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A Feasibility Study for the Production of Filter Aids from Kansas Volcanic Ash

KANSAS INDUSTRIAL MINERAL DEVELOPMENT

SINGLE "POPPED" ASH PARTICLE, ×235

By Ronald G. Hardy, Maynard P. Bauleke, Allison L. Hornbaker, William R. Hess, and William B. Hladik

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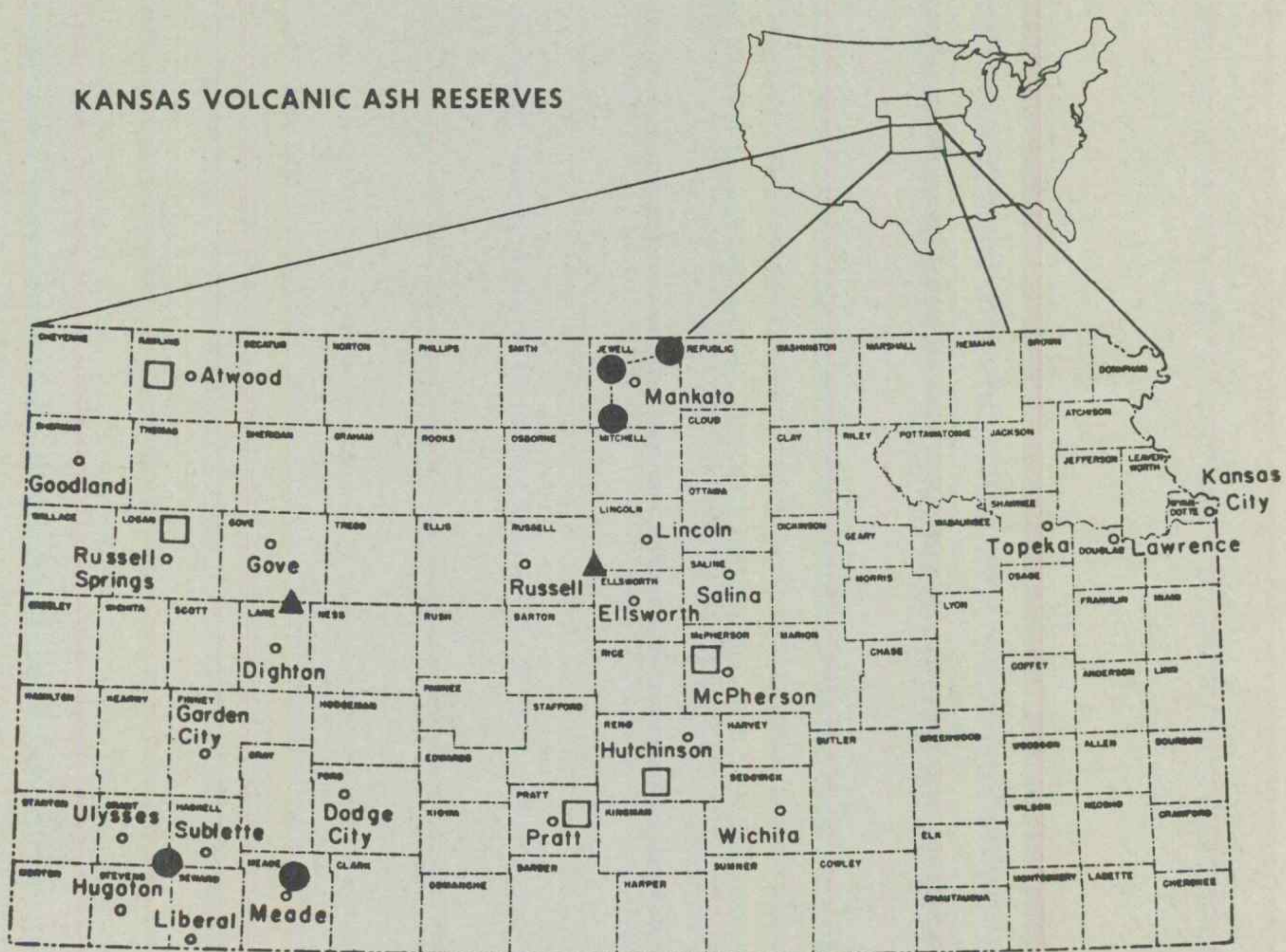
KANSAS VOLCANIC ASH RESERVES



☐ Less than 1,000,000 tons ▲ Greater than 1,000,000 tons ● Greater than 2,000,000 tons

KANSAS INDUSTRIAL MINERAL DEVELOPMENT--A FEASIBILITY STUDY FOR THE PRODUCTION OF FILTER AIDS FROM KANSAS VOLCANIC ASH

By

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INTRODUCTION

Volcanic ash, although a little-used Kansas resource, is available in forty counties with estimated reserves of more than 20 million tons. It was first produced in Kansas in the early 1900's, but not until the early 1920's did it become an important abrasive material. Total production to date is estimated at 2 million tons, the major use being as an abrasive in scouring compounds and soaps; additional uses include ceramic glazes, an additive in cement, and a filler and stabilizer in hot mix asphalt for paving. Unrecorded tonnages have also been used in construction of black-top (macadam) roads. From 1916 through 1944, Kansas ranked first among the states in volcanic ash production; peak production was about 52,000 tons in 1923. Since 1945, production has steadily declined, primarily because materials other than volcanic ash are now being used for abrasives; only two producers operated in 1964.

Kansas volcanic ash is a white to light-pearly gray material, consisting predominantly of small particles, or shards of volcanic rock glass. The ash presumably came from volcanoes located near the Rocky Mountains in the region west or southwest of Kansas. The ash was thrown into the air by explosive volcanic eruptions and was carried over Kansas by winds. The ash falls are of limited areal extent and range in thickness from a few inches to more than 30 feet. Western Kansas ash deposits of value for filter aid production are all of Pliocene or Pleistocene age.

This report on volcanic ash as a filter aid is one of the results of a search for new or different uses and applications of Kansas mineral commodities being carried on by the State Geological Survey of Kansas. This search encompasses basic product development, market evaluation, analysis of costs and price structure, and measures of profitability. Our investigations show that processed Kansas volcanic ash possesses properties similar to those of a class of other industrial minerals currently used as filter aids. This is, therefore, a feasibility study of the use of processed Kansas volcanic ash as a filter aid, a summary of laboratory studies to determine product characteristics, a market analysis relating to demand and market penetration, cost estimates and capital investment for producing volcanic ash filter aid, and a profitability analysis.

TECHNICAL DATA ON BLOATED VOLCANIC ASH AS A FILTER AID

When the small particles of Kansas Pearlette ash are rapidly heated to their softening temperature in a gas flame, occluded gases expand them into minute, thin-walled spheres which are solidified by sudden cooling. This expanded volcanic ash, after it has been crushed and classified, has desirable filter-aid properties and is comparable to expanded perlite, and diatomite (diatomaceous earth), a material composed of the siliceous skeletal remains of microscopic aquatic organisms called diatoms.

A filter aid is a material used to clarify, or remove finely divided substances from liquids. Ideally, a filter aid will form an extremely fine-filter surface which will retain all solids, prevent contact between the solids and the filter septum, and allow many filtering cycles. To perform these functions, filter-aid materials should be (1) inert and insoluble--they must not react with the liquids or solids, (2) incompressible--the filter-aid cake must be able to maintain high permeability under the pressure differentials developed in the filter, (3) irregularly shaped, porous, and small--the cake must have many tiny flow channels that are small enough to screen out solids, but numerous enough to provide optimum flow.

Filter aids are generally classified on the basis of their flow rate in a standardized test filtration using a raw sugar liquor. The filter aid is evaluated on the flow rate it permits and the degree of clarity achieved in the filtrate (Sharbaugh, 1962 and Skinner, et al, 1944).

Flow of a liquid through a filter is a function of the viscosity of the liquid and obstruction to flow. Obstructions include the resistance of the filter cake, the filter medium, and piping and mechanical features of the filter. The resistance of the filter cake depends upon whether the cake is loose or compacted, coarse or fine, and granular or gelatinous.

Filter aids are used for clarification in processing sugars, syrups, beer, wine and distilled liquors, fruit juices, beverages of all types, mineral, vegetable and animal oils, fats and waxes, varnishes and lacquers, lubricating oils, dry-cleaning fluids, water, sewage, trade wastes, and metallurgical slimes and solutions.

Test Procedures and Results

Pearlette volcanic ash was bloated, according to procedures previously described by Bauleke (1962). The bloated ash was crushed by passing it between a solid plate and a wooden roller, classified using standard screens into + 80 mesh, - 80 to + 100 mesh, - 100 to + 200 mesh, - 200 to + 325 mesh, and - 325 mesh sizes. For testing purposes, uncrushed composite, crushed composite, and uncrushed-mixed with minus 100 mesh fractions were also prepared.

Pre-coating characteristics and resistivity values for prepared Kansas volcanic ash fractions, as well as for some commercial diatomite filter aids, were determined at the Sanitary Engineering Department, Iowa State University, Ames, under the direction of Dr. E. R. Bauman.

The resistivity or K_3 value of a filter aid is shown by

$$K_3 = 2.22 \frac{h}{Q.W.} \text{ (at } 20^{\circ} \text{ C)}$$

where Q = discharge in ml/sec., h = head loss in inches of manometer fluid, and W = pre-coat weight in grams. The K_3 value is then expressed in feet minutes per pound gallon. Low K_3 values of a filter aid with proper pre-coat characteristics indicate higher rates of fluid flow. The results of tests are summarized in Table 1.

Table 1.--Resistivity factors of filter aids.

Type of filter aid		Resistivity $K_3 = \frac{ft.^5 \ min.}{lb. \ gal.}$
Group I	Diatomite	
	1) Commercial swimming pool filter aid	0.709
	2) Commercial dry cleaning filter aid	2.770
Group II	Volcanic ash	
	1) Sample, + 80 mesh	Too coarse, did not form uniform pre-coat
	2) Sample, - 80 + 100 mesh	0.113
	3) Sample, - 100 + 200 mesh	0.335
	4) Sample, - 200 + 325 mesh	1.940 excellent pre-coat
	5) Sample, - 325 mesh	Too fine material, passed septum
Group III	Volcanic ash	
	1) Composite, uncrushed	0.260
	2) Composite, crushed	1.525
	3) Sample, - 100 mesh	Did not form uniform pre-coat

Filter aids with acceptable resistivity properties can be made from bloated, crushed volcanic ash which has been classified under 100 mesh or 149 micron size down to 325 mesh size. It was noted that prepared ash samples coarser than 200 mesh had a tendency to float in the liquor. Undoubtedly, the floating particles consisted of bloated ash bubbles that had not been broken in the crushing process.

Tests were conducted to measure liquid-flow rates and degree of filtrate clarity in actual filtering operations. The apparatus used for these tests is similar to the apparatus described by Skinner et al (1944). A schematic diagram is shown in Figure 1. Three water suspensions or solutions were used. A one-percent suspension of Kentucky #4 ball clay in water, a one-percent suspension of iron oxide (Fe_2O_3) in water, and a raw sugar solution with a specific gravity of 1.25 were filtered utilizing prepared volcanic ash, diatomite, and perlite dispersed within the suspensions or solutions as filter aids. Flow rates were obtained for several percentages of filter aids as shown in Table 2. For - 325 mesh bloated and crushed volcanic ash, maximum effectiveness for a clay suspension and a sugar solution was achieved using 0.75 percent of filter aid. Effectiveness increased with increasing filter aid for the iron oxide suspension. The particle size distribution would most likely be a controlling factor for this effect rather than maximum size alone.

The relationship between time and filtrate volume is given in Table 3 for the - 325 mesh volcanic ash filter aid. The data for the 0.75 percent concentration of the - 325 mesh fraction are plotted in Figure 2.

Filtrate volumes, flow rates and relative clarity are shown in Table 4 for several commercial filter aids.

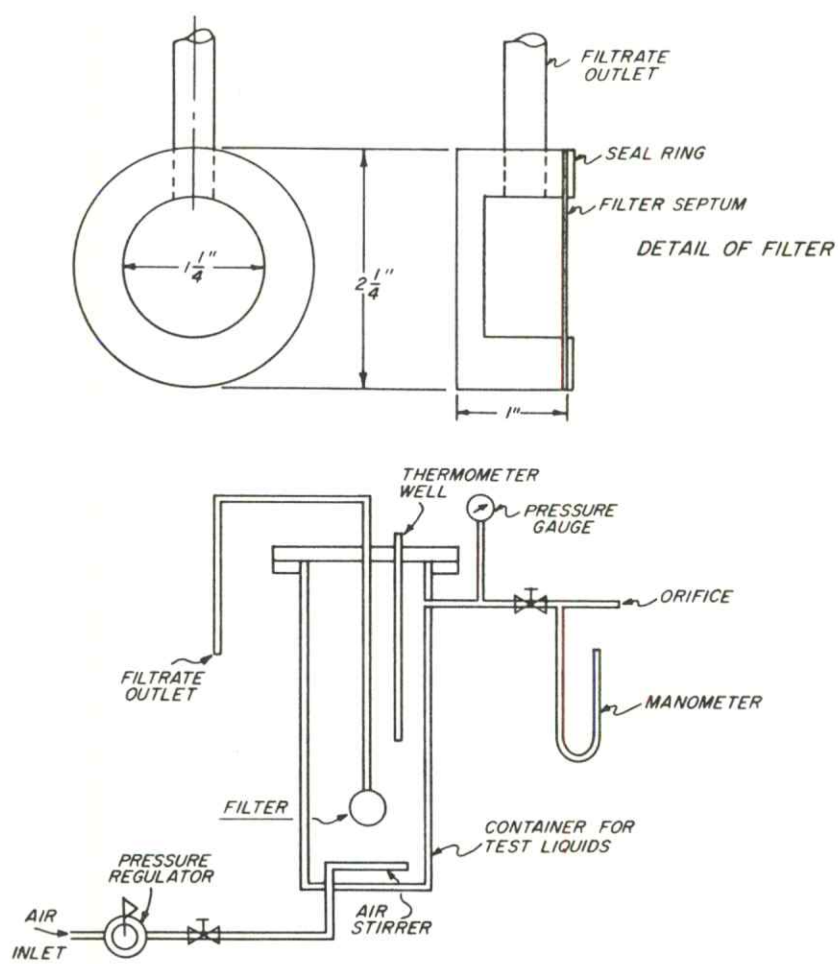

Fig. 1.--Schematic diagram of filter test cell.

Table 2.--Filtrate volumes and relative clarity data in relation to time for various concentrations of -325 volcanic ash using the three types of suspension.

Filter Aid Concentration in Percent	Type of Suspension: One Percent Clay		One Percent Fe_2O_3		Raw Sugar	
	Volume cc[a]	Relative Clarity[b]	Volume cc	Relative Clarity[b]	Volume cc	Relative Clarity[c]
0.25	60.5	20				
0.50	70.5	84				
0.75	90.5	110	385	373	440	240
1.00	86.0	41	515	330		
1.50					350	300

a/ cc per 20 minutes.

b/ Compared with distilled water.

c/ Compared with unfiltered raw sugar.

Table 3.--Time-filtrate volume relationships and relative clarity data for -325 mesh volcanic ash filter aid at 0.75 percent and 1.0 percent concentration.

Filter Aid Concentration in percent	Time, min.	Type of Suspension: One Percent Clay			One Percent Fe_2O_3			Raw Sugar		
		Vol. cc	Rate cc/min.	Relative Clarity[b]	Vol. cc	Rate cc/min.	Relative Clarity[b]	Vol. cc	Rate cc/min.	Relative Clarity[c]
0.75	2.5	24	9.6		120	48.0		140	56.0	
0.75	5.0	40	8.0		178	35.6		210	42.1	
0.75	10.0	62	6.2		267	26.7		310	31.0	
0.75	20.0	90	4.5	110	401	20.0	No data	440	22.0	240
1.0	2.5	20	8.0		142	56.6		100[a]	40.0	
1.0	5.0	33	6.1		214	42.9		150[a]	30.1	
1.0	10.0	56	5.6		336	33.6		240[a]	24.0	
1.0	20.0	86	4.3	41	512	25.6	330	350[a]	17.5	300

a/ Used 1.5 percent filter aid.

b/ Compared with distilled water.

c/ Compared with unfiltered raw sugar.

AMERICAN OPTICAL COLORIMETER MODEL 10131 was used to provide a relative measure of clarity of all filtrate samples. Samples of the filtrates from the clay and iron suspensions were compared

Table 4.--Flow rates and relative clarity data of commercial filter aids.

Filter Aid Concentration in percent	Time, min.	One Percent Clay Vol. cc	One Percent Clay Rate cc/min.	One Percent Clay Relative Clarity[b/]	One Percent Fe_2O_3 Vol. cc	One Percent Fe_2O_3 Rate cc/min.	One Percent Fe_2O_3 Relative Clarity[b/]	Raw Sugar Vol. cc	Raw Sugar Rate cc/min.	Raw Sugar Relative Clarity[c/]
		Commercial Swimming Pool Diatomite			Commercial Dry Cleaning Diatomite			Commercial Dry Cleaning Diatomite		
0.75	2.5	N.A.			108	43.1		180	71.9	
0.75	5.0	36.5	7.3		162	32.5		265	53.1	
0.75	10.0	54.5	5.5		246	24.6		390	39.0	
0.75	20.0	79.5	3.9	10	378	18.9	431	580	29.0	281
					Commercial Perlite			Commerical Perlite		
0.75	2.5				190	75.5		65	26.0	
0.75	5.0				289	37.9		80	16.0	
0.75	10.0				435	43.5	408	115	11.5	
0.75	20.0				N.A.	---		160	8.0	323
								Commercial Dry Cleaning Diatomite		
1.5	2.5							115	46.1	
1.5	5.0							250	50.0	
1.5	10.0							380	38.0	
1.5	20.0							550	27.5	No data

b/ Compared with distilled water.

c/ Compared with unfiltered raw sugar.

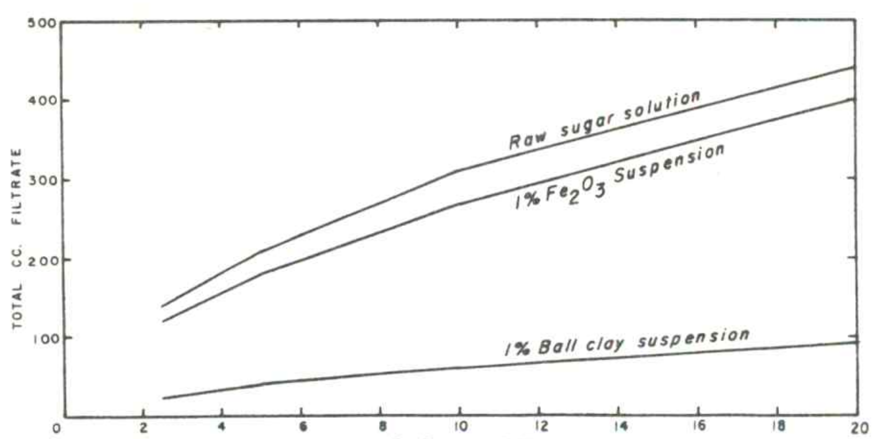

Fig. 2.--Test cell relationships between time and filtrate volume using -325 mesh volcanic ash filter aid.

with distilled water. Relative clarity is based on the amount of light passed by filtrates as compared with distilled water; higher figures indicate greater clarity. The standard comparison in the raw sugar determination is the unfiltered raw sugar solution. The filtrate was compared with the standard, higher readings indicating a clearer filtrate.

Crushed expanded volcanic ash of proper size performs well as a filter aid. Its measured ability to regulate flow rates and clarify suspensions and solutions is comparable to commercial expanded perlite and diatomite. For the particular samples on which flow rates and clarification determinations were made, an optimum quantity of filter aid was determined as measured by flow rate and clarity tests. The size gradation and maximum size affect filtration characteristics. It is essential that small expanded ash bubbles be broken during crushing to prevent the filter aid from floating in the suspensions.

MARKETS AND MARKET TRENDS

Introduction

A demand or market analysis seeks out and measures the factors that determine sales. There are at least two purposes of such an analysis: (1) forecasting sales and (2) manipulating demand. In this study of filter aids both aspects are covered, but emphasis is on manipulating demand, for it is this information that can be used for formulating sales policy and sales strategy. Using demand studies in an active rather than a passive way better equips a company to select the course of action that will maximize sales. Such studies can be particularly helpful in matching salesmen and sales effort with potential sales in various industries and territories as well as formulating price policy and evaluating packaging design, value of merchandising, technical assistance, etc.

The measurable determinants of demand for producers' goods usually differ from those for consumers' goods. Causes for distinctive demand behavior for producers' goods are: (1) buyers are professionals and hence, generally are more expert price-wise, and sensitive to substitutes than are buyers of consumers' goods; (2) their motives are more purely economic; products are bought, not for themselves alone, but for their profit prospects; (3) demand for producers' goods, being derived from consumption demand, fluctuates more violently than demand for consumers' goods.

Geographical Area Encompassed

The geographical area encompassed by this study of filter aid markets is generally the four-state area of Kansas, Nebraska, Missouri, and Iowa. Visits were made to the metropolitan areas of Wichita, Topeka, and Kansas City, Kansas, St. Louis, St. Joseph, and Kansas City, Missouri, Omaha, Nebraska, and Des Moines, Iowa. Populations of these metropolitan areas are given in Table 5. Because of their geographical location, sales in cities such as Kansas City, Omaha, and St. Louis are in more than one state. Only for Kansas City was an attempt made to proportion the sales between states.

Table 5.--Population of the major metropolitan areas within the four-state area[a/]. 1960

City	Population[b/]
St. Louis, Missouri	2,060,103
Kansas City, Kansas and Missoui	1,039,493
Wichita, Kansas	343,231
Topeka, Kansas	141,286
Omaha, Nebraska	457,873
Des Moines, Iowa	266,315

a/ Includes Iowa, Kansas, Missouri and Nebraska.

b/ United States Department of Commerce, Bureau of the Census, Statistical Abstract of the United States, 1961, pp. 14-20.

Survey Method and Scope

Because of the competitive nature of the filter-aid business and the type of information being requested, the survey was conducted primarily by personal contact with the suppliers and users. Although a mail survey was considered undesirable at first, a limited mail survey was attempted with surprisingly high returns, indicating that many complications might well be avoided by use of the mail in future market analyses.

The survey included comprehensive coverage of dry cleaning and swimming pool suppliers, with representative surveying of companies involved in:

Beer brewing
Corn processing
Soybean processing
Petroleum refining
Chemical processing
Oleomargarine manufacturing
Other food processing and industrial uses.

For the most part, cooperation was very good although several companies declined to divulge information; in others, the proper representative could not be contacted. Evaluation of coverage by industry is discussed in a later part of this report.

In all cases an attempt was made to obtain annual sales or usage in tons, freight cost, sales price (where applicable), brand and grade of filter aid. Other information, such as customer satisfaction and brand allegiance, was volunteered without solicitation.

Filter Aid Use and Demand

The two major types of filter aids currently in use are produced from diatomite (diatomaceous earth or diatomaceous silica) and perlite (volcanic glass). Chemically, diatomite is primarily silica and consists of the remains of microscopic aquatic organisms called diatoms. Perlite is a volcanic glass and chemically is primarily potassium-aluminum silicate.

Table 6.--Population of the United States, Kansas, and four-state area.
(thousands of people)

Year	United States	Kansas	Four-state area[a]
1954[b]	161,915	2,031	10,130
1958[b]	174,057	2,141	10,496
1961[b]	182,953	2,194	10,782
1970[c]	213,810	2,589	12,673

a/ Includes Iowa, Kansas, Missouri, and Nebraska.

b/ United States Department of Commerce, Bureau of the Census, Statistical Abstract of the United States, 1961, p. 9.

c/ Prediction assumes fertility rate same as 1955-57 level.

Table 7.--Total value added by manufacture in the United States, Kansas, and the four-state area - 1954, 1958, and 1961.
(billions of dollars)

Year	United States	Kansas	Four-state area[a]
1954[b]	$117.0	$1.0	$5.4
1958[b]	141.3	1.2	6.6
1961[c]	164.3	1.3	7.6
1970[d]	219.8	1.7	10.2

a/ Includes Iowa, Kansas, Missouri, and Nebraska.

b/ United States Department of Commerce, Bureau of the Census, United States Census of Manufacturers, 1958, Vol. I. Summary Statistics, p. 1-44 - 1-51.

c/ United States Department of Commerce, Bureau of the Census, Annual Survey of Manufacturers, 1961, p. 16-25.

d/ 3.0 percent (compounded) annual increase was used to computed these figures.

The demand in 1961 for these two major types of filter aids in the United States was estimated at 365,000 tons.[1] Of this, diatomite accounted for approximately 86 percent. Estimates of filter-aid sales in Kansas and the four-state area (Table 8) were derived by using population and value added by manufacture as base. Projected filter-aid demands for 1970, based on a constant per capita use and on value added by manufacture ratios, are 457,340 tons and 490,000 tons respectively.

Table 8.--Filter-aid sales in Kansas and four-state area based on population and value added to manufacture - 1961 and 1970.
(short tons)

Base	Kansas		Four-state area[a]	
	1961	1970	1961	1970
Population	4,377	5,165[b]	21,510	25,283[b]
Value added to manufacture	2,837	3,777[c]	16,887	22,664[c]

a/ Includes Iowa, Kansas, Missouri, and Nebraska

b/ Computed by assuming per capita use ratio will remain constant.

c/ Computed by assuming use per value added by manufacture ratio will remain constant.

The following sections discuss filter-aid sales by industry.

Dry Cleaning

Filter aids used in the filtering of dry cleaning solvents were estimated to represent 70 percent of the total national sales. With this in mind, special effort was made to insure complete coverage of suppliers of dry cleaners in the four-state area of Iowa, Kansas, Missouri, and Nebraska. Although the majority of suppliers contacted were able to give sales estimates only, it is our opinion that data in this report are reasonably accurate. These data represent more than 80 percent of the tonnage handled by 90 percent of the suppliers located in this area.

According to the market survey, filter aids sold to dry cleaning establishments in Kansas and in the four-state area in 1963 were approximately 315 tons and 1,835 tons respectively (Table 9). This represents 21 percent and 25 percent of the total survey tonnage in these areas. Assuming that these figures represent 80 percent of the actual market in these areas, that is, in Kansas and in the four-state area, the estimated actual use in Kansas would be 395 tons and in the four-state area 2,300 tons. This is considerably lower than estimates based on population and value added by manufacture (Table 8), probably due largely to the high percentage of rural inhabitants or to the inaccuracy of the national estimate.

Perlite sales in the four-state area account for only 1.3 percent of the total sales. This low sales penetration can be attributed to a very strong brand allegiance and customer satisfaction with diatomite

1/ "In the Bag: Filter Aid Growth". Chemical Week: August 12, 1961.

filter aids. Premature entry of the perlite processors into the filter aid field, forced by a major strike in the diatomite field in 1952, resulted in a distaste for perlite filter aids by the dry cleaning business. It was not until 1958 that major producers of perlite products re-entered the market.

Table 9.--Filter-aid sales by industry, state and four-state area in 1963. (Short tons as found by this survey[a/])

Use	Iowa	Kansas	Missouri	Nebraska	Four-state area
Dry cleaning	362	315	737	428	1,835
Swimming pool	130	106	194	130	567
Beer brewing	100	---	2,750	450	3,300
Other	---	1,051	570	---	1,621
Total	592	1,472	4,251	1,008	7,323

a/ These figures are survey data and do not reflect 100 percent of the actual market.

The nature of the dry cleaning business demands a high degree of clarity of the filtrate; flow rate is a secondary consideration. Assuming that volcanic ash filter aid characteristics are technically comparable with those of diatomite, a part of the market could be captured. This could be accomplished initially by contacting the numerous small suppliers who are not franchised dealers. These dealers necessarily pay approximately $40.00 per ton premium in purchasing filter aids from franchised dealers. However, it must be remembered that if ash is not technically comparable, the capturable market would be negligible.

The Swimming Pool Industry

The demand for filter aids by swimming-pool owners, as found by this survey, is 106 tons for Kansas and 567 tons for the four-state area (Table 9). Adjusting the survey data to more nearly approximate actual sales (Table 10) results in estimates of 150 tons for Kansas and 810 tons for the four-state area. Swimming pool suppliers were contacted because of the rapid growth of the number of swimming pools and the increasing use of filter aids in filtration. Because of the (1) expanding market, (2) low-brand allegiance, and (3) desired high-flow characteristics, a large percent of the swimming pool market should be capturable.

The Beer Brewing Industry

The beer brewing industry in the United States is another large user of filter aids, consuming approximately 23,000 tons per year. Within the four-state area annual production of eight breweries exceeds ten million barrels of beer, the processing of which requires an estimated 3,300 tons of filter aid. Five of these breweries were contacted; of these, all use diatomite filter aids. Three breweries had tried perlite, but only one found it satisfactory as a filter aid, and this particular brewery still prefers to use diatomite.

Table 10.--Estimated actual sales of filter aid in Kansas and four-state area based on survey data, 1963, (Short tons)

Use	Kansas	Four-state area a/
Dry cleaning	395 b/	2,300 b/
Swimming pool	150 c/	810 c/
Beer brewing	---	3,300
Other	2,100 c/	4,050 d/
Total	2,645	10,460

a/ Includes Iowa, Kansas, Missouri, and Nebraska.

b/ Assumes 20 percent error in survey data.

c/ Assumes 30 percent error in survey data.

d/ Assumes 60 percent error in survey data.

Data from one representative brewery were used to compute the filter aid used by beer brewers. The filter-aid tonnage used was then compared with national and regional beer production.

Filtration requirements in the beer-brewing industry are such that if any new type of filter aid is to penetrate this market, it must maintain a high degree of clarity and either (1) equal diatomite in flow rate while maintaining an appreciable price advantage, or (2) exceed diatomite in flow characteristics while equaling or possibly maintaining a price advantage.

Other Industrial and Food Processing Users

Survey efforts in fields other than those previously discussed were conducted by contacting representative companies of a particular industry. Filter-aid tonnages were obtained and related to the quantity of processed product; then this ratio was applied to the four-state or national production of this product to obtain total filter-aid amounts used by that industry. Companies contacted in this category used filter aids in corn and soybean processing, petroleum refining, oleomargarine processing, paint manufacturing, electroplating, chemical processing, and wine and vinegar production. Of these, petroleum refining was the largest user and corn processing next largest.

Sales penetration in any of these industries will depend primarily upon the characteristics of the filtration requirements. Perlite filter aids have been able to penetrate approximately 30 percent of the market as surveyed in the four-state area.

F.O.B. Price, Freight Costs and Retail Selling Price

F.O.B. price listings for filter aids vary with the grade and intended use. Examples are:

Dry cleaning	\$59.50 per short ton
Beer brewing	\$65.00 to \$70.00 per short ton
Swimming pools	\$72.00 per short ton
Other	\$50.00 to \$151.00 per short ton

Freight costs in the four-state area range from \$20.00 to \$26.00 per ton for diatomite and about half of this amount for perlite. Freight costs account for a sizeable portion of the cost to the user and can be attributed to their West Coast origin. If a filter aid were produced in Kansas, the producer would have an appreciable freight advantage.

Retail delivered prices for dry cleaning filter aids have these ranges:

Quantity (50 lb. bags)	Price range	Most common price
1	\$4.75 - \$4.60 - \$3.95	\$4.75
2 - 9	\$4.00 - \$3.95 - \$3.55	\$3.95
10 - 19	\$4.00 - \$3.55 - \$3.35	\$3.55
20 or more	\$3.35	\$3.35

Filter aids for swimming-pool filtration range from \$5.25 to \$7.95 per 50 pound bag, the most common price being about \$7.00 per bag. Seasonal demand and small-quantity users account for the increased margin. Bulk facilities were not encountered in any industrial group during the survey.

Probable Immediate Market Penetration and Market Share

Estimates of probable immediate market penetration for the first year of operation and probable market share in 1970 (assuming 5 years of prior operation) of volcanic ash as a filter aid have been made (Tables 11 through 18). These estimates have been made on the assumption that a filter aid made from volcanic ash will be technologically comparable with and priced competitively with diatomite although still maintaining an appreciable freight-cost advantage. In addition, other subjective determinants were used in the estimates. These determinants include, but are not necessarily limited to, brand allegiance customer satisfaction, effects of merchandising, and technical characteristics desired. Tables 19 and 20 summarize Tables 11 through 18, and convert percentages into tonnages.

Summary

Predictions in this analysis of probable immediate market penetration by volcanic ash as a filter aid of 372 tons for Kansas and 1,395 tons for the four-state area, and estimates of probable market share in 1970 after five years of operation of 876 tons for Kansas and 3,107 tons for the four-state area of Iowa, Kansas, Missouri and Nebraska may seem optimistic. It must be remembered, however, that these figures were based upon several important assumptions. Comparisons of the data on Tables 19 and 20 reflect different degrees of penetration and rates of growth by the various industry groups. These are the re-

Table 11.--Estimates of probable immediate market penetration for the initial year of operation in Kansas and the four-state area[a/] of the dry cleaning market.

Area	Portion of market (%)	Percent capturable	Probability of capturing	Weighted percent of market
Kansas	10	80	.8	6.4
	10	60	.4	2.4
	20	20	.3	1.2
	20	10	.2	.4
	20	5	.1	.1
	20	0	0	0
Total	100			10.5
Four-state area[a/]	10	80	.6	4.8
	10	60	.6	3.6
	20	20	.2	.8
	20	10	.1	.2
	20	5	.1	.1
	20	0	0	0
Total	100			9.5

a/ Includes Iowa, Kansas, Missouri, and Nebraska.

Table 12.--Estimates of probable market share in the four-state area[a/] at the end of five years of operation. (Dry cleaning market)

	Portion of market (%)	Percent capturable	Probability of capturing	Weighted percent of market
Four-state area[a/]	10	90	.8	7.20
	10	80	.6	4.80
	20	40	.4	3.20
	20	20	.4	1.60
	20	10	.2	.40
	10	5	.1	.05
	10	1	.1	.01
Total	100			17.26

a/ Includes Iowa, Kansas, Missouri, and Nebraska.

Table 13.--Estimates of probable immediate market penetration for the initial year of operation in Kansas and the four-state area[a]
(Swimming pool market)

Area	Portion of market (%)	Percent capturable	Probability of capturing	Weighted percent of market
Kansas	10	80	.8	6.4
	10	60	.6	3.6
	20	40	.4	2.4
	20	20	.3	1.2
	20	10	.2	.4
	20	5	.1	.1
Total	100			14.1
Four-state area[a]	10	80	.6	4.8
	10	60	.4	2.4
	20	40	.3	2.4
	20	20	.3	1.2
	20	10	.2	.4
	20	5	.1	.1
Total	100			11.3

a/ Includes Iowa, Kansas, Missouri, and Nebraska.

Table 14.--Estimates of probable market share in the four-state area[a] at the end of five years of operation.
(Swimming pool market)

	Portion of market (%)	Percent capturable	Probability of capturing	Weighted percent of market
Four-state area[a]	10	90	.9	8.1
	10	80	.8	6.4
	20	70	.6	8.4
	20	50	.5	5.0
	20	40	.4	3.2
	10	20	.4	.8
	10	10	.2	.2
Total	100			32.1

a/ Includes Iowa, Kansas, Missouri, and Nebraska.

Table 15.--Estimates of probable immediate market penetration in the four-state area[a]
(Beer brewing industry)

	Portion of market (%)	Percent capturable	Probability of capturing	Weighted percent of market
Four-state area[a]	10	90	.9	8.1
	10	50	.5	2.5
	20	20	.2	.8
	40	5	.1	.2
	20	1	.05	.1
Total	100			11.7

a/ Includes Iowa, Kansas, Missouri, and Nebraska .

Table 16.--Estimates of probable market share in the four-state area[a] at the end of five years of operation
(Beer brewing industry)

	Portion of market (%)	Percent capturable	Probability of capturing	Weighted percent of market
Four-state area[a]	10	90	.9	8.1
	10	60	.8	4.8
	20	50	.5	5.0
	20	20	.4	1.6
	20	10	.2	.4
	20	5	.1	.1
Total	100			20.0

a/ Includes Iowa, Kansas, Missouri, and Nebraska.

Table 17. --Estimates of probable immediate market penetration in the four-state area[a].
(Other industrial and food processing)

	Portion of market (%)	Percent capturable	Probability of capturing	Weighted percent of market
Four-state area[a]	10	80	.8	6.4
	10	60	.5	3.0
	20	40	.4	3.2
	20	20	.3	1.2
	20	20	.2	.8
	10	10	.1	.1
	10	5	.1	.05
Total	100			14.75

a/ Includes Iowa, Kansas, Missouri, and Nebraska .

Table 18. --Estimates of probable market share in the four-state area[a] at the end of five years of operation.
(Other industrial and food processing)

	Portion of market (%)	Percent capturable	Probability of capturing	Weighted percent of market
Four-state area[a]	10	90	.9	8.10
	10	80	.8	6.40
	20	60	.5	7.00
	20	40	.4	3.20
	20	20	.4	1.60
	10	10	.2	.20
	10	5	.1	.05
Total	100			26.55

a/ Includes Iowa, Kansas, Missouri, and Nebraska.

Table 19. --Summary of estimated probable immediate market share.

	Estimated market in tons[a]	Percent probable market share[b]	Tons probable market share
Kansas			
Dry cleaning	395	10.5	41
Swimming pool	150	14.1	21
Other	2,100	14.75	310
Total	2,645	14.0[d]	372
Four-state area[c]			
Dry cleaning	2,300	9.5	220
Swimming pool	810	11.3	92
Beer brewing	3,300	11.7	386
Other	4,050	14.75	697
Total	10,460	13.3[d]	1,395

a/ Adjusted survey data -- Table 10.

b/ From Tables 11, 13, 15, and 17.

c/ Includes Iowa, Kansas, Missouri, and Nebraska.

Table 20. --Summary of estimated probable market share -- 1970 for Kansas and the four-state area[a] after five years of operation.

	Estimated market in tons[a]	Percent probable market share[b]	Tons probable market share
Kansas			
Dry cleaning	515	17.26	88.8
Swimming pool	195	32.10	62.6
Other	2,730	26.55	724.8
Total	3,440	25.47[d]	876.2
Four-state area[c]			
Dry cleaning	2,990	17.26	516
Swimming pool	1,050	52.10	337
Beer brewing	4,290	20.00	858
Other	5,260	26.55	1,396
Total	13,590	22.86[d]	3,107

a/ Computations based on value added by manufacture and adjusted survey data - Table 10.

b/ From Tables 12, 14, 16, and 18.

c/ Includes Iowa, Kansas, Missouri, and Nebraska.

d/ These are averages, not totals.

sults of subjective demand determinants. Penetration into the swimming pool market is considered the most probable followed in order by other industrial and food processing, beer brewing, and the dry cleaning market.

Whatever the market, an enterprise contemplating a business venture involved in the production and sale of a filter aid made from volcanic ash must package its product in 40, 50 or 100 pound bags, maintain good quality control, and realize the value of merchandising. Advertising, technical assistance, and the accurate matching of salesmen and sales effort with potential sales will be of continuing prime importance.

ESTIMATED PLANT AND PRODUCT COSTS

The next logical consideration in deriving the over-all profitability of volcanic ash as a filter aid is the determination of estimated plant costs. Once plant costs have been determined, an estimate of product costs can be made. These cost estimates are contemporary with this report and must be adjusted by the reader to more nearly represent the times.

Plant Costs

In the absence of basic small-scale, continuous-flow pilot plant experience in producing volcanic ash filter aids, plant size, choice of equipment and estimated costs of a commercial operation can be subject to considerable error. Recently a large plant to produce diatomite filter aids was built at a cost of about $70.00 per annual ton of product at capacity production. A plant designed to produce volcanic ash filter aids requires, for the most part, similar basic processing steps and equipment. Therefore, we assume that a volcanic ash filter-aid plant could be built at a comparable cost.

Two plant cost estimates have been made, one based on a direct cost per annual ton (Aries and Newton, 1955) and the other using a 0.6 scaling factor (Chilton, 1960a). These estimates were then weighted by probabilities to give an expected value as a final estimate.

Plant cost estimates based on a direct cost per annual ton of capacity as compared with the reported[1/] plant investment for a diatomaceous earth filter aid plant:

Diatomaceous earth filter aid plant

Annual capacity	36,000 tons
Cost	$2,500,000.00
Cost/ton capacity	$69.50

Direct cost estimate for volcanic ash plant

Annual capacity (in tons)	1,000	2,000
Volcanic ash filter aid plant cost	$69,500.00	$139,000

1/ Engineering and Mining Journal, Vol. 165, No. 8, page 50, 1964.

Plant cost estimates using a 0.6 factor (Chilton, 1960a) for scaling with the reported plant investment for a diatomaceous earth filter aid plant:

$$\text{Factor} = \frac{\log \text{(Ratio plant costs)}}{\log \text{(Ratio plant capacities)}}$$

(a) 1,000 ton plant

$$0.6 = \frac{\log \frac{2,500,000}{\text{Vol. Ash Plant Cost (VPC)}}}{\log \frac{36,000}{1,000}}$$

VPC = $291,000

(b) 2,000 ton plant

$$\log \frac{36,000}{2,000} = \log 18$$

VPC = $441,000

Table 21 summarizes the estimated plant costs. Final estimates of plant costs were found to be approximately $180,000 for a 1000 ton annual capacity plant and approximately $ 320,000 for a 2000 ton annual capacity plant.

Table 21.--Summary of Estimated Plant Costs

Annual Plant Capacity (in tons)	Estimated Cost-direct Cost/ton Basis	Probability	Estimated Cost -0.6 Factor	Probability	Estimated Weighted Total-cost For Plant
1,000	$70,000	.50	$291,000	.50	$180,000
2,000	$140,000	.40	$441,000	.60	$320,000

Product Costs

The essential processing steps required to produce a filter aid from volcanic ash are: (1) extraction of the raw material, (2) transportation to and in-plant storage of this raw material, (3) screening, drying, and delivery to expanding furnace, (4) pyro-processing to expand the ash, (5) collection and crushing of the expanded ash, (6) classification of the expanded and crushed ash, (7) packaging, (8) storage of

Table 22.--Product cost estimate -- pre-pilot plant.

					Per ton product	
I -- Raw material delivered to plant, includes royalties, extraction, hauling. $2.50/ton						
Yield - tons raw ash/ton product				1.0	1.5	2.0
Cost/ton product				$2.50	$3.75	$5.00
II -- Fuel cost (Haus, 1949) Natural gas @ 30¢/MCF				$4.72	$7.08	$9.44
III -- Labor						
(1) Operating task	No. Men	Hrs. Day	Man Hrs.			
Raw material preparation						
Furnacing and classification	1	8	8			
Bagging and warehousing	1	8	8			
Miscellaneous	1	8	8			
Total	3		24			
Average labor rate -- $2.00/MH						
Total daily labor cost -- $48.00						
Total annual labor cost at 5 days/week and 52 weeks -- $12,480						
Annual production -- 2,000 tons						
Labor costs				$6.24	$6.24	$6.24
(2) Repair labor (Hackney, 1961)						
50% of 4% of fixed capital investment -- (300,000 x .04) x .50 = $6,000 annually				$3.00	$3.00	$3.00
Sub-total				$9.24	$9.24	$9.24
(3) Supervision -- considered to be part of operating labor -- working foreman				$0.00	$0.00	$0.00
Sub-total				$9.24	$9.24	$9.24
(4) Indirect payroll cost -- 20% of all labor				$1.85	$1.85	$1.85
Sub-total				$11.09	$11.09	$11.09
IV -- Cost of electricity						
Power requirements estimated at 0.02 KWH/lb product with a cost of 1.5¢/KWH						
Cost/ton - 2,000 x .02 x .02 x .015				$0.60	$0.60	$0.60
V -- Water -- assumed				$0.03	$0.03	$0.03
Sub-total				$0.63	$0.63	$0.63
VI -- Supplies and miscellaneous (Chilton, 1960)						
(1) Operating supplies 6% of operating labor -- .06 x 6.24				$0.36	$0.36	$0.36
(2) Repair supplies (Chilton, 1960) 50% of 4% of fixed capital investment (300,000 x .04) x .50 = $6,000				$3.00	$3.00	$3.00
Sub-total				$3.36	$3.36	$3.36

VII -- Fixed costs

(1) General work expense (Chilton, 1960) 3.0% of fixed investment .03 x 300,000 = $9,000 45.0% of labor .45 x 18,480 = 8,300 $17,300	$8.65	$8.65	$8.65
(2) Depreciation Plant life assumed to be 15 years (Chilton, 1960) 6 2/3% of $300,000 = $20,100/year	$10.00	$10.00	$10.00
Sub-total	$18.65	$18.65	$18.65
VIII -- Total Cost	$40.95	$44.56	$48.17

Table 23.--Summary of product cost estimate

Production Percent capacity -- Tons Product		Annual 100 2,000 per ton			Annual 100 2,000 per 2,000 tons	
Raw Material and Fuel Cost						
Volcanic ash	$2.50	$3.75	$5.00	$5,000	$ 7,500	$10,000
Natural gas	4.72	7.08	9.44	9,400	14,160	18,880
Sub-total	7.22	10.83	14.44	14,400	21,660	28,880
Utilities						
Electricity	.60	.60	.60	1,200	1,200	1,200
Water	.03	.03	.03	60	60	60
Sub-total	0.63	0.63	0.63	1,260	1,260	1,260
Labor						
Operating	6.24	6.24	6.24	12,500	12,500	12,500
Repair	3.00	3.00	3.00	6,000	6,000	6,000
Supervision[a/]	-----	-----	-----	------	------	------
Indirect charge	1.85	1.85	1.85	3,700	3,700	3,700
Sub-total	11.09	11.09	11.09	22,200	22,200	22,200
Supplies and Miscellaneous						
Operating supplies	.36	.36	.36	700	700	700
Repair supplies	3.00	3.00	3.00	6,000	6,000	6,000
Sub-total	3.36	3.36	3.36	6,700	6,700	6,700
Fixed Costs						
General work expense	8.65	8.65	8.65	17,300	17,300	17,300
Depreciation	10.00	10.00	10.00	20,000	20,000	20,000
Sub-total	18.65	18.65	18.65	37,300	37,300	37,300
Total	$40.95	$44.56	$48.17	$81,860	$89,120	$96,340

a/ With this operation one man could be designated as a working foreman.

the packaged product, and (9) loading and shipping of the product.

For purposes of this estimate, maximum plant capacity was assumed to be 2,000 tons of product annually on a one shift basis. Market estimation indicates that this tonnage should be entirely absorbed at some period during an estimated plant life of 15 years; additional capacity could be gained by a more than one shift operation.

General Data

Annual product output at capacity, tons	2,000
Estimated working days/year	250
Daily production, tons	8
Working day, hours	8
Unit weight of raw ash, lbs/ft^3	66
Unit weight of expanded ash, lbs/ft^3	5
Cubic feet of expanded ash	3,200
Unit weight of product, lbs/ft^3	10
Cubic feet of product per day	1,600
Estimated plant cost	$300,000

A PROFITABILITY MEASURE APPLIED TO THE VOLCANIC ASH FILTER-AID PROJECT

The quantifiable measure used for economic evaluation of a manufacturing project is the expected profit. The ratio relating profit to investment in some manner is known as rate of return on investment.

A number of such ratios are commonly used and the one selected for this analysis is known as the interest rate of return, profitability index, discounted cash flow, or internal rate of return. Briefly, it calculates the interest rate at which the company's outstanding investment is repaid by proceeds from a project. There are some variations in this method; the technique selected for this analysis is described in Chemical Engineering, May 1961 (Hackney, 1961a). A company can value a project in terms of a constant annual rate of interest that will be produced on the unreturned balance of investment during a project's life. Any money netted by the project in excess of this constant annual "interest rate of return" is credited against project investment. Interest rate of return is set so investment is reduced to zero at the end of the project's life. This interest rate on the unreturned balance is an excellent measure of net effective project profitability.

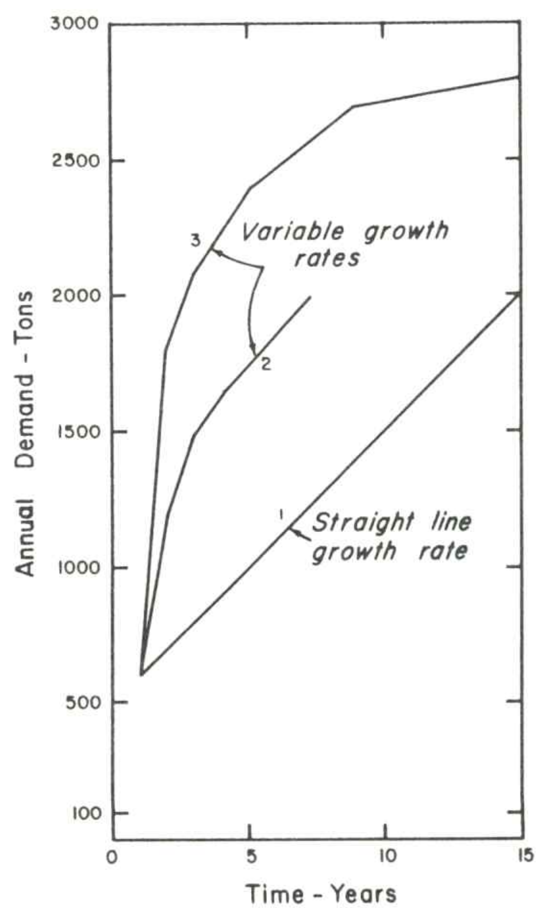

Fig. 3.--Hypothetical market demand growth schedules for volcanic ash filter aid.

In order to study profitability it is necessary to assign some kind of a rate of market growth for this project. Figure 3 shows three possibilities which are used in analyzing a profitability index.

Number one assumes a straight line rate of growth from 600 tons per year to 2,000 tons per year in 15 years. This would most likely be the least desirable growth of sales pattern. The number two relationship shows a doubling of sales for the second year, then for the next two years sales increase at one-half the preceding years' rates until the assumed maximum of 2,000 tons is reached.

Curve three assumes that sales will triple in the second year then be half the first year's sales at

Table 24.--Interest rate of return table assuming a given capital

Year	Sales, tons per year[a/]	S Gross sales @ $60/ton	M Manu-facturing cost	D Depreci-ation	P Net book profit before federal income tax	T Income tax @ 52%	F Net cash flow S-M-T
0		0		0	0	0	0
1	600	$ 36,000	$51,000	$20,000	-$35,000	0	-$15,000
2	1,200	72,000	56,000	20,000	-4,000	0	16,000
3	1,500	90,000	58,000	20,000	12,000	0	32,000
4	1,650	99,000	59,000	20,000	20,000	0	49,000
5	1,750	105,000	60,000	20,000	25,000	13,000	32,000
6	1,850	111,000	60,800	20,000	30,000	15,600	34,600
7	2,000	120,000	61,000	20,000	39,000	20,300	38,700
8	2,000	120,000	61,000	20,000	39,000	20,300	38,700
9	2,000	120,000	61,000	20,000	39,000	20,300	38,700
10	2,000	120,000	61,000	20,000	39,000	20,300	38,700
11	2,000	120,000	61,000	20,000	39,000	20,300	38,700

a/ Sales as per schedule 1.

b/ Gross investment less working capital, assumed spent over year prior to start up.

c/ Working capital.

succeeding increasing time intervals. This latter estimate would suggest a strong merchandising effort and represents an optimum situation.

The first analysis is given in Table 24. With the specifications as stipulated the unreturned balance increases to a constant $400,000, thus indicating that the plant investment is not recoverable. This suggests that the rate of interest is too high, initial investment too great, or sales realization inadequate. Using zero percent interest, investment shows a recovery between 10 and 11 years; therefore the interest rate of return is probably on the order of 2 to 5 percent.

investment and interest rate of return to calculate project life.

I Investment	R Interest returned $\frac{B_1+B_2}{2}$[e] x 10%	C Capital returned F-I-R	B_1 Balance unreturned	R Interest returned 0%	C Capital returned F-I-R	B_1 Balance unreturned
$300,000[b]	$15,800[d]	-$315,800		0	-$300,000	
10,000[c]	34,500	-59,500	$315,800	0	-25,000	300,000
0	38,610	-22,610	375,800	0	16,000	325,000
0	40,100	-8,100	397,400	0	32,000	309,000
0	40,200	8,400	405,500	0	49,000	277,000
0	40,600	8,100	397,100	0	32,000	228,000
0	40,100	4,500	389,000	0	34,600	196,000
0	39,100	300	384,500	0	38,700	161,400
0	38,400	300	384,200	0	38,700	122,700
0	38,400		384,100	0	38,700	84,000
0				0	38,700	45,300
				0	38,700	6,600

d/ The dollar interest return to the Company for an individual year is the interest rate of return times the average unreturned investment for the year.

e/ $B_2 = \frac{B1\,(1 + \frac{r}{2}) + I - F}{1 - \frac{r}{2}}$ where r = selected interest rate.

Table 25.--Interest rate of return table assuming a given

Year	Sales, tons per year[a/]	S Gross sales @ $72/ton	M Manu-facturing cost	D Depreci-ation	P Net book profit before federal income tax
0	0				
1	600	$43,200	$51,000	$20,000	-$27,800
2	1,200	86,400	56,000	20,000	10,400
3	1,500	108,000	58,000	20,000	30,000
4	1,650	118,800	59,000	20,000	39,800
5	1,750	126,000	60,000	20,000	46,000
6	1,850	133,000	60,800	20,000	52,200
7	2,000	144,000	61,000	20,000	63,000
8	2,000	144,000	61,000	20,000	63,000
9	2,000	144,000	61,000	20,000	63,000
10	2,000	144,000	61,000	20,000	63,000
11	2,000	144,000	61,000	20,000	63,000
12	2,000	144,000	61,000	20,000	63,000
13	2,000	144,000	61,000	20,000	63,000
14	2,000	144,000	61,000	20,000	63,000
15	2,000	144,000	61,000	20,000	63,000

a/ Sales as per schedule 1.

b/ Gross investment less working capital, assumed spent over year prior to start up.

c/ Working capital.

d/ The dollar interest return to the Company for an individual year is the interest rate of returns times the average unreturned investment for the year.

e/ $B_2 = \frac{B_1 (1 + \frac{r}{2}) + I - F}{1 - \frac{r}{2}}$ where r = selected interest rate.

capital investment and interest rate of return to calculate project life.

T Income tax @ 52%	F Net cash flow S-M-T	I Invest- ment	R Interest returned $\frac{B_1+B_2}{2}$ [e] x 10%	C Capital returned F-I-R	B_1 Balance unre- turned
		$300,000 [b]	$15,300 [d]	-$315,300	
0	-$7,800	10,000 [c]	34,115	-51,900	$315,300
0	20,400	0	37,600	-17,200	367,200
$15,600	34,400	0	38,600	-4,200	384,400
20,700	39,100	0	38,800	300	388,600
24,000	42,000	0	38,600	3,400	388,300
27,200	45,000	0	38,700	6,300	384,900
32,800	50,200	0	37,200	13,000	378,600
32,800	50,200	0	35,200	15,000	365,600
32,800	50,200	0	34,300	15,700	350,600
32,800	50,200	0	32,600	17,600	334,900
32,800	50,200	0	30,700	19,500	317,300
32,800	50,200	0	28,600	21,600	297,800
32,800	50,200	0	26,400	23,800	276,200
32,800	50,200	0	23,800	26,400	252,400
32,800	50,200	0	20,800	29,400	196,600

Table 26.--Interest rate of return table assuming a given capital

Year	Sales, tons per year[a]	S Gross sales @ $60/ton	M Manu- facturing cost	D Depreci- ation	P Net book profit before federal income tax	T Income tax @ 52%	F Net cash flow S-M-T
0	0	0	0	0	0	0	0
1	600	$36,000	$44,000	$13,200	-$21,200		-$8,000
2	1,800	108,000	53,300		41,500	$11,000	43,700
3	2,100	126,000	55,600		57,200	29,800	40,600
4	2,400	144,000	57,900		72,900	38,000	48,100
5	2,700	162,000	60,300		88,500	46,000	55,700
6	2,800	168,000	61,000		93,800	49,000	58,000
7	2,800	168,000	61,000		93,800	49,000	58,000
8	2,800	168,000	61,000		93,800	49,000	58,000

a/ Sales as per schedule 1.

b/ Gross investment less working capital, assumed spent over year prior to start up.

c/ Working capital.

d/ The dollar interest return to the Company for an individual year is the interest rate of return times the average unreturned investment for the year.

e/ $B_2 = \frac{B1\ (1 + \frac{r}{2}) + I - F}{1 - \frac{r}{2}}$ where r = selected interest rate.

investment and interest rate of return to calculate project life.

I Invest- ment	R Interest returned $\frac{B_1+B_2}{2}$[e] x 10%	C Capital returned F-I-R	B_1 Balance unre- turned	R Interest returned $\frac{B_1+B_2}{2}$ x 20%	C Capital returned F-I-R	B_1 Balance unre- turned
$200,000[b]	$10,500[d]	-$210,500		$22,200	-$222,200	
6,000[c]	22,100	36,100	$210,500	30,920	-45,000	$222,200
0	23,700	20,000	246,600	54,600	-10,900	267,000
0	21,700	18,900	226,600	57,300	-16,700	277,900
0	19,800	28,300	207,700	60,260	-12,200	294,600
0	16,000	39,700	179,400	62,100	- 6,400	306,800
0	11,400	46,600	139,700	63,100	- 5,100	313,000
0	7,000	51,000	93,100	64,200	- 6,000	318,000
0	1,415	44,000	42,100			

Table 25 is an analysis using the same specifications as for Table 24, except that the unit sales price of the product is increased from $60.00 per ton to $72.00 per ton. With an assumed interest rate of 10 percent, at the end of 15 years there remains an unreturned balance of approximately $200,000; if credit is taken for salvage, this would be reduced further. Again a lower interest rate is indicated.

Several changes in specifications were assumed in order to construct Table 26. A sales schedule according to Curve 3, Figure 3 was adopted, the plant investment was reduced to $200,000 and the cost of manufacturing estimated according to Table 27. Under these conditions, investment recovery at 10 percent interest rate of return requires 8-plus years. Therefore, a higher rate of return is indicated, most likely in the 12-15 percent bracket.

Table 27.--Estimated cost of manufacturing.

		Per ton	Annual
Raw material		$2.50	
Fuel		4.72	
		7.22	
Labor			
Operating			$12,480
Repair (200,000 x .04) x .50			4,000
Total			16,480
Supervision			
Indirect payroll cost @ 20 percent			3,296
Total			19,776
Electricity and water		.60	1,200
Supplies			
6 percent operating labor			750
Operating repair - same as repair labor			4,000
Total			4,750
Fixed costs			
General works expense			
3 percent of investment	-- $6,000		
45 percent of labor	-- 7,416		
	13,416		13,500
Depreciation			
15 years -- 6 2/3 percent of 200,000			(13,300)
Total annual charges less depreciation			$39,200
Total variable charges per ton		$7.82	

Table 28.--Profit and loss estimate based on annual sales of 2,000 tons at average sales price of $60.00 per ton.

	Raw material cost/ton		
	$2.50	$3.75	$5.00
Direct material cost	14,400.00	21,660.00	28,880.00
Other direct variable costs	30,160.00	30,160.00	30,160.00
Fixed costs	37,300.00	37,300.00	37,300.00
Total product costs	$ 81,860.00	$ 89,120.00	$ 96,340.00
	(82,000.00)	(89,000.00)	(96,000.00)
Total sales	$120,000.00	$120,000.00	$120,000.00
Operating expense	82,000.00	89,000.00	96,000.00
Operating profit before taxes	38,000.00	31,000.00	24,000.00
Income tax @ 52 percent	20,000.00	16,000.00	12,000.00
Net profit	$ 18,000.00	$ 15,000.00	$ 12,000.00
Percent return on gross investment of $300,000, after taxes	6.0	5.0	4.0
Pay-back time (years) $\frac{\text{Investment}}{\text{Net profit + deprec.}}$ =	7.9	8.6	9.4
Break-even point in tons (Aires and Newton, 1955)	1,080	1,110	1,150
Shutdown point in tons (Aires and Newton, 1955)	200	201	216

In addition to profitability the degree of risk in obtaining the desired profitability must be considered. Projects with low returns are ordinarily of little or no risk; high-risk ventures command high rates of return. The relationship between degree of risk and acceptable interest rate of return is a matter of policy decision; thus an assessment of risk is necessary.

A suggested rate of risk is as follows (Hackney, 1961a):

High risk: Project involving considerable novelty or based on raw material, products, sales data somewhat unproved.	25.0 percent
Fair risk: Project somewhat outside the present field of activity or novel projects and processes that have been thoroughly investigated.	16.0 percent

Average risk: Usually projects in a present field of operation, but involving some novel element or lack of definite market information.	12.0 percent
Good risk: These are expansions of existing operations where there is a known market.	9.0 percent
Excellent risk: These projects usually are designed to improve yield or reduce labor costs on a known process.	6.0 percent or less

Finally, a systematic review of the risk status will at least uncover areas requiring more investigation.

CONCLUSIONS

Markets

The demand for filter aids in Kansas, Missouri, Nebraska, and Iowa correlates more accurately with the value added in manufacturing than with population. This demand for filter aids should increase gradually in proportion to the increase of value added in manufacturing.

Penetration into the market of a new filter aid made from volcanic ash will be slow and somewhat difficult initially. The quality of a volcanic ash filter aid must be equal to and preferably greater than present perlite types. Technical knowledge of the product and its application is absolutely necessary for this type of commodity to sell effectively.

Sales of Kansas volcanic ash filter aid should initially be 700 to 900 tons annually with growth to 3,000 tons over a 5 year period. This is based on a four-state market area of Kansas, Missouri, Nebraska and Iowa.

Plant Costs

A facility to produce filter aids from volcanic ash will require specialized equipment, namely furnace and crusher. The classification and collection equipment for the product must be efficient and effective to insure proper quality control. These suggest that a filter-aid plant for processing volcanic ash will require a sizeable investment, most likely in the range of 150 to 200 dollars per annual ton of product.

Product Costs

Product costs are based on a plant that would produce filter aids only. The final cost per ton for this product, based on present knowledge, will very likely be in the 40 to 50 dollar per ton bracket.

Profitability

Sixty dollars per ton f.o.b., place of manufacture, was arbitrarily selected for a selling price. This represents a fairly frequently quoted price in the trade; and, furthermore, suggests that user savings are possible through freight differentials.

At this stage of development, a project to produce volcanic ash filter aids would be a fair to high risk. On the other hand, the interest rate of return estimated from sales realization and necessary investment would be extremely low, namely 3 to 5 percent. Considering the risk involved it should be 16 to 25 percent.

An increase in sales realization, if this could be obtained by increasing tonnage produced and sold rather than increasing sales price, and a reduced capital investment, would shift the profitability to a more favorable range.

Generally speaking, penetration into the swimming pool market is considered favorable because of the expanding market and weak brand allegiance. In the dry cleaning and beer brewing industries, market penetration should prove to be more difficult as a result of the high clarity and rate of flow requirements, as well as strong customer satisfaction and strong brand allegiance. Market capture into other fields of food processing and industrial uses will depend upon the characteristics desired in the filter aid.

This particular analysis applies to the situation under which a small isolated industry might be established. Obviously the analysis would not be applicable to a manufacturing facility which is a part of a multi-product organization, the latter having laboratory facilities, sales, and merchandising channels and some overlapping management.

As indicated previously, a market area consisting of the four states, i. e., Kansas, Missouri, Nebraska, and Iowa, was used to calculate a potential total market. It is entirely reasonable to contemplate a substantially larger market embracing states east of the Mississippi River. A filter aid manufactured in Kansas should have a shipping cost advantage to this area compared with products from Texas and the Mountain and Western states.

This analysis is based on the use of expanded ash solely for a filter aid. Some other market for this product, based on its lightness of weight, color, texture, and insulating properties should exist. If so, then a market could be expanded into these areas.

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