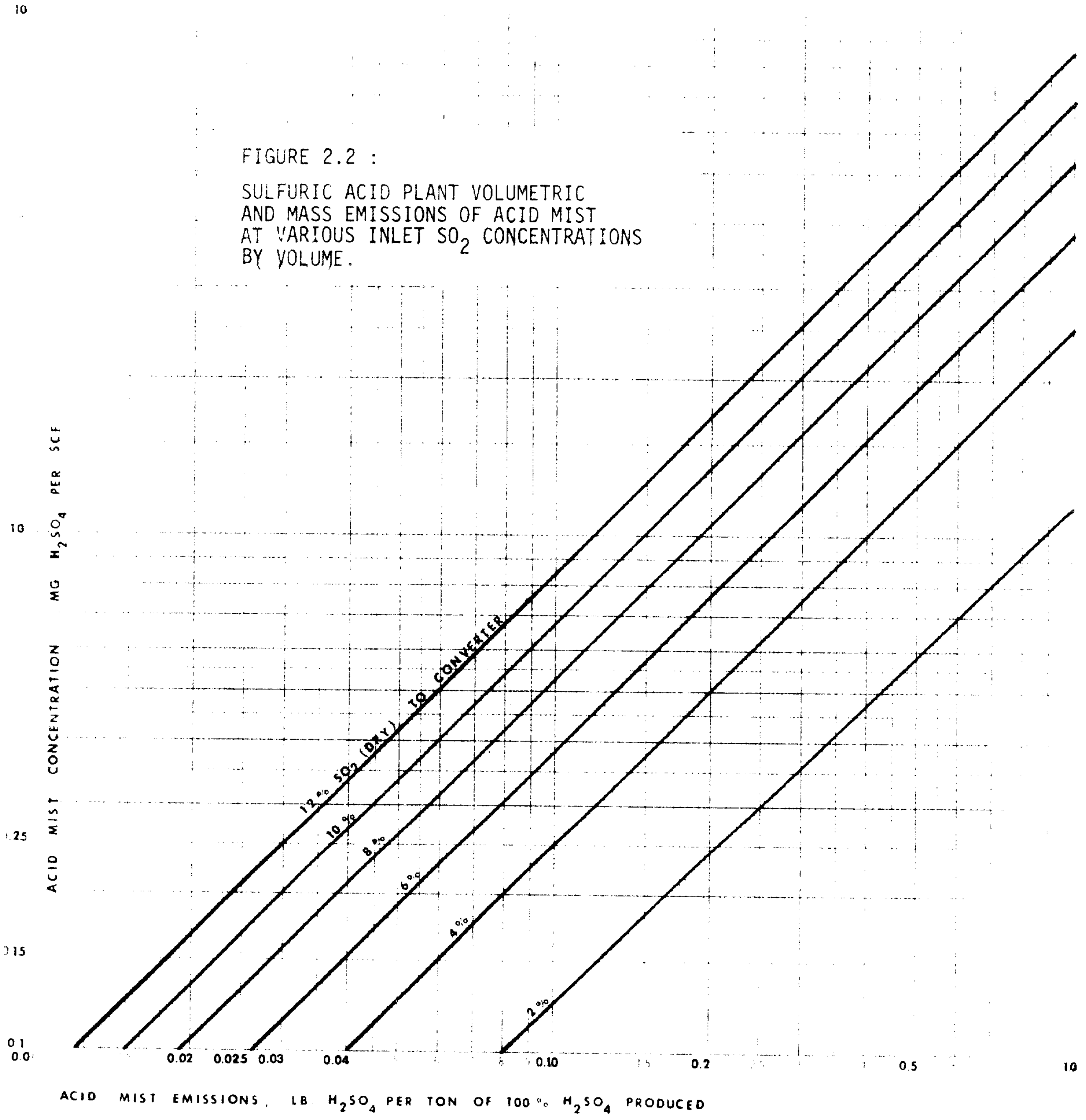


FIGURE 2.2 :

SULFURIC ACID PLANT VOLUMETRIC AND MASS EMISSIONS OF ACID MIST AT VARIOUS INLET SO_2 CONCENTRATIONS BY VOLUME.

2.3 Visible Emissions

Acid mist in exhaust gases create visible emissions ranging from white to blue depending on particle size, concentration and background. Where there is no control of mist opacities generally range from 80 to 100 percent.

There has been no firm correlation between opacity and the various acid mist parameters that are believed to offset visible emissions. Nevertheless, it has been demonstrated that opacity is a function of acid mist concentration and that visible emissions can be eliminated by controlling acid mist to reasonable levels.

2.4 Oxides of Nitrogen

Nitrogen oxides present in the converter gas also cause acid mist emissions since they reduce the efficiency of the absorption tower. Nitrogen oxides may result from the fixation of atmospheric nitrogen in high temperature sulfur furnaces, or might be due to nitrogen compounds in the feedstocks. Nitrogen oxides can be held to a reasonable minimum by using the same techniques which have been applied to steam generators. For instance, in the decomposition of spent acid containing nitrogen compounds, operation at furnace temperatures less than about 2,000°F and a low oxygen content will generally keep nitrogen oxides concentrations below 100 ppm.[9]

3.0 CONTROL TECHNOLOGY

3.1 Control of Sulfur Dioxide

There are many chemical means of removing SO_2 from gas streams and a few physical mechanisms. Almost any soluble alkaline material will absorb a significant fraction of SO_2 even in a crude scrubber. Sulfur dioxide has in fact for years been removed from many process gases where the SO_2 adversely affected the product. The problems of removing SO_2 from acid plant gases are principally concerned with finding the least expensive mechanism.

In this document we have directed our efforts to two processes that have been adequately demonstrated and that have relatively wide applicability. These are the dual absorption process and the sodium sulfite-bisulfite scrubbing process. Both systems increase acid production and do not yield by-products.

Several additional processes are also described. Some in fact have been adequately demonstrated to operate within or close to the performance standard. Should economic factors change, these or other SO_2 removal processes might prove attractive to owners and operators of new sulfuric acid plants.

3.1.1 Dual Absorption

Over twenty plants of this type have been operating successfully in Europe for several years using both elemental sulfur and roaster gas as feed.

In the dual absorption process, Figure 3.1, as opposed to single absorption, a greater fraction of the sulfur in the feedstock is converted to sulfuric acid. The SO_3 formed in the primary converter stages is removed in a primary absorption tower and the remainder of the gas is returned to the final conversion stages. Removal of a product of a reversible reaction

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

drives the oxidation further toward completion approaching the reaction equilibrium expressed by

$$K = \frac{(SO_3)}{(SO_2)(O_2)^{1/2}}$$

where K is the reaction equilibrium constant peculiar to the temperature of the reaction and the parenthetical entities are the molar quantities of the gases involved.

The resulting SO_3 is absorbed in a secondary absorption tower obtaining at least 99.7 percent overall conversion of the sulfur to sulfuric acid.

The dual absorption process permits higher inlet SO_2 concentrations than normally used in single absorption plants since the second conversion step effectively handles the residual SO_2 from the first conversion step. Higher inlet SO_2 concentrations permit a reduction in equipment size which partially offsets the cost of the additional equipment required for a dual absorption plant. The dual absorption equipment occupies little more space than a conventional plant even though an additional absorber is required.

Spent acid or H_2S may be used as feedstock in a dual absorption process

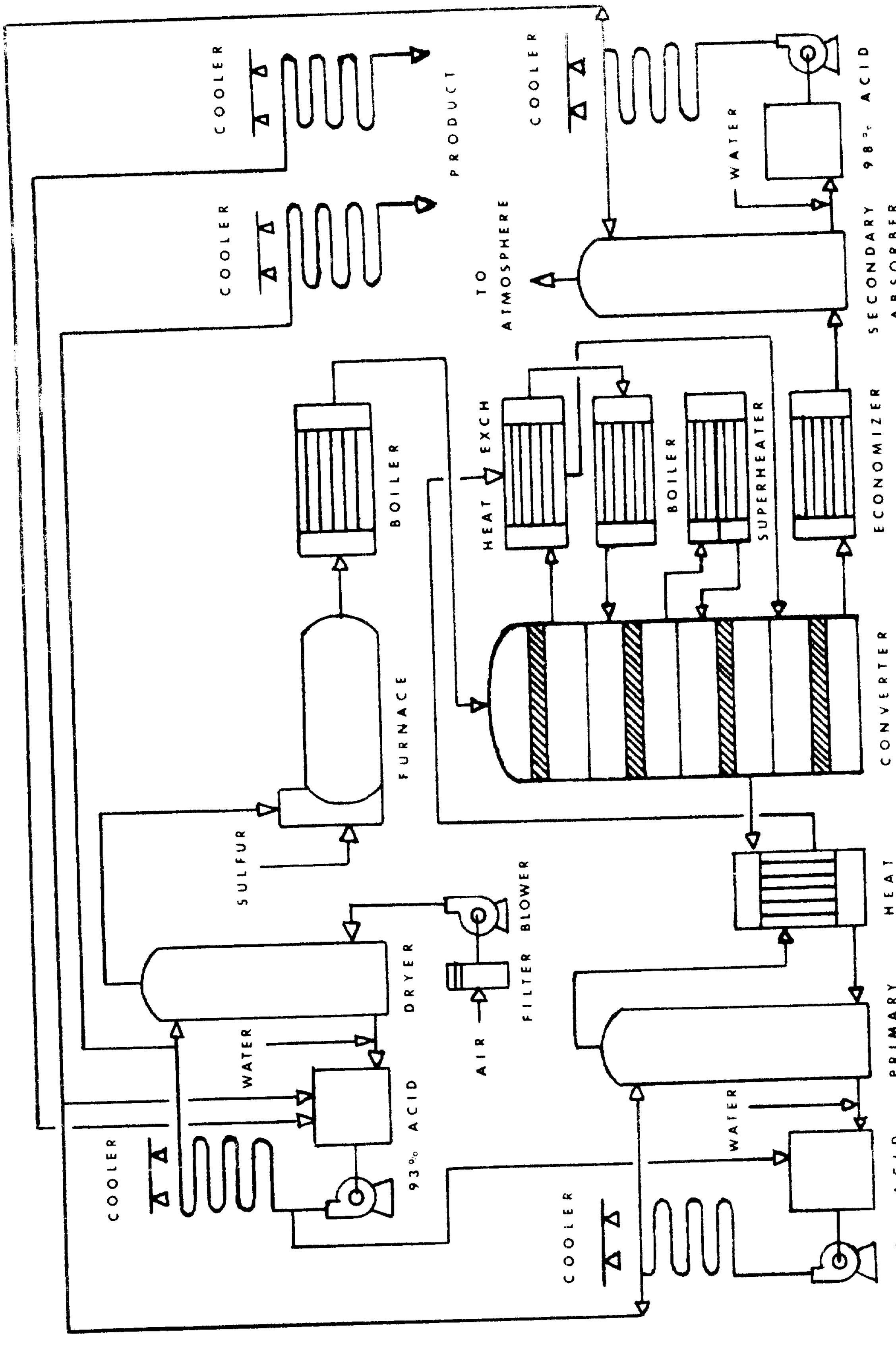


FIGURE 3.1 DUAL ABSORPTION SULFURIC ACID PLANT

with appropriate conventional process gas pretreatment.

The dual absorption process requires the same types of equipment as the conventional single absorber design. Although additional equipment is required the on-stream factor and manpower requirements are the same.

The literature[10] reveals operating data from a number of European dual absorption plants. Table 3.1 summarizes average sulfur dioxide emissions from several of these plants. Mass emission rates presented are estimated from Figure 2.1 since the pertinent production rate was not given.

Emissions from the only operating dual absorption plant in the United States were measured using the modified Shell Development Company method. This plant owned by American Cyanamid Company, was designed and constructed by Monsanto Enviro-Chem Systems, Inc. It is located near Linden, New Jersey. Table 3.2 presents the sulfur dioxide emission from this plant on both the volumetric and mass basis. Prior emission test data obtained by the company is also shown for comparison.

If dual absorption is added to existing single absorption plants, the heat necessary to re-heat the gas exiting the primary absorber can be provided by either heat exchange with the converter gas, mixing in a small quantity of gas directly from the sulfur furnace, or by using an outside heat source. The choice is dictated by individual plant considerations such as availability of waste steam. Of course, the economics change somewhat for each of these methods.

TABLE 3.1 OPERATING DATA FOR EUROPEAN DUAL ABSORPTION PLANTS[10]

Plant	SO_2 Source	Capacity Tons/Day H_2SO_4	Gas Flow (SCFM)	SO_2 Inlet Concentration Range %	Conversion Efficiency Range %	Outlet SO_2 Concentration PPM	Range lb/ton
1. Farbenfabriken Bayer AG Leverkusen Werke, Germany Plant #1	Roasting Sulfide Ore	550	28,700	8.2-9.3	99.71 to 99.83	139 to 260	2.0 to 3.1
Plant #2	Elemental Sulfur	550	27,700	8.5-9.2	99.78 to 99.83	148 to 202	2.0 to 2.5
2. Farbenfabriken Bayer Dormagen Werke, Germany	Roasting of Sulfide Ores	550	-	9.0-9.7 (avg. 9.4)	99.27 to 99.5	510 to 790	6.5 to 9.2
3. Berzelius Metallhutten AG, Homburg Zinkhutte Duisberg, Germany	Roasting of Zinc Ore	220	15,600	5.9-6.4	99.60 to 99.73	190 to 300	3.7 to 5.5
4. Sud-Chemie AG Kehleim Werke, Munich, Germany	Elemental Sulfur	110	6,900	9.09-9.23	99.90 to 99.92	74 to 91	1.0 to 1.2
5. Saurefabrik Schweizerhalle, Basel, Switzerland	Elemental Sulfur	220	-	9.9-10.5	99.48 to 99.81	220 to 600	2.4 to 7.0

TABLE 3.2

SULFUR DIOXIDE STACK EMISSIONS FROM A DOMESTIC DUAL ABSORPTION SULFURIC ACID PLANT

Test No.	Tester	Production Tons/Day	Gas Flow SCFM	SO_2 ppm	SO_2 lbs/ton
1	EPA	365	21,669	126	1.92
2	EPA	360	16,226	131	1.52
3	EPA	360	17,283	122	1.51
4	Company	360	-	133	est.1.60
5	Company	300	-	208	-
6	Company	300	-	320	-
7	Company	300	-	309	-
8	Company	300	-	276	-
9	Company	700	-	259	est.3.0
10	Company	700	-	212	est.2.5
11	Company	700	-	420	est.4.6

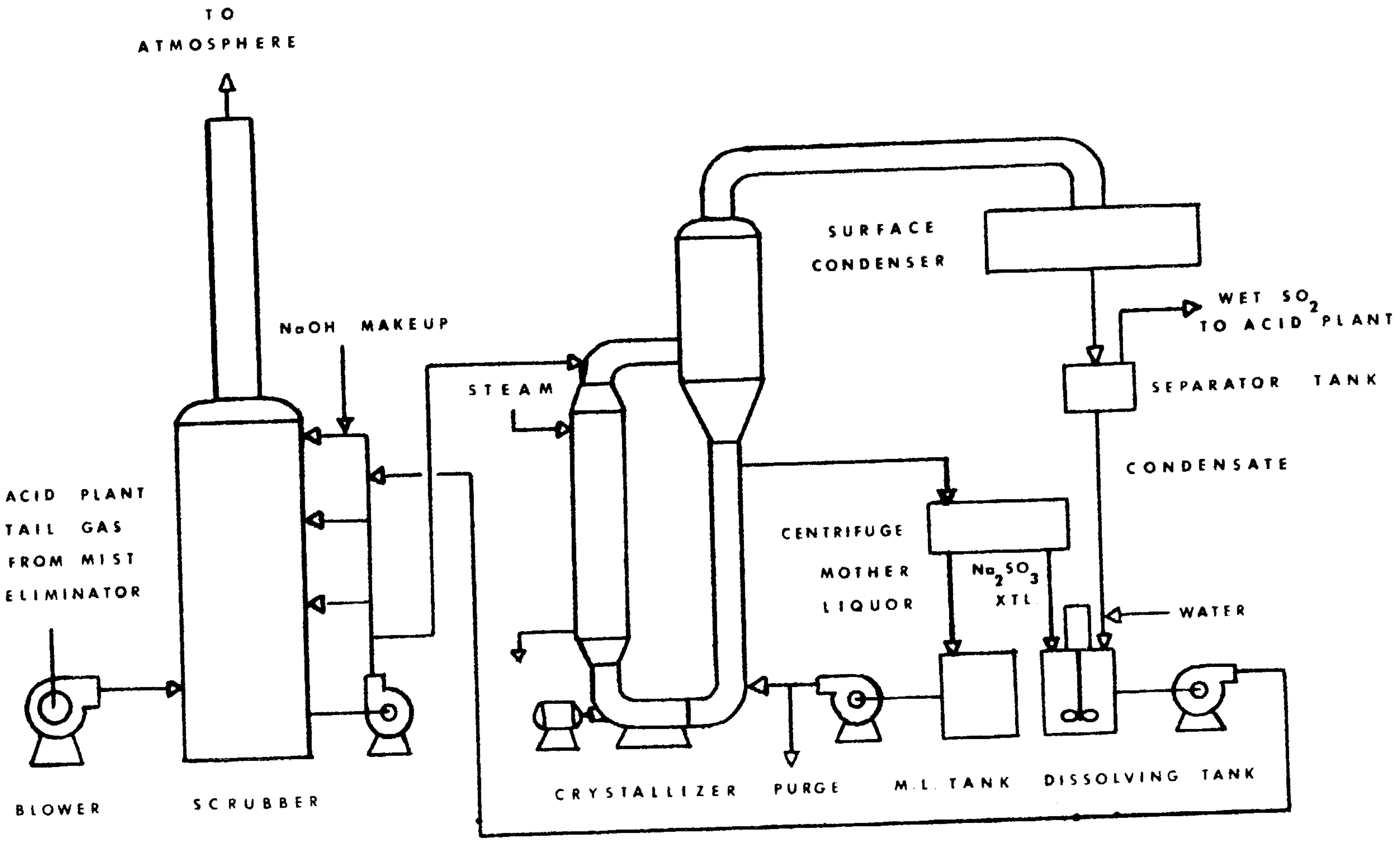
3.1.2 Sodium Sulfite - Bisulfite Scrubbing

Tail gas recovery systems are generally applicable to all classes of contact acid plants. They can provide simultaneous control of SO_2 and to some extent SO_3 and acid mist. To date only the sodium sulfite-bisulfite process has been demonstrated to be capable of meeting the SO_2 limit when taking cost into consideration. Others such as ammonia scrubbing can meet the standard but costs are highly dependent on the marketability of by-products for which there may be little demand.

The Wellman-Power Gas sodium sulfite-bisulfite scrubbing system is presently used to recover SO_2 from the tail gas of a spent acid sulfuric acid plant operated by the Olin Corporation in Paulsboro, New Jersey. The plant has been in normal operation since January, 1971.

In the Wellman-Power Gas process, Figure 3.2, the tail gases are first passed through a mist eliminator to reduce acid mist. Following mist removal, the SO_2 is absorbed in a three stage absorber with a sodium sulfite solution. A sodium bisulfite solution results and is fed to a heated crystallizer where sodium sulfite crystals are formed and SO_2 gas and water vapor are released. The crystals are separated from the mother liquor and dissolved in the recovered condensate for recycle to the absorber. The recovered wet SO_2 is sent back to the acid plant.

In all processes employing sulfite-bisulfite absorption even without regeneration, some portion of the sulfite is oxidized to sulfate, from which the sulfur dioxide cannot be regenerated in the heating sequence.



3.2 WELLMAN-POWER GAS, INC. SULFUR DIOXIDE RECOVERY SODIUM SYSTEM

This sulfate must be purged from the system. In the Paulsboro plant, some thiosulfate is also formed. Apparently the extent of oxidation is dependent on several factors such as the oxygen content of the gas stream, the temperature and residence time of the liquor in the recovery sections, and the presence of contaminants that may act as oxidation catalysts.

Although the Paulsboro plant purge stream presently amounts to about two to three gallons per minute, this represents a loss of recovered SO_2 as well as a disposal problem. The designer is studying means of eliminating the purge stream or possibly converting it to a saleable by-product.

The designer has determined additional design parameters through the experience of starting up, modifying and operating its first sodium sulfite-bisulfite system. They state that the major equipment components of the Paulsboro plant are oversized and that the capital costs of future plants can be reduced.

SO_2 emissions from the scrubber stack were tested using the EPA modified Shell Development Company method. Table 3.3 presents measured sulfur dioxide emissions on both the volumetric and mass basis. The single absorption spent acid plant was operating at full rate while the scrubber was using two out of three stages.

TABLE 3.3

SULFUR DIOXIDE EMISSIONS FROM SODIUM SULFITE-BISULFITE SCRUBBER SERVING A SULFURIC ACID PLANT

Test No.	Production Tons/Day	Gas Flow SCFM	SO_2 ppm	SO_2 lb/ton
1	730	35,141	250	2.59
2	730	36,292	227	2.85

3.1.3 SNPA-Topsoe

The SNPA-Topsoe process is presently operating on a sulfur recovery unit in Lacq, France. The process was jointly developed by Ste. Nat. de Petroles d'Aquitaine (SNPA) and Haldor Topsoe, a Danish Engineering firm. The process catalytically oxidizes SO_2 to SO_3 and produces a 92 to 94 percent acid. The outlet concentration at Lacq is about 500 ppm of SO_2, using a feed gas containing less than one percent SO_2. There appears to be no inherent reasons why emissions can't be as low as 200 ppm for a 4000 ppm SO_2 inlet gas. In addition, the designers claim that their absorber and concentrator forms no acid mist.

3.1.4 Lurgi Sulfacid

The Lurgi Sulfacid process has limitations because it produces a weak acid, about 10 percent H_2SO_4. To the extent that a process produces a weak acid, it is undesirable bacause of the possible disruption of the acid plants thermal and water balances. In this case the attached acid plant efficiency would have to be 99 percent or better to assimilate all of the 10 percent acid without supplementary heat being required. The process however, is in commercial operation in Europe.

3.1.5 Magnesium Oxide - Sulfite Scrubbing

The Chemico-Basic process involves the absorption of SO_2 into a magnesium oxide-sulfite water slurry with calcination to recover the SO_2 and magnesium oxide. The designers state that the process can reduce SO_2 emissions from 33 lb/ton to 2.0 lb/ton of acid. Although the process is not yet in commercial operation, a pilot scale unit has been operated successfully on a side stream from an acid plant.

Because the necessary auxiliary equipment, such as calciners, is usually available in sizes larger than required for sulfuric acid plants, this process is best suited for plants producing over 1000 tons of acid per day. The designer, in fact, recommends incorporating the calcination and sulfur recovery step in one large central plant using spent absorber liquor from various sources such as power plants and sulfuric acid plants.

3.1.6 Ammonia Scrubbing

The Cominco process uses anhydrous ammonia (NH_3) and water make-up in a two-stage scrubbing system to remove SO_2 from acid plant tail gas. Excess ammonium sulfite-bisulfite solution is reacted with sulfuric acid in a stripper to evolve SO_2 gas and produce an ammonium sulfate by-product solution. The SO_2 is returned to the acid plant while the solution is treated for the production of fertilizer grade ammonium sulfate. The process is dependent on a suitable market for ammonium sulfate.

This process has been used by the Olin Corporation in two acid plants located in Pasadena and Beaumont, Texas since 1953 and 1957, respectively The typical scrubber stack emission contains about 300 ppm SO_2.[11] If 8.5 percent or higher SO_2 converter inlet gas compositions are used this process will meet new source SO_2 emission standards.

3.1.7 Molecular Sieves

This process utilizes a proprietary molecular sieve system in which SO_2 is adsorbed on synthetic zeolites. The designer states that the process is capable of reducing emissions from an acid plant to 10 to 50 ppm SO_2 or from 0.2 to 1.0 lb SO_2 per ton of acid. The system has two sieve beds in series. The first adsorbs acid mist, SO_3, and acid vapor while the second adsorbs SO_2. The adsorbed material is desorbed by purified hot tail gas from the operating system and sent back to the acid plant. An operating system would be expected to have two or three beds in parallel to accomodate the desorbtion and possible cooling cycles.

Scale-up of the process is underway prior to installation on a sulfuric acid plant operated by the designer. If the system were perfected on a full-scale basis it would appear capable of achieving an extremely low level of both SO_2 and acid mist.

3.1.8 Enriched Oxygen Process

An approach in preliminary development uses a rich oxygen stream for sulfur combustion. The obvious advantage is a less voluminous exit gas stream such that all process vessels and control equipment can be of smaller size. The process obviously requires a source of oxygen or oxygen rich air. It is uncertain what oxygen strength would be practical. From the air pollution control standpoint 100 percent oxygen would be most advantageous. Essentially all of the SO_3 could be absorbed and any residual SO_2 and oxygen fed back to the front of the process. There is no indication at this date whether the approach is feasible.

3.2 Control of Acid Mist

There are several devices in use today which are capable of meeting the acid mist standard - 0.15 lb. per ton of acid produced. In addition it is probable that some of the SO_2 control schemes which will be applied to sulfuric acid plants will also collect acid mist to various extents. The acid absorber offgas usually passes through a conventional mist eliminator prior to entering the SO_2 control apparatus. The resultant double collection should effectively lower acid mist releases below 0.15 lb. per ton of acid.

We have concentrated our effort in this document on two basic devices that have been adequately demonstrated and are applicable to all contact process sulfuric acid plants. These devices are electrostatic precipitators and fiber mist eliminators. The latter is available in three different configurations covering a range of efficiencies required for various plants having low to high acid mist loadings and coarse to fine mist particle sizes respectively. The three fiber mist eliminator configurations are:

(1) Vertical tubes
(2) Vertical panels
(3) Horizontal dual pads

Table 3.4 compares manufacturers' generally expected results of electrostatic and applicable fiber mist eliminators.[12,13,14]

TABLE 3.4 COMPARISON OF ELECTROSTATIC AND FIBER MIST ELIMINATORS[12,13,14]

Mist Eliminator	Electrostatic	Tubular	Panel	Dual Pad
Item				
Collection Efficiency				
Above 3 microns	99%	100%	100%	100%
Less than 3 microns	nearly 100%	95-99+%	90-98%	93-99+%
Emission Level				
99% Acid Plants[a]	0.10 lb/ton	0.02 lb/ton	0.10 lb/ton	0.11 lb/ton
Oleum Plants[a]	0.02 lb/ton	0.02 lb/ton	0.10 lb/ton	0.11 lb/ton
Pressure Drop Inches W.G.	less than 1	5 to 15	6 to 8	10

a) Based on manufacturers' generally expected results, calculated for 8 percent SO_2 to converter.

3.2.1 Electrostatic Precipitator

The first electrostatic precipitator used commercially was put in service removing acid mist from the tail gas of a contact sulfuric acid plant in California in 1910.[6] This type of equipment has been used for many years in the purification section of spent acid plants and related plants using smelter gas. These devices were lead lined with vertical tubes, lead required to prevent corrosion from the relatively dilute acid environment. A later variation has been used on the tail gases from acid plants. This equipment is constructed of mild steel with long vertical panels dividing the precipitator shell into ducts which are charged to attract mist particles.

The electrostatic precipitator is most effective on the smallest mist particles, such as encountered in oleum producing plants. They can be provided with overall efficiencies up to 99 percent. Gas velocities must be low, 3 to 5 feet per second, but the pressure drop is usually less than one inch water gauge which means that no auxiliary blower is required, an important feature when considering retrofit. Efficiency is improved by increasing the length of duct, or residence time. Power requirements are nominal, ranging from 25 to 90 KVA for 50 to 1,500 tons per day plants, respectively.

One drawback is the relatively large size of the equipment, ranging from 5' x 11' x 25' high for a 150 tons per day plant to 30' x 30' x 40' high for a 1,500 tons per day acid plant.[12]

In addition, electrostatic precipitators are quite expensive to install and maintain in this service. For this reason, they have not been too widely adopted for cleaning up sulfuric acid plant absorbing tower exit gases.[15]

3.2.2 Fiber Mist Eliminators

Fiber mist eliminators utilize the mechanisms of impaction and interception to capture large to intermediate size acid mist particles and Brownian movement to effectively collect low to submicron size particles. Fibers used may be chemically resistant glass or fluorocarbon. The structural parts may be type 316 stainless steel, alloy 20 stainless steel, or glass fiber reinforced plastics.

3.2.2.1 Tubular Mist Eliminator

Tubular mist eliminators consist of a number of vertically oriented tubular fiber elements installed in the top of the absorber on new acid plants or in a separate tank above or beside the absorber on existing plants. Each element usually consists of glass fibers packed between two concentric screens. The bottom end cover is equipped with a liquid seal pot. Mist particles collected on the surface of the fibers become a part of the liquid film which wets the fibers. The liquid film is moved horizontally through the fiber beds by the gas drag and is moved downward by gravity. The liquid overflows the seal pot continuously returning to the process. Depending on the size of the sulfuric acid plant, anywhere from 5 to 100 elements may be used.

The tubular fiber mist eliminator is designed for high efficiency collection utilizing the Brownian motion exhibited by the smaller mist particles. The low superficial velocity of gas passing through the fiber bed - 15 to 40 feet per minute - provides sufficient residence time for nearly all of the small mist particles in random motion to contact the wet fibers effecting removal from the gas stream. The probability that such a particle could pass through the bed following the resultant greatly lengthened travel path is very low.

3.2.2.2 Panel Mist Eliminator

Panel mist eliminators use fiber panel elements mounted in a polygon framework closed at the bottom by a slightly conical drain pan equipped with an acid seal pot. The polygon top is surmounted by a circular ring which is welded to the inside of the absorption tower head. Each panel element consists of fibers packed between two flat parallel screens. In large, high velocity towers, recent designs have incorporated double polygons, one inside the other, to obtain more bed area in a given tower cross section.

As in the high efficiency tubular mist eliminator above, the gas flows horizontally through the bed, however at a much higher velocity using the impaction mechanism for collection of the mist particles. Collection efficiency increases as the gas flow is increased in this type of mist collector. Gas leaving the bed flows upward to the exit port while the collected liquid drains downward across the pan and out through the seal pot back into the tower or to a separate drain system.

3.2.2.3 Dual Mist Pads

Two circular fluorocarbon fiber beds are oriented horizontally in a cylindrical enclosure one above the other, so that the coarse fraction of the acid mist is removed by the first pad and the fine fraction by the other. The entire unit may be located adjacent to or positioned on an absorption tower.

This unit uses the high velocity impaction mist collection mechanism as does the panel mist eliminator, however, the collected acid drains downward through the pads countercurrent to the gas flow obtaining a scrubbing action as well. Collected acid may be drained from external connections or returned directly to the absorber through liquid seal traps.

4.0 INSTRUMENTATION

The control of SO_2 and acid mist at sulfuric acid production facilities is dependent on several variables. The two demonstrated processes - dual absorption and sodium sulfite scrubbing - both respond to variations in process conditions which can cause excessive emissions. In order to optimize SO_2 control, operators will be required to install, operate, and maintain in calibration suitable equipment for the continuous monitoring and recording of sulfur dioxide (SO_2). Instrumentation for acid mist monitoring is desirable, however no applicable equipment is available at the present time. Sampling ports are to be located downstream of air pollution control equipment at suitable test points. The operator will be required to provide such other operating information as is necessary to relate measured SO_2 concentrations to the standard of performance.

The instruments shall be capable of measuring SO_2 concentrations over the range 0 to 1000 ppm by volume. The accuracy required by the regulation--plus or minus 20 percent with a 95 percent confidence level--is deemed acceptable for monitoring purposes although greater accuracy might be required for specific source tests.

Requisite equipment for SO_2 monitoring is available. The Environmental Protection Agency is reviewing recently developed SO_2 instruments and will provide guidance to owners and operators who request such information.

A list of SO_2 monitoring devices acceptable for the purposes of this standard will be available on or about February 1, 1972. Lists of instruments for SO_2 and other pollutants will be revised periodically as new instruments are developed and refined.

5.0 CONTROL COSTS

5.1 Sulfur Dioxide

Of the six control processes described previously, costs are presented for the two demonstrated processes, dual absorption and sodium sulfite scrubbing; neither produce by-products in any quantity. There are insufficient data for valid comparison of the others.

5.1.1 Dual Absorption

The only operating dual absorption plant in the United States has a capacity of 700 T/day, uses dark molten sulfur for the feed, and produces 93 and 98 percent acid and oleum.

Capital cost was approximately 5.25 million dollars. It was estimated that the cost of the dual absorption over conventional single absorption amounted to 0.95 million dollars or 22 percent additional capital. This may be compared with the 12 to 18 percent range of additional dual absorption capital requirements presented by Donovan and Stuber[16] for sulfur burning plants. See Table 5.1 for further cost comparisons.

An EPA funded study estimated capital cost for such a plant of 750 T/day capacity at 2.5 million dollars,[17] a significantly lower value. Wellman-Power Gas, licensee for the LURGI dual absorption process, estimates a 700 750 T/day plant capital cost at about 3 million dollars. Local construction labor conditions can add somewhat to this figure, depending on the location. The EPA study estimated the additional cost per ton of acid produced in a dual absorption plant compared to the production cost in

TABLE 5.1

COMPARATIVE COSTS FOR NEW DUAL ABSORPTION VS. SINGLE ABSORPTION PLANTS[16]

Cost of conventional plants taken as 1.0

	Sulfur Burning
Capital	1.12 to 1.18
Operating Costs	
Raw Material	0.98
Labor	1.00
Electric Power	1.20 to 1.30
Cooling Water	1.10 to 1.20
Maintenance	1.10 to 1.16
Indirect Charges	
Depreciation	1.12 to 1.18
General Overhead	1.02 to 1.04

a conventional single-stage absorption plant.[18] This amounted to \$0.41/T, \$0.18/T, and \$0.12/T for 250 T/D, 750 T/D, and 1,500 T/D acid plants respectively. Obviously these figures may be low considering the prior plant capital difference. Substituting 0.95 million dollars capital difference in the EPA calculation, interpolating, and calculating the basic cost differences assuming average factors from Table 6.1 yields, for example, \$1.05 additional cost per ton of acid produced in a 700 T/day plant. This calculation is shown in Table 5.2. Note that return on investment is not included

TABLE 5.2

COMPARATIVE COST OF DUAL ABSORPTION VS. SINGLE ABSORPTION SULFUR BURNING CONTACT SULFURIC ACID PROCESSES*

Sulfuric Acid Production - 700 T/D (Basis: 330 Day/Yr.)

Conversion Rate 99.7% or Stack Emission Max. 4 lb. SO_2/Ton;Acid Mist Max. 0.15 lbH_2SO_4/ton

Capital Investment Difference $950,000

Raw Materials and Utilities Difference			
Sulfur Credit	@ $25/T		$ 63,000
Electricity	@ 1¢/KWH		22,000
Cooling Water	@ 1¢/T		9,000
Process Water	@ 2¢/T		0
B.F. Water	@ 5¢/T		0
Steam Reduction	@ $0.60/Ton		30,000
		(Credit)	$ 2,000

Operating Expense Difference		
Maintenance	4% of Capital Cost	$ 38,000
Overhead	70% of Maintenance	26,600
		$ 64,600

Indirect Cost Difference		
Depreciation	10% of Capital Difference	$ 95,000
Interest	7 1/2% of Capital Difference	71,300
Taxes & Insurance	1 1/2% of Capital Difference	14,200
		180,500
	Annual Operating Cost Difference	$ 242,100

$\frac{\$\ 242,100}{(700)(330)}$ = $1.05/Ton of Acid Produced Control Cost (including Acid Mist)

*Adapted from EPA study calculation[19].

5.1.2 Sodium Sulfite - Bisulfite Scrubbing

The Wellman Power Gas SO_2 recovery process which uses sodium sulfite-bisulfite scrubbing, under present operating conditions, is controlling stack emissions to 2 to 4 lb. SO_2/ton of acid produced at a cost of $1.94 per ton. The cost of the present operation using actual plant data is presented in Table 5.3. The EPA study cost factors are used to obtain comparative values.[20] Note that the cost per ton of acid produced is neither credited or penalized for the soda and sulfur values lost in the purge stream. Again return on investment is not included.

The capital cost may be reduced in future plants by use of smaller equipment and process simplification. The designer has stated that a sulfite-bisulfite system on a 750 ton per day acid plant could be built for about 1.3 million dollars capital investment. Also only half as much caustic soda would be required as for the existing facility. Assuming all other factors being equal, the control cost would then be $1.53 per ton of acid produced.

TABLE 5.3

COMPARATIVE COST OF WELLMAN-POWER GAS SO_2 RECOVERY PROCESS*

Sulfuric Acid Production - 750 T/D (Basis: 330 Day/Yr.)
Gas rate, Approximately 37,000 SCFM
SO_2 in 53 lb/Ton; SO_2 out 2 to 3 lb/Ton
Capital Investment $1,500,000

Raw Materials and Utilities		
Sodium Hydroxide	@ $65/T	$ 98,000
Electricity	@ 1¢/KWH	13,000
Cooling Water	@ 1¢/T	600
Steam	@ $0.60/T	42,700
Credit for Recovered SO_2	@ $25/T equivi. Sulfur	-62,000
		$ 92,300
Operating Expenses		
Maintenance	4% of Capital	60,000
Overhead	70% of Maintenance	42,000
		$ 102,000
Indirect Costs		
Depreciation	10% of Capital	$150,000
Interest	7 1/2% of Capital	112,500
Taxes & Insurance	1 1/2% of Capital	22,500
		$285,000
	Annual Operating Cost	$479,300

Cost per ton of Acid Produced
$479,300/247,500 = $1.94/Ton Control Cost

*Adapted from EPA study calculation[19]

5.2 Acid Mist

The approximate investment cost and the annualized cost per ton of acid produced for different types of acid mist control systems are shown in table 5.4.

The cost for acid mist control is a small fraction of the total plant investment cost. Thus, control of emissions to the new performance standards of a maximum of 0.15 lb of total acid per ton of acid produced is possible for all types of sulfuric acid plants. Some types of plants, such as elemental sulfur burning plants producing a maximum strength acid of 99 percent, could control emissions to much less than 0.15 lb. H_2SO_4/Ton at low cost. Oleum producing plants can also control acid mist emissions to this level at approximately the same cost[23], using similar high efficiency apparatus.

TABLE 5.4

APPROXIMATE CAPITAL INVESTMENT REQUIREMENTS FOR VARIOUS ACID MIST CONTROL SYSTEMS AND ANNUALIZED COST PER TON OF ACID PRODUCED [21,22]

APPROXIMATE CAPITAL INVESTMENT REQUIREMENT - NEW PLANTS

Control System	50 T/D (3,750 ACFM)	250 T/D (18,700 ACFM)	750 T/D (56,000 ACFM)	1,500 T/D (112,000 ACFM)
Dual Fiber Pad Type[22]	11,000	21,000	37,000	57,000
Tubular Fiber Type	55,000	70,000	105,000	170,000
Panel Fiber Type	14,000	23,000	55,000	95,000
Electrostatic Precipitator	60,000	85,000	105,000	200,000

ANNUALIZED COST PER TON OF ACID PRODUCED

Control System	50 T/D (3,750 ACFM)	250 T/D (18,700 ACFM)	750 T/D (56,000 ACFM)	1,500 T/D (112,000 ACFM)
Dual Fiber Pad Type*	0.13	0.05	0.03	
Tubular Fiber Type	0.90	0.22	0.07	
Panel Fiber Type	0.22	0.05	0.03	
Electrostatic Precipitator	1.05	0.25	0.22	

NOTE:

Size and cost depends upon tail gas flow rate and on design efficiency. Costs are given for sulfur burning plants only with no oleum production. Adjustments proportional to gas flow must be made for various plants.

*Interpolated.

TABLE 5.4

APPROXIMATE CAPITAL INVESTMENT REQUIREMENTS FOR VARIOUS ACID MIST CONTROL SYSTEMS AND ANNUALIZED COST PER TON OF ACID PRODUCED[21,22]

APPROXIMATE CAPITAL INVESTMENT REQUIREMENT - NEW PLANTS

Control System	50 T/D (3,750 ACFM)	250 T/D (18,700 ACFM)	750 T/D (56,000 ACFM)	1,500 T/D (112,000 ACFM)
Dual Fiber Pad Type[22]	11,000	21,000	37,000	57,000
Tubular Fiber Type	55,000	70,000	105,000	170,000
Panel Fiber Type	14,000	23,000	55,000	95,000
Electrostatic Precipitator	60,000	85,000	105,000	200,000

ANNUALIZED COST PER TON OF ACID PRODUCED

Control System	50 T/D (3,750 ACFM)	250 T/D (18,700 ACFM)	750 T/D (56,000 ACFM)	1,500 T/D (112,000 ACFM)
Dual Fiber Pad Type*	0.13	0.05	0.03	
Tubular Fiber Type	0.90	0.22	0.07	
Panel Fiber Type	0.22	0.05	0.03	
Electrostatic Precipitator	1.05	0.25	0.22	

NOTE:

Size and cost depends upon tail gas flow rate and on design efficiency. Costs are given for sulfur burning plants only with no oleum production. Adjustments proportional to gas flow must be made for various plants.

*Interpolated.

6.0 RETROFITTING EXISTING SULFURIC ACID PLANTS

The standard of performance was developed for new and substantially modified sulfuric acid plants. Except for modifications, the SO_2 emission limit does not apply to existing facilities. The acid mist emission limit does not apply directly to existing facilities although similar limits must be developed by each State pursuant to Section 111(d). Nevertheless, it is recognized that in many areas, State and local agencies will have to consider available means of reducing SO_2 emissions from existing sources including sulfuric acid plants. Suggestions are provided as to what avenues may be open to existing plants. The feasibility of any particular approach will depend on the specifics of the operation.

All plants, including those that are completely uncontrolled, could benefit from continuous SO_2 monitoring. Knowledge of exit SO_2 concentrations will allow operators to adjust process variables for maximum SO_2 absorption and for maximum SO_2 control if abatement equipment should be in use. The problems of adapting these modifications and determining cost obviously will vary appreciably from plant to plant.

6.1 Sulfur Dioxide

Modifications which can be considered to reduce SO_2 emissions from uncontrolled plants are:

1. Add more catalyst to converter beds or change catalyst to a more efficient type. Many installations can lower SO_2 emissions to about 2000 ppm using the most active catalysts.

2. Reduce production rate. This obviously increases the cost of each ton of acid produced. Some modern single absorption plants may obtain 1,000 ppm SO_2 emissions by operating at about half rate.

3. Retrofit either dual absorption or sodium sulfite scrubbing processes to achieve new source standards of 4.0 lb SO_2 per ton of acid produced.

4. Retrofit an ammonium sulfite scrubbing process if local conditions favor production and sale of ammonium sulfate.

5. Retrofit a promising process now under development such as the use of molecular sieves to adsorb SO_2 and residual acid mist. Designers state that it is possible to lower emissions to essentially no acid mist and 10 to 40 ppm SO_2 using such a system.

6.2 Acid Mist

Acid mist emission reduction modifications required for new and existing contact sulfuric acid plants include:

1. Addition of a fiber mist eliminator or appropriate electrostatic precipitator.

2. Addition of a system using one of the above in combination with a SO_2 control process.

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