PLANT REQUIREMENTS FOR MANUFACTURE OF SULFURIC ACID

TECHNICAL AIDS BRANCH
INTERNATIONAL COOPERATION ADMINISTRATION
Washington, D. C.

FOREWORD

This brochure is one of a series of reports resulting from overseas technical inquiries on factory or commercial establishments, operation, management, and engineering. The report is designed to provide only a general picture of the factors that must be considered in establishing and operating a factory of this type. In most cases, plans for actual installations will require expert engineering and financial advice in order to meet specific local conditions.

Mention of the name of any firm, product, or process in this report is not to be considered a recommendation or an endorsement by the International Cooperation Administration, but merely a citation that is typical in its field.

The original report was prepared by Arthur D. Little, Inc., Cambridge, Massachusetts, in February 1958 under contract to the Office of Technical Services, U. S. Department of Commerce, for the technical aids program of ICA.

Technical information, as well as review, was provided by P. Poliakoff, Industrial Consultant, 126 Eleventh Avenue, New York 11, New York.

* * * * * * * * * * *

This report has been revised and rewritten by George H. Andrews Engineering Associates, Inc., 411 Southern Building, Washington 5, D. C.

* * * * *

For further information and assistance, contact should be made with the local Productivity Center, Industrial Institute, Servicio, or United States Operations Mission.

Code Number
PR-85

October 1961

TABLE OF CONTENTS

S U L F U R I C A C I D

INTRODUCTION

The purpose of this report is to present basic information for establishing a plant in a foreign country to produce sulfuric acid.

Sulfuric acid is one of the most important materials upon which our industrial society depends. The following is a partial list of the industries which are its consumers: agriculture, chemical, petroleum, coal products, iron and steel, paints and pigments, rayon and cellulose film. Total U. S. production of sulfuric acid in 1955 was reported at about 15,000,000 tons.

GENERAL ASSUMPTIONS

In order to make realistic estimates in this report, certain assumptions are made. These are:

1. The costs of the building and general facilities are based on United States prices.

2. Material costs are based on sizes and specifications of materials used in the United States.

3. Labor costs are based on the average for the industry as recently published by the United States Bureau of Labor Statistics.

4. Adequate power and water are available at the plant site.

5. Adequate transportation facilities are available at the plant site.

6. The plant operates three eight-hour shifts per day, seven days per week, three hundred and thirty days per year.

7. No special provision is made for the training of new personnel. It is assumed that learner's rates are paid in such cases.

8. The following items cannot be estimated realistically:

   A. Land value.
   B. Distribution and selling costs.
   C. In-freight and out-freight.
   D. Administrative costs.
   E. Taxes.

   While general estimates will be made of each of these items, for the purpose of completing cost estimates, adjustment should be made in accordance with actual local costs.

   In fact, all cost estimates contained in this report should be adjusted to conform to local conditions.

9. Columns are provided in the tables included in this report to facilitate the conversion of cost figures to conform with local costs.

PRODUCT SPECIFICATIONS

Sulfuric acid, H_2SO_4 produced from sulfur.

PRODUCTION CAPACITY

The production capacity of this plant is fifty tons per day or 16,500 short tons of sulfuric acid per year based on operating the plant twenty-four hours per day, three hundred and thirty days per year.

MANUFACTURING UNIT

The manufacturing unit for sulfuric acid is 2,000 pounds or one short ton.

MANUFACTURING OPERATIONS

Sulfuric acid is manufactured by the combustion of sulfur in air, catalytic conversion of the resulting sulfur dioxide to sulfur trioxide, and absorption of the sulfur trioxide in water. The following chemical reactions apply.

$$S + 3/2\ O_2 \longrightarrow SO_2 + 1/2\ O_2 \text{ (Sulfur Burner)}$$

$$SO_2 + 1/2\ O_2 \longrightarrow SO_3 \quad (V_2O_5 \text{ Catalyst Converter})$$

$$SO_3 + H_2O \longrightarrow H_2SO_4 \quad \text{(Absorber-in strong } H_2SO_4\text{)}$$

All of these reactions are highly exothermic. The energy is used to produce steam for use in the sulfuric acid plant or in other facilities.

Sulfur Unloading

Sulfur is usually delivered in bulk by barge and/or rail depending on the relative locations of the sulfur source and the sulfuric acid plant. Sulfur is delivered often and regularly to an outdoor storage pile. Unloading facilities have not been included as a part of this description or estimate since their design will depend on the location of the specific plant. The process described in this report begins with the delivered sulfur.

Sulfur Melting

Sulfur enters the process through a sulfur melter. The melter consists of a carbon steel tank set in the ground and equipped with steam coils. Solid sulfur is scooped into the melter from the pile by a tractor. Molten sulfur is pumped from the melter to a burner. Solids which do not settle in the melter are removed by a filter.

Sulfur Burning

Air is dried by passing it through a packed tower where it is brought in contact with strong sulfuric acid. Dried air in excess of the amount required for complete combustion to SO_3 is introduced to the burner together with molten sulfur. Various types of burners have been employed but many modern plants have adopted the pressure atomized gun type designs. A conventional fire brick combustion chamber is used. Hot combustion gas from the burner containing SO_2, O_2 and N_2 enters a waste heat boiler where it is cooled to about 410°C. Before entering the converter, the gas is filtered to prevent ash from entering the converter and fouling the catalyst.

Conversion

The converter is a single insulated vertical steel vessel containing two separate sections. Vanadium pentoxide catalyst is supported on steel plates in each section. The gas from the hot gas filter enters the top of the converter at 410°C, passes through the first vanadium

catalyst bed, and leaves at 600°C with approximately 70 per cent of the sulfur as the trioxide. Before entering the second catalyst bed, the gas is cooled in a waste heat boiler. After leaving the second catalyst bed over 97 per cent of the sulfur has been converted to the trioxide.

Absorption

The cooled gases are scrubbed with 98 per cent sulfuric acid in order to absorb the sulfur trioxide. The absorber is a steel tower lined with acid-proof brick and packed with ceramic rings. The absorbing acid is pumped from storage to the top of the tower. The concentrated acid from the tower is diluted to 98 per cent acid in the pump tank by the addition of water, is then cooled in banks of tubes which are sprayed with water, and then returned to the pump tank. Thus the temperature and concentration of the acid in the pump tank are maintained at desired levels. The pump tank is a horizontal brick-lined tank. Product acid is transferred from the pump tank to storage tanks from which tank cars, carboys, and drums are loaded as required.

DIRECT MATERIALS

The only direct material purchased is sulfur. About 35.50 short tons of sulfur are required for 100 short tons of sulfuric acid.

Based on these figures the annual requirements of sulfur would

amount to about 4,858 short tons.

The current cost of sulfur is about $22.00 per ton. Therefore, the annual cost of sulfur would amount to 4,858 x $22.00 or about $106,876.

SUPPLIES

Item	Annual Cost Estimated	Actual
Lubricants and hand tools	$ 100	_____
Laboratory supplies	300	_____
Maintenance	1,400	_____
Office supplies	200	_____
TOTAL	$ 2,000	_____

DIRECT LABOR

Occupation	Number Required	Hourly Rate	Annual Cost Estimated	Actual
Skilled operators	9	$2.00	$ 36,000	_____
Semi-skilled operators	3	1.75	10,500	_____
Unskilled	3	1.50	9,000	_____
TOTAL	15		$ 55,500	_____

INDIRECT LABOR

Occupation	Number Required	Annual Cost Estimated	Actual
Manager and bookkeeper	1	$ 10,000	_____
Chemical engineer	1	10,000	_____
Maintenance	1	5,000	_____
TOTAL	3	$ 25,000	_____

FLOW SHEET

A flow sheet indicating the sequence of operations for the production of sulfuric acid is shown on the last page of this report.

PLANT SITE

To provide for eventual expansion, this plant should be situated on about one acre of land. The site should be located as advantageously as possible with respect to transportation, power, water, fuel, and sources of labor and markets.

The cost of the site is estimated at $1,000.

BUILDING

To provide for future expansion, a one story building 100 feet by 200 feet, or about 20,000 square feet of floor space will be

required. The cost of the building is estimated at about $80,000.

POWER

The connected load for this plant is estimated at 60 horsepower. The annual cost of power is estimated at $1,000.

WATER

About 2,200,000 gallons of water are used annually for all purposes. The cost of water is estimated at about $500.

FUEL

The annual consumption of fuel oil is estimated at 20,000 gallons. The annual cost of fuel oil is estimated at $2,000.

PRODUCTION TOOLS AND EQUIPMENT

Sulfuric acid plants are designed and installed as complete units, in accordance with existing local conditions. The plants are sold as package plants with or without installation costs. It is recommended that a plant be purchased on an installed basis and preferably on a turnkey basis.

Because sulfuric acid plants are sold on a packaged plant basis, and the engineering design is a part of the total cost, the cost of

individual pieces of equipment is not shown in this report.

The installation will consist of the following principal items:

Unloading conveyor	Economizer
Sump pump	Absorber
Melter	Blower
Filter	Cooler
Burner	Pump tank
Boilers (2)	Storage tank
Gas filter	Piping and fittings
Converter	Other tools and equipment

The total cost of a sulfuric acid plant for a capacity of 50 short tons per day or 16,500 short tons per year is estimated at about $430,000, installed, complete and ready to operate.

A turnkey operation of the plant would incur an additional cost, depending on the length of time the plant was operated on that basis. As previously stated a turnkey operation of the plant is recommended.

Since this plant consists principally of tanks, pumps and pipes and is specially designed, no pictures of equipment are included.

FURNITURE AND FIXTURES

Item	Number Required	Unit Cost	Cost Estimated	Cost Actual
Desks and chairs	2	$150	$ 300	_____
File cabinets	2	75	150	_____
Typewriter	1	150	150	_____
Adding machine	1	100	100	_____
TOTAL			$ 700	_____

DEPRECIATION

Description	Estimated Cost	Years Life	Annual Cost Estimated	Annual Cost Actual
Building	$ 80,000	20	$ 4,000	_____
Production tools and equipment	430,000	10	43,000	_____
Furniture and fixtures	700	10	70	_____
TOTAL			$ 47,070	_____

MANUFACTURING OVERHEAD

Item	Annual Cost Estimated	Actual
Depreciation	$ 47,070	_____
Indirect labor	25,000	_____
Power	1,000	_____
Water	500	_____
Fuel	2,000	_____
Supplies	2,000	_____
TOTAL	$ 77,570	_____

MANUFACTURING COSTS

Item	Annual Cost Estimated	Actual
Direct materials	$ 106,876	_____
Direct labor	55,500	_____
Manufacturing overhead	77,570	_____
TOTAL	$ 239,946	_____

FIXED ASSETS

Item	Annual Cost Estimated	Actual
Land	$ 1,000	_____
Building	80,000	_____
Production tools and equipment	430,000	_____
Furniture and fixtures	700	_____
TOTAL	$ 511,700	_____

WORKING CAPITAL

Item		Cost Estimated	Actual
Direct materials	30 days	$ 8,900	_____
Direct labor	30 days	4,600	_____
Manufacturing overhead	30 days	6,500	_____
Reserve for sales collections	30 days	30,750	_____
TOTAL		$ 50,750	_____

CAPITAL REQUIREMENTS

Item	Cost Estimated	Actual
Fixed assets	$ 511,700	_____
Working capital	50,750	_____
TOTAL	$ 562,450	_____

SALES REVENUE

The annual production of this plant is 16,500 short tons of sulfuric acid. The current selling price is $22.35 per short ton.

Based on these figures the gross sales revenue would amount to about $369,000.

RECAPITULATION OF COSTS, SALES AND PROFITS

Item	Estimated Cost		Actual Cost
Direct materials	$ 106,876		_____
Direct labor	55,500		_____
Manufacturing overhead	77,570		_____
Total manufacturing cost		$239,946	_____
Interest on loans	17,000		_____
Insurance	2,000		_____
Legal	1,000		_____
Auditing	2,000		_____
Unforeseen expense	8,054		_____
Total administrative costs		30,054	_____
Sales commissions		12,000	_____
Travel, bad debts, discounts and allowances, freight-out		3,000	_____
Profit before taxes		84,000	_____
Total annual gross sales		$369,000	_____

BUDGET CONTROL:

A requisition form designed to provide accurate records of procurement and indicate the purpose of procurement with the least amount of time and effort is shown on the following page.

This form has an account number for each type of the various expenditures which the manager will review in detail, monthly or oftener, in order to control his expenses. Some items, such as power and water, are usually under contract and are easily checked by reference to monthly bills. For simplification, items (marked with an asterisk below) are omitted from the purchase requisition. Variations in the labor costs are easily reviewed by examination of the payroll vouchers. The simplified type of control thus provided makes certain that the manager can control expenditures promptly.

Following the requisition form, a sample voucher check is shown. Voucher checks should be used for the payment of all expenditures and the appropriate book account number placed on each voucher.

At the end of each month the manager will receive a statement of all expenditures broken down by budget accounts. If the expenditures exceed the budgeted monthly allowances of any of the accounts, the bookkeeper will furnish the manager with a break-down of all expenditures relative to the budgeted accounts exceeded. All these supporting data can be secured by reference to the purchase requisitions and the check vouchers. This reference will enable the manager to determine what caused the over-expenditure and take corrective action.

If at any time during each month it becomes apparent that expenditures will exceed any of the budget accounts, the bookkeeper will bring this to the attention of the manager for his information and action.

BUDGET CONTROL ACCOUNTS:

Account Number		Monthly Expense	Monthly Budget	Annual Budget	Actual
10	Administrative	$_____	$ 1,833	$22,000	$_____
20	Sales	_____	1,250	15,000	_____
30	Direct Materials	_____	8,906	106,876	_____
40	Supplies	_____	166	2,000	_____
51	Power*	_____	88	1,000	_____
52	Water*	_____	41	500	_____
53	Fuel	_____	166	2,000	_____
60	Unforeseen Expense (Reserve Account)	_____	671	8,054	_____
71	Direct Labor*	_____	4,625	55,500	_____
72	Indirect Labor*	_____	2,083	25,000	_____
80	Depreciation (Reserve Account)	_____	3,922	47,070	_____

PURCHASE REQUISITION	COMPANY NAME	DATE

☐ 10 ADMINISTRATION ☐ 40 SUPPLIES

☐ 20 SALES ☐ 50 UTILITIES

☐ 30 MATERIALS ☐ 60 UNFORESEEN EXPENSE

INDICATE BELOW THE USE OF MATERIALS

☐ DIRECT MATERIALS ☐ MAINTENANCE SERVICES

☐ MAINTENANCE MATERIALS ☐ OPERATING SUPPLIES

	PLEASE ORDER THESE MATERIALS OR SERVICES	DELIVERY WANTED	
QUANTITY	DESCRIPTION	UNIT	TOTAL

QUOTES FROM		REQUISITIONED BY	
QUOTES FROM		APPROVED BY	
QUOTES FROM		ORDER NO.	ORDER DATE

R. W. MITCHELL MANUFACTURING COMPANY
1422 BOSWORTH STREET, S. E.

65-22
514

ANYWHERE, U. S. A. _____ 19____ No. 10000

PAY _____ DOLLARS $ _____

TO THE ORDER OF

R. W. MITCHELL MANUFACTURING COMPANY

TO FIRST NATIONAL BANK
ANYWHERE, U. S. A.

BY SAMPLE CHECK
VICE PRESIDENT

YOUNG & SELDEN CO

·ACCOUNT NUMBER

Sample voucher check to be used for the payment of all expenditures in connection with Budget Control.

R. W. MITCHELL MANUFACTURING COMPANY

ENGINEERS:

The services of professional engineers are desirable in the design of this plant, even though the proposed plant is small.

A correct design is one which provides the greatest economy in the investment of funds and establishes the basis of operation that will be most profitable in the beginning and will also be capable of expansion without expensive alteration.

The addresses of professional engineers who specialize in industrial design, some of whom may be willing to undertake such work on low cost projects overseas, can be secured by reference to the published cards in various engineering magazines. They may also be reached through their national organizations, one of which is the

National Society of Professional Engineers
2029 K Street, Northwest,
Washington 6, D. C.

Manufacturers of industrial equipment employ engineers familiar with the design and installation of their specialized products. These manufacturers are usually willing to give prospective customers the benefit of technical advice by those engineers in determining the suitability of their equipment in any proposed project.

The equipment manufacturers also know, and can recommend, professional engineers in private practice, who are willing and able to provide appropriate consulting services.

TRAINING:

Manufacturing an inferior quality of product during the training period could create sales resistance that might be difficult to cope with later. To avoid such possibilities, the quality of the product should be maintained at all times, including the training period.

In some areas skilled operators may be available locally. In other areas all the operators may have to be trained.

If skilled operators are not available, adequate training would be assured by using one or more of the following methods:

A. If the plant is designed and installed by a competent engineering firm, the contract should be negotiated, if possible, on a turn-key basis. On this basis the contractor agrees to operate the plant and produce the quality and quantity of the product stated in the contract for an agreed period of time. Such a contract would assure adequate personnel training, since full quantity and quality could not be produced with an untrained organization.

B. The engineering firm that designs and installs the plant can usually make training arrangements to have key personnel placed, for training purposes, in a foreign industry that produces the same type of product. This would provide training for the key personnel while the plant is being installed.

C. If neither of the above methods is possible, then qualified and experienced individuals should be employed for the key positions, either permanently or temporarily, to perform the key operations and assist in training the organization, even if they must be secured outside the country.

D. The manager should have years of successful experience in this type of business and be fully qualified in all phases of management, including the training of employees.

SAFETY:

There is always danger of accident and injury in any industrial plant. Because of this, the manager should take specific action to bring to the attention of each employee the importance of safety precautions and intelligent first aid.

Practically all machines have safety appliances, and the manager should see that these are in good working condition and that the operators are making full use of them.

In addition to constant watchfulness to make sure that all practicable safety precautions are taken, first aid supplies should be readily available. One complete first aid kit should be maintained near the manager's office, and others at appropriate places throughout the plant. Some of the employees should be trained to provide first aid service.

The use of accident posters in the plant have proved to be of value in reducing accidents. It is recommended that such posters be used, and that some direct special action be taken by the manager, at least once each month, to bring to the attention of all personnel the importance of safety precautions.

A fire brigade should be established and each member trained as to his responsibility in case of fire. Fire drills should be conducted periodically.

It is recommended that the employees be encouraged to offer suggestions or recommendations relative to prevention of accidents, removal of fire hazards and maintaining general interest in all safety factors.

OTHER CONSIDERATIONS

There are other important subjects, shown below, that should be fully investigated and considered. Information on these subjects is usually available from such sources as banks, government agencies, exporters and importers, wholesalers, retailers, transportation companies and manufacturers.

MATERIALS AND SUPPLIES

1. Are all materials and supplies available locally?
2. Is the local material market competitive?
3. Is satisfactory delivery of local materials assured at reasonable prices?
4. What materials and supplies must be imported?
5. Are they available in world markets at competitive prices?
6. Would prompt delivery of imported materials and supplies be assured so that large inventories would not be required?

MARKET FACTORS

1. Is there already a demand for the product?
   - A. Who are the principal consumers?
   - B. Who are possible new consumers?

2. How is demand for the product now satisfied?
   - A. By local production? If so, what is the volume of annual production?
   - B. What percentage of consumption is filled by local production?
   - C. By imports? If so, what is the volume of annual imports?
   - D. What percentage of consumption is met by imports?
   - E. From what areas are imports derived?

3. What is the estimated annual increase in local consumption over the next five years?
   - A. How were such estimates made?
   - B. By reference to official figures on population growth, family budgets, imports, etc.?
   - C. By consultation with trade or industry, ministries, associations, bankers, commercial houses, wholesalers, retailers, industrial consumers, etc.?

4. If the product is already being manufactured, can the existing and estimated future local market absorb production of the new plant without price-cutting or other dislocations?

5. Would the estimated sales price and quality of the new product make it competitive with an imported equivalent?
   A. After adjusting cost to local conditions, is the estimated sales price of the product so high that tariff protection is necessary to protect it from imports?

EXPORT MARKETS:

1. Could the product compete in export markets on the basis of price, quality and dependability of supply?
2. Can export markets for the product be developed?
3. If so, in what areas and in what annual volume?
4. What procedures would be necessary to develop export markets?
5. What would it cost?

MARKETING PROBLEMS:

1. In calculating costs of the product, has adequate allowance been made for the expense of a sales department, advertising and promotion that might be required?

2. Do consumer prejudices against locally manufactured products exist?
   A. If so, why?
   B. Would they apply to the new product?
   C. If so, how could they be overcome and what would it cost to do so?

3. Do marketing and distribution facilities for the product exist?
   A. If not, can they be set up?
   B. What would it cost to do so?

4. Will the product be sold to:
   A. Wholesalers?
   B. Retailers?
   C. Direct to consumer?
   D. Other industries?
   E. Government?

ECONOMIC FACTORS:

1. How much foreign exchange (and in what currency) is required to import machinery, equipment and supplies:
   - A. How much foreign exchange (and in what currency) is required for annual interest payments and amortization of any loans contracted to import machinery and equipment, or for payment of royalties and technical services?
   - B. How much foreign exchange (and in what currency) is required for annual import of raw materials and supplies?
   - C. What are estimated annual foreign exchange earnings and in what currencies?
   - D. Has careful consideration been given to the possibility of depreciation in the foreign exchange value of the local currency?
   - E. Has careful consideration been given to the possibility of import controls, or restrictions on availabilities of foreign exchange necessary to operate the business?
   - F. What benefits would the new business bring to the economy in the use of local raw materials: in employment and in technology?
   - G. Do dependable facilities exist for transportation, power, fuel, water and sewage?
     - (1) If not, can existing deficiencies be eliminated satisfactorily?
     - (2) What would be the cost to do so?

PERSONNEL:

1. Is there an adequate labor supply near the plant location?
   - A. If not, how can the problem be solved?

2. Can the problem of training competent management and supervisory personnel be solved?
   - A. Also, the training of skilled labor?
   - B. Is technical advice available in the locality?
   - C. If not, where can it be obtained and what will it cost?

LAWS AND REGULATIONS:

1. Do existing labor laws, government regulations, laws and taxes favor establishment of new business?
   - A. If not, can existing obstacles be removed?
   - B. If so, how and when?

FINANCIAL FACTORS:

1. Technical advice on selection of machinery and equipment.
   A. In selecting the machinery and equipment for the new plant, have reputable and competent engineers and technicians been consulted?
   B. Have they been asked for advice on the most suitable types of machinery and equipment for the process and locality?
   C. Have they carefully compared costs of various suppliers?
   D. Credit terms offered purchasers?

FINANCIAL REQUIREMENTS OF THE PROJECT:

1. In estimating the cost of the project, has careful consideration been given to:
   A. The effect on costs of delays in construction schedules?
   B. In delivery and installation of machinery and equipment?
   C. In import of essential raw materials and supplies?

2. In calculating cash flow and working capital requirements, has careful consideration been given to:
   A. Maintaining adequate inventories of raw materials?
   B. Supplies and spare parts?
   C. Seasonal fluctuations in the business?
   D. The time required to liquidate credit sales to customers and bad debts?
   E. The period necessary to get the plant into production?
   F. Cash required to amortize its principle loans?

3. If the economy is in a period of inflation, has full allowance been made for the influence of rising prices and wages on the cost of the project and on working capital requirements?

SHORT TERM BANK CREDITS:

1. Has it been possible to make arrangements with local banks to finance short-time working capital requirements of the business?

FINANCIAL PLAN:

1. Has a definite plan to finance the project been worked out?
   A. Is sufficient capital available locally?
   B. If not, what is the plan to obtain the required capital?

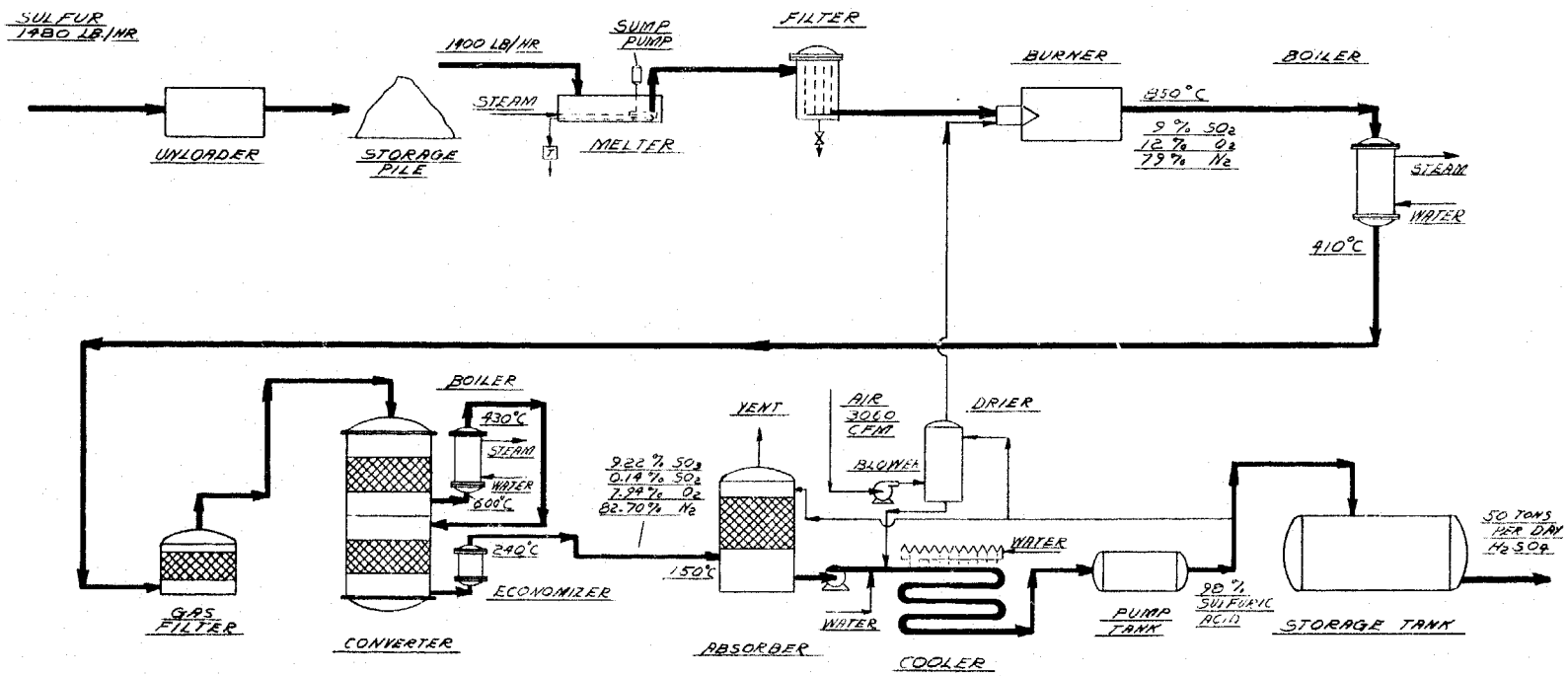
BIBLIOGRAPHY

Textbooks -

"Chemical Engineer's Handbook," John H. Perry
Third Edition 1950, 1942 pp. Illustrated $21.00
McGraw-Hill Book Company, Inc.
Mathematical tables and principles of chemical engineering.

"Unit Operations of Chemical Engineering"
McCabe and Smith, 956 pp., 1956, Illustrated $11.50
McGraw-Hill Book Co., Inc.
330 West 42nd Street
New York 36, New York

Tables and reactions for chemical engineers.



FLOW SHEET
CONTACT SULFURIC ACID
50 TONS H_2SO_4 PER DAY