

Information Circular 8566

Economic Availability of Byproduct Fluorine in the United States

(In Two Sections)

- 1. Utilization of Byproduct Fluosilicic Acid
in the Manufacture of Aluminum Fluoride**
- 2. Utilization of Byproduct Fluosilicic Acid
in the Manufacture of Calcium Fluoride**

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CONTENTS

Page

Section 1. Utilization of Byproduct Fluosilicic Acid in the Manufacture of Aluminum Fluoride

Abstract.....	1
Introduction.....	1
Acknowledgments.....	2
Potential sources of byproduct fluorine.....	2
Process description.....	5
Capital investment and production costs.....	8
Supply cost evaluation.....	8
Conclusions.....	9
References.....	11
Appendix A.--Cost analysis of a 5,000-ton-per-year plant.....	13
Appendix B.--Cost analysis of a 10,000-ton-per-year plant.....	22
Appendix C.--Cost analysis of a 25,000-ton-per-year plant.....	31
Appendix D.--Cost analysis of a 50,000-ton-per-year plant.....	40
Appendix E.--Cost analysis of a 100,000-ton-per-year plant.....	49

Section 2. Utilization of Byproduct Fluosilicic Acid in the Manufacture of Calcium Fluoride

Abstract.....	59
Introduction.....	59
Process description.....	60
Capital costs.....	61
Operating costs.....	61
Conclusions.....	62
Appendix F.--Cost analysis of a 5,000-ton-per-year plant.....	63
Appendix G.--Cost analysis of a 10,000-ton-per-year plant.....	70
Appendix H.--Cost analysis of a 25,000-ton-per-year plant.....	77
Appendix I.--Cost analysis of a 50,000-ton-per-year plant.....	84
Appendix J.--Cost analysis of a 100,000-ton-per-year plant.....	91

ILLUSTRATIONS

1. Process flow diagram, AlF_3 process.....	6
2. Economic availability of byproduct 100 percent H_2SiF_6 (sources pooled by geographic region) at various price levels of AlF_3	8
3. Price-output curve for AlF_3	10
4. Process flow diagram for calcium fluoride.....	60
5. Price-output curve for calcium fluoride.....	62

TABLES

1. Resources of phosphate rock in the United States.....	3
2. Potential fluorine recovery from phosphate rock processing by phosphate uses in the United States--1968.....	4

TABLES--Continued

	<u>Page</u>
3. Potential availability of byproduct fluosilicic acid (100 per- cent) in the United States--1968.....	5
A-1. Calculation of selling price of aluminum fluoride.....	13
A-2. Financial analysis.....	14
A-3. Total capital requirements.....	14
A-4. Equipment cost summary, reaction section.....	15
A-5. Equipment cost summary, crystallization section.....	16
A-6. Equipment cost summary, drying section.....	17
A-7. Equipment cost summary, bagging section.....	18
A-8. Equipment cost summary, scrubbing section.....	19
A-9. Working capital.....	19
A-10. Estimated annual operating cost.....	20
A-11. General manning table.....	21
B-1. Calculation of selling price of aluminum fluoride.....	22
B-2. Financial analysis.....	23
B-3. Total capital requirements.....	23
B-4. Equipment cost summary, reaction section.....	24
B-5. Equipment cost summary, crystallization section.....	25
B-6. Equipment cost summary, drying section.....	26
B-7. Equipment cost summary, bagging section.....	27
B-8. Equipment cost summary, scrubbing section.....	28
B-9. Working capital.....	28
B-10. Estimated annual operating cost.....	29
B-11. General manning table.....	30
C-1. Calculation of selling price of aluminum fluoride.....	31
C-2. Financial analysis.....	32
C-3. Total capital requirements.....	32
C-4. Equipment cost summary, reaction section.....	33
C-5. Equipment cost summary, crystallization section.....	34
C-6. Equipment cost summary, drying section.....	35
C-7. Equipment cost summary, bagging section.....	36
C-8. Equipment cost summary, scrubbing section.....	37
C-9. Working capital.....	37
C-10. Estimated annual operating cost.....	38
C-11. General manning table.....	39
D-1. Calculation of selling price of aluminum fluoride.....	40
D-2. Financial analysis.....	41
D-3. Total capital requirements.....	41
D-4. Equipment cost summary, reaction section.....	42
D-5. Equipment cost summary, crystallization section.....	43
D-6. Equipment cost summary, drying section.....	44
D-7. Equipment cost summary, bagging section.....	45
D-8. Equipment cost summary, scrubbing section.....	46
D-9. Working capital.....	46
D-10. Estimated annual operating cost.....	47
D-11. General manning table.....	48
E-1. Calculation of selling price of aluminum fluoride.....	49
E-2. Financial analysis.....	50
E-3. Total capital requirements.....	50

TABLES--Continued

	<u>Page</u>
E-4. Equipment cost summary, reaction section.....	51
E-5. Equipment cost summary, crystallization section.....	52
E-6. Equipment cost summary, drying section.....	53
E-7. Equipment cost summary, bagging section.....	54
E-8. Equipment cost summary, scrubbing section.....	55
E-9. Working capital.....	55
E-10. Estimated annual operating cost.....	56
E-11. General manning table.....	57
F-1. Selling price of calcium fluoride.....	63
F-2. Financial analysis.....	64
F-3. Total capital requirements.....	64
F-4. Equipment cost summary for ammonia reactor section.....	65
F-5. Equipment cost summary for silica drying and bagging section.....	66
F-6. Equipment cost summary for calcium fluoride reactor section with lime slaker.....	67
F-7. Equipment cost summary for calcium fluoride drying and bagging section.....	68
F-8. Working capital.....	68
F-9. Estimated annual operating cost.....	69
G-1. Selling price of calcium fluoride.....	70
G-2. Financial analysis.....	71
G-3. Total capital requirements.....	71
G-4. Equipment cost summary for ammonia reactor section.....	72
G-5. Equipment cost summary for silica drying and bagging section.....	73
G-6. Equipment cost summary for calcium fluoride reactor section with lime slaker.....	74
G-7. Equipment cost summary for calcium fluoride drying and bagging section.....	75
G-8. Working capital.....	75
G-9. Estimated annual operating cost.....	76
H-1. Selling price of calcium fluoride.....	77
H-2. Financial analysis.....	78
H-3. Total capital requirements.....	78
H-4. Equipment cost summary for ammonia reactor section.....	79
H-5. Equipment cost summary for silica drying and bagging section.....	80
H-6. Equipment cost summary for calcium fluoride reactor section with lime slaker.....	81
H-7. Equipment cost summary for calcium fluoride drying and bagging section.....	82
H-8. Working capital.....	82
H-9. Estimated annual operating cost.....	83
I-1. Selling price of calcium fluoride.....	84
I-2. Financial analysis.....	85
I-3. Total capital requirements.....	85
I-4. Equipment cost summary for ammonia reactor section.....	86
I-5. Equipment cost summary for silica drying and bagging section.....	87
I-6. Equipment cost summary for calcium fluoride reactor section with lime slaker.....	88

TABLES--Continued

	<u>Page</u>
I-7. Equipment cost summary for calcium fluoride drying and bagging section.....	89
I-8. Working capital.....	89
I-9. Estimated annual operating cost.....	90
J-1. Selling price of calcium fluoride.....	91
J-2. Financial analysis.....	92
J-3. Total capital requirements.....	92
J-4. Equipment cost summary for ammonia reactor section.....	93
J-5. Equipment cost summary for silica drying and bagging section.....	94
J-6. Equipment cost summary for calcium fluoride reactor section with lime slaker.....	95
J-7. Equipment cost summary for calcium fluoride drying and bagging section.....	96
J-8. Working capital.....	96
J-9. Estimated annual operating cost.....	97

ECONOMIC AVAILABILITY OF BYPRODUCT FLUORINE IN THE UNITED STATES

(In Two Sections)

1. Utilization of Byproduct Fluosilicic Acid in the Manufacture of Aluminum Fluoride

by

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ABSTRACT

Domestic byproduct fluorine (in fluosilicic acid) availability at various price levels of aluminum fluoride were determined and a contingency availability curve developed. The supply of byproduct fluosilicic acid is restricted in amount to certain geographic regions, where plants processing phosphate rock are located, and the byproduct can be collected. The maximum possible U.S. annual supply, based on potential plant capacities, is 373,400 tons of fluosilicic acid containing 295,400 tons of fluorine. Based on inputs of 5, 10, 25, 50, and 100 thousand tons per year, five levels of producing aluminum fluoride from fluosilicic acid (100 percent) were costed. Based on a 12-percent discounted cash flow rate, including the cost of salvaging the fluosilicic acid, the calculated selling price of aluminum fluoride ranged from \$233 per ton to \$448 per ton. At the higher price, 98 percent of the potential supply of byproduct fluosilicic acid could be used profitably; at the lower price only 46 percent could be used profitably.

INTRODUCTION

This study is a cost evaluation of the technical processes and costs of producing aluminum fluoride (AlF_3) from byproduct fluosilicic acid (H_2SiF_6), which is usually wasted in the processing of phosphate rock to produce fertilizers. Five plants with fluosilicic acid input levels ranging from 5 to 100 thousand tons per year were designed and costed.

Studies of the economic availability of U.S. byproduct fluorine were undertaken by the Bureau of Mines in recent years to determine the possibility of conserving this potentially valuable resource and to protect the environment. In 1970, 19 percent of the fluorine used in the United States was from domestic production, nearly all of which was derived from the mineral fluorite, commonly called fluorspar.

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The largest source of byproduct fluosilicic acid in the United States is from the processing of phosphate rock. Fluorine occurs principally in the mineral fluorapatite, which is the principal constituent in the phosphate rock used to manufacture fertilizers; fluorine constitutes about 3.5 percent of the fluorapatite in the phosphate rock. Part of the fluorine is volatilized during processing and is usually passed into a scrubber where the fluorine reacts to form a dilute aqueous solution of fluosilicic acid. This solution is usually wasted by neutralization with limestone or lime but may be concentrated to a 15 to 18 percent solution which is suitable for use as a raw material in the manufacture of various fluoride chemicals. Numerous processes and techniques have been developed relating to the recovery of volatilized fluorine (1, 3-4, 10-13, 16).²

Although several processes exist for converting fluosilicic acid to aluminum fluoride (5, 7), the process chosen for costing in this report is essentially one developed by Austrian Nitrogenworks, Ltd. (Oesterreichischen Stickstoffwerke AG), and is covered by Austrian patent No. 217008-9 (14-15).

The process was described by Weinrotter (21) in 1964 and later (presumably 1968) in an advertising pamphlet by Buss, Ltd. (2), Basle, Switzerland, builders of plants to produce aluminum fluoride from fluosilicic acid. Both publications were used extensively in costing the process. Requirements for fluosilicic acid, aluminum hydroxide, electric power, heating gas or oil, steam, cooling water, and compressed air, per unit of product aluminum fluoride based on practical experience, were reported by Buss, Ltd. These data which differed slightly from theoretical are used in the present cost study. The flow sheet presented is basically adapted from both the Weinrotter and Buss publications, but also contains minor changes introduced by the authors after consultation with various equipment manufacturers.

ACKNOWLEDGMENTS

The authors wish to thank the numerous persons associated with various aluminum companies, phosphate companies, equipment manufacturers, and the Tennessee Valley Authority, who were most helpful in supplying useful information for this study. In addition, the assistance of the Staff, Eastern Field Operation Center, Bureau of Mines, Pittsburgh, Pa., in the final preparation of Part 1 is appreciated.

POTENTIAL SOURCES OF BYPRODUCT FLUORINE

A large potential source of byproduct fluorine exists as waste fluosilicic acid (H_2SiF_6) generated in processing phosphate rock to produce fertilizers and other phosphate products.

Practically all commercial deposits of phosphate rock are impure varieties of the mineral fluorapatite, expressed chemically as $\text{Ca}_{10}(\text{PO}_4)_6\text{F}_2$. The workable deposits contain from 18 to 90 percent available tricalcium phosphate, $\text{Ca}_3(\text{PO}_4)_2$, more generally called bone phosphate of lime (BPL) by the trade.

²Underlined numbers in parentheses refer to items in the references preceding the appendixes.

Domestic deposits usually average 30 percent BPL; after beneficiating the largest share marketed contains between 70 and 76 percent BPL. The known phosphate rock resources in the United States are presented in table 1 and are estimated to contain an average of about 3.5 percent of fluorine or 2.5 billion tons. The availability of this fluorine, however, depends upon the quantity of phosphate rock processed annually and the wide percentage ranges of fluorine evolved and recovered as H_2SiF_6 at different types of phosphate processing plants.

TABLE 1. - Resources of phosphate rock in the United States (17)
(million short tons)

Source	Marketable product	
	More than 60 percent BPL	40 to 60 percent BPL
Florida.....	2,285	26,152
North Carolina ¹	2,240	7,760
Tennessee.....	90	6,046
Subtotal.....	4,615	39,938
Other ²	3,360	22,400
Total.....	7,975	62,358

¹Beaufort County.

²Includes Arkansas, Idaho, Montana, Utah, and Wyoming.

Byproduct fluorine may be recovered in fluosilicic acid which is produced by scrubbing the gases evolved during the manufacture of wet process phosphoric acid, normal superphosphate, triple superphosphate, other fertilizers, nitraphosphates, elemental phosphorus, and stock and poultry feed.

According to English (6), 35 to 50 percent of the fluorine in phosphate rock is volatilized in the manufacture of wet process phosphoric acid. About 95 percent of the liberated fluorine can be recovered. Personal communications with phosphate industry personnel tended to support these figures. From 70 to 120 pounds (average 90 pounds) of recoverable fluorine per ton of P_2O_5 produced was reported. The average of 90 pounds was used for calculations in this report and is equivalent to 40 percent volatilization combined with 92 percent recovery of volatilized fluorine. One ton of fluorine is contained in 1.264 tons of fluosilicic acid.

In the manufacture of normal superphosphate, 11 to 42 percent of the fluorine in the phosphate rock is volatilized, the average is 21.4 percent (20). The average volatilization and a recovery factor of 95 percent were used in calculations for this report. In the manufacture of triple superphosphate an average of 4 percent fluorine is evolved (9). A 95-percent recovery factor was assumed. In the manufacture of nitraphosphates, a minor part of the industry, the assumption was made that about 33 percent of the fluorine in the phosphate rock is volatilized and a recovery of 95 percent is possible.

Industry sources indicated that in the manufacture of elemental phosphorus by the electric furnace method recoverable fluorine is 0.35 percent

of the rock processed. In the defluorination of phosphate rock for stock and poultry feed, over 98 percent of the fluorine in the phosphate rock is volatilized.

Table 2 lists the potential fluorine tonnages recoverable from processing phosphate rock, by uses in 1968.

TABLE 2. - Potential fluorine recovery from phosphate rock processing by phosphate uses in the United States--1968 (19)

Use	Rock (thousand short tons)	Percent of phosphate rock recoverable as fluorine	Recoverable fluorine (thousand short tons)	Percent fluorine recovered by use
Phosphoric acid (wet process).	9,532	1.29	123	67.4
Electric furnace phosphorus...	6,117	0.35	21	11.6
Triple superphosphate.....	3,858	0.13	5	2.7
Normal superphosphate.....	3,708	0.712	26	14.3
Nitrphosphate.....	6	1.1	0	0.6
Stock and poultry feed.....	238	2.70	6	3.3
Other fertilizers.....	1,324	-	-	-
Other uses.....	438	-	-	-
Total.....	25,221	-	181	(¹)

¹Does not add to 100 percent because of incomplete data.

The projected domestic demand for phosphate rock through the year 2000 indicates an annual growth rate of 3.0 to 4.8 percent. Assuming that the phosphate rock use pattern remains the same, the availability of byproduct fluorine from phosphate rock processing should follow these rates of growth. The availability of byproduct fluorine in 1968 was 181,000 tons; at the projected growth rates, there would be from 466,000 to 811,000 tons of fluorine available in the year 2000. Domestic phosphate rock resources are sufficiently large to supply byproduct fluorine for several hundred years at the present consumption rate.

In 1968, fluorine consumption (demand) was 646,000 short tons. If the recoverable byproduct fluorine from phosphate rock processing had been available for domestic consumption in 1968 it would have supplied 28 percent of the demand. The maximum potential processing capacity of fluosilicic acid by all plants in the United States is 373,350 short tons, an amount that would supply 46 percent of the current demand for fluorine (table 3). The actual processing capacity is shown as 181,000 short tons of fluorine or 228,784 short tons of fluosilicic acid (table 2). Extending these projections to the year 2000 when U.S. fluorine demand is expected to be 2.4 million tons (18), the availability of byproduct fluorine from phosphate rock processing (assuming same recovery factor) could contribute from 19 percent (low phosphate projection) to 34 percent (high phosphate projection) of the fluorine demand.

TABLE 3. - Potential availability of byproduct fluosilicic acid
(100 percent) in the United States--1968 (8)
(short tons)

State	Potential annual H_2SiF_6 manufacturing			
	Wet process phosphoric acid	Concentrated super-phosphates	Elemental phosphorus	Total
Alabama.....	-	30	1,390	1,420
Arkansas.....	2,800	-	-	2,800
California.....	5,000	-	-	5,000
Delaware.....	2,000	-	-	2,000
Florida.....	171,100	2,380	2,020	175,500
Idaho, Utah, Montana, Washington.	23,100	280	10,740	34,120
Illinois, Indiana, Missouri, Minnesota.....	36,300	40	-	36,340
Louisiana, Mississippi.....	63,200	190	-	63,390
New York.....	-	-	250	250
North Carolina.....	19,500	210	-	19,710
South Carolina.....	-	-	370	370
Tennessee.....	-	-	10,490	10,490
Texas, Oklahoma.....	21,900	60	-	21,960
Total.....	344,900	3,190	25,260	373,350

Another source of byproduct fluorine could be from the calcination of topaz. However, domestic topaz deposits large enough for commercial development as a source material for production of high-alumina refractories are limited and no commercial operations are known. Byproduct fluorine from this source was not considered in this study.

There are several other minor sources of byproduct fluorine, such as aluminum and uranium processing plants where fluorine compounds are used and fluorine evolved. These emissions are usually recovered and reused in the respective processes and were not considered in this study.

PROCESS DESCRIPTION

The process is based on the reaction of aluminum hydroxide with a pre-concentrated solution of fluosilicic acid to form aluminum fluoride and silicon dioxide. The overall equation is: $2Al(OH)_3 + H_2SiF_6 = 2AlF_3 + SiO_2 + 4H_2O$.

The following description traces the process stream. The numbers immediately following equipment names refer to the corresponding number shown on the flow diagram in figure 1. Heavy lines in the flow diagram represent the process stream; the light lines represent the process effluents.

Byproduct 15 to 18 percent aqueous fluosilicic acid is pumped from a storage tank (1), containing 7 days supply, to a heating and measuring tank (3) containing a submerged graphite heat exchanger which is supplied steam by a steam boiler (2). The fluosilicic acid is heated to 160° F.

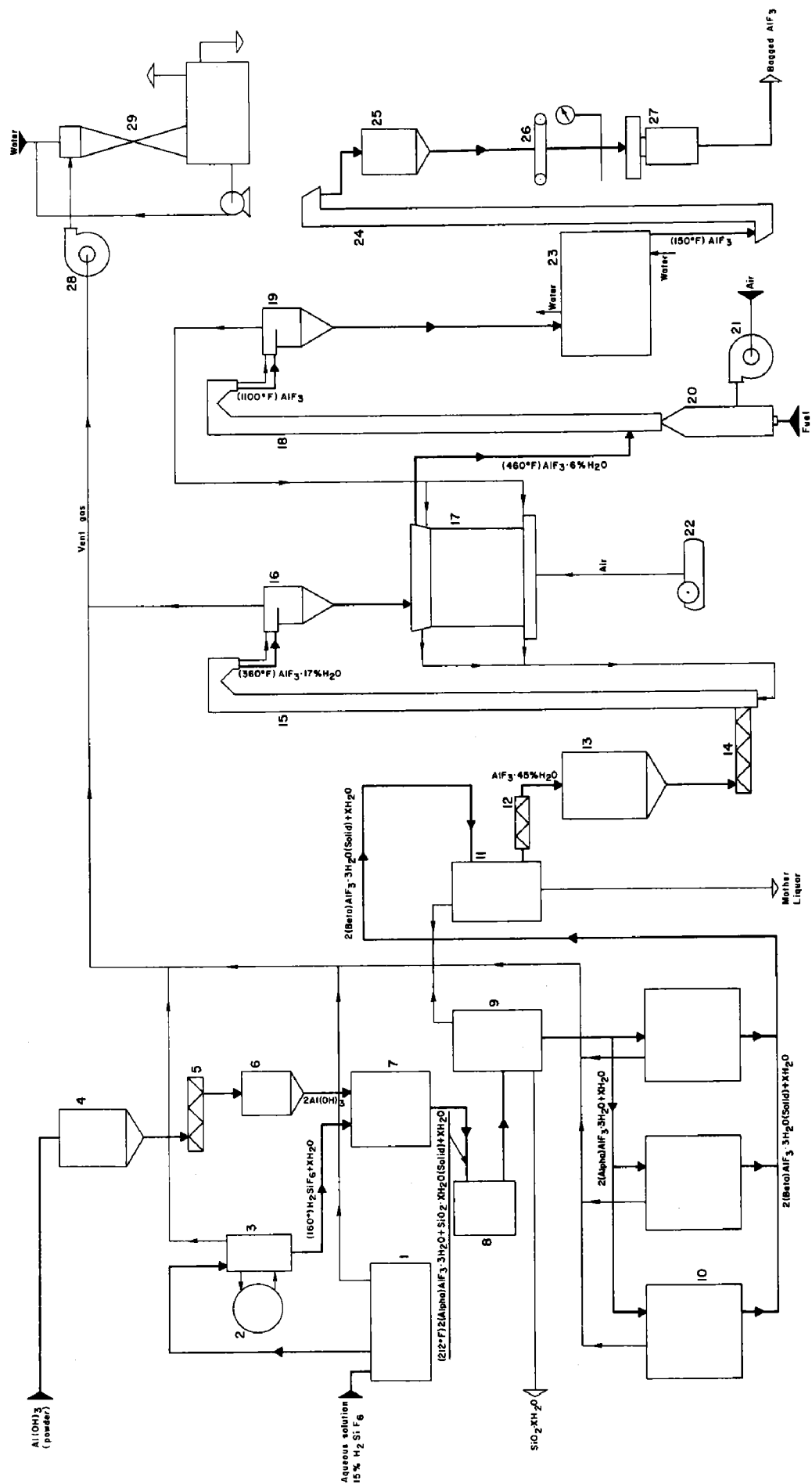


FIGURE 1. - Process Flow Diagram, AlF_3 Process.

Aluminum hydroxide ($\text{Al}(\text{OH})_3$) from a storage tank (4) containing a 7-day supply is moved by a screw conveyor (5) to a measuring tank (6). Fluosilicic acid and aluminum hydroxide in the weight ratio of 1 to 1.0166, respectively, are introduced to a reactor (7) where the mixture reacts exothermically while being stirred. The temperature during reaction rises to 212°F . The completely reacted mixture mainly contains water, the soluble (alpha) structural modification of aluminum fluoride trihydrate ($\text{AlF}_3 \cdot 3\text{H}_2\text{O}$), and precipitated hydrated silica ($\text{SiO}_2 \cdot \text{H}_2\text{O}$). At this point timing is very important, as the alpha modification of $\text{AlF}_3 \cdot 3\text{H}_2\text{O}$ very slowly starts passing to the insoluble beta modification causing its precipitation from the solution along with silica. Sufficient precipitation of silica must be allowed to insure a final AlF_3 product low in silica. The time of reaction is about 15 minutes. After reaction the products are rapidly emptied into a feed tank (8) which immediately starts dispensing the entire mixture to a centrifuge (9) which separates the silica from the aluminum fluoride.

The solution containing $\text{AlF}_3 \cdot 3\text{H}_2\text{O}$ flows to crystallizers (10) where the alpha modification $\text{AlF}_3 \cdot 3\text{H}_2\text{O}$ passes irreversibly to the beta modification while being stirred for about 4 hours. Twelve crystallizers (three are shown) were considered necessary to allow the continuous operation of all equipment. The feed tank (8) was added to the originally proposed plant scheme for the same purpose. After crystallization, the beta $\text{AlF}_3 \cdot 3\text{H}_2\text{O}$ is separated from the mother liquor by centrifuge (11) and moved by screw conveyor (12) to a storage tank (13). The mother liquor is recycled but occasionally must be rejected if the phosphate and iron content become too high.

At this point the $\text{AlF}_3 \cdot 3\text{H}_2\text{O}$ contains about 5 percent external moisture and about 40 percent structural water.

Drying of the product is accomplished in three stages. A screw conveyor (14) delivers the wet $\text{AlF}_3 \cdot 3\text{H}_2\text{O}$ to a flash dryer (15) operating at 360°F , where total moisture is reduced to about 17 percent. The product passed via cyclone unit (16) to a fluid-bed dryer (17), operating at 460°F where the moisture content is lowered to 6 percent structural water. The $\text{AlF}_3 \cdot 6$ percent H_2O flows then to a final flash dryer (18) operating at $1,100^\circ \text{F}$ where all remaining water is removed and a 97- to 98-percent- AlF_3 product is collected by a cyclone (19). According to Weinrotter the final drying step is critical, since the residence time at $1,100^\circ \text{F}$ must be 1 second or less to prevent the decomposition of AlF_3 and the loss of fluorine. The dryers are heated by fuel oil or natural gas and require a heating unit (20), an air blower (21), and an air compressor (22).

The dried AlF_3 then flows to a water-cooled rotary jacketed cooler (23) where the temperature is dropped to about 150°F . The cooled AlF_3 is conveyed by the bucket elevator (24) to a storage tank (25) having a 3-day storage capacity. A belt feeder (26) delivers the final product to a weighing, bagging, and sealing unit (27).

All gases generated from the process are exhausted by a blower (28) to a complete air scrubbing system (29).

CAPITAL INVESTMENT AND PRODUCTION COSTS

Capital investments and operating costs were determined separately for five hypothetical plants designed to produce aluminum fluoride from byproduct fluosilicic acid. The plants utilized the same types of equipment and the same production process but differed in annual capacity to consume fluosilicic acid. The five plant sizes costed were 5, 10, 25, 50, and 100 thousand tons per year. Appendixes A through E provide the capital investment and production cost details for each of the plants.

SUPPLY COST EVALUATION

Byproduct fluosilicic acid (100 percent) for use in manufacturing aluminum fluoride is restricted by availability to various geographic localities of the United States. Table 3

summarizes the maximum potential U.S. availability of byproduct fluosilicic acid from all sources based on Jan. 1, 1969, data on the phosphate and phosphorus production capacities in various States. The total potential available tonnage of fluosilicic acid was 373,400 tons containing 295,400 tons of fluorine.

Figure 2 graphically shows the domestic availability of byproduct fluosilicic acid at various price levels.

The price of aluminum fluoride output for a 5,000-tpy fluosilicic acid input was estimated to be \$448 per ton (table A-1). At this price about 366,500 tons of fluosilicic acid (98 percent of the potential national supply of byproduct fluorine) would be available. Fluosilicic acid outputs of 5,000 tpy or less are not considered since the minimum size plant is 5,000 tpy input.

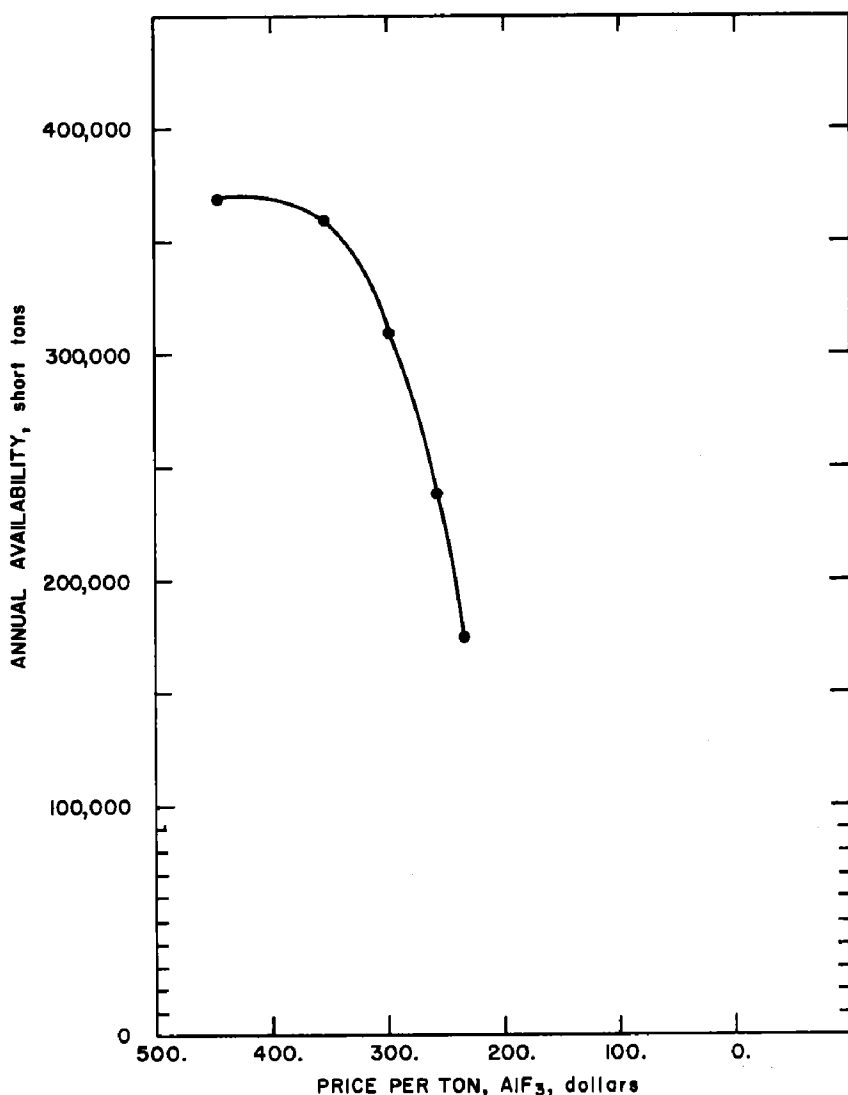


FIGURE 2. - Economic Availability of Byproduct 100 Percent H_2SiF_6 (Sources Pooled by Geographic Region) at Various Price Levels of AlF_3 .

A plant with an input of 10,000 tpy fluosilicic acid could sell the output for \$353 per ton (table B-1). At this price 361,500 tons of fluosilicic acid or 96.8 percent of the total potential supply would be available.

A plant with an input of 25,000 tpy fluosilicic acid could sell the output for \$299 per ton (table C-1) which is within the current price range (\$260 to \$310 per ton) of technical grade anhydrous aluminum fluoride. At this price 309,350 tons of fluosilicic acid or 82.9 percent of the potential total would be available.

At the 50,000-tpy input level, the output could be sold for \$259 per ton (table D-1). At a price of \$259 per ton 238,890 tons of input or 64 percent of the potential domestic supply of 373,400 tons is available.

At the 100,000-tpy input level, only Florida would have enough pooled byproduct fluosilicic acid to support a plant of this size. The output from this plant would sell for \$233 per ton (table E-1), which is well below the current price range. Economic availability at this price level is about 175,500 tons of input per year or 47 percent of the total 1968 national supply.

Figure 3 indicates the sales price of the aluminum fluoride produced at five designed plant consumption levels of input fluosilicic acid. The curve was generated from the selling price data based on the cost evaluations for five plants. The price of the product at each output level is shown on the curve, which is represented by $Y_c = aX^b$. The price output relationship along the curve at various production levels should be interpreted with caution in view of the small number of observations used in generating the curve.

CONCLUSIONS

The largest potential domestic source of fluorine occurs in the phosphate rock resources of the United States. The known phosphate rock resources are estimated to contain an average of about 3.5 percent of fluorine or 2.5 billion tons. Because it can only be recovered as a byproduct, its availability is dependent upon the domestic production capacities of phosphate rock processing plants.

The fluorine is recovered in fluosilicic acid which, as a raw material costing \$96 to \$78 per ton, is proposed for use in the manufacture of various fluoride chemicals. This report concerns the economic availability of byproduct fluosilicic acid at various prices of aluminum fluoride. At prices within the current 1971 market range of \$260 to \$310 per ton, technical anhydrous AlF_3 can be produced from phosphate rock, which is competitive with AlF_3 produced from other sources.

The maximum possible U.S. annual available supply from phosphate rock processing, based on current annual phosphate potential processing plant capacities, is 373,350 tons of H_2SiF_6 containing 295,372 tons of fluorine.

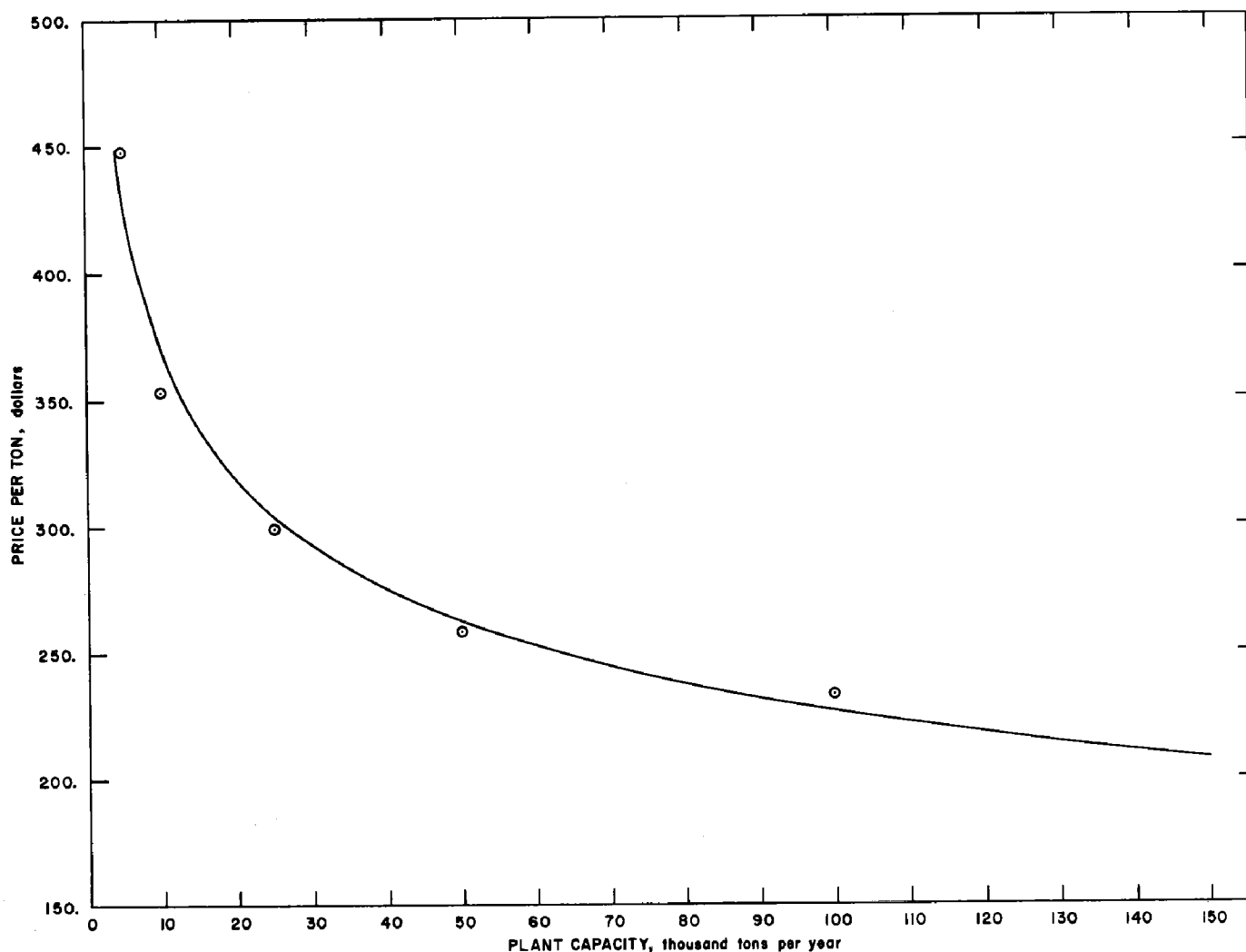


FIGURE 3. - Price-Output Curve for AlF_3 .

At a price of \$448 per ton for aluminum fluoride, 98 percent of the current maximum possible supply is available; at \$353 per ton, 96.8 percent is available; at \$299 per ton, which is within the current 1971 price range of aluminum fluoride, 82.9 percent is available; at \$259 per ton, 64.0 percent is available; and at \$233 per ton, well below the current price range of aluminum fluoride, 46 percent of the total annual U.S. supply is available.

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APPENDIX A.--COST ANALYSIS OF A 5,000-TON-PER-YEAR PLANT

TABLE A-1. - Calculation of selling price of aluminum fluoride

12 percent discounted cash flow rate of return (20 years):	
R = \$2,642,500/7.469.....	\$353,800
Depreciation.....	<u>118,000</u>
Net profit.....	235,800
Federal income tax (50 percent taxable income):	
Gross profit.....	471,600
Net operating cost.....	<u>1,392,100</u>
Sales.....	1,863,700
Taxes:	
Taxable income.....	471,600
Federal income tax.....	<u>235,800</u>
Net profit.....	235,800
Cash flow:	
Net profit.....	235,800
Depreciation.....	<u>118,000</u>
Total.....	353,800
Sales price per ton AlF_3 (\$1,863,700/4,163 ¹).....	447.68
¹ Product (AlF_3) output, tpy.	

Note: Formula:
$$P = R \frac{(1+r)^n}{r(1+r)^n}$$

where P = total capital requirements,

R = present value of P due in 20 years at 12 percent compound interest,

r = 12 percent,

n = 20 years,

and R = P/7.469 (present value of \$1.00 due in 20 years at 12 percent interest).

TABLE A-2. - Financial analysis

Revenue from sales.....	\$1,863,700
Operating cost.....	1,392,100
Gross profit (taxable income).....	471,600
Federal income tax, 50 percent.....	235,800
Net profit.....	235,800
ANNUAL CASH FLOW	
Net profit.....	235,800
Depreciation.....	118,000
Cash flow.....	353,800

TABLE A-3. - Total capital requirements

Unit	Cost	Percent
Reaction section.....	\$420,800	15.9
Crystallization section.....	383,000	14.5
Drying section.....	849,000	32.1
Bagging section.....	70,000	2.6
Scrubbing section.....	12,500	.5
Subtotal.....	1,735,300	65.6
Plant facilities.....	174,800	6.6
Plant utilities.....	262,100	9.9
Total plant cost (insurance and tax bases).....	2,172,200	82.3
Interest during construction.....	174,800	6.6
Subtotal for depreciation.....	2,347,000	88.9
Working capital.....	295,500	11.1
Total investment.....	2,642,500	100.0

TABLE A-4. - Equipment cost summary, reaction section

Item	Cost		Total cost
	Material	Labor	
Storage tank (H_2SiF_6), 1.....	\$37,500	\$3,700	\$41,200
Pump and motor, 1.....	700	100	800
Steam boiler, 1.....	6,700	700	7,400
Heating and measuring tank, 1.....	800	100	900
Heat exchanger, 1.....	700	100	800
Storage tank ($\text{Al}(\text{OH})_3$), 1.....	16,000	1,600	17,600
Screw conveyor, 1.....	900	100	1,000
Measuring and feed bin tank, 1.....	500	100	600
Reactor and agitator, 1.....	5,000	500	5,500
Feed storage tank ($\text{AlF}_3 + \text{SiO}_2$), 1.....	1,100	100	1,200
Centrifuge, 1.....	59,500	10,500	70,000
Subtotal.....	129,400	17,600	147,000
Foundations.....	12,900	16,100	29,000
Structures.....	9,700	4,900	14,600
Buildings.....	25,900	25,900	51,800
Instrumentation.....	2,600	1,300	3,900
Electrical.....	12,900	9,700	22,600
Piping.....	2,600	1,300	3,900
Painting.....	600	1,800	2,400
Miscellaneous.....	6,700	6,100	12,800
Subtotal.....	73,900	67,100	141,000
Total direct.....	203,300	84,700	288,000
Field indirect.....			43,200
Total construction.....			331,200
Engineering.....			16,600
Overhead and administration.....			16,600
			364,400
Contingency.....			36,400
			400,800
Fee.....			20,000
Total.....			420,800

TABLE A-5. - Equipment cost summary, crystallization section

Item	Cost		Total cost
	Material	Labor	
Crystallizers, 12.....	\$60,000	\$3,000	\$63,000
Screw conveyor, 1.....	900	100	1,000
Centrifuge, 1.....	59,000	6,000	65,000
Screw conveyor, 1.....	900	100	1,000
Subtotal.....	120,800	9,200	130,000
Foundations.....	12,100	15,100	27,200
Structures.....	9,100	4,600	13,700
Buildings.....	24,200	24,200	48,400
Instrumentation.....	2,400	1,200	3,600
Electrical.....	12,100	9,100	21,200
Piping.....	2,400	1,200	3,600
Painting.....	600	1,800	2,400
Miscellaneous.....	6,300	5,700	12,000
Subtotal.....	69,200	62,900	132,100
Total direct.....	190,000	72,100	262,100
Field indirect.....			39,300
Total construction.....			301,400
Engineering.....			15,100
Overhead and administration.....			15,100
			331,600
Contingency.....			33,200
			364,800
Fee.....			18,200
Total.....			383,000

TABLE A-6. - Equipment cost summary, drying section

Item	Cost		Total cost
	Material	Labor	
Storage tank, 1.....	\$21,000	\$1,000	\$22,000
Screw conveyor, 1.....	900	100	1,000
Flash dryer and cyclone, 1.....	85,000	10,000	95,000
Fluid bed dryer, 1.....	63,000	7,000	70,000
Flash dryer and cyclone, 1.....	75,300	7,500	82,800
Heating unit, 1.....	500	100	600
Blower, 1.....	1,100	100	1,200
Compressor, 1.....	6,400	600	7,000
Cooler, 1.....	4,700	500	5,200
Subtotal.....	257,900	26,900	284,800
Foundations.....	26,800	33,500	60,300
Structures.....	20,100	10,100	30,200
Buildings.....	53,500	53,500	107,000
Instrumentation.....	5,400	2,700	8,100
Electrical.....	26,800	20,100	46,900
Piping.....	5,400	2,700	8,100
Painting.....	1,300	3,900	5,200
Miscellaneous.....	13,900	12,700	26,600
Subtotal.....	153,200	139,200	292,400
Total direct.....	411,100	166,100	577,200
Field indirect.....			88,400
Total construction.....			665,600
Engineering.....			33,900
Overhead and administration.....			33,900
			733,400
Contingency.....			74,600
			808,000
Fee.....			41,000
Total.....			849,000

TABLE A-7. - Equipment cost summary, bagging section

Item	Cost		Total cost
	Material	Labor	
Conveyor, 1.....	\$1,500	\$200	\$1,700
Storage tank, 1.....	6,700	300	7,000
Belt feeder, 1.....	1,800	200	2,000
Weighing, bagging and sealing unit, 1...	12,000	1,000	13,000
Subtotal.	22,000	1,700	23,700
Foundations.....	2,200	2,800	5,000
Structures.....	1,700	900	2,600
Buildings.....	4,400	4,400	8,800
Instrumentation.....	400	200	600
Electrical.....	2,200	1,700	3,900
Piping.....	400	200	600
Painting.....	100	300	400
Miscellaneous.....	1,100	1,100	2,200
Subtotal.....	12,500	11,600	24,100
Total direct.....	34,500	13,300	47,800
Field indirect.....			7,200
Total construction.....			55,000
Engineering.....			2,800
Overhead and administration.....			2,800
			60,600
Contingency.....			6,100
			66,700
Fee.....			3,300
Total.....			70,000

TABLE A-8. - Equipment cost summary, scrubbing section

Item	Cost		Total cost
	Material	Labor	
Scrubbing unit including blower, rubber lined pump, polyvinyl chloride piping, and stack, 1.....	\$3,500	\$300	\$3,800
Subtotal.....	3,500	300	3,800
Foundations.....	400	500	900
Structures.....	300	200	500
Buildings.....	700	700	1,400
Instrumentation.....	100	100	200
Electrical.....	400	300	700
Piping.....	100	100	200
Painting.....	100	300	400
Miscellaneous.....	200	200	400
Subtotal.....	2,300	2,400	4,700
Total direct.....	5,800	2,700	8,500
Field indirect.....			1,300
Total construction.....			9,800
Engineering.....			500
Overhead and administration.....			500
			10,800
Contingency.....			1,100
			11,900
Fee.....			600
Total.....			12,500

TABLE A-9. - Working capital

Item	Cost	Percent
Raw materials and utilities.....60 days..	\$127,700	43.2
Direct labor and supervision.....3 months..	44,900	15.2
Payroll overhead.....3 months..	11,200	3.8
Operating supplies and spare parts.....3 months..	33,800	11.4
Indirect costs.....4 months..	40,100	13.6
Fixed cost.....0.5 percent of insurance base..	10,900	3.7
Miscellaneous expense.....	26,900	9.1
Total.....	295,500	100.0

TABLE A-10. - Estimated annual operating cost

Item	Cost per ton	Annual cost	Percent
Direct cost:			
Raw materials and utilities:			
Fuel.....	\$8.48	\$35,300	2.5
Power.....	3.56	14,800	1.1
Fluosilicic acid (H_2SiF_6).....	96.08	400,000	28.7
Aluminum hydroxide ($Al(OH)_3$).....	75.50	314,300	22.6
Subtotal.....	-	764,400	54.9
Direct labor and supervision:			
Labor.....	21.71	90,400	6.5
Supervision.....	12.97	54,000	3.9
Subtotal.....	-	144,400	10.4
Plant maintenance:			
Electrician-mechanic.....	5.04	21,000	1.5
Material (spare parts) (5 percent of equipment costs).....	26.23	109,300	7.9
Subtotal.....	-	130,300	9.4
Payroll overhead (25 percent of payroll).....	10.78	44,900	3.2
Operating supplies (20 percent of plant maintenance).....	6.26	26,100	1.9
Total direct costs ¹	266.66	1,110,100	79.8
Indirect cost (administration and general overhead): 40 percent labor, maintenance, and supplies.....	28.89	120,300	8.6
Fixed cost:			
Taxes and insurance (2 percent of plant cost)..	10.49	43,700	3.1
Depreciation and deferred expenses (5 percent of subtotal for depreciation).....	28.34	118,000	8.5
Total annual operating cost ¹	334.40	1,392,100	100.0

¹Figures may not add to totals shown because of rounding.

TABLE A-11. - General manning table

Unit and personnel	Shifts			Man shifts per day	Wages, dollars per man hour	Wages, dollars per day	Days per year	Annual cost, dollars	Salaried workers, dollars per year	Total annual cost, dollars
	Day	Eve-ning	Night							
Supervision:										
Superintendent (chemical engineer)...	1	-	-	1	-	-	-	-	18,000	-
Plant foremen.....	1	1	1	3	-	-	-	-	36,000	-
Subtotal.....	-	-	-	4	-	-	-	-	54,000	54,000
Services:										
Office manager-bookkeeper.....	1	-	-	1	-	-	-	-	8,000	-
Clerk-typist.....	1	-	-	1	-	-	-	-	6,000	-
Subtotal.....	-	-	-	2	-	-	-	-	14,000	14,000
Plant operation:										
Equipment operator.....	1	1	1	3	3.25	26.00	330	25,700	-	-
Plant helpers.....	2	2	2	6	3.00	24.00	330	47,500	-	-
Baggers.....	2	-	-	2	3.25	26.00	330	17,200	-	-
Subtotal.....	-	-	-	11	-	-	-	90,400	-	90,400
Maintenance: Electrician-mechanic.....	1	1	-	2	4.00	32.00	330	21,100	-	21,100
Total cost.....	-	-	-	-	-	-	-	-	-	179,500

APPENDIX B.--COST ANALYSIS OF A 10,000-TON-PER-YEAR PLANT

TABLE B-1. - Calculation of selling price of aluminum fluoride

12 percent discounted cash flow rate of return (20 years):	
R = \$3,472,400/7.469.....	\$464,900
Depreciation.....	<u>151,300</u>
Net profit.....	313,600
Federal income tax (50 percent taxable income):	
Gross profit.....	627,200
Net operating cost.....	<u>2,315,000</u>
Sales.....	2,942,200
Taxes:	
Taxable income.....	627,200
Federal income tax.....	<u>313,600</u>
Net profit.....	313,600
Cash flow:	
Net profit.....	313,600
Depreciation.....	<u>151,300</u>
Total.....	464,900
Sales price per ton AlF_3 (\$2,942,200/8,326 ¹).....	353.37
¹ Product (AlF_3) output, tpy.	

Note: Formula: $P = R \frac{(1+r)^n}{r(1+r)^n}$

where P = total capital requirements,

R = present value of P due in 20 years at 12 percent compound interest,

r = 12 percent,

n = 20 years,

and R = $P/7.469$ (present value of \$1.00 due in 20 years at 12 percent interest).

TABLE B-2. - Financial analysis

Revenue from sales.....	\$2,942,200
Operating cost.....	2,315,000
Gross profit (taxable income).....	627,200
Federal income tax, 50 percent.....	313,600
Net profit.....	313,600
ANNUAL CASH FLOW	
Net profit.....	313,600
Depreciation.....	151,300
Cash flow.....	464,900

TABLE B-3. - Total capital requirements

Unit	Cost	Percent
Reaction section.....	\$625,700	18.0
Crystallization section.....	537,900	15.5
Drying section.....	952,000	27.4
Bagging section.....	89,900	2.6
Scrubbing section.....	13,800	.4
Subtotal.....	2,219,300	63.9
Plant facilities.....	224,300	6.4
Plant utilities.....	336,200	9.6
Total plant cost (insurance and tax bases).....	2,779,800	80.1
Interest during construction.....	224,100	6.5
Subtotal for depreciation.....	3,003,900	86.6
Working capital.....	468,500	13.4
Total investment.....	3,472,400	100.0

TABLE B-4. - Equipment cost summary, reaction section

Item	Cost		Total cost
	Material	Labor	
Storage tank (H_2SiF_6), 1.....	\$62,000	\$6,200	\$68,200
Pump and motor, 1.....	900	100	1,000
Steam boiler, 1.....	8,300	800	9,100
Heating and measuring tank, 1.....	1,100	100	1,200
Heat exchanger, 1.....	1,100	100	1,200
Storage tank ($\text{Al}(\text{OH})_3$), 1.....	24,000	2,400	26,400
Screw conveyor, 1.....	900	100	1,000
Measuring and feed bin tank, 1.....	600	100	700
Reactor and agitator, 1.....	7,000	700	7,700
Feed storage tank ($\text{AlF}_3 + \text{SiO}_2$), 1.....	1,700	200	1,900
Centrifuge, 1.....	81,000	14,600	95,600
Subtotal.....	188,600	25,400	214,000
Foundations.....	19,400	24,300	43,700
Structures.....	14,500	7,300	21,800
Buildings.....	38,800	38,800	77,600
Instrumentation.....	3,900	2,000	5,900
Electrical.....	19,400	14,600	34,000
Piping.....	3,900	2,000	5,900
Painting.....	1,000	3,000	4,000
Miscellaneous.....	10,900	9,200	20,100
Subtotal.....	111,800	101,200	213,000
Total direct.....	300,400	126,600	427,000
Field indirect.....			64,900
Total construction.....			491,900
Engineering.....			24,900
Overhead and administration.....			24,900
			541,700
Contingency.....			54,200
			595,900
Fee.....			29,800
Total.....			625,700

TABLE B-5. - Equipment cost summary, crystallization section

Item	Cost		Total cost
	Material	Labor	
Crystallizers, 12.....	\$85,200	\$8,500	\$93,700
Screw conveyor, 1.....	900	100	1,000
Centrifuge, 1.....	81,000	8,100	89,100
Screw conveyor, 1.....	900	100	1,000
Subtotal.....	168,000	16,800	184,800
Foundations.....	16,800	21,000	37,800
Structures.....	12,600	6,300	18,900
Buildings.....	33,600	33,600	67,200
Instrumentation.....	3,400	1,700	5,100
Electrical.....	16,800	12,600	29,400
Piping.....	3,400	1,700	5,100
Painting.....	800	2,400	3,200
Miscellaneous.....	8,700	7,900	16,600
Subtotal.....	96,100	87,200	183,300
Total direct.....	264,100	104,000	368,100
Field indirect.....			55,200
Total construction.....			423,300
Engineering.....			21,200
Overhead and administration.....			21,200
			465,700
Contingency.....			46,600
			512,300
Fee.....			25,600
Total.....			537,900

TABLE B-6. - Equipment cost summary, drying section

Item	Cost		Total cost
	Material	Labor	
Storage tank, 1.....	\$30,000	\$3,000	\$33,000
Screw conveyor, 1.....	900	100	1,000
Flash dryer and cyclone, 1.....	85,000	8,500	93,500
Fluid bed dryer, 1.....	82,000	8,000	90,000
Flash dryer and cyclone, 1.....	75,300	7,500	82,800
Heating unit, 1.....	800	100	900
Blower, 1.....	3,200	300	3,500
Compressor, 1.....	9,000	900	9,900
Cooler, 1.....	4,700	500	5,200
Subtotal.....	290,900	28,900	319,800
Foundations.....	30,100	37,600	67,700
Structures.....	22,500	11,300	33,800
Buildings.....	60,200	60,200	120,400
Instrumentation.....	6,000	3,000	9,000
Electrical.....	30,100	22,600	52,700
Piping.....	6,000	3,000	9,000
Painting.....	1,500	4,500	6,000
Miscellaneous.....	15,600	14,200	29,800
Subtotal.....	172,000	156,400	328,400
Total direct.....	462,900	185,300	648,200
Field indirect.....			98,800
Total construction.....			747,000
Engineering.....			37,900
Overhead and administration.....			37,900
			822,800
Contingency.....			83,400
			906,200
Fee.....			45,800
Total.....			952,000

TABLE B-7. - Equipment cost summary, bagging section

Item	Cost		Total cost
	Material	Labor	
Conveyor, 1.....	\$1,500	\$200	\$1,700
Storage tank, 1.....	12,900	1,300	14,200
Belt feeder, 1.....	1,800	200	2,000
Weighing, bagging and sealing unit, 1..	12,000	1,200	13,200
Subtotal.....	28,200	2,900	31,100
Foundations.....	2,800	3,500	6,300
Structures.....	2,100	1,100	3,200
Buildings.....	5,600	5,600	11,200
Instrumentation.....	600	300	900
Electrical.....	2,800	2,100	4,900
Piping.....	600	300	900
Painting.....	100	300	400
Miscellaneous.....	1,400	1,300	2,700
Subtotal.....	16,000	14,500	30,500
Total direct.....	44,200	17,400	61,600
Field indirect.....			9,200
Total construction.....			70,800
Engineering.....			3,500
Overhead and administration.....			3,500
			77,800
Contingency.....			7,800
			85,600
Fee.....			4,300
Total.....			89,900

TABLE B-8. - Equipment cost summary, scrubbing section

Item	Cost		Total cost
	Material	Labor	
Scrubbing unit including blower, rubber lined pump, polyvinyl chloride piping, and stack, 1.....	\$3,800	\$400	\$4,200
Subtotal.....	3,800	400	4,200
Foundations.....	400	500	900
Structures.....	300	200	500
Buildings.....	800	800	1,600
Instrumentation.....	100	100	200
Electrical.....	400	300	700
Piping.....	100	100	200
Painting.....	100	300	400
Miscellaneous.....	600	200	800
Subtotal.....	2,800	2,500	5,300
Total direct.....	6,600	2,900	9,500
Field indirect.....			1,400
Total construction.....			10,900
Engineering.....			500
Overhead and administration.....			500
			11,900
Contingency.....			1,200
			13,100
Fee.....			700
Total.....			13,800

TABLE B-9. - Working capital

Item	Cost	Percent
Raw materials and utilities.....60 days..	\$255,000	54.5
Direct labor and supervision.....3 months..	50,000	10.7
Payroll overhead.....3 months..	13,400	2.7
Operating supplies and spare parts.....3 months..	43,600	9.4
Indirect cost.....4 months..	49,900	10.7
Fixed cost.....0.5 percent of insurance base..	14,000	3.0
Miscellaneous expense.....	42,600	9.0
Total.....	468,500	100.0

TABLE B-10. - Estimated annual operating cost

Item	Cost per ton	Annual cost	Percent
Direct cost:			
Raw materials and utilities:			
Fuel.....	\$8.47	\$70,500	3.0
Power.....	3.56	29,500	1.3
Fluosilicic acid (H_2SiF_6).....	96.08	800,000	34.6
Aluminum hydroxide ($\text{Al}(\text{OH})_3$).....	75.66	630,000	27.2
Subtotal.....	-	1,530,000	66.1
Direct labor and supervision:			
Labor.....	13.72	114,200	4.9
Supervision.....	6.49	54,000	2.3
Subtotal.....	-	168,200	7.3
Plant maintenance:			
Electrician-mechanic.....	3.81	31,700	1.4
Material (spare parts) (5 percent of total plant cost).....	16.83	140,100	6.0
Subtotal.....	-	171,800	7.4
Payroll overhead (25 percent of payroll).....	6.43	53,500	2.3
Operating supplies (20 percent of plant maintenance).....	4.13	34,400	1.5
Total direct costs ¹	278.04	1,957,900	84.6
Indirect cost (administration and general overhead): 40 percent labor, maintenance, and supplies.....	17.99	149,800	6.5
Fixed cost:			
Taxes and insurance (2 percent of plant cost)..	6.73	56,000	2.4
Depreciation and deferred expenses (5 percent of subtotal for depreciation).....	18.17	151,300	6.5
Total annual operating cost ¹	278.07	2,315,000	100.0

¹Figures may not add to totals shown because of rounding.

APPENDIX C.--COST ANALYSIS OF A 25,000-TON-PER-YEAR PLANT

TABLE C-1. - Calculation of selling price of aluminum fluoride

12 percent discounted cash flow rate of return (20 years):	
R = \$6,381,500/7.469.....	\$854,400
Depreciation.....	<u>269,700</u>
Net profit.....	584,700
Federal income tax (50 percent taxable income):	
Gross profit.....	1,169,400
Net operating cost.....	<u>5,059,300</u>
Sales.....	6,228,700
Taxes:	
Taxable income.....	1,169,400
Federal income tax.....	<u>584,700</u>
Net profit.....	584,700
Cash flow:	
Net profit.....	584,700
Depreciation.....	<u>269,700</u>
Total.....	854,400
Sales price per ton AlF_3 (\$6,228,700/20,815 ¹).....	299.24
¹ Product (AlF_3) output, tpy.	

Note: Formula: $P = R \frac{(1+r)^n}{r(1+r)^n}$

where P = total capital requirements,

R = present value of P due in 20 years at 12 percent compound interest,

r = 12 percent,

n = 20 years,

and R = $P/7.469$ (present value of \$1.00 due in 20 years at 12 percent interest).

TABLE C-2. - Financial analysis

Revenue from sales.....	\$6,228,700
Operating cost.....	5,059,300
Gross profit (taxable income).....	1,169,400
Federal income tax, 50 percent.....	584,700
Net profit.....	584,700
ANNUAL CASH FLOW	
Net profit.....	584,700
Depreciation.....	269,700
Cash flow.....	854,400

TABLE C-3. - Total capital requirements

Unit	Cost	Percent
Reaction section.....	\$1,354,600	21.2
Crystallization section.....	1,091,700	17.1
Drying section.....	1,407,400	22.0
Bagging section.....	125,000	1.9
Scrubbing section.....	16,900	.3
Subtotal.....	3,995,600	62.5
Plant facilities.....	399,600	6.3
Plant utilities.....	599,300	9.4
Total plant cost (insurance and tax bases).....	4,994,500	78.2
Interest during construction.....	399,600	6.3
Subtotal for depreciation.....	5,394,100	84.5
Working capital.....	987,400	15.5
Total investment.....	6,381,500	100.0

TABLE C-4. - Equipment cost summary, reaction section

Item	Cost		Total cost
	Material	Labor	
Storage tank (H_2SiF_6), 1.....	\$112,000	\$11,200	\$123,200
Pump and motor, 1.....	1,300	100	1,400
Steam boiler, 1.....	18,000	1,800	19,800
Heating and measuring tank, 1.....	1,800	200	2,000
Heat exchanger, 1.....	3,700	400	4,100
Storage tank ($\text{Al}(\text{OH})_3$), 1.....	50,000	5,000	55,000
Screw conveyor, 1.....	1,300	100	1,400
Measuring and feed bin tank, 1.....	1,000	100	1,100
Reactor and agitator, 1.....	9,800	1,000	10,800
Feed storage tank ($\text{AlF}_3 + \text{SiO}_2$), 1.....	3,000	300	3,300
Centrifuge, 3.....	221,000	22,000	243,000
Subtotal.....	422,900	42,200	\$465,100
Foundations.....	42,300	52,900	95,200
Structures.....	31,700	15,900	47,600
Buildings.....	84,600	84,600	169,200
Instrumentation.....	8,500	4,300	12,800
Electrical.....	42,300	31,700	74,000
Piping.....	8,500	4,300	12,800
Painting.....	2,100	6,300	8,400
Miscellaneous.....	22,000	20,000	42,000
Subtotal.....	242,000	220,000	462,000
Total direct.....	664,900	262,200	927,100
Field indirect.....			139,100
Total construction.....			1,066,200
Engineering.....			53,300
Overhead and administration.....			53,300
			1,172,800
Contingency.....			117,300
			1,290,100
Fee.....			64,500
Total.....			1,354,600

TABLE C-5. - Equipment cost summary, crystallization section

Item	Cost		Total cost
	Material	Labor	
Crystallizers, 12.....	\$117,600	\$11,800	\$129,400
Screw conveyor, 1.....	1,100	100	1,200
Centrifuge, 3.....	221,000	22,100	243,100
Screw conveyor, 1.....	1,100	100	1,200
Subtotal.....	340,800	34,100	374,900
Foundations.....	34,100	42,600	76,700
Structures.....	25,600	12,800	38,400
Buildings.....	68,200	68,200	136,400
Instrumentation.....	6,800	3,400	10,200
Electrical.....	34,100	25,600	59,700
Piping.....	6,800	3,400	10,200
Painting.....	1,700	5,100	6,800
Miscellaneous.....	17,700	16,100	33,800
Subtotal.....	195,000	177,200	372,200
Total direct.....	535,800	211,300	747,100
Field indirect.....			112,100
Total construction.....			859,200
Engineering.....			43,000
Overhead and administration.....			43,000
			945,200
Contingency.....			94,500
			1,039,700
Fee.....			52,000
Total.....			1,091,700

TABLE C-6. - Equipment cost summary, drying section

Item	Cost		Total cost
	Material	Labor	
Storage tank, 1.....	\$45,000	\$4,500	\$49,500
Screw conveyor, 1.....	1,700	200	1,900
Flash dryer and cyclone, 1.....	180,800	18,100	198,900
Fluid bed dryer, 1.....	109,000	11,000	120,000
Flash dryer and cyclone, 1.....	75,300	7,500	82,800
Heating unit, 1.....	1,200	100	1,300
Blower, 1.....	5,900	600	6,500
Compressor, 1.....	12,100	1,200	13,300
Cooler, 1.....	8,400	800	9,200
Subtotal.....	439,400	44,000	483,400
Foundations.....	43,900	54,900	98,800
Structures.....	33,000	16,500	49,500
Buildings.....	87,900	87,900	175,800
Instrumentation.....	8,800	4,400	13,200
Electrical.....	43,900	32,900	76,800
Piping.....	8,800	4,400	13,200
Painting.....	2,200	6,600	8,800
Miscellaneous.....	22,900	20,800	43,700
Subtotal.....	251,400	228,400	479,800
Total direct.....	690,800	272,400	963,200
Field indirect.....			144,500
Total construction.....			1,107,700
Engineering.....			55,400
Overhead and administration.....			55,400
			1,218,500
Contingency.....			121,900
			1,340,400
Fee.....			67,000
Total.....			1,407,400

TABLE C-7. - Equipment cost summary, bagging section

Item	Cost		Total cost
	Material	Labor	
Conveyor, 1.....	\$1,500	\$200	\$1,700
Storage tank, 1.....	23,600	2,400	26,000
Belt feeder, 1.....	1,800	200	2,000
Weighing, bagging and sealing unit, 1..	12,000	1,200	13,200
Subtotal.....	38,900	4,000	42,900
Foundations.....	3,900	4,900	8,800
Structures.....	2,900	1,500	4,400
Buildings.....	7,800	7,800	15,600
Instrumentation.....	800	400	1,200
Electrical.....	3,900	2,900	6,800
Piping.....	800	400	1,200
Painting.....	200	600	800
Miscellaneous.....	2,000	1,900	3,900
Subtotal.....	22,300	20,400	42,700
Total direct.....	61,200	24,400	85,600
Field indirect.....			12,800
Total construction.....			98,400
Engineering.....			4,900
Overhead and administration.....			4,900
			108,200
Contingency.....			10,800
			119,000
Fee.....			6,000
Total.....			125,000

TABLE C-8. - Equipment cost summary, scrubbing section

Item	Cost		Total cost
	Material	Labor	
Scrubbing unit, including blower, rubber lined pump, polyvinyl chloride piping, and stack, 1.....	\$5,000	\$500	\$5,500
Subtotal.....	5,000	500	5,500
Foundations.....	500	600	1,100
Structures.....	400	200	600
Buildings.....	1,000	1,000	2,000
Instrumentation.....	100	100	200
Electrical.....	500	400	900
Piping.....	100	100	200
Painting.....	100	300	400
Miscellaneous.....	300	300	600
Subtotal.....	3,000	3,000	6,000
Total direct.....	8,000	3,500	11,500
Field indirect.....			1,700
Total construction.....			13,200
Engineering.....			700
Overhead and administration.....			700
			14,600
Contingency.....			1,500
			16,100
Fee.....			800
Total.....			16,900

TABLE C-9. - Working capital

Item	Cost	Percent
Raw materials and utilities.....60 days..	\$637,500	64.6
Direct labor and supervision.....3 months..	65,000	6.6
Payroll overhead.....3 months..	17,500	1.8
Operating supplies and spare parts.....3 months..	77,000	7.8
Indirect cost.....4 months..	75,600	7.7
Fixed cost.....0.5 percent of insurance base..	25,000	2.5
Miscellaneous expense.....	89,800	9.0
Total.....	987,400	100.0

TABLE C-10. - Estimated annual operating cost

Item	Cost per ton	Annual cost	Percent
Direct cost:			
Raw materials and utilities:			
Fuel.....	\$8.47	\$176,300	3.5
Power.....	3.55	73,800	1.5
Fluosilicic acid (H_2SiF_6).....	96.08	2,000,000	39.5
Aluminum hydroxide ($\text{Al}(\text{OH})_3$).....	75.66	1,575,000	31.1
Subtotal.....	-	3,825,100	75.6
Direct labor and supervision:			
Labor.....	7.86	163,700	3.2
Supervision.....	2.59	54,000	1.1
Subtotal.....	-	217,700	4.3
Plant maintenance:			
Electrician-mechanic.....	2.03	42,200	0.8
Material (spare parts) (5 percent of equipment costs).....	12.00	249,700	4.9
Subtotal.....	-	291,900	5.7
Payroll overhead (25 percent of payroll).....	-	70,000	1.4
Operating supplies (20 percent of plant maintenance).....	2.80	58,200	1.2
Total direct costs ¹	214.41	4,462,900	88.2
Indirect cost (administration and general overhead): 40 percent labor, maintenance, and supplies.....	10.89	226,800	4.5
Fixed cost:			
Taxes and insurance (2 percent of plant cost)..	4.80	99,900	2.0
Depreciation and deferred expenses (5 percent of subtotal for depreciation).....	12.96	269,700	5.3
Total annual operating cost ¹	243.06	5,059,300	100.0

¹Figures may not add to totals shown because of rounding.

TABLE C-11. - General manning table

Unit and personnel	Shifts			Man shifts per day	Wages, dollars per man hour	Wages, dollars per day	Days per year	Annual cost, dollars	Salaried workers, dollars per year	Total annual cost, dollars
	Day	Eve-ning	Night							
Supervision:										
Superintendent (chemical engineer)...	1	-	-	1	-	-	-	-	18,000	-
Plant foremen.....	1	1	1	3	-	-	-	-	36,000	-
Subtotal.....	-	-	-	4	-	-	-	-	54,000	54,000
Services:										
Office manager-bookkeeper.....	1	-	-	1	-	-	-	-	8,000	-
Clerk-typist.....	1	1	-	2	-	-	-	-	12,000	-
Subtotal.....	-	-	-	3	-	-	-	-	20,000	20,000
Plant operation:										
Equipment operator.....	2	2	2	6	3.25	26.00	330	51,500	-	-
Plant helpers.....	4	4	4	12	3.00	24.00	330	95,000	-	-
Baggers.....	2	-	-	2	3.25	26.00	330	17,200	-	-
Subtotal.....	-	-	-	20	-	-	-	163,700	-	163,700
Maintenance: Electrician-mechanic.....	2	1	1	4	4.00	32.00	330	42,200	-	42,200
Total cost.....	-	-	-	-	-	-	-	-	-	279,900

APPENDIX D.--COST ANALYSIS OF A 50,000-TON-PER-YEAR PLANT

TABLE D-1. - Calculation of selling price of aluminum fluoride

12 percent discounted cash flow rate of return (20 years):	
R = \$10,365,900/7.469.....	\$1,387,900
Depreciation.....	410,800
Net profit.....	977,100
Federal income tax (50 percent taxable income):	
Gross profit.....	1,954,200
Net operating cost.....	8,808,200
Sales.....	10,762,400
Taxes:	
Taxable income.....	1,954,200
Federal income tax.....	977,100
Net profit.....	977,100
Cash flow:	
Net profit.....	977,100
Depreciation.....	410,800
Total.	1,387,900
Sales price per ton AlF_3 (\$10,762,400/41,630 ¹).....	258.53
¹ Product (AlF_3) output, tpy.	

Note: Formula:
$$P = R \frac{(1+r)^n}{r(1+r)^n}$$

where P = total capital requirements,

R = present value of P due in 20 years at 12 percent compound interest,

r = 12 percent,

n = 20 years,

and R = P/7.469 (present value of \$1.00 due in 20 years at 12 percent interest).

TABLE D-2. - Financial analysis

Revenue from sales.....	\$10,762,400
Operating cost.....	8,808,200
Gross profit (taxable income).....	1,954,200
Federal income tax, 50 percent.....	977,100
Net profit.....	977,100
ANNUAL CASH FLOW	
Net profit.....	977,100
Depreciation.....	410,800
Cash flow.....	1,387,900

TABLE D-3. - Total capital requirements

Unit	Cost	Percent
Reaction section.....	\$2,530,300	24.4
Crystallization section.....	1,940,300	18.7
Drying section.....	1,765,100	17.0
Bagging section.....	176,300	1.7
Scrubbing section.....	15,900	.2
Subtotal.....	6,427,900	62.0
Plant facilities.....	642,800	6.2
Plant utilities.....	964,200	9.3
Total plant cost (insurance and tax bases).....	8,034,900	77.5
Interest during construction.....	642,800	6.2
Subtotal for depreciation.....	8,677,700	83.7
Working capital.....	1,688,200	16.3
Total investment.....	10,365,900	100.0

TABLE D-4. - Equipment cost summary, reaction section

Item	Cost		Total cost
	Material	Labor	
Storage tank (H_2SiF_6), 2.....	\$224,000	\$22,400	\$246,400
Pump and motor, 1.....	1,700	200	1,900
Steam boiler, 1.....	48,000	4,800	52,800
Heating and measuring tank, 1.....	2,900	300	3,200
Heat exchanger, 1.....	4,900	500	5,400
Storage tank ($\text{Al}(\text{OH})_3$), 1.....	83,000	800	83,800
Screw conveyor, 1.....	1,500	200	1,700
Measuring and feed bin tank, 1.....	1,400	100	1,500
Reactor and agitator, 1.....	16,400	1,600	18,000
Feed storage tank ($\text{AlF}_3 + \text{SiO}_2$), 1.....	4,500	500	5,000
Centrifuge, 5.....	405,000	40,500	445,500
Subtotal.....	793,300	71,900	865,200
Foundations.....	79,300	99,100	178,400
Structures.....	59,500	29,800	89,300
Buildings.....	158,700	158,700	317,400
Instrumentation.....	15,900	8,000	23,900
Electrical.....	79,300	59,500	138,800
Piping.....	15,900	8,000	23,900
Painting.....	4,000	12,000	16,000
Miscellaneous.....	41,300	37,500	78,800
Subtotal.....	453,900	412,600	866,500
Total direct.....	1,247,200	484,500	1,731,700
Field indirect.....			259,800
Total construction.....			1,991,500
Engineering.....			99,600
Overhead and administration.....			99,600
			2,190,700
Contingency.....			219,100
			2,409,800
Fee.....			120,500
Total.....			2,530,300

TABLE D-5. - Equipment cost summary, crystallization section

Item	Cost		Total cost
	Material	Labor	
Crystallizers, 12.....	\$196,800	\$19,700	\$216,500
Screw conveyor, 1.....	2,000	200	2,200
Centrifuge, 5.....	405,000	40,500	445,500
Screw conveyor, 1.....	2,000	200	2,200
Subtotal.....	605,800	60,600	666,400
Foundations.....	60,600	75,800	136,400
Structures.....	45,400	22,700	68,100
Buildings.....	121,200	121,200	242,400
Instrumentation.....	12,100	6,100	19,200
Electrical.....	60,600	45,500	106,100
Piping.....	12,100	6,100	18,200
Painting.....	3,000	9,000	12,000
Miscellaneous.....	31,500	28,600	60,100
Subtotal.....	346,500	315,000	661,500
Total direct.....	952,300	375,600	1,327,900
Field indirect.....			199,200
Total construction.....			1,527,100
Engineering.....			76,400
Overhead and administration.....			76,400
			1,679,900
Contingency.....			168,000
			1,847,900
Fee.....			92,400
Total.....			1,940,300

TABLE D-6. - Equipment cost summary, drying section

Item	Cost		Total cost
	Material	Labor	
Storage tank, 1.....	\$65,000	\$6,500	\$71,500
Screw conveyor, 1.....	2,000	200	2,200
Flash dryer and cyclone, 1.....	275,000	27,500	302,500
Fluid bed dryer, 1.....	136,400	13,600	150,000
Flash dryer and cyclone, 1.....	75,300	7,500	82,800
Heating unit, 1.....	1,500	200	1,700
Blower, 1.....	8,500	900	9,400
Compressor, 1.....	19,800	2,000	21,800
Cooler, 1.....	17,400	1,700	19,100
Subtotal.....	600,900	60,100	661,000
Foundations.....	60,100	75,100	135,200
Structures.....	45,100	22,500	67,600
Buildings.....	120,000	120,000	240,000
Instrumentation.....	12,000	6,000	18,000
Electrical.....	60,100	45,000	105,100
Piping.....	12,000	6,000	18,000
Painting.....	3,000	9,000	12,000
Miscellaneous.....	31,300	28,400	59,700
Subtotal.....	343,600	312,000	655,600
Total direct.....	944,500	372,100	1,316,600
Field indirect.....			145,900
Total construction.....			1,462,500
Engineering.....			55,900
Overhead and administration.....			55,900
			1,574,300
Contingency.....			123,100
			1,697,400
Fee.....			67,700
Total.....			1,765,100

TABLE D-7. - Equipment cost summary, bagging section

Item	Cost		Total cost
	Material	Labor	
Conveyor, 1.....	\$1,500	\$200	\$1,700
Storage tank, 1.....	37,500	3,800	41,300
Belt feeder, 1.....	2,000	200	2,200
Weighing, bagging and sealing unit, 1..	12,000	1,200	13,200
Subtotal.....	53,000	5,400	58,400
Foundations.....	5,300	6,600	11,900
Structures.....	4,000	2,000	6,000
Buildings.....	14,600	10,600	25,200
Instrumentation.....	1,100	600	1,700
Electrical.....	5,300	4,000	9,300
Piping.....	1,100	600	1,700
Painting.....	300	900	1,200
Miscellaneous.....	2,800	2,500	5,300
Subtotal.....	34,500	27,800	62,300
Total direct.....	87,500	33,200	120,700
Field indirect.....			18,100
Total construction.....			138,800
Engineering.....			6,900
Overhead and administration.....			6,900
			152,600
Contingency.....			15,300
			167,900
Fee.....			8,400
Total.....			176,300

TABLE D-8. - Equipment cost summary, scrubbing section

Item	Cost		Total cost
	Material	Labor	
Scrubbing unit, including blower, rubber lined pump, polyvinyl chloride piping, and stack, 1.....	\$4,500	\$500	\$5,000
Subtotal.....	4,500	500	5,000
Foundations.....	500	600	1,100
Structures.....	300	200	500
Buildings.....	1,000	1,000	2,000
Instrumentation.....	100	100	200
Electrical.....	500	400	900
Piping.....	100	100	200
Painting.....	100	300	400
Miscellaneous.....	300	300	600
Subtotal.....	2,900	3,000	5,900
Total direct.....	7,400	3,500	10,900
Field indirect.....			1,600
Total construction.....			12,500
Engineering.....			600
Overhead and administration.....			600
			13,700
Contingency.....			1,400
			15,100
Fee.....			800
Total.....			15,900

TABLE D-9. - Working capital

Item	Cost	Percent
Raw materials and utilities.....60 days..	\$1,180,600	69.9
Direct labor and supervision.....3 months..	76,700	4.5
Payroll overhead.....3 months..	20,900	1.2
Operating supplies and spare parts.....3 months..	115,800	6.9
Indirect cost.....4 months..	102,700	6.1
Fixed cost.....0.5 percent of insurance base..	38,000	2.3
Miscellaneous expense.....	153,500	9.1
Total.....	1,688,200	100.0

TABLE D-10. - Estimated annual operating cost

Item	Cost per ton	Annual cost	Percent
Direct cost:			
Raw materials and utilities:			
Fuel.....	\$8.47	\$352,500	4.0
Power.....	3.54	147,500	1.7
Fluosilicic acid (H_2SiF_6).....	84.07	3,500,000	39.7
Aluminum hydroxide ($\text{Al}(\text{OH})_3$).....	74.07	3,083,700	35.0
Subtotal.....	-	7,083,700	80.4
Direct labor and supervision:			
Labor.....	4.55	189,300	2.1
Supervision.....	1.30	54,000	0.7
Subtotal.....	-	243,300	2.8
Plant maintenance:			
Electrician-mechanic.....	1.52	63,400	0.7
Material (spare parts) (5 percent of equipment costs).....	9.02	375,400	4.3
Subtotal.....	-	438,800	5.0
Payroll overhead (25 percent of payroll).....	2.01	83,700	1.0
Operating supplies (20 percent of plant maintenance).....	2.11	87,800	1.0
Total direct costs ¹	190.66	7,937,300	90.2
Indirect cost (administration and general overhead): 40 percent labor, maintenance, and supplies.....	7.40	308,000	3.5
Fixed cost:			
Taxes and insurance (2 percent of plant cost)..	3.65	152,100	1.7
Depreciation and deferred expenses (5 percent of subtotal for depreciation).....	9.87	410,800	4.6
Total annual operating cost ¹	211.58	8,808,200	100.0

¹Figures may not add to totals shown because of rounding.

APPENDIX E.--COST ANALYSIS OF A 100,000-TON-PER-YEAR PLANT

TABLE E-1. - Calculation of selling price of aluminum fluoride

12 percent discounted cash flow rate of return (20 years):	
R = \$18,340,300/7.469.....	\$2,455,200
Depreciation.....	<u>763,700</u>
Net profit.....	1,691,500
Federal income tax (50 percent taxable income):	
Gross profit.....	3,383,000
Net operating cost.....	<u>16,037,000</u>
Sales.....	19,420,000
Taxes:	
Taxable income.....	3,383,000
Federal income tax.....	<u>1,691,500</u>
Net profit.....	1,691,500
Cash flow:	
Net profit.....	1,691,500
Depreciation.....	<u>763,700</u>
Total.....	2,455,200
Sales price per ton AlF_3 (\$19,420,000/83,260 ¹).....	233.25
¹ Product (AlF_3) output, tpy.	

Note: Formula:
$$P = R \frac{(1+r)^n}{r(1+r)^n}$$

where P = total capital requirements,

R = present value of P due in 20 years at 12 percent compound interest,

r = 12 percent,

n = 20 years,

and R = P/7.469 (present value of \$1.00 due in 20 years at 12 percent interest).

TABLE E-2. - Financial analysis

Revenue from sales.....	\$19,420,000
Operating cost.....	16,037,000
Gross profit (taxable income).....	3,383,000
Federal income tax, 50 percent.....	1,691,500
Net profit.....	1,691,500
ANNUAL CASH FLOW	
Net profit.....	1,691,500
Depreciation.....	763,700
Cash flow.....	2,455,200

TABLE E-3. - Total capital requirements

Unit	Cost	Percent
Reaction section.....	\$5,031,800	27.4
Crystallization section.....	3,574,600	19.5
Drying section.....	2,383,200	12.9
Bagging section.....	324,700	1.8
Scrubbing section.....	17,200	.1
Subtotal.....	11,331,500	61.7
Plant facilities.....	1,133,200	6.2
Plant utilities.....	1,699,700	9.3
Total plant cost (insurance and tax bases).....	14,164,400	77.2
Interest during construction.....	1,133,200	6.2
Subtotal for depreciation.....	15,297,600	83.4
Working capital.....	3,042,700	16.6
Total investment.....	18,340,300	100.0

TABLE E-4. - Equipment cost summary, reaction section

Item	Cost		Total cost
	Material	Labor	
Storage tank (H_2SiF_6), 4.....	\$448,000	\$44,800	\$492,800
Pump and motor, 1.....	2,600	300	2,900
Steam boiler, 2.....	96,000	9,600	105,600
Heating and measuring tank, 1.....	4,000	400	4,400
Heat exchanger, 1.....	9,200	900	10,100
Storage tank ($\text{Al}(\text{OH})_3$), 2.....	166,000	16,600	182,600
Screw conveyor, 1.....	2,100	200	2,300
Measuring and feed bin tank, 1.....	2,300	200	2,500
Reactor and agitator, 1.....	25,100	2,500	27,600
Feed storage tank ($\text{AlF}_3 + \text{SiO}_2$), 1.....	6,000	600	6,600
Centrifuge, 10.....	810,000	81,000	891,000
Subtotal.....	1,571,300	157,100	1,728,400
Foundations.....	157,100	196,400	353,500
Structures.....	117,800	58,900	176,700
Buildings.....	314,300	314,300	628,600
Instrumentation.....	31,400	15,700	47,100
Electrical.....	157,100	117,800	274,900
Piping.....	31,400	15,700	47,100
Painting.....	7,900	23,700	31,600
Miscellaneous.....	81,700	74,300	156,000
Subtotal.....	898,700	816,800	1,715,500
Total direct.....	2,470,000	973,900	3,443,900
Field indirect.....			516,600
Total construction.....			3,960,500
Engineering.....			198,000
Overhead and administration.....			198,000
			4,356,500
Contingency.....			435,700
			4,792,200
Fee.....			239,600
Total.....			5,031,800

TABLE E-5. - Equipment cost summary, crystallization section

Item	Cost		Total cost
	Material	Labor	
Crystallizers, 12.....	\$301,200	\$30,100	\$331,300
Screw conveyor, 1.....	2,500	300	2,800
Centrifuge, 10.....	810,000	81,000	891,000
Screw conveyor, 1.....	2,500	300	2,800
Subtotal.....	1,116,200	111,700	1,227,900
Foundations.....	111,600	139,500	251,100
Structures.....	83,700	41,900	125,600
Buildings.....	223,200	223,200	446,400
Instrumentation.....	22,300	11,200	33,500
Electrical.....	111,600	83,700	195,300
Piping.....	22,300	11,200	33,500
Painting.....	5,600	16,800	22,400
Miscellaneous.....	58,000	52,800	110,800
Subtotal.....	638,300	580,300	1,218,600
Total direct.....	1,754,500	692,000	2,446,500
Field indirect.....			367,000
Total construction.....			2,813,500
Engineering.....			140,700
Overhead and administration.....			140,700
			3,094,900
Contingency.....			309,500
			3,404,400
Fee.....			170,200
Total.....			3,574,600

TABLE E-6. - Equipment cost summary, drying section

Item	Cost		Total cost
	Material	Labor	
Storage tank, 1.....	\$93,000	\$9,300	\$102,300
Screw conveyor, 1.....	2,400	200	2,600
Flash dryer and cyclone, 1.....	307,000	30,700	337,700
Fluid bed dryer, 1.....	207,500	20,700	228,200
Flash dryer and cyclone, 1.....	75,300	7,500	82,800
Heating unit, 1.....	2,000	200	2,200
Blower, 1.....	16,000	1,600	17,600
Compressor, 1.....	24,200	2,400	26,600
Cooler, 1.....	27,000	2,700	29,700
Subtotal.....	754,400	75,300	829,700
Foundations.....	73,900	92,400	166,300
Structures.....	55,400	27,700	83,100
Buildings.....	147,800	147,800	295,600
Instrumentation.....	14,800	7,400	22,200
Electrical.....	73,900	55,400	129,300
Piping.....	14,800	7,400	22,200
Painting.....	3,700	11,100	14,800
Miscellaneous.....	38,400	34,900	73,300
Subtotal.....	422,700	384,100	806,800
Total direct.....	1,177,100	459,400	1,636,500
Field indirect.....			242,900
Total construction.....			1,879,400
Engineering.....			93,100
Overhead and administration.....			93,100
			2,065,600
Contingency.....			204,900
			2,270,500
Fee.....			112,700
Total.....			2,383,200

TABLE E-7. - Equipment cost summary, bagging section

Item	Cost		Total cost
	Material	Labor	
Conveyor, 1.....	\$1,500	\$200	\$1,700
Storage tank, 1.....	64,300	6,400	70,700
Belt feeder, 1.....	2,700	300	3,000
Weighing, bagging and sealing unit, 2..	24,000	2,400	26,400
Subtotal.....	92,500	9,300	101,800
Foundations.....	9,300	11,600	20,900
Structures.....	6,900	3,500	10,400
Buildings.....	18,600	18,600	37,200
Instrumentation.....	1,900	9,500	11,400
Electrical.....	9,300	6,900	16,200
Piping.....	1,900	9,500	11,400
Painting.....	500	1,500	2,000
Miscellaneous.....	4,800	6,100	10,900
Subtotal.....	53,200	67,200	120,400
Total direct.....	145,700	76,500	222,200
Field indirect.....			33,300
Total construction.....			255,500
Engineering.....			12,800
Overhead and administration.....			12,800
			281,100
Contingency.....			28,100
			309,200
Fee.....			15,500
Total.....			324,700

TABLE E-8. - Equipment cost summary, scrubbing section

Item	Cost		Total cost
	Material	Labor	
Scrubbing unit, including blower, rubber lined pump, polyvinyl chloride piping, and stack, 1.....	\$5,200	\$500	\$5,700
Subtotal.....	5,200	500	5,700
Foundations.....	500	600	1,100
Structures.....	400	200	600
Buildings.....	1,000	1,000	2,000
Instrumentation.....	100	100	200
Electrical.....	500	400	900
Piping.....	100	100	200
Painting.....	100	300	400
Miscellaneous.....	300	300	600
Subtotal.....	3,000	3,000	6,000
Total direct.....	8,200	3,500	11,700
Field indirect.....			1,800
Total construction.....			13,500
Engineering.....			700
Overhead and administration.....			700
			14,900
Contingency.....			1,500
			16,400
Fee.....			800
Total.....			17,200

TABLE E-9. - Working capital

Item	Cost	Percent
Raw materials and utilities.....60 days..	\$2,187,700	71.9
Direct labor and supervision.....3 months..	97,900	3.2
Payroll overhead.....3 months..	27,800	.9
Operating supplies and spare parts.....3 months..	215,300	7.1
Indirect cost.....4 months..	166,900	5.5
Fixed cost.....0.5 percent of insurance base..	70,700	2.3
Miscellaneous expense.....	276,400	9.1
Total.....	3,042,700	100.0

TABLE E-10. - Estimated annual operating cost

Item	Cost per ton	Annual cost	Percent
Direct cost:			
Raw materials and utilities:			
Fuel.....	\$8.47	\$705,000	4.4
Power.....	3.54	295,000	1.8
Fluosilicic acid (H_2SiF_6).....	78.07	6,500,000	40.5
Aluminum hydroxide ($\text{Al}(\text{OH})_3$).....	67.58	5,626,400	35.1
Subtotal.....	-	13,126,400	81.8
Direct labor and supervision:			
Labor.....	3.28	273,300	1.7
Supervision.....	.65	54,000	.3
Subtotal.....	-	327,300	2.0
Plant maintenance:			
Electrician-mechanic.....	.76	63,400	0.4
Material (spare parts) (5 percent of equipment costs).....	8.49	707,200	4.4
Subtotal.....	-	770,600	4.8
Payroll overhead (25 percent of payroll).....	1.34	111,200	0.7
Operating supplies (20 percent of plant maintenance).....	1.85	154,100	1.0
Total direct costs ¹	174.03	14,489,600	90.3
Indirect cost (administration and general overhead): 40 percent labor, maintenance, and supplies.....	6.01	500,800	3.1
Fixed cost:			
Taxes and insurance (2 percent of plant cost).	3.40	282,900	1.8
Depreciation and deferred expenses (5 percent of subtotal for depreciation).....	9.17	763,700	4.8
Total annual operating cost ¹	192.61	16,037,000	100.0

¹Figures may not add to totals shown because of rounding.

TABLE E-11. - General manning table

Unit and personnel	Shifts			Man shifts per day	Wages, dollars per man per hour	Wages, dollars per day	Days per year	Annual cost, dollars	Salaried workers, dollars per year	Total annual cost, dollars
	Day	Eve-ning	Night							
Supervision:										
Superintendent (chemical engineer)...	1	-	-	1	-	-	-	-	18,000	-
Plant foremen.....	1	1	1	3	-	-	-	-	36,000	-
Subtotal.....	-	-	-	4	-	-	-	-	54,000	54,000
Services:										
Office manager-bookkeeper.....	1	1	1	3	-	-	-	-	24,000	-
Clerk-typist.....	2	2	1	5	-	-	-	-	30,000	-
Subtotal.....	-	-	-	8	-	-	-	-	54,000	54,000
Plant operation:										
Equipment operator.....	4	4	4	12	3.25	26.00	330	103,000	-	-
Plant helpers.....	5	5	5	15	3.00	24.00	330	118,800	-	-
Baggers.....	2	2	2	6	3.25	26.00	330	51,500	-	-
Subtotal.....	-	-	-	33	-	-	-	273,300	-	273,300
Maintenance: Electrician-mechanic.....	2	2	2	6	4.00	32.00	330	63,400	-	63,400
Total cost.....	-	-	-	-	-	-	-	-	-	444,700

ECONOMIC AVAILABILITY OF BYPRODUCT FLUORINE IN THE UNITED STATES

(In Two Sections)

2. Utilization of Byproduct Fluosilicic Acid in the Manufacture of Calcium Fluoride

by

Walter C. Lorenz¹

ABSTRACT

Estimated cost studies are made for five different size plants that produce acid-grade calcium fluoride from waste fluosilicic acid recovered from wet process phosphoric acid and superphosphate fertilizer manufacture. Plant capacities are designed to use 5, 10, 25, 50, and 100 thousand tons of waste material annually, and the calculated selling price per ton for acid-grade calcium fluoride required to realize a cash flow of 12 percent from each plant was \$408, \$247, \$133, \$98, and \$74, respectively. Plants with annual capacities of 100 thousand tons or more can be operated to produce a product that could be sold at current price levels. The cost of salvaging the byproduct fluosilicic acid is not included in this cost analysis.

INTRODUCTION

The purpose of this study is to make an economic and technical evaluation of a chemical process for the production of acid-grade calcium fluoride (CaF_2) from waste fluosilicic acid (H_2SiF_6), which is a byproduct in the manufacture of wet process phosphoric acid and superphosphate fertilizer. Evaluations are made for five different size plants, which are designed to compare the required per-ton-product selling price on the basis of plant size. The required selling price is calculated to yield a 12-percent rate of return on investment. Since the availability of fluorine as byproduct H_2SiF_6 in the United States is discussed in detail in Section 1, it will not be repeated in Section 2.

The process used as a basis for design in this study was developed in a laboratory investigation by Metallurgy Research Center of the Bureau of Mines in Albany, Oreg.²

Each plant is assumed to be located as an integrated addition adjacent to one or more wet process phosphoric acid or superphosphate fertilizer manufacturing plants. It is assumed that the waste byproduct H_2SiF_6 will be

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²Blake, H. E., Jr., W. C. Thomas, K. W. Moser, J. L. Reuss, and H. Dolezal. Utilization of Waste Fluosilicic Acid (In Two Sections). Section 1. Laboratory Investigations. Section 2. Cost Evaluations. BuMines Rept. of Inv. 7502, 1971, 60 pp.

obtained directly from the manufacturing plant without cost, which includes scrubbing and salvaging of the H_2SiF_6 . Liquid anhydrous ammonia (NH_3) will be purchased and delivered in tank cars. High purity calcium oxide (CaO) will be purchased and delivered in carload lots. These three chemicals are the raw materials for CaF_2 production.

PROCESS DESCRIPTION

A flowsheet for the production of acid-grade CaF_2 is shown in figure 4. The flowsheet represents five different size plants with an input of 5, 10, 25, 50, and 100 thousand tons per year of a 15-percent aqueous solution of H_2SiF_6 .

The process for making CaF_2 from H_2SiF_6 is based on (1) the removal of silica (SiO_2) by precipitation with NH_3 ; and, (2) the subsequent precipitation of CaF_2 from ammonium fluoride (NH_4F) using calcium hydroxide (Ca(OH)_2). The reaction for the two operations are as follows:

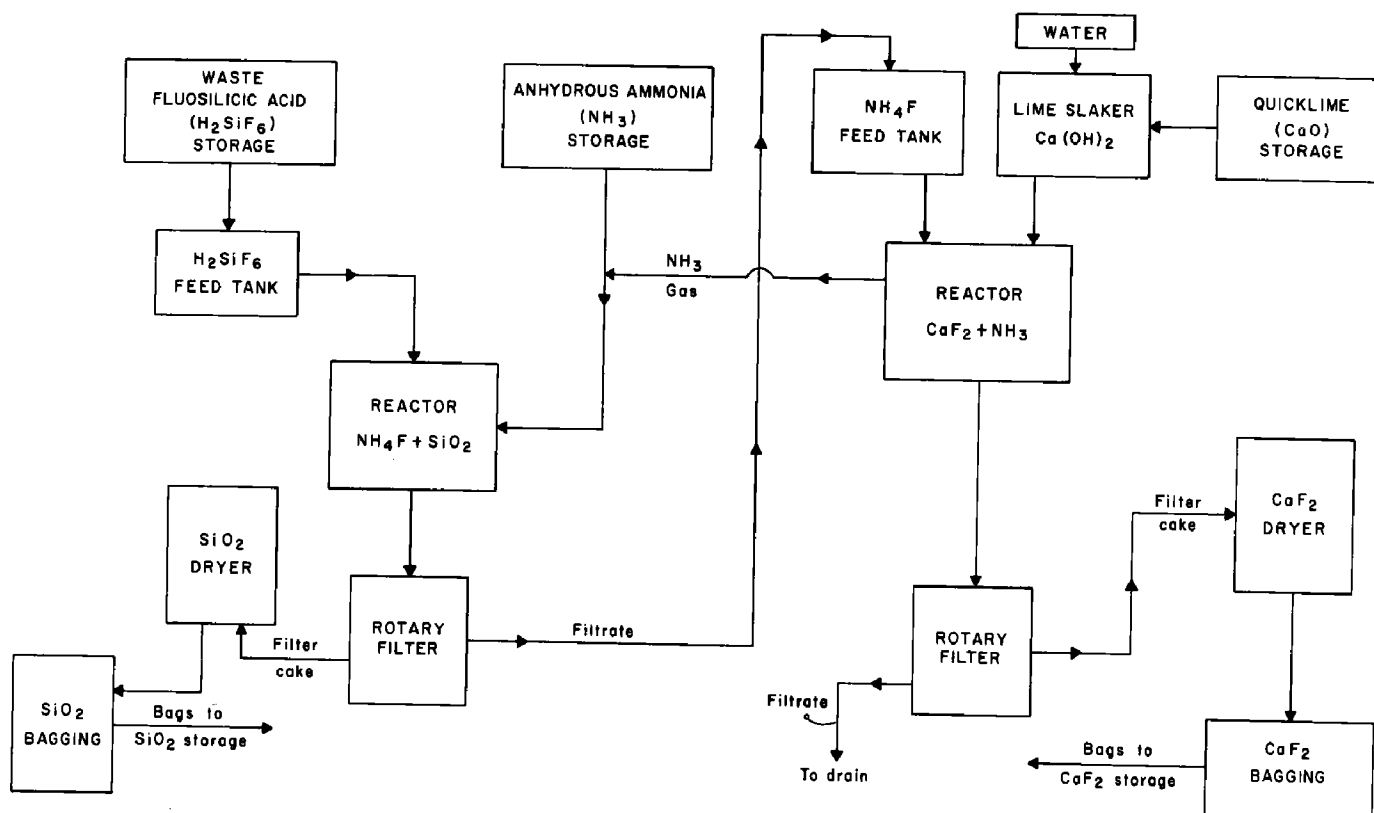
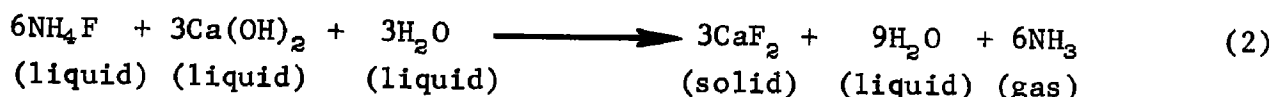
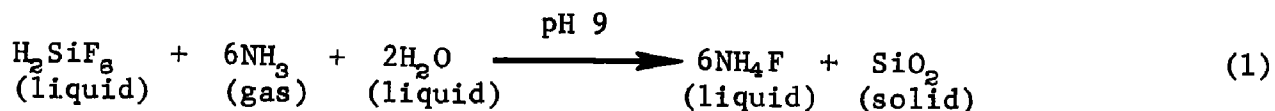


FIGURE 4. - Process Flow Diagram for Calcium Fluoride.

The 15 percent aqueous solution of H_2SiF_6 is neutralized with NH_3 and raised to pH 9 to precipitate all SiO_2 from the solution, forming soluble NH_4F . The reaction is carried out in a stainless steel reactor, equipped with an agitator. The reaction temperature is controlled at about 100°F to hold NH_3 in solution. The reaction mixture is filtered to remove the solid SiO_2 , which is dried, bagged, and stored until sold; the filtrate NH_4F is pumped to a feed tank above a second reactor.

The NH_4F filtrate is reacted with $\text{Ca}(\text{OH})_2$ to produce CaF_2 and NH_3 . The reaction is controlled at about 160°F with constant agitation. When the reaction is completed, the mixture is filtered to remove the CaF_2 , which is dried, bagged, and stored until shipped. The NH_3 evolved from the reaction is returned to the process for the additional production of NH_4F and SiO_2 .

CAPITAL COSTS

Estimated capital investments are summarized in tables F-3, G-3, H-3, I-3, and J-3 for plant sizes 5, 10, 25, 50, and 100 thousand tons per year of input H_2SiF_6 , respectively. Capital investments include process equipment, facilities, utilities, piping, construction costs, and other direct and indirect costs (appendixes F through J).

OPERATING COSTS

Annual operating costs for the five plants are given in tables F-9, G-9, H-9, I-9, and J-9. Raw materials and utilities costs are based on current 1971 quotations. Labor was calculated on the basis of \$3.75 per hour and maintenance at \$3.80 per man-hour. Other costs include overhead, plant supplies, indirect costs, maintenance supplies, taxes, insurance, and depreciation (tables F-3, G-3, H-3, I-3, and J-3). Credit was taken for the SiO_2 production, as well as for NH_3 released from the reaction of $\text{Ca}(\text{OH})_2$ and NH_4F .

The working capital shown in tables F-8, G-8, H-8, I-8, and J-8 include a 60-day supply of raw materials, a 3-month payroll, overhead, supplies, maintenance material, and indirect, fixed, and miscellaneous costs.

The comparative sales prices are calculated for each plant (tables F-1, G-1, H-1, I-1, and J-1). Figure 5 shows the selling price of acid-grade calcium fluoride at five production design levels. The curve was generated from the selling price data based on the cost evaluations for the five plants. The price of the product at each output level is shown on the curve, which is represented by $Y_c = aX^b$. The price-output relationship along the curve at various design production levels should be interpreted with caution in view of the small number of observations used in generating the curve.

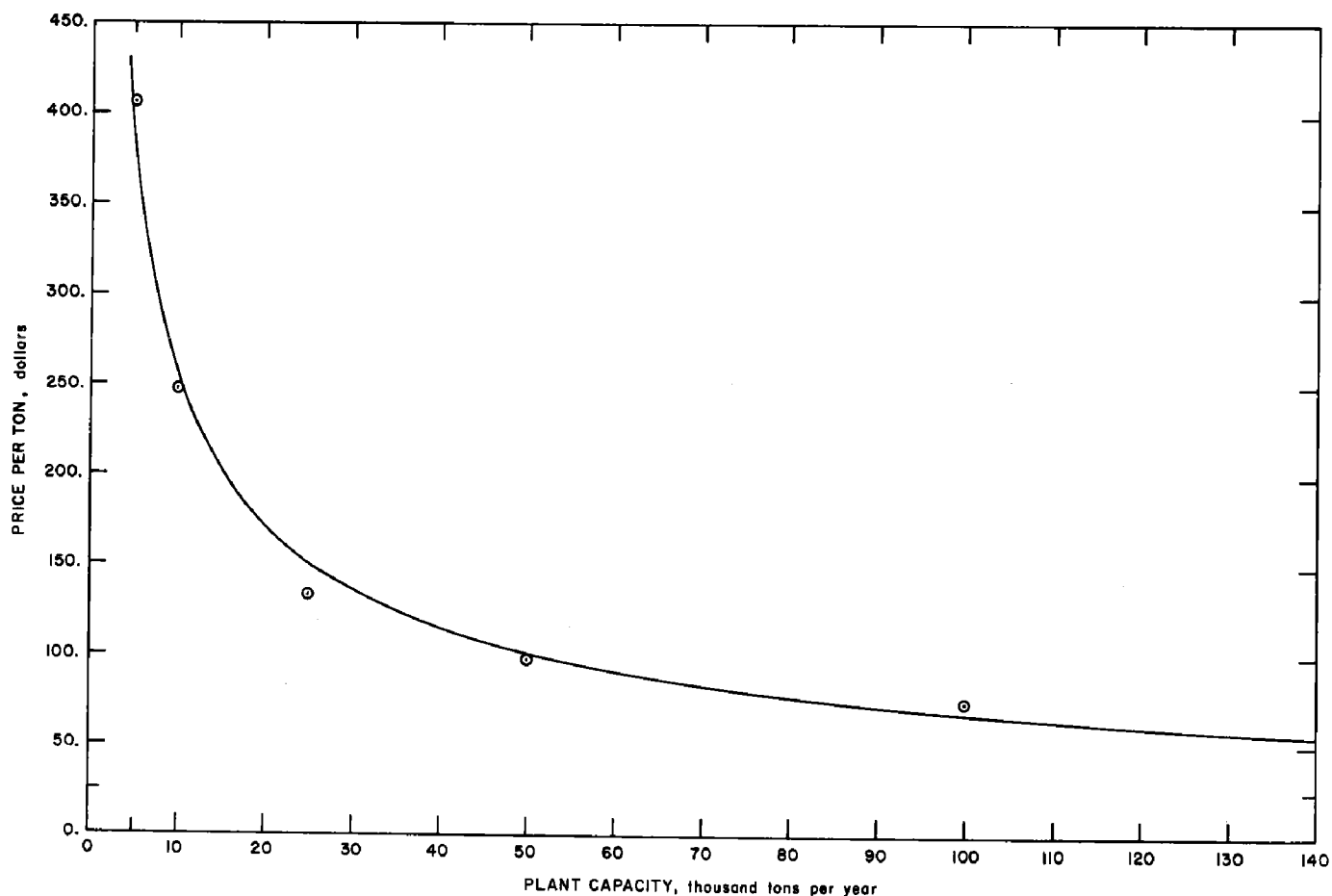


FIGURE 5. - Price-Output Curve for Calcium Fluoride.

CONCLUSIONS

This report indicates that, at various design production levels, profits of 12 percent are possible at the indicated price levels for output. The plants are designed to produce a profitable product at the prices indicated per ton of output; however, the selling prices for plants less than 100 thousand tons are far in excess of current 1971 domestic market prices (\$67 to \$81 per ton in carload lots in bags). Therefore, at these computed figures and designed operating levels, these plants do not produce a competitive product at current domestic prices. However, the price per ton of \$74 for the 100 thousand ton plant is within the range of the current market price.

APPENDIX F.--COST ANALYSIS OF A 5,000-TON-PER-YEAR PLANT

TABLE F-1. - Selling price of calcium fluoride

12 percent discounted cash flow rate of return (11 years):	
R = \$648,200/5.938.....	\$109,200
Depreciation.....	<u>50,500</u>
Net profit.....	58,700
Federal income tax (50 percent of taxable income):	
Gross profit.....	117,400
Net operating cost.....	<u>383,800</u>
Sales.....	501,200
Taxes:	
Taxable income.....	117,400
Federal income tax.....	<u>58,700</u>
Net profit.....	58,700
Cash flow:	
Net profit.....	58,700
Depreciation.....	<u>50,500</u>
Total.....	109,200
Sales price per ton CaF_2 (\$501,200/1,227 ¹).....	408.48
¹ Product (CaF_2) output, tpy.	

Note: Formula: $P = R \frac{(1+r)^n}{r(1+r)^n}$

where P = total capital requirements,

R = present value of P due in 11 years at 12 percent compound interest,

r = 12 percent,

n = 11 years,

and R = P/5.938 (present value of \$1.00 due in 11 years at 12 percent interest).

TABLE F-2. - Financial analysis

Revenue from sales.....	\$501,200
Operating cost.....	388,100
	113,100
Credit.....	4,300
Gross profit (taxable income).....	117,400
Federal income tax, 50 percent.....	58,700
Net profit.....	58,700
ANNUAL CASH FLOW	
Net profit.....	58,700
Depreciation.....	50,500
Cash flow.....	109,200

TABLE F-3. - Total capital requirements

Unit	Cost	Percent
Reaction section (NH ₄ F).....	\$231,000	35.6
Drying and bagging section (SiO ₂).....	38,000	5.9
Reaction section (CaF ₂).....	155,800	24.0
Drying and bagging section (CaF ₂).....	37,400	5.8
Subtotal.....	462,200	71.3
Plant facilities.....	34,700	5.4
Plant utilities.....	46,200	7.1
Total plant cost (insurance and tax bases).....	543,100	83.9
Interest during construction.....	11,600	1.8
Subtotal for depreciation.....	554,700	85.7
Working capital.....	93,500	14.3
Total investment.....	648,200	100.0

TABLE F-4. - Equipment cost summary for ammonia reactor section

Item	Cost		Total cost
	Material	Labor	
Storage tank (H_2SiF_6), 1.....	\$31,000	\$3,100	\$34,100
Pump and motor (H_2SiF_6), 1.....	2,400	600	3,000
Storage tank (NH_3), 1.....	15,100	1,500	16,600
Feed tank (H_2SiF_6), 1.....	4,000	400	4,400
Reactor and agitator (NH_4F), 1.....	13,800	1,400	15,200
Filter, vacuum rotary drum (SiO_2), 1...	5,200	500	5,700
Subtotal.....	71,500	7,500	79,000
Foundations.....	3,600	4,800	8,400
Structures.....	4,300	2,200	6,500
Buildings.....	2,900	2,900	5,800
Instrumentation.....	5,000	2,000	7,000
Electrical.....	5,000	3,800	8,800
Piping.....	25,000	13,000	38,000
Painting.....	400	1,200	1,600
Miscellaneous.....	3,600	2,900	6,500
Subtotal.....	49,800	32,800	83,600
Total direct.....	121,300	40,300	161,600
Field indirect.....			20,200
Total construction.....			181,800
Engineering.....			9,100
Overhead and administration.....			9,100
			200,000
Contingency.....			20,000
			220,000
Fee.....			11,000
Total.....			231,000

TABLE F-5. - Equipment cost summary for silica
drying and bagging section

Item	Cost		Total cost
	Material	Labor	
Belt conveyor and motor, 1.....	\$1,900	\$200	\$2,100
Bucket elevator and motor, 1.....	1,500	200	1,700
Rotary dryer and burner, 1.....	3,000	300	3,300
Exhaust fan and motor, 1.....	600	200	800
Screw conveyor and motor, 1.....	400	100	500
Bucket elevator and motor, 1.....	1,500	200	1,700
Bagging machine and motor, 1.....	1,000	100	1,100
Bag storage area, 1.....	1,800	200	2,000
Fork lift truck, 1.....	4,100	400	4,500
Subtotal.....	15,800	1,900	17,700
Foundations.....	800	1,100	1,900
Structures.....	600	300	900
Buildings.....	800	800	1,600
Instrumentation.....	300	100	400
Electrical.....	900	700	1,600
Piping.....	800	400	1,200
Painting.....	100	300	400
Miscellaneous.....	600	500	1,100
Subtotal.....	4,900	4,200	9,100
Total direct.....	20,700	6,100	26,800
Field indirect.....			3,100
Total construction.....			29,900
Engineering.....			1,500
Overhead and administration.....			1,500
			32,900
Contingency.....			3,300
			36,200
Fee.....			1,800
Total.....			38,000

TABLE F-6. - Equipment cost summary for calcium fluoride reactor section with lime slaker

Item	Cost		Total cost
	Material	Labor	
Storage silo (CaO), 1.....	\$1,000	\$100	\$1,100
Screw conveyor and motor, 1.....	500	100	600
Bucket elevator and motor, 1.....	1,500	200	1,700
Feed hopper (CaO), 1.....	2,000	200	2,200
Water feed tank, 1.....	2,900	300	3,200
Lime slaker (Ca(OH) ₂), 1.....	7,600	800	8,400
Pump and motor (NH ₄ F), 1.....	2,400	600	3,000
Feed tank (NH ₄ F), 1.....	4,000	400	4,400
Reactor and agitator (CaF ₂), 1.....	19,600	2,000	21,600
Filter, vacuum rotary drum (CaF ₂), 1...	6,100	600	6,700
Agitator for filter tank, 1.....	700	100	800
Subtotal.....	48,300	5,400	53,700
Foundations.....	2,400	3,200	5,600
Structures.....	2,900	1,500	4,400
Buildings.....	1,900	1,900	3,800
Instrumentation.....	3,400	1,400	4,800
Electrical.....	3,400	2,600	6,000
Piping.....	16,900	8,500	25,400
Painting.....	200	600	800
Miscellaneous.....	2,400	1,900	4,300
Subtotal.....	33,500	21,600	55,100
Total direct.....	81,800	27,000	108,800
Field indirect.....			13,500
Total construction.....			122,300
Engineering.....			6,100
Overhead and administration.....			6,100
			134,900
Contingency.....			13,500
			148,400
Fee.....			7,400
Total.....			155,800

TABLE F-7. - Equipment cost summary for calcium fluoride
drying and bagging section

Item	Cost		Total cost
	Material	Labor	
Belt conveyor and motor, 1.....	\$1,900	\$200	\$2,100
Bucket elevator and motor, 1.....	1,500	200	1,700
Rotary dryer and burner, 1.....	5,600	600	6,200
Exhaust fan and motor, 1.....	1,400	400	1,800
Screw conveyor and motor, 1.....	500	100	600
Bucket elevator and motor, 1.....	1,500	200	1,700
Bagging machine and motor, 1.....	1,000	100	1,100
Bag storage area, 1.....	1,800	200	2,000
Subtotal.....	15,200	2,000	17,200
Foundations.....	800	1,100	1,900
Structures.....	600	300	900
Buildings.....	800	800	1,600
Instrumentation.....	300	100	400
Electrical.....	900	700	1,600
Piping.....	800	400	1,200
Painting.....	100	300	400
Miscellaneous.....	600	500	1,100
Subtotal.....	4,900	4,200	9,100
Total direct.....	20,100	6,200	26,300
Field indirect.....			3,100
Total construction.....			29,400
Engineering.....			1,500
Overhead and administration.....			1,500
			32,400
Contingency.....			3,200
			35,600
Fee.....			1,800
Total.....			37,400

TABLE F-8. - Working capital

Item	Capital	Percent
Raw materials and utilities.....60 days..	\$5,000	5.3
Direct labor and supervision.....3 months..	43,800	46.8
Payroll overhead--25 percent.....3 months..	11,000	11.8
Operating supplies.....3 months..	1,200	1.3
Maintenance materials.....3 months..	500	0.5
Indirect cost.....4 months..	24,300	26.0
Fixed cost.....0.5 percent of insurance base..	2,700	2.9
Miscellaneous expense.....	5,000	5.4
Total.....	93,500	100.0

TABLE F-9. - Estimated annual operating cost

Item	Cost per ton	Unit Cost	Total	Per- cent
Direct cost:				
Raw materials and utilities:				
Fuel (43 gpd x 330 dpy x \$0.1022/gal).....	\$1.14	\$1,400	-	0.4
Power (21 kw x 7,920 hpy x \$0.03084/kwh)....	4.16	5,100	-	1.3
NH ₃ (2.43 tpd x 330 dpy x \$68.00/ton).....	44.42	54,500	-	14.0
CaO (2.66 tpd x 330 dpy x \$17.50/ton).....	12.55	15,400	-	4.0
Credit recycle NH ₃ (2.07 tpd x 330 dpy x \$68.00/ton).....	-37.82	-46,400	30,000	-12.0
Direct labor and supervision:				
Labor (96 man-hour day x \$3.75 x 365 dpy)...	107.09	131,400	-	33.8
Supervision (15 percent of labor).....	16.06	19,700	151,100	5.1
Plant maintenance:				
Maintenance labor (two men at \$3.80/man-hour)	16.30	20,000	-	5.2
Supervision (20 percent of maintenance labor)	3.26	4,000	-	1.0
Maintenance material.....	1.63	2,000	26,000	0.5
Payroll overhead (25 percent of payroll).....	35.70	43,800	43,800	11.3
Operating supplies (20 percent of maintenance)	3.91	4,800	4,800	1.2
Total direct cost.....	-	-	255,700	65.9
Indirect cost: Administration and general over- head (40 percent labor, maintenance, and supplies).....	59.33	72,800	72,800	18.8
Fixed cost:				
Taxes and insurance (2 percent of plant cost).	7.50	9,200	-	-
Depreciation (9.1 percent of subtotal for depreciation).....	41.16	50,500	59,700	15.3
Subtotal operating.....	316.39	-	388,200	100.0
Credits (SiO ₂ bagged, 325 tons at \$13.50/ton)....	-3.59	-	-4,400	-
Total annual operating cost.....	312.80	-	383,800	-

APPENDIX G.--COST ANALYSIS OF A 10,000-TON-PER-YEAR PLANT

TABLE G-1. - Selling price of calcium fluoride

12 percent discounted cash flow rate of return (11 years):	
R = \$938,500/5.938.....	\$158,000
Depreciation.....	<u>76,300</u>
Net profit.....	81,700
Federal income tax (50 percent of taxable income):	
Gross profit.....	163,400
Net operating cost.....	<u>443,600</u>
Sales.....	607,000
Taxes:	
Taxable income.....	163,400
Federal income tax.....	<u>81,700</u>
Net profit.....	81,700
Cash flow:	
Net profit.....	81,700
Depreciation.....	<u>76,300</u>
Total.....	158,000
Sales price per ton CaF ₂ (\$607,000/2,454 ¹).....	247.35
¹ Product (CaF ₂) output, tpy.	

Note: Formula: $P = R \frac{(1+r)^n}{r(1+r)^n}$

where P = Total capital requirements,

R = present value of P due in 11 years at 12 percent compound interest,

r = 12 percent,

n = 11 years,

and R = P/5.938 (present value of \$1.00 due in 11 years at 12 percent interest).

TABLE G-2. - Financial analysis

Revenue from sales.....	\$607,000
Operating cost.....	452,200
	154,800
Credit.....	8,600
Gross profit (taxable income).....	163,400
Federal income tax, 50 percent.....	81,700
Net profit.....	81,700
ANNUAL CASH FLOW	
Net profit.....	81,700
Depreciation.....	76,300
Cash flow.....	158,000

TABLE G-3. - Total capital requirements

Unit	Cost	Percent
Reaction section (NH ₄ F).....	\$376,700	40.1
Drying and bagging section (SiO ₂).....	53,200	5.7
Reaction section (CaF ₂).....	205,300	21.9
Drying and bagging section (CaF ₂).....	56,200	6.0
Subtotal.....	691,400	73.7
Plant facilities.....	51,900	5.5
Plant utilities.....	74,300	7.9
Total plant cost (insurance and tax bases).....	817,600	87.1
Interest during construction.....	20,400	2.2
Subtotal for depreciation.....	838,000	89.3
Working capital.....	100,500	10.7
Total investment.....	938,500	100.0

TABLE G-4. - Equipment cost summary for ammonia reactor section

Item	Cost		Total cost
	Material	Labor	
Storage tank (H_2SiF_6), 1.....	\$43,300	\$4,300	\$47,600
Pump and motor (H_2SiF_6), 1.....	2,400	600	3,000
Storage tank (NH_3), 1.....	23,100	2,300	25,400
Feed tank (H_2SiF_6), 1.....	5,800	600	6,400
Reactor and agitator (NH_4F), 1.....	19,600	2,000	21,600
Cooling tower for water, 1.....	12,600	1,300	13,900
Filter, vacuum rotary drum (SiO_2), 1....	8,100	800	8,900
Subtotal.....	114,900	11,900	126,800
Foundations.....	5,700	7,600	13,300
Structures.....	6,900	3,500	10,400
Buildings.....	4,600	4,600	9,200
Instrumentation.....	8,000	3,200	11,200
Electrical.....	8,000	6,000	14,000
Piping.....	40,200	20,100	60,300
Painting.....	600	1,800	2,400
Miscellaneous.....	5,700	4,600	10,300
Subtotal.....	79,700	51,400	131,100
Total direct.....	194,600	63,300	257,900
Field indirect.....			38,700
Total construction.....			296,600
Engineering.....			14,800
Overhead and administration.....			14,800
			326,200
Contingency.....			32,600
			358,800
Fee.....			17,900
Total.....			376,700

TABLE G-5. - Equipment cost summary for silica drying and bagging section

Item	Cost		Total cost
	Material	Labor	
Belt conveyor and motor, 1.....	\$1,900	\$200	\$2,100
Bucket elevator and motor, 1.....	1,500	200	1,700
Rotary dryer and burner, 1.....	4,300	400	4,700
Exhaust fan and motor, 1.....	1,300	300	1,600
Screw conveyor and motor, 1.....	400	100	500
Bucket elevator and motor, 1.....	1,500	200	1,700
Bagging machine and motor, 1.....	2,500	300	2,800
Storage hopper above baggar, 1.....	1,600	200	1,800
Bag storage area, 1.....	2,100	200	2,300
Fork lift truck, 1.....	4,100	400	4,500
Subtotal.....	21,200	2,500	23,700
Foundations.....	1,100	1,500	2,600
Structures.....	900	500	1,400
Buildings.....	1,100	1,100	2,200
Instrumentation.....	400	200	600
Electrical.....	1,300	1,000	2,300
Piping.....	1,100	600	1,700
Painting.....	100	300	400
Miscellaneous.....	900	700	1,600
Subtotal.....	6,900	5,900	12,800
Total direct.....	28,100	8,400	36,500
Field indirect.....			5,400
Total construction.....			41,900
Engineering.....			2,100
Overhead and administration.....			2,100
			46,100
Contingency.....			4,600
			50,700
Fee.....			2,500
Total.....			53,200

TABLE G-6. - Equipment cost summary for calcium fluoride reactor section with lime slaker

Item	Cost		Total cost
	Material	Labor	
Storage silo (CaO), 1.....	\$1,500	\$200	\$1,700
Screw conveyor and motor, 1.....	700	100	800
Bucket elevator and motor, 1.....	1,500	200	1,700
Feed hopper (CaO), 1.....	1,800	200	2,000
Water feed tank, 1.....	4,300	400	4,700
Lime slaker (Ca(OH) ₂), 1.....	10,700	1,100	11,800
Pump and motor (NH ₄ F), 1.....	2,400	600	3,000
Feed tank (NH ₄ F), 1.....	5,800	600	6,400
Reactor and agitator (CaF ₂), 1.....	24,200	2,400	26,600
Filter, vacuum rotary drum (CaF ₂), 1..	9,500	1,000	10,500
Subtotal.....	62,400	6,800	69,200
Foundations.....	3,100	4,100	7,200
Structures.....	3,700	1,900	5,600
Buildings.....	2,500	2,500	5,000
Instrumentation.....	4,400	1,800	6,200
Electrical.....	4,400	3,300	7,700
Piping.....	21,800	10,900	32,700
Painting.....	300	900	1,200
Miscellaneous.....	3,100	2,500	5,600
Subtotal.....	43,300	27,900	71,200
Total direct.....	105,700	34,700	140,400
Field indirect.....			21,100
Total construction.....			161,500
Engineering.....			8,100
Overhead and administration.....			8,100
			177,700
Contingency.....			17,800
			195,500
Fee.....			9,800
Total.....			205,300

TABLE G-7. - Equipment cost summary for calcium fluoride
drying and bagging section

Item	Cost		Total cost
	Material	Labor	
Belt conveyor and motor, 1.....	\$1,900	\$200	\$2,100
Bucket elevator and motor, 1.....	1,500	200	1,700
Rotary dryer and burner, 1.....	8,600	900	9,500
Exhaust fan and motor, 1.....	2,100	500	2,600
Screw conveyor and motor, 1.....	700	100	800
Bucket elevator and motor, 1.....	1,500	200	1,700
Bagging machine and motor, 1.....	2,500	300	2,800
Storage hopper above bagger, 1.....	1,600	200	1,800
Bag storage area, 1.....	2,100	200	2,300
Subtotal.....	22,500	2,800	25,300
Foundations.....	1,100	1,500	2,600
Structures.....	900	500	1,400
Buildings.....	1,100	1,100	2,200
Instrumentation.....	500	200	700
Electrical.....	1,400	1,100	2,500
Piping.....	1,100	600	1,700
Painting.....	100	300	400
Miscellaneous.....	900	700	1,600
Subtotal.....	7,100	6,000	13,100
Total direct.....	29,700	8,800	38,400
Field indirect.....			5,800
Total construction.....			44,200
Engineering.....			2,200
Overhead and administration.....			2,200
			48,600
Contingency.....			4,900
			53,500
Fee.....			2,700
Total.....			56,200

TABLE G-8. - Working capital

Item	Capital	Percent
Raw materials and utilities.....60 days..	\$9,900	9.9
Direct labor and supervision.....3 months..	43,800	43.6
Payroll overhead--25 percent.....3 months..	11,000	10.9
Operating supplies.....3 months..	1,200	1.2
Maintenance materials.....3 months..	800	0.8
Indirect cost.....4 months..	24,400	24.3
Fixed cost.....0.5 percent of insurance base..	4,100	4.0
Miscellaneous expense.....	5,300	5.3
Total.....	100,500	100.0

TABLE G-9. - Estimated annual operating cost

Item	Cost per ton	Unit cost	Total	Per- cent
Direct cost:				
Raw materials and utilities:				
Fuel (85 gpd × 330 dpy × \$0.1022/gal).....	\$1.18	\$2,900	-	0.6
Power (41 kw × 7,920 hpy × \$0.03084/kwh)..	4.07	10,000	-	2.1
NH ₃ (4.85 tpd × 330 dpy × \$65.00/ton).....	42.36	104,000	-	23.0
CaO (5.32 tpd × 330 dpy × \$17.50/ton).....	12.63	31,000	-	7.0
Credit recycle NH ₃ (4.12 tpd × 330 dpy × \$65.00/ton).....	-36.01	-88,400	\$59,500	-19.5
Direct labor and supervision:				
Labor (96 man-hour/day × \$3.75 × 365 dpy).	53.52	131,400	-	29.0
Supervision (15 percent of labor).....	8.02	19,700	151,100	4.4
Plant maintenance:				
Maintenance labor (two men at \$3.80/man- hour).....	8.15	20,000	-	4.4
Supervision (20 percent of maintenance labor).....	1.63	4,000	-	0.9
Maintenance material.....	1.26	3,100	27,100	0.7
Payroll overhead (25 percent of payroll)....	17.84	43,800	43,800	9.7
Operating supplies (20 percent of maintenance)	1.96	4,800	4,800	1.0
Total direct cost.....	-	-	286,300	63.3
Indirect cost: Administration and general overhead (40 percent of labor, maintenance, and supplies).....	29.82	73,200	73,200	16.2
Fixed cost:				
Taxes and insurance (2 percent of plant cost) .	6.68	16,400	-	3.6
Depreciation (9.1 percent of subtotal for depreciation).....	31.08	76,300	92,700	16.9
Subtotal operating.....	184.19	-	452,200	100.0
Credits (SiO ₂ bagged, 637 tons at \$13.50/ton).....	-3.42	-	-8,600	-
Total annual operating cost.....	180.77	-	443,600	-

APPENDIX H.--COST ANALYSIS OF A 25,000-TON-PER-YEAR PLANT

TABLE H-1. - Selling price of calcium fluoride

12 percent discounted cash flow rate of return (11 years):	
R = \$1,444,800/5.938.....	\$243,300
Depreciation.....	<u>120,600</u>
Net profit.....	122,700
Federal income tax (50 percent of taxable income):	
Gross profit.....	245,400
Net operating cost.....	<u>571,800</u>
Sales.....	817,200
Taxes:	
Taxable income.....	245,400
Federal income tax.....	<u>122,700</u>
Net profit.....	122,700
Cash flow:	
Net profit.....	122,700
Depreciation.....	<u>120,600</u>
Total.....	243,300
Sales price per ton CaF ₂ (\$817,200/6,136 ¹).....	133.18
¹ Product (CaF ₂) output, tpy.	

Note: Formula: $P = R \frac{(1+r)^n}{r(1+r)^n}$

where P = total capital requirements,

R = present value of P due in 11 years at 12 percent compound interest,

r = 12 percent,

n = 11 years,

and R = P/5.938 (present value of \$1.00 due in 11 years at 12 percent interest).

TABLE H-2. - Financial analysis

Revenue from sales.....	\$817,200
Operating cost.....	593,300
	223,900
Credit.....	21,500
Gross profit (taxable income).....	245,400
Federal income tax, 50 percent.....	122,700
Net profit.....	122,700
ANNUAL CASH FLOW	
Net profit.....	122,700
Depreciation.....	120,600
Cash flow.....	243,300

TABLE H-3. - Total capital requirements

Unit	Cost	Percent
Reaction section (NH ₄ F).....	\$568,300	39.3
Drying and bagging section (SiO ₂).....	65,900	4.6
Reaction section (CaF ₂).....	368,900	25.5
Drying and bagging section (CaF ₂).....	90,500	6.3
Subtotal.....	1,093,600	75.7
Plant facilities.....	82,000	5.7
Plant utilities.....	117,600	8.1
Total plant cost (insurance and tax bases).....	1,293,200	89.5
Interest during construction.....	32,300	2.2
Subtotal for depreciation.....	1,325,500	91.7
Working capital.....	119,300	8.3
Total investment.....	1,444,800	100.0

TABLE H-4. - Equipment cost summary for ammonia reactor section

Item	Cost		Total cost
	Material	Labor	
Storage tank (H_2SiF_6), 1.....	\$52,000	\$5,200	\$57,200
Pump and motor (H_2SiF_6), 2.....	4,800	1,200	6,000
Storage tank (NH_3), 2.....	40,200	4,000	44,200
Compressor--2 stage (NH_3), 1.....	15,000	4,000	19,000
Feed tank (H_2SiF_6), 2.....	7,000	700	7,700
Reactor and agitator (NH_4F), 2.....	27,600	2,800	30,400
Cooling tower for water, 1.....	12,600	1,300	13,900
Filter, vacuum rotary drum (SiO_2), 1...	12,900	1,300	14,200
Subtotal.....	172,100	20,500	192,600
Foundations.....	8,600	11,400	20,000
Structures.....	10,300	5,200	15,500
Buildings.....	6,800	6,800	13,600
Instrumentation.....	12,000	4,800	16,800
Electrical.....	12,000	9,000	21,000
Piping.....	60,200	30,100	90,300
Painting.....	900	2,700	3,600
Miscellaneous.....	8,600	6,900	15,500
Subtotal.....	119,400	76,900	196,300
Total direct.....	291,500	97,400	388,900
Field indirect.....			58,300
Total construction.....			477,200
Engineering.....			22,400
Overhead and administration.....			22,400
			492,000
Contingency.....			49,200
			541,200
Fee.....			27,100
Total			568,200

TABLE H-5. - Equipment cost summary for silica
drying and bagging section

Item	Cost		Total cost
	Material	Labor	
Belt conveyor and motor, 1.....	\$2,200	\$200	\$2,400
Bucket elevator and motor, 1.....	1,500	200	1,700
Rotary dryer and burner, 1.....	7,400	700	8,100
Exhaust fan and motor, 1.....	1,900	500	2,400
Screw conveyor and motor, 1.....	600	100	700
Bucket elevator and motor, 1.....	1,500	200	1,700
Bagging machine and motor, 1.....	2,500	300	2,800
Storage hopper above bagger, 1.....	1,600	200	1,800
Bag storage area, 1.....	3,000	300	3,300
Fork lift truck, 1.....	4,500	500	5,000
Subtotal.....	26,700	3,200	29,900
Foundations.....	1,300	1,700	3,000
Structures.....	1,100	600	1,700
Buildings.....	1,300	1,300	2,600
Instrumentation.....	500	200	700
Electrical.....	1,600	1,200	2,800
Piping.....	1,300	700	2,000
Painting.....	100	300	400
Miscellaneous.....	1,100	900	2,000
Subtotal.....	8,300	6,900	15,200
Total direct.....	35,000	10,100	45,100
Field indirect.....			6,800
Total construction.....			51,900
Engineering.....			2,600
Overhead and administration.....			2,600
			57,100
Contingency.....			5,700
			62,800
Fee.....			3,100
Total.....			65,900

TABLE H-6. - Equipment cost summary for calcium fluoride reactor section with lime slaker

Item	Cost		Total cost
	Material	Labor	
Storage silo (CaO), 1.....	\$2,500	\$300	\$2,800
Screw conveyor and motor, 1.....	1,000	100	1,100
Bucket elevator and motor, 1.....	1,500	200	1,700
Feed hopper (CaO), 1.....	1,800	200	2,000
Water feed tank, 1.....	4,300	400	4,700
Lime slaker (Ca(OH) ₂), 1.....	34,600	3,500	38,100
Pump and motor (NH ₄ F), 1.....	2,400	600	3,000
Feed tank (NH ₄ F), 2.....	8,800	900	9,700
Reactor and agitator (CaF ₂), 2.....	39,200	3,900	43,100
Filter, vacuum rotary drum (CaF ₂), 1....	16,200	1,600	17,800
Subtotal.....	112,300	11,700	124,000
Foundations.....	5,600	7,400	13,000
Structures.....	6,700	3,400	10,100
Buildings.....	4,500	4,500	9,000
Instrumentation.....	7,900	3,200	11,100
Electrical.....	7,900	5,900	13,800
Piping.....	39,300	19,700	59,000
Painting.....	600	1,800	2,400
Miscellaneous.....	5,600	4,500	10,100
Subtotal.....	78,100	50,400	128,500
Total direct.....	190,400	62,100	252,500
Field indirect.....			37,900
Total construction.....			290,400
Engineering.....			14,500
Overhead and administration.....			14,500
			319,400
Contingency.....			31,900
			351,300
Fee.....			17,600
Total.....			368,900

TABLE H-7. - Equipment cost summary for calcium fluoride
drying and bagging section

Item	Cost		Total cost
	Material	Labor	
Belt conveyor and motor, 1.....	\$2,200	\$200	\$2,400
Bucket elevator and motor, 1.....	1,500	200	1,700
Rotary dryer and burner, 1.....	16,000	1,600	17,600
Exhaust fan and motor, 1.....	3,000	800	3,800
Screw conveyor and motor, 1.....	700	100	800
Bucket elevator and motor, 1.....	1,500	200	1,700
Bagging machine and motor, 1.....	3,700	400	4,100
Storage hopper above bagger, 1.....	1,600	200	1,800
Bag storage area, 1.....	6,500	700	7,200
Subtotal.....	36,700	4,400	41,100
Foundations.....	1,800	2,400	4,200
Structures.....	1,500	800	2,300
Buildings.....	1,800	1,800	3,600
Instrumentation.....	700	300	1,000
Electrical.....	2,200	1,700	3,900
Piping.....	1,800	900	2,700
Painting.....	100	300	400
Miscellaneous.....	1,500	1,200	2,700
Subtotal.....	11,400	9,400	20,800
Total direct.....	48,100	13,800	61,900
Field indirect.....			9,300
Total construction.....			71,200
Engineering.....			3,600
Overhead and administration.....			3,600
			78,400
Contingency.....			7,800
			86,200
Fee.....			4,300
Total.....			90,500

TABLE H-8. - Working capital

Item	Capital	Percent
Raw materials and utilities.....60 days..	\$24,700	20.7
Direct labor and supervision.....3 months..	43,800	36.7
Payroll overhead--25 percent.....3 months..	11,000	9.2
Operating supplies.....3 months..	1,200	1.0
Maintenance materials.....3 months..	1,200	1.0
Indirect cost.....4 months..	24,600	20.6
Fixed cost.....0.5 percent of insurance base..	6,500	5.5
Miscellaneous expense.....	6,300	5.3
Total.....	119,300	100.0

TABLE H-9. - Estimated annual operating cost

Item	Cost per ton	Unit cost	Total	Per- cent
Direct cost:				
Raw materials and utilities:				
Fuel (214 gpd x 330 dpy x \$0.1022/gal)....	\$1.17	\$7,200	-	1.3
Power (104 kw x 7,920 hpy x \$0.03084/kwh)....	4.14	25,400	-	4.3
NH ₃ (12.12 tpd x 330 dpy x \$65.00/ton)....	42.37	260,000	-	43.8
CaO (13.3 tpd x 330 dpy x \$17.50/ton)....	12.52	76,800	-	12.8
Credit recycle NH ₃ (10.3 tpd x 330 dpy x \$65.00/ton).....	-36.02	-221,000	\$148,000	-37.2
Direct labor and supervision:				
Labor (96 man-hour day x \$3.75 x 365 dpy)....	21.41	131,400	-	22.1
Supervision (15 percent of labor).....	3.21	19,700	151,100	3.3
Plant maintenance:				
Maintenance labor (two men at \$3.80/man- hour).....	3.26	20,000	-	3.4
Supervision (20 percent of maintenance labor).....	0.65	4,000	-	0.7
Maintenance material.....	0.78	4,800	28,800	0.8
Payroll overhead (25 percent of payroll)....	7.14	43,800	43,800	7.4
Operating supplies (20 percent of maintenance)	0.78	4,800	4,800	0.8
Total direct cost.....	-	-	376,900	63.5
Indirect cost: Administration and general overhead (40 percent of labor, maintenance, and supplies).....	12.04	73,900	73,900	12.5
Fixed cost:				
Taxes and insurance (2 percent of plant cost).. Depreciation (9.1 percent of subtotal for depreciation).....	3.57 19.98	21,900 120,600	- 142,500	3.7 20.3
Subtotal operating.....	97.00	-	593,300	100.0
Credits (SiO ₂ bagged, 1,591 tons at \$13.50/ton).....	3.81	-	21,500	-
Total annual operating cost.....	93.19	-	571,800	-

APPENDIX I.--COST ANALYSIS OF A 50,000-TON-PER-YEAR PLANT

TABLE I-1. - Selling price of calcium fluoride

12 percent discounted cash flow rate of return (11 years):	
R = \$2,166,000/5.938	\$364,800
Depreciation.....	<u>181,700</u>
Net profit.....	183,100
Federal income tax (50 percent of taxable income):	
Gross profit.....	366,200
Net operating cost.....	<u>837,100</u>
Sales.....	1,203,300
Taxes:	
Taxable income.....	366,200
Federal income tax.....	<u>183,100</u>
Net profit.....	183,100
Cash flow:	
Net profit.....	183,100
Depreciation.....	<u>181,700</u>
Total.....	364,800
Sales price per ton CaF_2 (\$1,203,300/12,273 ¹).....	98.04
¹ Product (CaF_2) output, tpy.	

Note: Formula: $P = R \frac{(1+r)^n}{r(1+r)^n}$

where P = total capital requirements,

R = present value of P due in 11 years at 12 percent compound interest,

r = 12 percent,

n = 11 years,

and R = $P/5.938$ (present value of \$1.00 due in 11 years at 12 percent interest).

TABLE I-2. - Financial analysis

Revenue from sales.....	\$1,203,300
Operating cost.....	879,600
	323,700
Credit.....	42,500
Gross profit (taxable income).....	366,200
Federal income tax, 50 percent.....	183,100
Net profit.....	183,100
ANNUAL CASH FLOW	
Net profit.....	183,100
Depreciation.....	181,700
Cash flow.....	364,800

TABLE I-3. - Total capital requirements

Unit	Cost	Percent
Reaction section (NH ₃).....	\$948,900	43.8
Drying and bagging section (SiO ₂).....	92,800	4.3
Reaction section (CaF ₂).....	474,400	21.9
Drying and bagging section (CaF ₂).....	131,400	6.1
Subtotal.....	1,647,500	76.1
Plant facilities.....	123,600	5.7
Plant utilities.....	177,100	8.2
Total plant cost (insurance and tax bases).....	1,948,200	90.0
Interest during construction.....	48,700	2.2
Subtotal for depreciation.....	1,996,900	92.2
Working capital.....	169,100	7.8
Total investment.....	2,166,000	100.0

TABLE I-4. - Equipment cost summary for ammonia reactor section

Item	Cost		Total cost
	Material	Labor	
Storage tank (H_2SiF_6), 2.....	\$104,000	\$10,400	\$114,400
Pump and motor (H_2SiF_6), 2.....	4,800	1,200	6,000
Storage tank (NH_3), 4.....	80,000	8,000	88,000
Compressor--2 stage (NH_3), 1.....	15,000	4,000	19,000
Feed tank (H_2SiF_6), 3.....	10,500	1,100	11,600
Reactor and agitator (NH_4F), 3.....	41,400	4,100	45,500
Cooling tower for water, 1.....	13,200	1,300	14,500
Filter, vacuum rotary drum (SiO_2), 1...	19,400	1,900	21,300
Subtotal.....	288,300	32,000	320,300
Foundations.....	14,400	19,200	33,600
Structures.....	17,300	8,700	26,000
Buildings.....	11,500	11,500	23,000
Instrumentation.....	20,200	8,100	28,300
Electrical.....	20,200	15,200	35,400
Piping.....	100,900	50,500	151,400
Painting.....	1,400	4,200	5,600
Miscellaneous.....	14,400	11,500	25,900
Subtotal.....	200,300	128,900	329,200
Total direct.....	488,600	160,900	649,500
Field indirect.....			97,400
Total construction.....			746,900
Engineering.....			37,300
Overhead and administration.....			37,300
			821,500
Contingency.....			82,200
			903,700
Fee.....			45,200
Total.....			948,900

TABLE I-5. - Equipment cost summary for silica drying and bagging section

Item	Cost		Total cost
	Material	Labor	
Belt conveyor and motor, 1.....	\$2,200	\$200	\$2,400
Bucket elevator and motor, 1.....	1,500	200	1,700
Rotary dryer and burner, 1.....	14,000	1,400	15,400
Exhaust fan and motor, 1.....	1,900	500	2,400
Screw conveyor and motor, 1.....	600	100	700
Bucket elevator and motor, 1.....	1,500	200	1,700
Bagging machine and motor, 1.....	2,500	300	2,800
Storage hopper above bagger, 1.....	3,100	300	3,400
Bag storage area, 1.....	5,000	500	5,500
Fork lift truck, 1.....	5,300	600	5,900
Subtotal.....	37,600	4,300	41,900
Foundations.....	1,900	2,500	4,400
Structures.....	1,500	800	2,300
Buildings.....	1,900	1,900	3,800
Instrumentation.....	800	300	1,100
Electrical.....	2,300	1,700	4,000
Piping.....	1,900	1,000	2,900
Painting.....	100	300	400
Miscellaneous.....	1,500	1,200	2,700
Subtotal.....	11,900	9,700	21,600
Total direct.....	49,500	14,000	63,500
Field indirect.....			9,500
Total construction.....			73,000
Engineering.....			3,700
Overhead and administration.....			3,700
			80,400
Contingency.....			8,000
			88,400
Fee.....			4,400
Total.....			92,800

TABLE I-6. - Equipment cost summary for calcium fluoride reactor section with lime slaker

Item	Cost		Total cost
	Material	Labor	
Storage silo (CaO), 2.....	\$5,000	\$500	\$5,500
Screw conveyor and motor, 2.....	2,000	200	2,200
Bucket elevator and motor, 1.....	1,500	200	1,700
Feed hopper (CaO), 1.....	1,800	200	2,000
Water feed tank, 1.....	4,300	400	4,700
Lime slaker (Ca(OH) ₂), 1.....	34,600	3,500	38,100
Pump and motor (NH ₄ F), 1.....	2,400	200	2,600
Feed tank (NH ₄ F), 3.....	13,200	1,300	14,500
Reactor and agitator (CaF ₂), 3.....	58,800	5,900	64,700
Filter, vacuum rotary drum (CaF ₂), 1...	21,300	2,100	23,400
Subtotal.....	144,900	14,500	159,400
Foundations.....	7,200	9,600	16,800
Structures.....	8,700	4,400	13,100
Buildings.....	5,800	5,800	11,600
Instrumentation.....	10,100	4,000	14,100
Electrical.....	10,100	7,600	17,700
Piping.....	50,700	25,400	76,100
Painting.....	700	2,100	2,800
Miscellaneous.....	7,200	5,800	13,000
Subtotal.....	100,500	64,700	165,200
Total direct.....	245,400	79,200	324,600
Field indirect.....			48,700
Total construction.....			373,300
Engineering.....			18,700
Overhead and administration.....			18,700
			410,700
Contingency.....			41,100
			451,800
Fee.....			22,600
Total.....			474,400

TABLE I-7. - Equipment cost summary for calcium fluoride drying and bagging section

Item	Cost		Total cost
	Material	Labor	
Belt conveyor and motor, 1.....	\$2,200	\$200	\$2,400
Bucket elevator and motor, 1.....	1,500	200	1,700
Rotary dryer and burner, 1.....	25,000	2,500	27,500
Exhaust fan and motor, 1.....	4,000	1,000	5,000
Screw conveyor and motor, 1.....	400	100	500
Bucket elevator and motor, 1.....	1,500	200	1,700
Bagging machine and motor, 1.....	3,700	400	4,100
Storage hopper above bagger, 1.....	1,600	200	1,800
Bag storage area, 1.....	13,100	1,300	14,400
Subtotal.....	53,000	6,100	59,100
Foundations.....	2,700	3,600	6,300
Structures.....	2,100	1,100	3,200
Buildings.....	2,700	2,700	5,400
Instrumentation.....	1,100	400	1,500
Electrical.....	3,200	2,400	5,600
Piping.....	2,700	1,400	4,100
Painting.....	200	600	800
Miscellaneous.....	2,100	1,700	3,800
Subtotal.....	16,800	13,900	30,700
Total direct.....	69,800	20,000	89,800
Field indirect.....			13,500
Total construction.....			103,300
Engineering.....			5,200
Overhead and administration.....			5,200
			113,700
Contingency.....			11,400
			125,100
Fee.....			6,300
Total.....			131,400

TABLE I-8. - Working capital

Item	Capital	Percent
Raw materials and utilities.....60 days..	\$44,600	26.4
Direct labor and supervision.....3 months..	56,200	33.2
Payroll overhead--25 percent.....3 months..	14,100	8.3
Operating supplies.....3 months..	1,800	1.1
Maintenance materials.....3 months..	1,800	1.1
Indirect cost.....4 months..	31,900	18.9
Fixed cost.....0.5 percent of insurance base..	9,700	5.7
Miscellaneous expense.....	9,000	5.3
Total.....	169,100	100.0

TABLE I-9. - Estimated annual operating cost

Item	Cost per ton	Unit cost	Total	Per- cent
Direct cost:				
Raw materials and utilities:				
Fuel (331 gpd x 330 dpy x \$0.1022/gal)....	\$0.91	\$11,200	-	1.3
Power (104 kw x 7,920 hpy x \$0.03084/kwh)...	2.07	25,400	-	2.9
NH ₃ (24.2 tpd x 330 dpy x \$65.00/ton)....	42.30	519,100	-	59.0
CaO (26.6 tpd x 330 dpy x \$17.50/ton)....	12.76	153,600	-	17.5
Credit recycle NH ₃ (20.6 tpd x 330 dpy x \$65.00/ton).....	-36.00	-441,800	\$267,500	-50.3
Direct labor and supervision:				
Labor (120 man-hour day x \$3.75 x 365 dpy)	13.39	164,300	-	18.7
Supervision (15 percent of labor).....	2.00	24,600	188,900	2.8
Plant maintenance:				
Maintenance labor (two men at \$3.80/man- hour).....	2.44	30,000	-	3.4
Supervision (20 percent of maintenance labor).....	0.49	6,000	-	0.7
Maintenance material.....	0.59	7,300	43,300	0.8
Payroll overhead (25 percent of payroll)....	4.58	56,200	56,200	6.4
Operating supplies (20 percent of maintenance)	0.59	7,200	7,200	0.8
Total direct cost.....		-	563,100	64.0
Indirect cost: Administration and general overhead (40 percent of labor, maintenance, and supplies).....	7.81	95,800	95,800	10.9
Fixed cost:				
Taxes and insurance (2 percent of plant cost) ..	3.18	39,000	-	4.4
Depreciation (9.1 percent of subtotal for depreciation).....	14.80	181,700	220,700	20.7
Subtotal operating.....	71.91	-	879,600	100.0
Credits (SiO ₂ bagged, 3,150 tons at \$13.50/ton).....	3.70	-	42,500	-
Total annual operating cost.....	68.21	-	837,100	-

APPENDIX J.--COST ANALYSIS OF A 100,000-TON-PER-YEAR PLANT

TABLE J-1. - Selling price of calcium fluoride

12 percent discounted cash flow rate of return (11 years):	
R = \$3,370,900/5.938.....	\$567,700
Depreciation.....	<u>284,400</u>
Net profit.....	283,300
Federal income tax (50 percent of taxable income):	
Gross profit.....	566,600
Net operating cost.....	<u>1,260,700</u>
Sales.....	1,827,300
Taxes:	
Taxable income.....	566,600
Federal income tax.....	<u>283,300</u>
Net profit.....	283,300
Cash flow:	
Net profit.....	283,300
Depreciation.....	<u>284,400</u>
Total.....	567,700
Sales price per ton CaF ₂ (\$1,827,300/24,515 ¹).....	74.45
¹ Product (CaF ₂) output, tpy.	

Note: Formula: $P = R \frac{(1+r)^n}{r(1+r)^n}$

where P = total capital requirements,

R = present value of P due in 11 years at 12 percent compound interest,

r = 12 percent,

n = 11 years,

and R = P/5.938 (present value of \$1.00 due in 11 years at 12 percent interest).

TABLE J-2. - Financial analysis

Revenue from sales.....	\$1,827,300
Operating cost.....	1,346,600
	480,700
Credit.....	85,900
Gross profit (taxable income).....	566,600
Federal income tax, 50 percent.....	283,300
Net profit.....	283,300
ANNUAL CASH FLOW	
Net profit.....	283,300
Depreciation.....	284,400
Cash flow.....	567,700

TABLE J-3. - Total capital requirements

Unit	Cost	Percent
Reaction section (NH ₄ F).....	\$1,633,900	48.5
Drying and bagging section (SiO ₂).....	118,700	3.5
Reaction section (CaF ₂).....	650,000	19.3
Drying and bagging section (CaF ₂).....	176,300	5.2
Subtotal.....	2,578,900	76.5
Plant facilities.....	193,400	5.7
Plant utilities.....	277,200	8.2
Total plant cost (insurance and tax bases).....	3,049,500	90.4
Interest during construction.....	76,200	2.3
Subtotal for depreciation.....	3,125,700	92.7
Working capital.....	245,200	7.3
Total investment.....	3,370,900	100.0

TABLE J-4. - Equipment cost summary for ammonia reactor section

Item	Cost		Total cost
	Material	Labor	
Storage tank (H_2SiF_6), 4.....	\$208,000	\$20,800	\$228,800
Pump and motor (H_2SiF_6), 2.....	6,400	1,400	7,800
Storage tank (NH_3), 8.....	160,000	16,000	176,000
Compressor--2 stage (NH_3), 1.....	15,000	4,000	19,000
Feed tank (H_2SiF_6), 4.....	14,000	1,400	15,400
Reactor and agitator (NH_4F), 4.....	55,200	5,500	60,700
Cooling tower for water, 1.....	13,200	1,300	14,500
Filter, vacuum rotary drum (SiO_2), 1...	25,800	2,600	28,400
Subtotal.....	497,600	53,000	550,600
Foundations.....	24,900	33,100	58,000
Structures.....	29,900	15,000	44,900
Buildings.....	19,900	19,900	39,800
Instrumentation.....	34,800	13,900	48,700
Electrical.....	34,800	26,100	60,900
Piping.....	174,200	87,100	261,300
Painting.....	2,500	7,500	10,000
Miscellaneous.....	24,900	19,200	44,100
Subtotal.....	345,900	221,800	567,700
Total direct.....	843,500	274,800	1,118,300
Field indirect.....			167,700
Total construction.....			1,286,000
Engineering.....			64,300
Overhead and administration.....			64,300
			1,414,600
Contingency.....			141,500
			1,556,100
Fee.....			77,800
Total.....			1,633,900

TABLE J-5. - Equipment cost summary for silica
drying and bagging section

Item	Cost		Total cost
	Material	Labor	
Belt conveyor and motor, 1.....	\$2,600	\$300	\$2,900
Bucket elevator and motor, 1.....	1,500	200	1,700
Rotary dryer and burner, 1.....	17,000	1,700	18,700
Exhaust fan and motor, 1.....	3,000	800	3,800
Screw conveyor and motor, 1.....	600	100	700
Bucket elevator and motor, 1.....	1,500	200	1,700
Bagging machine and motor, 1.....	2,500	300	2,800
Storage hopper above bagger, 1.....	3,100	300	3,400
Bag storage area, 1.....	10,000	1,000	11,000
Fork lift truck, 1.....	6,500	700	7,200
Subtotal.....	48,300	5,600	53,900
Foundations.....	2,400	3,200	5,600
Structures.....	1,900	1,000	2,900
Buildings.....	2,400	2,400	4,800
Instrumentation.....	1,000	400	1,400
Electrical.....	2,900	2,200	5,100
Piping.....	2,400	1,200	3,600
Painting.....	100	300	400
Miscellaneous.....	1,900	1,500	3,400
Subtotal.....	15,000	12,200	27,200
Total direct.....	63,300	17,800	81,100
Field indirect.....			12,200
Total construction.....			93,300
Engineering.....			4,700
Overhead and administration.....			4,700
			102,700
Contingency.....			10,300
			113,000
Fee.....			5,700
Total.....			118,700

TABLE J-6. - Equipment cost summary for calcium fluoride reactor section with lime slaker

Item	Cost		Total cost
	Material	Labor	
Storage silo (CaO), 4.....	\$10,000	\$1,000	\$11,000
Screw conveyor and motor, 4.....	4,000	400	4,400
Bucket elevator and motor, 1.....	1,500	200	1,700
Feed hopper (CaO), 1.....	1,800	200	2,000
Water feed tank, 1.....	4,300	400	4,700
Lime slaker (Ca(OH) ₂), 1.....	34,600	3,500	38,100
Pump and motor (NH ₄ F), 1.....	3,200	800	4,000
Feed tank (NH ₄ F), 4.....	17,600	1,800	19,400
Reactor and agitator (CaF ₂), 4.....	78,400	7,800	86,200
Filter, vacuum rotary drum (CaF ₂), 1...	29,100	2,900	32,000
Subtotal.....	184,500	19,000	203,500
Foundations.....	9,200	12,200	21,400
Structures.....	11,100	5,500	16,600
Buildings.....	7,400	7,400	14,800
Instrumentation.....	12,900	5,200	18,100
Electrical.....	12,900	9,700	22,600
Piping.....	64,600	32,300	96,900
Painting.....	900	2,700	3,600
Miscellaneous.....	9,200	7,400	16,600
Subtotal.....	128,200	82,400	210,600
Total direct.....	312,700	101,400	414,100
Field indirect.....			62,100
Total construction.....			476,200
Engineering.....			23,800
Overhead and administration.....			23,800
			523,800
Contingency.....			52,400
			576,200
Fee.....			28,800
Total.....			605,000

TABLE J-7. - Equipment cost summary for calcium fluoride
drying and bagging section

Item	Cost		Total cost
	Material	Labor	
Belt conveyor and motor, 1.....	\$2,600	\$300	\$2,900
Bucket elevator and motor, 1.....	1,500	200	1,700
Rotary dryer and burner, 1.....	30,000	3,000	33,000
Exhaust fan and motor, 1.....	5,000	1,300	6,300
Screw conveyor and motor, 1.....	700	100	800
Bucket elevator and motor, 1.....	1,500	200	1,700
Bagging machine and motor, 1.....	3,700	400	4,100
Storage hopper above bagger, 1.....	1,600	200	1,800
Bag storage area, 1.....	25,000	2,500	27,500
Subtotal.....	71,600	8,200	79,800
Foundations.....	3,600	4,800	8,400
Structures.....	2,900	1,500	4,400
Buildings.....	3,600	3,600	7,200
Instrumentation.....	1,400	600	2,000
Electrical.....	4,300	3,200	7,500
Piping.....	3,600	1,800	5,400
Painting.....	200	600	800
Miscellaneous.....	2,900	2,300	5,200
Subtotal.....	22,500	18,400	40,900
Total direct.....	94,100	26,600	120,700
Field indirect.....			18,100
Total construction.....			138,800
Engineering.....			6,900
Overhead and administration.....			6,900
			152,600
Contingency.....			15,300
			167,900
Fee.....			8,400
Total.....			176,300

TABLE J-8. - Working capital

Item	Capital	Percent
Raw materials and utilities.....60 days..	\$86,400	35.2
Direct labor and supervision.....3 months..	68,700	28.0
Payroll overhead--25 percent.....3 months..	17,200	7.0
Operating supplies.....3 months..	2,400	1.0
Maintenance materials.....3 months..	2,900	1.2
Indirect cost.....4 months..	39,400	16.1
Fixed cost.....0.5 percent of insurance base..	15,200	6.2
Miscellaneous expense.....	13,000	5.3
Total.....	245,200	100.0

TABLE J-9. - Estimated annual operating cost

Item	Cost per ton	Unit cost	Total	Per- cent
Direct cost:				
Raw materials and utilities:				
Fuel (855 gpd x 330 dpy x \$0.1022/gal) ..	\$1.17	\$28,800	-	2.1
Power (115 kw x 7,920 hpy x \$0.03084/kwh) ..	1.14	28,100	-	2.1
NH ₃ (48.41 tpd x 330 dpy x \$65.00/ton) ..	42.31	1,038,400	-	77.1
CaO (53.2 tpd x 330 dpy x \$17.50/ton) ..	12.52	307,200	-	22.8
Credit recycle NH ₃ (41.15 tpd x 330 dpy x \$65.00/ton)	-36.02	-884,000	\$518,500	-65.6
Direct labor and supervision:				
Labor (144 man-hour day x \$3.75 x 365 dpy) ..	8.03	197,000	-	14.6
Supervision (15 percent of labor)	1.21	29,600	226,700	2.2
Plant maintenance:				
Maintenance labor (two men at \$3.80/man- hour)	1.63	40,000	-	3.0
Supervision (20 percent of maintenance labor)	0.33	8,000	-	0.6
Maintenance material	0.46	11,400	59,400	0.8
Payroll overhead (25 percent of payroll) ..	2.80	68,700	68,700	5.1
Operating supplies (20 percent of maintenance)	0.39	9,600	9,600	0.7
Total direct cost	-	-	882,900	65.5
Indirect cost: Administration and general overhead (40 percent of labor, maintenance, and supplies)	4.82	118,300	118,300	8.8
Fixed cost:				
Taxes and insurance (2 percent of plant cost) ..	2.49	61,000	-	4.5
Depreciation (9.1 percent of subtotal for depreciation)	11.59	284,400	345,400	21.2
Subtotal operating	54.87	-	1,346,600	100.0
Credits (SiO ₂ bagged, 6,364 tons at \$13.50/ton)	3.51	-	85,900	-
Total annual operating cost	51.36	-	1,260,700	-

