AN ECONOMIC EVALUATION ON THE LOCATION OF A FINE CHEMICAL PLANT IN OKLAHOMA

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PREFACE

In this work the author investigates the economic potential of Oklahoma as a location for a fine chemical plant. The fine chemical chosen is pyrethrum and the locations selected, Pryor and Stillwater, Oklahoma. A general evaluation procedure is developed for making similar location evaluations.

The author gratefully acknowledges the considerate and patient understanding of Dr. Robert H. Dodd, under whose guidance this work was carried out. To the other members of the faculty, I wish to express appreciation for their interest and encouragement.

Furthermore, I wish to acknowledge the use of the facilities provided by the School of Chemical Engineering of the Oklahoma Institute of Technology.

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INTRODUCTION

The purpose of this investigation is to determine whether it is economically feasible to locate a fine chemical plant in Oklahoma. Because of the number of chemicals and locations which might be considered, it was necessary to restrict these by making an arbitrary selection of each.

That segment of the fine chemical industry chosen was the manufacture of alkaloids and botanicals, and the economics of pyrethrum production selected as typical. Because of the limited number of concerns currently engaged in this industry, it was felt that it could be more accurately studied.

The locations selected were Stillwater and Pryor, Oklahoma--Stillwater because it was the location at which the investigation was to be conducted and Pryor because of its increasing industrial development resulting from low cost utilities.

It was decided that from the detailed investigation it should be possible to determine a generalized method of approach for plant location evaluations.

Previous investigations for Oklahoma have been limited to the state's economic potential as a location for a heavy chemical industry, one which produces large quantities of relatively low cost per pound products.[2] In general, the preceding type of manufacture requires a much larger capital investment than does the manufacture of fine chemicals whose production consists primarily of high cost per pound products in small quantities.

Because the capital required is smaller and the economics somewhat dissimilar to that of heavy chemical manufacture, it was felt that should this investigation prove the advisability of Oklahoma as a location for a fine chemical plant, the possibility of starting such an enterprise would not be limited to a few large chemical concerns but could possibly be undertaken by a group of individuals. Based on this premise, this investigation was undertaken with the hope that it might aid in furthering industrial development in Oklahoma.

FACTORS INFLUENCING PRODUCT COST WHICH VARY WITH GEOGRAPHICAL LOCATION

Others have attempted to determine the relative importance of the factors to be evaluated in plant location surveys for the chemical industry in general.[16,20] However, in this investigation only the following factors were considered as influencing the selection of a location for a fine chemical plant.

1. Proximity of Plant to Raw Materials
2. Proximity of Plant to Markets
3. Fuel Rates
4. Electricity Rates
5. Water Rates
6. Labor Rates
7. Construction Costs
8. Local and State Taxes

The relative importance of each factor was determined for each plant location.

Existing Competition

In determining the advisability of either Stillwater or Pryor, Oklahoma, as a location for a fine chemical plant manufacturing alkaloids, the first step was to determine who the major competitors would be and their locations. The following information was obtained concerning manufacturers who are at present engaged in the production of pyrethrum or other botanicals of that nature.[12]

1. Chemical Insecticide Corp. - Metuchen, N. J.
2. Meer Corporation - North Bergen, N. J.
3. S. B. Penick & Company - Lyndhurst, N. J.

4. Prentiss Drug & Chem. Co. - Brooklyn, N. Y.
5. John Powell & Co. - Brooklyn, N. Y.
6. Inland Alkaloid Co. - Tipton, Ind.
7. McLaughlin Gormley King Co. - Minneapolis, Minn.
8. U. S. Industrial Chemicals Co. (Div. of Food Mach.) - Baltimore, Md.

Potential Competition in Oklahoma

In considering the location of an alkaloid plant in Stillwater or Pryor, it was necessary to investigate existing concerns to determine whether they might have the required facilities to enter into competition. Information was obtained on the location of the various companies in the state of Oklahoma listing themselves as chemical manufacturers.[3] A group of these companies was visited to determine the type of operation being conducted at each. Of the eighteen companies visited, the majority were found to be engaged primarily in the compounding of various chemical products as listed below.

Type of Production	Number of plants
Fertilizers	1
Water-treating chemicals	2
Insecticides, herbicides, pesticides	2
Flavor extracts	2
Lacquer, paint, wax solvents	3
No chemical products	10

None was engaged in the manufacture of basic chemicals on a plant scale production basis or had the facilities available to do so. It was concluded that no potential competition exists in Oklahoma. If a potential competitor had been found, it would have been necessary to determine and analyze the items of manufacturing expense at his location.

Since the majority of pyrethrum flowers produced today come from Kenya, Africa, the delivered cost differential between any two of the locations would be approximately the difference in transportation cost from the dockside of the nearest seaport to the plant sites.[15] The majority of raw materials for alkaloids are produced outside the United States.

Listed in Table I are the costs per 100 pounds for delivering pyrethrum flowers or other similar materials from the nearest seaport to the various plants.

TABLE I

TRANSPORTATION COST OF RAW MATERIALS

Location	Seaport	Freight Cost $/100 lbs
Pryor, Okla.	Houston	$2.31
Stillwater, Okla.	Houston	2.31
Tipton, Ind.	New York	3.08
Minneapolis, Minn.	New York	3.76
Brooklyn, N. Y.	New York	.84
N. Bergen, Metuchen & Lyndhurst, N. J.	New York	.84
Baltimore, Md.	Baltimore	.84

The cost of transportation of the finished product to various market locations is listed in Table II on page 6.* These locations do not include a number of west coast markets to which Pryor and Stillwater could ship more cheaply than the other locations.

*Market Locations furnished by Mr. Roy W. Hagelin, chemical broker, New York, N. Y.

TABLE II

FREIGHT RATES TO MARKETS, CLASS 85, LCL ($/100 LBS)

To / From	Pryor, Okla.	Stillwater, Okla.	N. Bergen & Lyndhurst, N J	Metuchen, N. J.	Brooklyn, N. Y.	Tipton, Ind.	Minneapolis, Minn.	Baltimore, Md.
Atlanta, Ga.	3.04	3.22	3.13	3.08	3.12	2.49	3.56	2.74
Boston, Mass.	4.50	4.79	1.64	1.69	1.64	3.22	3.91	2.11
Bridgeport, Conn.	4.40	4.60	1.15	1.23	1.15	3.13	3.81	1.75
Bristol, Tenn.	3.28	3.47	2.54	2.44	2.54	2.26	3.47	2.11
Brooklyn, N. Y.	4.21	4.44	.84	.84	----	3.08	3.76	1.49
Buffalo, N. Y.	3.56	3.76	2.01	1.96	2.01	2.16	2.98	2.06
Canton, O.	3.23	3.45	2.36	2.26	2.35	1.69	2.88	2.06
Chicago, Ill.	2.64	2.83	3.18	3.13	3.18	1.30	2.06	2.93
Cleveland, O.	3.23	3.42	2.44	2.35	2.44	1.69	2.78	2.17
Columbus, O.	3.04	3.22	2.59	2.49	2.59	1.40	2.74	2.21
Decatur, Ill.	2.25	2.39	3.32	3.22	3.32	1.37	2.20	3.03
Detroit, Mich.	3.13	3.32	2.59	2.54	2.59	1.58	2.49	2.54
Ft. Wayne, Ind.	2.84	3.03	2.88	2.78	2.88	1.09	3.32	2.59
Ft. Worth, Tex.	1.75	1.75	4.64	4.59	4.64	3.22	2.39	4.30
Indianapolis, Ind.	2.59	2.88	2.98	2.93	2.98	.84	2.44	2.64
Jacksonville, Fla.	3.52	3.71	3.32	3.25	3.32	3.27	4.20	2.98
Jersey City, N. J.	4.21	4.45	.84	.84	.84	3.08	3.76	1.49
Kalamazoo, Mich.	2.89	3.08	2.88	2.88	2.88	1.37	2.20	2.74
Lynchburg, Va.	3.71	3.91	2.06	1.96	2.06	2.49	3.61	1.52
Milwaukee, Wisc.	2.74	2.98	3.08	3.17	3.08	1.58	1.86	3.08
New Bedford, Mass.	4.50	4.69	1.64	1.69	1.64	3.27	3.91	2.11
New Brunswick, N.J.	4.15	4.40	.84	.84	.84	2.88	3.71	1.37
New York, N. Y.	4.21	4.44	.84	.84	.84	3.08	3.76	1.49
Nutley, N. J.	4.21	4.44	.84	.84	.84	3.08	3.76	1.49
Omaha, Neb.	2.01	2.60	4.10	4.00	4.10	2.49	1.91	3.86
Orangeburg, N. Y.	4.21	4.44	.84	.84	.84	3.08	3.76	1.49
Pearl River, N. Y.	4.21	4.44	1.26	.92	1.26	3.03	3.71	1.52
Philadelphia, Pa.	4.06	4.30	1.12	.97	1.12	2.78	3.76	1.15
Pittsburgh, Pa.	3.37	3.62	2.11	2.06	2.11	1.91	3.18	1.81
Portland, Ore.	6.08	8.28	9.80	9.80	9.80	9.42	7.52	9.80
Rahway, N. J.	4.21	4.44	.84	.84	.84	3.08	3.76	1.49
Richmond, Va.	3.91	4.10	1.92	1.81	1.92	2.74	3.81	1.37
Springfield, Mass.	4.30	4.50	1.33	1.42	1.33	3.08	3.71	1.91
Stoneham, Mass.	4.50	4.69	1.64	1.69	1.64	3.22	3.91	2.11
St. Louis, Mo.	2.01	2.30	3.08	3.42	3.18	1.69	2.36	3.17
Worchester, Mass.	4.40	4.59	1.52	1.58	1.52	3.17	3.81	2.01
West Plains, Mo.	1.64	1.96	3.98	3.86	3.98	2.34	2.93	3.61

The labor rates for each location appear below in Table III.

TABLE III

LABOR RATES

Location	Average of All Industries	Adjusted Average for Chemical Industries
Stillwater	1.65 $/hr.	1.74 $/hr.
Pryor	----	1.85
Brooklyn	1.85	1.95
Baltimore	1.87	1.97
Minneapolis	1.87	1.97
Lyndhurst	1.93	2.04
Metuchen	1.93	2.04
North Bergen	1.93	2.04
Tipton	1.98	2.09

The labor rates at Stillwater and Pryor were ascertained by local surveys. Labor rates for all other locations were computed by taking information on average industrial wage rates at each location and multiplying by the ratio of the average of chemical industry wage rates to the average of all industrial wage rates.[19]

Figures 1, 2 and 3 on the following pages show the comparison of gas, electricity and water costs at varying rates of consumption for each location. Data from which these plots were made are found in Appendix A.

FIGURE 1
FUEL COSTS AT EACH LOCATION

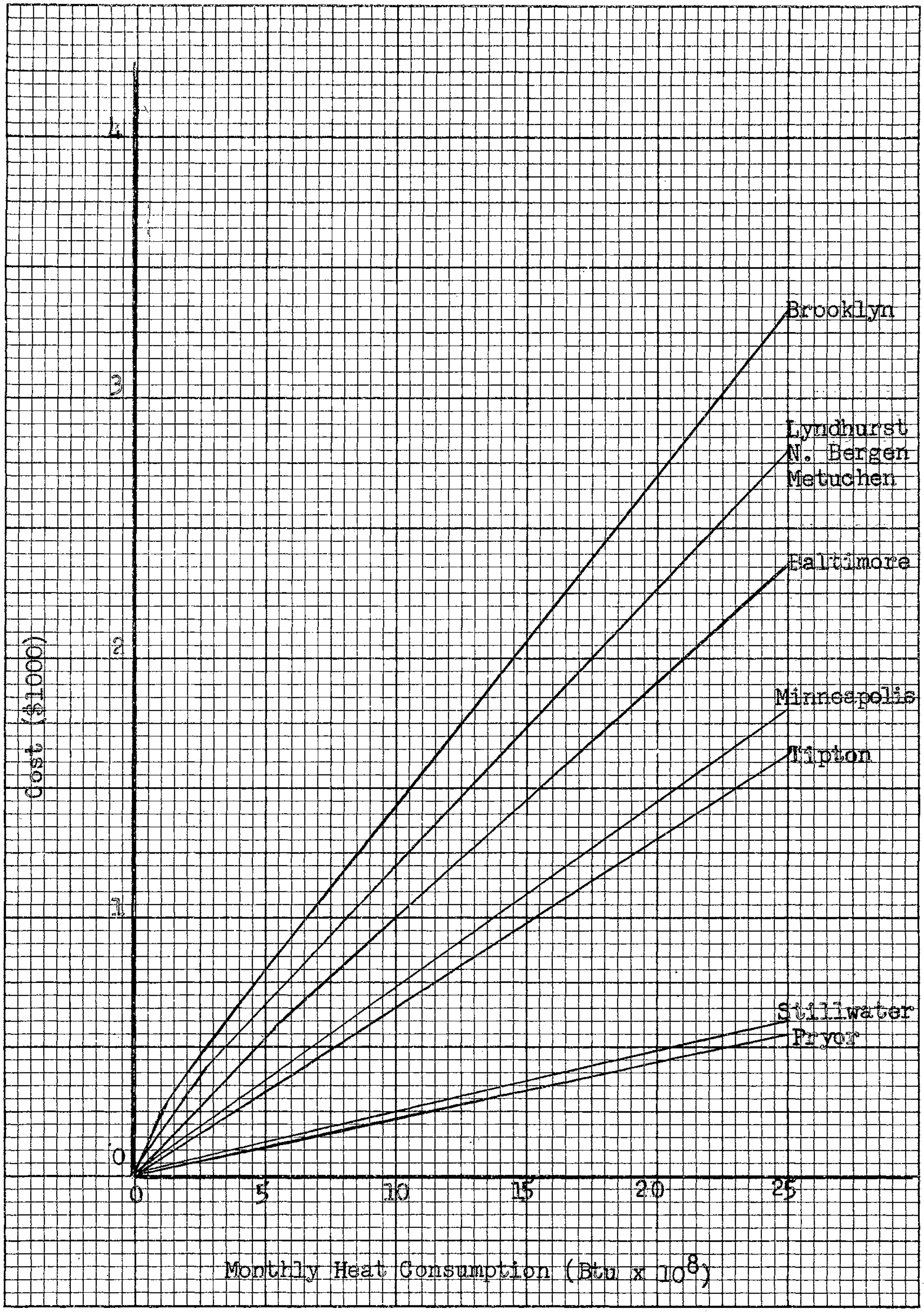


FIGURE 2
ELECTRICITY COSTS AT EACH LOCATION

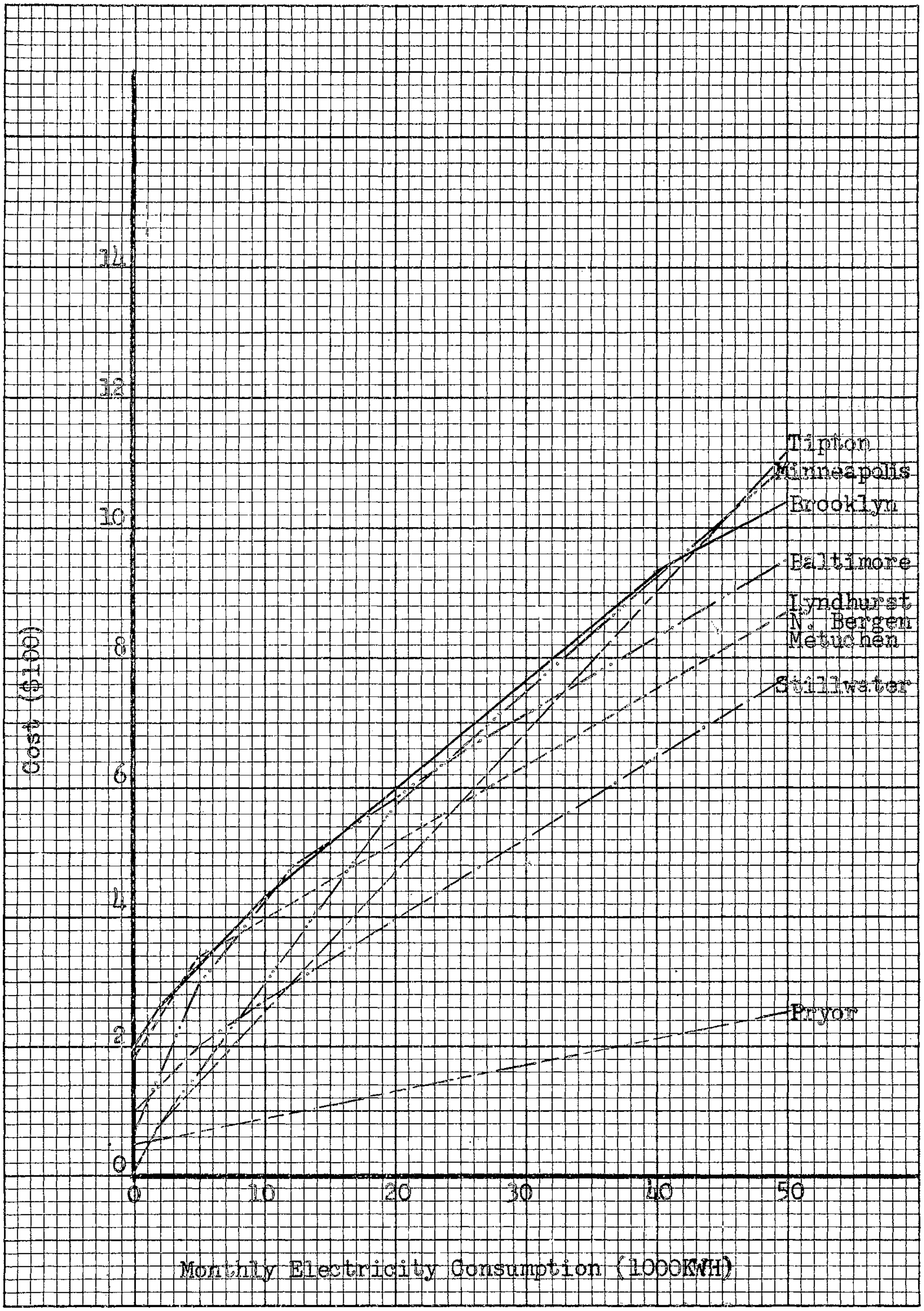
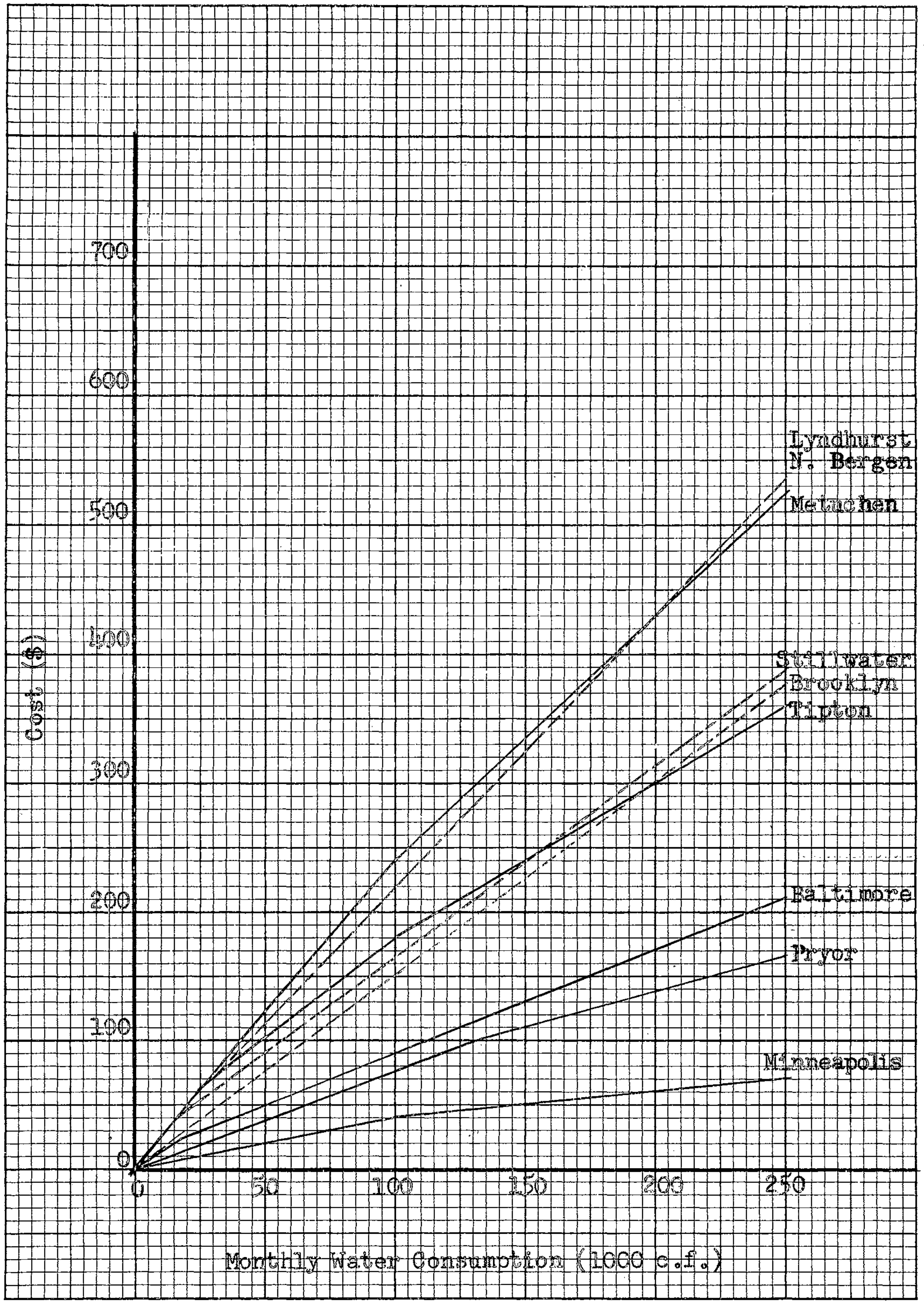


FIGURE 3
WATER COSTS AT EACH LOCATION



The plant construction cost indices for each of the locations are listed below.*

1.	Pryor	-	100
2.	Stillwater	-	100
3.	Baltimore	-	110
4.	Minneapolis	-	120
5.	Brooklyn	-	135
6.	Lyndhurst	-	115
7.	Metuchen	-	115
8.	North Bergen	-	115
9.	Tipton	-	120

The local and state tax rates and the comparison of assessed valuation to actual cost for each location are listed in Table IV on the following page.

*Private communication, Mr. L. W. Trowbridge, Chief Estimator, The Lummus Company, New York, N. Y.

TABLE IV

STATE AND LOCAL TAX INFORMATION

Recurring Taxes State & Local	Stillwater Okla.	N. Bergen N. J.	Metuchen N. J.	Lyndhurst N. J.	Brooklyn N. Y.	Minneapolis Minn.	Tipton Ind.	Baltimore Md.	Pryor Okla.
Income Tax (State)	4% Net Income	None	None	None	5½% Net Income**	6½% Net Income	¼% Gross Income	4% Net Income**	4% Net Income
Franchise Tax	1/8% Capital Used	1/5% of Net Worth	1/5% of Net Worth	1/5% of Net Worth	------	------	------	$100 per $500,000	1/8% of Capital Used
Taxes on Intangible Properties or Assets	2 mills on cash & bank deposits 4 mills on accounts receivable Stocks & Bonds	local	local	local	local	local	local	local	2 mills on cash & bank deposits 4 mills on accts. rec. Stocks & Bonds
Taxes on Real, Personal and Intangible Property (Local)	48.2 mills	73.81 mills	96.40 mills	81.8 mills	37.9 mills (Real property only)	149 mills	29.8 mills	31.6 mills	45.60 mills
Income Taxes	None	None	None	None	1/5% of Gross Income	None	None	None	None
% Assessed Valuation is of Actual Cost	55%*	50.53%	19.8%	28.7%	83%	37%	33 1/3% Sale Value	67%	10%*

*Information obtained from local tax assessors

**Federal Income Tax not deductible in computation of net income.

DETERMINATION AND COMPARISON OF COST OF PRODUCT DELIVERED

Several methods for making a comparison of the factors listed in the preceding section for each of the nine locations were considered. The method which seemed to be of greatest adaptability and sensitivity is discussed in the following paragraphs and is the method used in this comparison.

Basis of Comparison

To make a valid comparison of tax and utility rates between the locations, it was necessary to make the following assumptions.

Plant Capacity

The assumption was made that the plant design and capacity were the same for each location. A figure of $500,000 was selected as a representative value of the plant investment for a fine chemical manufacturing establishment, and this figure was used as the plant cost at Pryor, Oklahoma. The plant costs for the remaining locations were determined by applying the construction cost indices listed on page 11 in the preceding section. Plant costs as determined by this method are given below.

Location	Plant Investment Cost
1. Pryor, Oklahoma	$500,000
2. Stillwater, Oklahoma	$500,000
3. Baltimore, Maryland	$550,000
4. Lyndhurst, New Jersey	$575,000
5. Metuchen, New Jersey	$575,000
6. North Bergen, New Jersey	$575,000
7. Tipton, Indiana	$600,000

8. Minneapolis, Minnesota $600,000

9. Brooklyn, New York $675,000

Net Product Sales

A figure for the net product sales at Pryor, Oklahoma, was determined by applying the average ratio of net sales to plant investments for twenty chemical product companies to the assumed plant investment cost of $500,000.[13] The value of net sales determined was $573,000 per year. Since it was assumed that all plants were of the same capacity, the net sales were assumed to be the same for all plants.

Net Annual Profit

This figure was calculated by applying to the assumed value of net sales of $573,000 the average ratio of net profit to net sales for twenty chemical product companies. The value determined was $54,500 per year, which represents the undistributed profit before dividends.

Manufacturing Requirements

Labor, fuel, water and energy requirements were assumed to be the same for all locations.

Freight Costs

With the above assumptions in view, it was then necessary to determine how the last factor--that of freight costs--might be introduced into the system of analysis.

From Table I the additional costs of the raw materials to inland producers may be determined. However, to establish the cost of shipping the product from a location that is isolated from the majority of the markets, a basis of comparison had to be developed.

Assumptions so far had been based on equality of plant size, net annual sales, net annual profit and identical manufacturing requirements. It was decided that a line could be established geographically which would represent points to which Pryor and an existing competitor might ship at equal profit and equal delivered price per pound. In establishing this line all cost differentials for labor, fuel, electricity, freight (raw materials and finished product) and local and state taxes between the two locations would be considered.

Plotting on a map such a line for each location in competition with Pryor defines a preferential marketing area for the product.

Local and State Taxes

In the analysis of tax rate structures of the various states and localities concerned, it was necessary to fix values for several items to place all companies on a comparable basis. Except for the figure in item one, the following figures and definitions are based upon information from the financial reports of twenty chemical product companies.[13]

1. Gross fixed assets - $500,000 for Pryor, Oklahoma. The gross value of all lands, buildings and equipment. Other locations determined by construction cost. (See page 13.)

2. Net profit - $54,500, the net income of the company after federal and state taxes prior to payment of dividends to the stockholders.

3. Net sales - $573,000, the amount of product sales after all discounts.

4. Net worth - $403,000, the book value of the ownership interest in the company. It is the sum of what the original stockholders subscribed plus what the company subsequently earned and retained in the business.

5. Bank deposits - $63,000, the current cash asset of the company.

6. Accounts receivable - $69,000, the amount due the company for sales on credit.

7. Stocks and bonds - $83,000, the investment of the company in stocks and bonds.

Comparison of Locations

With the aid of the preceding basis of comparison it was possible to calculate the relative cost of manufacture for each location by use of the data in the preceding section.

Local and State Tax Costs

From the preceding and information listed in Table IV on page 12, the costs of state and local taxes were computed for each location and are found in Table V on the following page.

Amount and Value of Product Produced

The current value of pyrethrum is $42.75 per gallon (100/1 basis, 10 grams pyrethrins per 100 c.c. odorless base).[11] In order to have an annual net sales of $573,000 it would be necessary to produce 13,400 gallons product per year assuming the current price to be representative of the average. To produce this amount would require 1,092,000 pounds of pyrethrum flowers (0.9% pyrethrins) per year.[7]

Raw Material Freight Cost

This figure was calculated for each location by applying the information in Table I to the amount of pyrethrum flowers required to produce one hundred pounds product (1,324 pounds pyrethrum flowers per 100 pounds solution, 100:1 basis).[7] This information is shown in Table VI on page 21. The cost of transporting 7.26 gallons of ethylene dichloride and forty-one gallons of odorless petroleum solvent daily to each plant was assumed to be approximately the same and any differential insignificant in comparison with other differentials in items of cost.

Estimate of Labor, Fuel, Water and Power Costs

In order to make a reasonable estimate of the above requirements

TABLE V

ANNUAL STATE AND LOCAL TAX COSTS FOR EACH LOCATION

	Stillwater	N Bergen	Metuchen	Lyndhurst	Brooklyn	Minneapolis	Tipton	Baltimore	Pryor
Actual Plant Cost	500,000	575,000	575,000	575,000	675,000	600,000	600,000	550,000	500,000
Assessed Valuation of Plant	275,000	291,000	114,000	165,000	305,000*	222,000	200,000	368,000	50,000
Local Property Tax	13,250	21,500	11,000	13,500	13,900	33,100	5,960	11,600	2,280
Local Income Tax	---	---	---	---	1,146	---	---	---	---
State Income Tax	2,875	---	---	---	9,000	6,100	1,435	6,020	2,420
State Property Tax	710	---	---	---	---	---	---	---	---
Fed. Income Tax	77,700	83,200	71,800	74,400	85,000	101,500	67,000	78,200	65,500
State Franchise Tax	504	806	806	806	---	---	---	100	504
TOTAL	94,339	105,506	83,606	88,706	109,046	140,700	74,395	95,920	71,414

*Real property only - estimated from information on real and personal property for three of the companies per 100 pounds of product, it was necessary to investigate the method of manufacture.[7]

A charge of 1500 pounds of pyrethrum flowers is introduced into an extractor which consists of a vertical tank mounted on trunnions. The extractor is fitted with a false bottom to permit flow of the solvent and retention of the flowers.

The charge is then extracted by use of approximately 400 gallons of ethylene dichloride. The extract is distilled under vacuum yielding approximately 100 pounds of pyrethrins and oleoresin. The marc from the extractor is distilled to remove the ethylene dichloride remaining. The amount of ethylene dichloride lost per 1500-pound batch is approximately three gallons.

The pyrethrins are then separated from the oleoresin by use of a satisfactory odorless petroleum solvent and are sent to a calibrated tank for mixing to the proper concentration.

The solution is chilled to 0°C and held there for three days. It is then treated with a filter aid and pumped through a filter press to the product storage tanks. A flow diagram of this process appears in Figure 4 on page 20.

From the above information the following estimates were made based on comparison of this process to similar ones for which labor and utility requirements are known. The basis throughout is 300 days operation per year, eight hours per day.

Item	Requirements/mo.	Requirements/100 lbs. product
Labor (man hours)	768	11.63
Fuel (Btu)	0.5×10^9	7.6×10^6
Electricity (KWH)	10,000	151.5
Water (c.f.)	50,000	756

With the preceding information it was then possible to make a cost analysis for each location.

Cost of Variables for Each Location

In Table VI the cost of each factor considered in this investigation is listed for each location with the exception of freight cost to transport product from plant to market. The cost of these factors was totaled for each location and from Table VI the following list of plant locations in order of increasing product cost prepared.

1. Pryor, Oklahoma
2. Metuchen, New Jersey
3. Lyndhurst, New Jersey
4. Baltimore, Maryland
5. Tipton, Indiana
6. Stillwater, Oklahoma
7. Brooklyn, New York
8. North Bergen, New Jersey
9. Minneapolis, Minnesota

As an example of what the freight costs might be for the final product, Table II, page 6, lists the costs per 100 pounds for shipment to various market locations from each plant location. It is obvious that the cost of shipping the final product is much less significant than the cost of transporting the raw material from the dockside to the plant.

It was felt at this point that it was not necessary to consider the freight cost of marketing the product and establish a marketing area. It is quite obvious that a manufacturer in Pryor, Oklahoma, could market his product anywhere at a greater advantage than the competitors.

FIGURE 4
FLOW DIAGRAM FOR PYRETHRUM MANUFACTURE

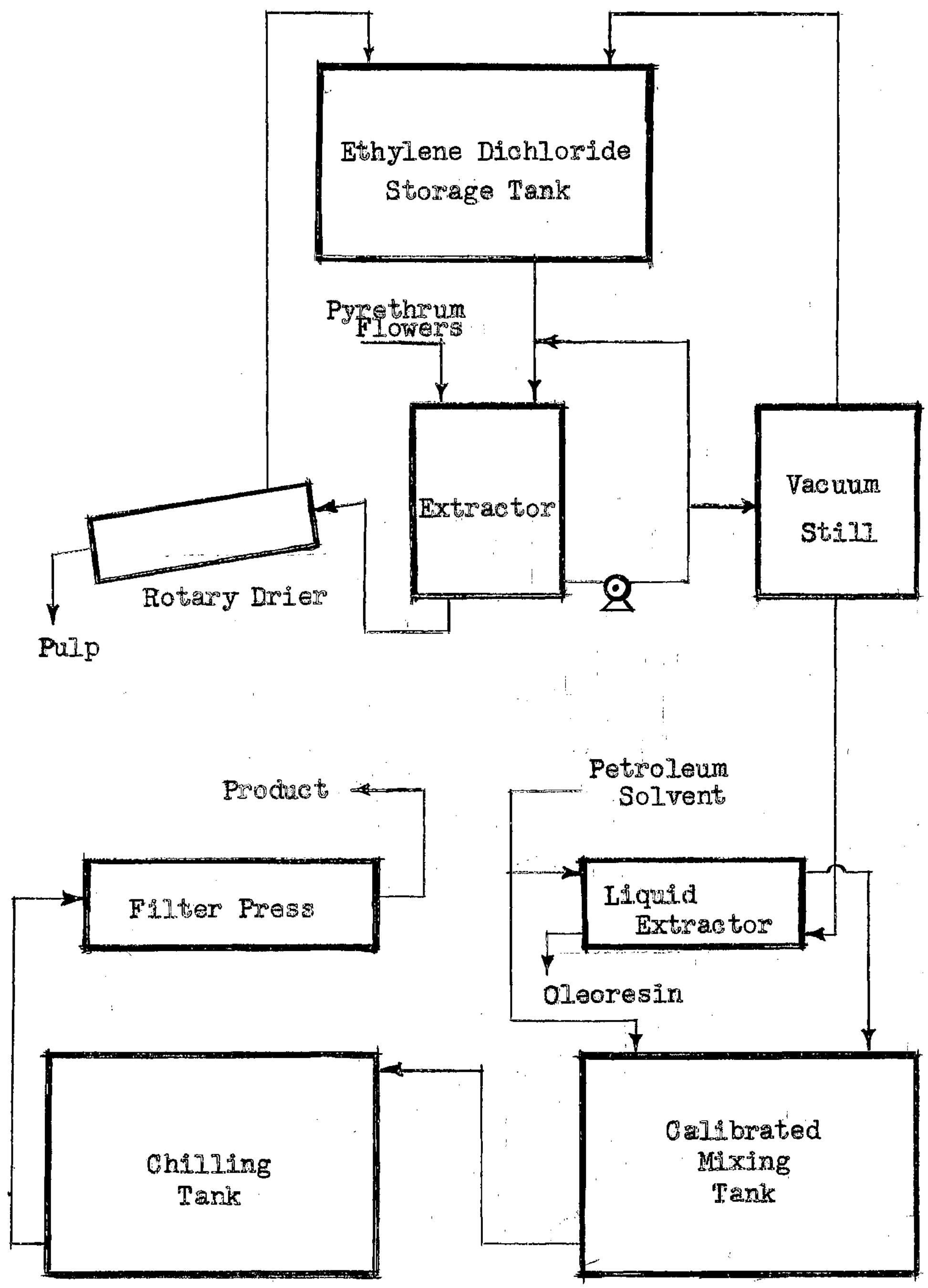


TABLE VI

PRODUCT COST FACTORS AT EACH LOCATION
DOLLARS PER 100 LBS PRODUCT

Item	Stillwater Okla.	Pryor Okla.	N. Bergen N. J.	Metuchen N. J.	Lyndhurst N. J.	Brooklyn N. Y.	Minneapolis Minn.	Tipton Ind.	Baltimore Md.
Freight Cost Raw Materials	$30.60	30.60	11.13	11.13	11.13	11.13	49.80	40.80	11.13
Labor	$20.30	21.50	23.80	23.80	23.80	22.70	23.00	24.40	22.90
Fuel	$ 1.92	1.35	10.00	10.00	10.00	12.10	5.05	5.15	8.23
Electricity	$ 4.12	1.36	5.99	5.99	5.99	6.47	4.50	4.23	6.35
Water	$ 1.54	.57	1.65	1.82	1.65	1.14	.30	1.60	1.08
Federal Local & State Taxes	$114.00	86.60	127.90	101.40	107.70	132.50	170.50	90.10	115.10
TOTAL	$172.48	141.98	190.47	154.14	160.27	186.04	253.15	166.38	164.79

While Pryor is the lowest in taxes, fuel, electricity and second lowest in labor and water, it loses its advantage by virtue of manufacturing an item which requires 1,324 pounds of raw material to be shipped from a seaport to manufacture 100 pounds of product.

As a result of this analysis, it would seem that the plant located in Minnesota should be unable to compete. However, it is one of the oldest and apparently one of the more successful of the firms being considered. As a proposed explanation several peculiarities which have been observed regarding the pyrethrum and alkaloid industry are presented for consideration.

The cost of raw materials such as pyrethrum flowers constitute the largest item of expense in the manufacture of pyrethrum. If the current listed market price of $.45 per pound, f.o.b. New York, for pyrethrum flowers were applied to this analysis, it would prohibit the manufacture of pyrethrum by any of the producers considered. As an example, at Baltimore, the most favorable location, the cost of pyrethrum flowers at $.45 per pound would result in a raw material cost that is 8.9 times the total cost of all the factors considered in Table VI and 86 per cent of the listed market price of the product. Therefore, it is necessary for a pyrethrum manufacturer to concentrate his efforts on purchasing raw materials at lower cost than his competitors. Since this involves contractual agreements with producers in various overseas locations, companies which have been in business a number of years are at a considerable advantage.[14]

Another factor to be considered in the manufacture of alkaloids is the possibility of crop failure as a result of climatic conditions or plant infections. The resulting price increase in raw material and the occurrence of a shortage may result in inability to fill customer orders. In the case of botanicals such as pyrethrum and rotenone, the customer may possibly turn to the use of the newer synthetics such as allethrin.

As a result of the preceding analysis, it would seem inadvisable to consider further the manufacture of alkaloids in Oklahoma, not because such a plant would be unable to compete but rather that the advantages of Oklahoma as a location would not be utilized to the fullest extent.

In the section following, a method is devised for evaluating other types of fine chemical manufacture which might be able to utilize the advantages of relatively low-priced labor, utilities and taxes in Oklahoma.

GENERAL EVALUATION PROCEDURE

In establishing the general evaluation procedure it was decided a mathematical treatment would be the simplest and most direct. In making this mathematical analysis, the assumptions of equal production, sales and profit were made as in Section II. The following definitions apply.

ΔC - total difference in product costs, proposed location minus competitor's

ΔE - difference in monthly electricity costs, proposed location minus competitor's

ΔF - difference in monthly fuel costs, proposed location minus competitor's

ΔL - difference in monthly labor cost, proposed location minus competitor's

M - average monthly sales in dollars

P - selling price of product, dollars per pound, f.o.b., wks.

ΔR - difference in monthly raw materials cost proposed location minus competitor's

ΔT - difference in monthly tax costs, proposed location minus competitor's

ΔW - difference in monthly water costs, proposed location minus competitor's

<u>Summation of Monthly Cost Differences</u>

The expression below indicates the factors which must be evaluated in determining product cost differentials between the proposed location and the location of a competitor.

$$\Delta C = \Delta E + \Delta R + \Delta F + \Delta W + \Delta T + \Delta L$$

ΔC, the differential cost advantage, is the difference in dollars per month in manufacturing and raw materials costs between the two locations but does not include product delivery costs. If the sign of $\triangle C$ is negative, the proposed location has a monthly differential cost advantage equal to the value of $\triangle C$.

Freight Rate Expression

If the differential cost advantage, as determined by the foregoing expression, is used to expand the preferential marketing area, it is necessary to develop an expression for freight costs in terms of distance shipped. The following rate equations have been suggested as being applicable to the L.C.L. shipment of machinery, class 85:[20]

Eastern United States,

$$\text{cents/100 lbs.} = 55 \text{ cents} + (0.12 \text{ cent} \times M)$$

Western United States, 1,000 to 2,400 miles,

$$\text{cents/100 lbs.} = -80 \text{ cents} + (0.26 \text{ cent} \times M)$$

where M = distance in air line miles.

It was decided that a freight rate equation similar to the above might be developed by use of the information in Table II. This information was plotted against map miles rather than air line miles since the ease with which the former may be obtained permits a more rapid calculation. Figures 5 and 6 represent a plot of freight rates against map miles for Pryor and Brooklyn to various locations as listed in Table VII. Although the two lines do not pass through all the points, they represent the data sufficiently well for the purpose intended. The slopes of these two lines are:

$$\text{Pryor} = \frac{\$2.53/100 \text{ lbs.}}{1{,}000 \text{ miles}}$$

$$\text{Brooklyn} = \frac{\$2.51/100 \text{ lbs.}}{1{,}000 \text{ miles}}$$

FIGURE 5
COMPARISON OF FREIGHT RATES WITH DISTANCE FOR PRYOR

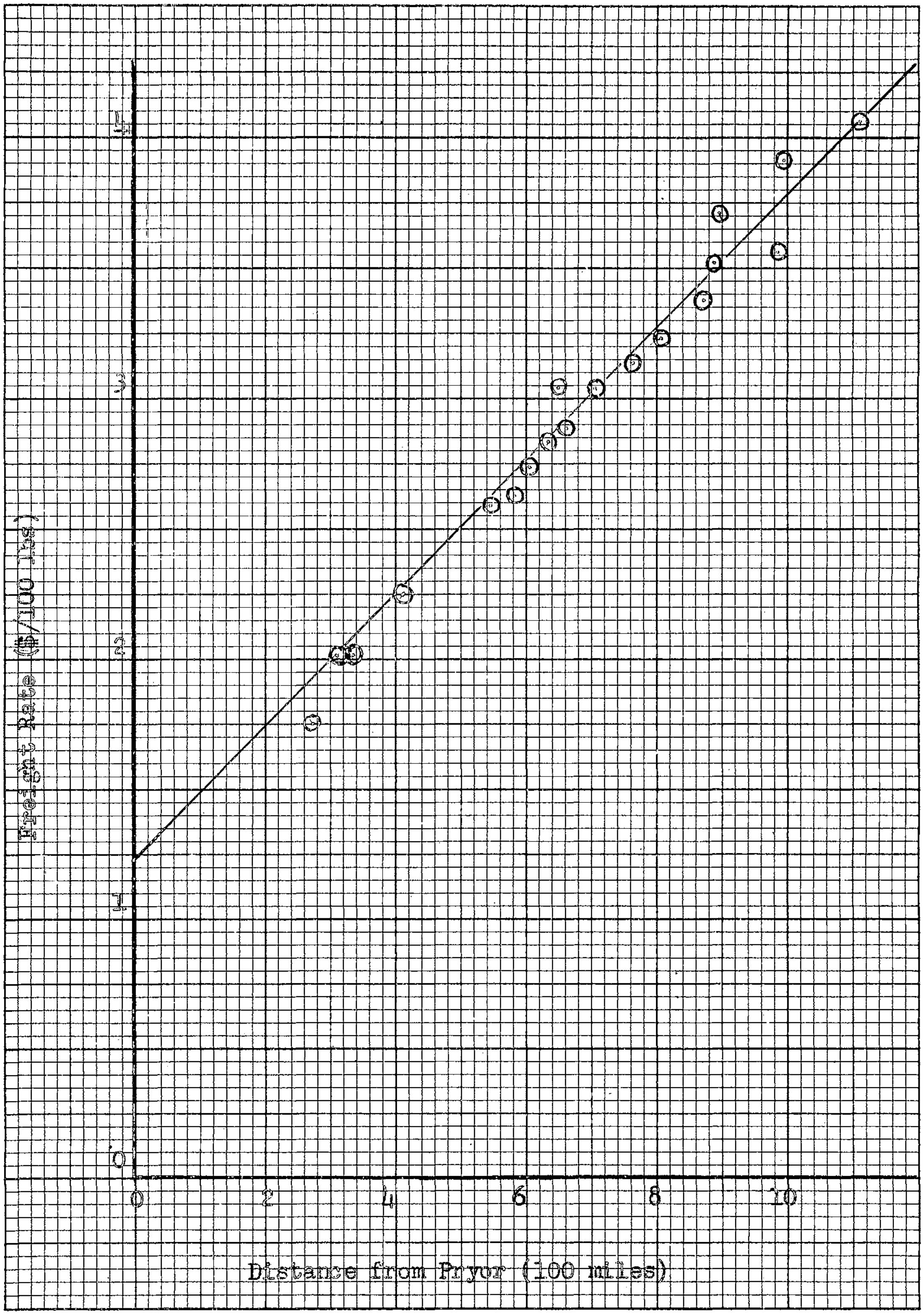


FIGURE 6
COMPARISON OF FREIGHT RATES WITH DISTANCE FOR BROOKLYN

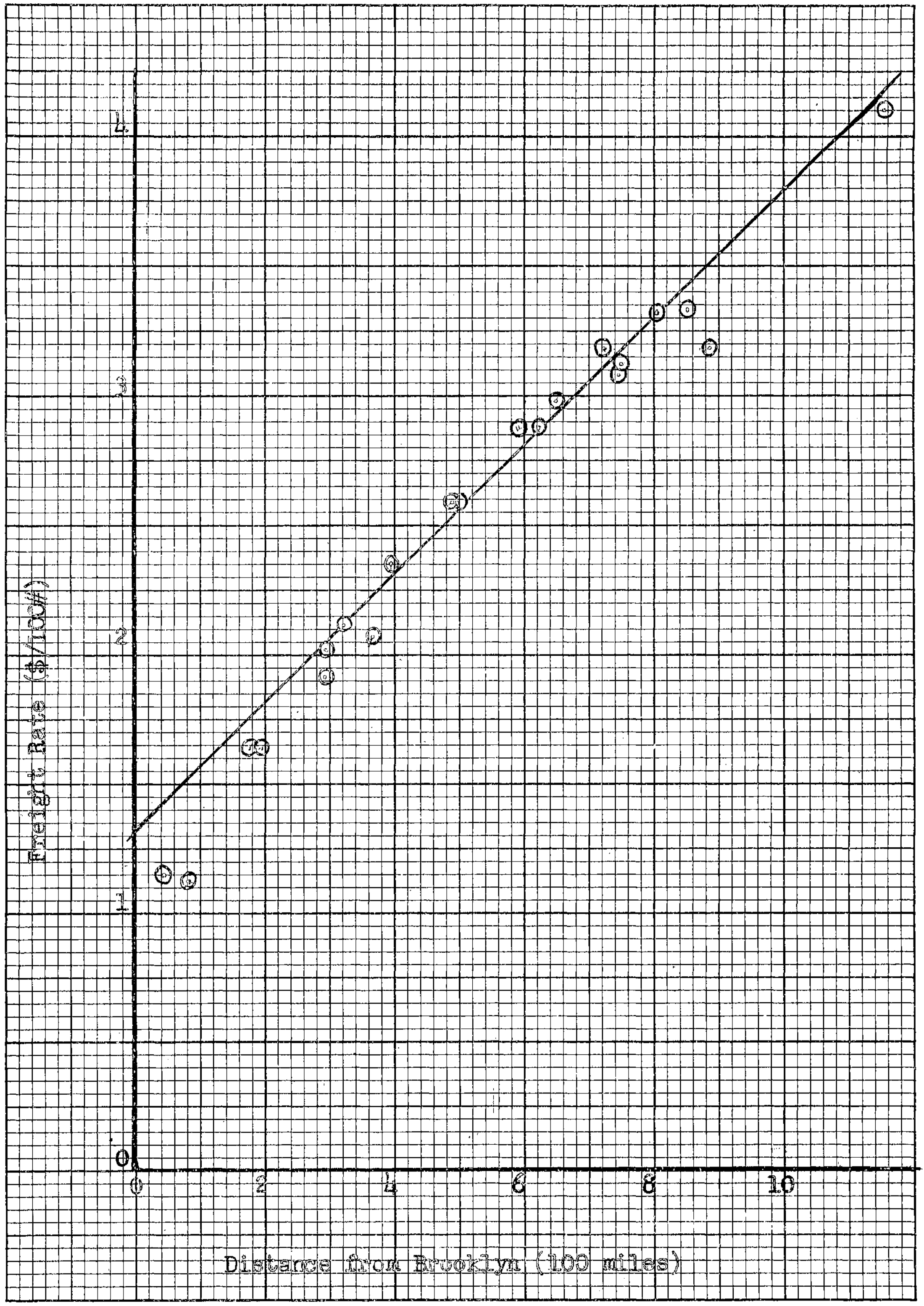


TABLE VII

COMPARISON OF MAP MILES AND SHIPPING RATES

Market Point	Brooklyn		Pryor	
	Miles	Rate $/100lbs	Miles	Rate $/100lbs
Atlanta, Ga.	750	3.12	650	3.04
Boston, Mass.	195	1.64	1362	4.50
Bridgeport, Conn.	42.5	1.15	1250	4.40
Buffalo, N. Y.	297	2.01	985	3.56
Canton, O.	396	2.35	808	3.23
Chicago, Ill.	720	3.18	584	2.64
Columbus, O.	487	2.59	708	3.04
Decatur, Ill.	803	3.32	413	2.25
Detroit, Mich.	496	2.59	766	3.13
Ft. Wayne, Ind.	590	2.88	637	2.84
Ft. Worth, Tex.	1405	4.64	274	1.75
Indianapolis, Ind.	650	2.98	546	2.59
Jacksonville, Fla.	850	3.32	896	3.52
Kalamazoo, Mich.	620	2.88	657	2.89
Lynchburg, Va.	366	2.06	896	3.71
Milwaukee, Wisc.	744	3.08	603	2.74
New Bedford, Mass.	177	1.64	1830	4.50
Philadelphia, Pa.	82.5	1.12	1112	4.06
Omaha, Neb.	1155	4.10	336	2.01
Pittsburgh, Pa.	319	2.11	873	3.37
Richmond, Va.	289	1.92	991	3.91
St. Louis, Mo.	885	3.18	313	2.01

The constants are

Pryor = \$1.24/100 lbs.

Brooklyn = \$1.28/100 lbs.

Since these plots represent shipping from west to east in one case and east to west in the other, the close agreement between the two seems to indicate only one rate equation is required. The equation based on the averages appears below.

Freight Rate (\$/100 lbs.) = (Distance in 1,000 miles) (2.52) + 1.26

This equation is for class 85 chemicals (not otherwise included by name in the freight rating tables) in cartons, drums, packages, cans and containers other than carboys.

Establishment of Preferential Marketing Area

With the foregoing equation it is possible to determine the lines of equal delivered price and equal profit between each competitor and the proposed location and thereby establish the preferential marketing area. This was done by placing the location being considered at the intersection or zero point of a system of Cartesian coordinates. The coordinates of the competitor's location were determined in the usual manner. An equation which includes the differential cost advantage $\triangle C$ and the freight rate equation was developed for any point (x,y) representing a market location where the two plants might sell their product at equal price and make the same profit per pound as follows:

Cost to ship from proposed location to point (x,y) =

$$(x^2 + y^2)^{\frac{1}{2}} \; 2.52 + 1.26$$

Cost to ship from competitor's plant located at coordinates (A,B) to point (x,y) = $\left[(A - x)^2 + (B - y)^2\right]^{\frac{1}{2}} \; 2.52 + 1.26$

where x and y are distances in thousands of miles and the freight cost is in dollars per hundred pounds.

Introducing the differential cost advantage, $\triangle C$, the following equation is derived for the line of equal delivered price and equal profit between any two locations.

$$100P\left(\frac{\triangle C}{M}\right) + (x^2 + y^2)^{\frac{1}{2}}\, 2.52 + 1.26 = \left[(A - x)^2 + (B - y)^2\right]^{\frac{1}{2}} 2.52 + 1.26$$

Since the foregoing relationship does not permit solving easily for y in terms of x, the expression was transferred to polar coordinates with the reference or thrust line taken as that line between the proposed location and the competitor's location. The following definitions apply:

d = distance between proposed location and competitor's plant (in 1,000 miles)

r = distance to market from proposed location (in 1,000 miles)

θ = the angle between the reference line and line from proposed location to market

The expression thus obtained is

$$\cos\theta = \frac{r^2 + d^2 - \left[\frac{100P(\triangle C)}{2.52M} + r\right]^2}{2dr}$$

In terms of r:

$$r = \frac{d^2 - \left(\frac{100P\triangle C}{2.52M}\right)^2}{2d\cos\theta + 2\left(\frac{100P\triangle C}{2.52M}\right)}$$

When $\theta = 0$, $\cos\theta = 1$ and the above expression simplifies to the following, which indicates how far toward the competitor's plant the proposed location could market a product at price P with an advantage of $\triangle C$

$$r = \frac{d - \frac{100P\triangle C}{2.52M}}{2}$$

Given a certain advantage of ΔC, the following expression permits calculating the lowest unit selling price of a product which could be delivered and sold at the competitor's location and make identical profit per pound

$$P = \frac{-d\ (2.52)\ (M)}{100\Delta C}$$

Method of Evaluating Monthly Cost Differences

In the evaluation of the preceding expressions, it is necessary that the following information be known regarding the chemical being considered for manufacture.

1. The firms currently engaged in commercial production of the chemical

2. The value of the factors which influence product cost at the competitors' and proposed locations

3. Either the water, fuel, electricity and labor cost percentages of the total product selling price or

4. The water, fuel, electricity and labor requirements per 100-pounds product

With the foregoing information it is possible to determine for a particular factor the difference in the cost between the proposed location and a competitor's location. In the following paragraphs the method of calculation is described for each factor.

Cost of Raw Materials:

If there is no difference in the cost of raw materials (f.o.b. the supplier's plant) between locations, the raw material cost differential is the difference in freight costs. This may be calculated by determining the amount of raw materials required per month and the average shipping rate at each location. Should differences in cost of raw materials exist, these should be added to the freight costs.

Local and State Taxes:

These are computed on an annual basis and then converted to monthly costs for each location.

Cost of Labor and Utilities:

There are two methods which may be used in determining the costs of these at each location. The most accurate requires information on the man hours, KWH, Btus. or pounds of steam and cubic feet of water that are required to manufacture a specified amount of product. This is the preferred method.

The other method is used when the foregoing information is not available. It utilizes information which may be in the form of an estimate of the percentages the cost of labor and utilities are of the product selling price. In the use of this method in the procedure established herein, it is recommended that these percentages be used in calculating the monthly labor and utilities costs at the locations having the highest rates for each. The monthly consumptions of labor and utilities are then calculated by dividing the monthly cost by these highest rates. The consumptions calculated are the same as those for other locations by virtue of a previous assumption and allows the computation of labor and utilities cost at each location. The reason the monthly costs are applied to the location having the highest rates is the consumption which is then calculated is a minimum. This tends to reduce the cost differentials between locations which grow larger as the monthly consumption increases (see Figure 1, page 8) and results in a more conservative estimate.

As an example of how the preceding might be applied to particular problems, the following illustrations are presented.

Illustration 1

Given: The location of a fine chemical plant at Pryor, Oklahoma, is being considered. The current market price of the chemical is $.30 per pound, f.o.b. New York. The existing competitors are located at Baltimore, Maryland; Tipton, Indiana; and Brooklyn, New York. The following percentages of the product selling price, which have been suggested as applying to organic chemicals manufacture, will be assumed applicable.[1]

Materials and Supplies	52.9%	Selling Price of Product
Wages	11.8%	"
Fuel and Electricity	6.6%	"
Salaries and Administration	9.2%	"
Other items (including taxes, interest, profit, legal services)	19.5%	"
	100.0%	"

In addition, the assumption may be made that the utility breakdown is:

Fuel	4.0%	Selling Price of Product
Electricity	2.0%	"
Water	0.6%	"
	6.6%	"

To find: What area the proposed plant at Pryor might be able either to sell the chemical at a lower delivered price than the competitor and make the same profit per pound or sell at the competitor's delivered price and make a larger profit per pound.

Solution: The assumptions regarding equal plant capacity, net sales, and net profit at all locations will be made in order that the comparison of taxes and utility rates will be valid. The values of plant cost, plant capacity, net sales and net profit will be those assumed in Section II. The information contained in Table V on annual tax costs at each location may then be used.

The graphs for water, gas and electricity at these locations are those previously constructed--Figures 1, 2, 3 on pages 8, 9, 10. With a net annual sales of $573,000, the monthly costs of fuel, gas and water are calculated as follows. Monthly fuel costs at location having highest fuel rate = 4% x 573,000/12 = $1910. Consulting Figure 1 indicates that Brooklyn, New York, has the highest fuel rate of the locations considered. The monthly consumption which results in a cost of $1910 at Brooklyn is determined and the cost for the same consumption read for the other locations. The same procedure is used for water and electricity and the information entered in Table VIII, page 36.

Monthly labor costs are calculated by first determining at what location the rates are highest from Table III. The man hours/month required may then be computed by dividing the monthly labor costs by the highest labor rates, which in this illustration are the rates at Tipton.

$$\frac{11.8\% \times \$573,000/12}{\$2.09} = \text{man hours required per month}$$

Assuming labor efficiency to be the same at each location, it is now possible to calculate the labor costs at other locations since their labor requirements have been assumed to be the same. The costs appear in Table VIII.

In determining the costs of raw materials delivered to each location, it is necessary to know:

1. Point of purchase by each plant
2. The freight rates from that location to the plant
3. The ratio of raw materials required per pound of product
4. Any differences in raw materials price, f.o.b. suppliers' plants

For this illustration it will be assumed that the foregoing information was obtained for each location. The costs of raw materials are those listed in Table VIII. It should be pointed out that if no difference exists in f.o.b. prices of raw materials from the various suppliers, freight costs only are considered.

Table VIII lists the foregoing costs for each location and the cost differential between Pryor and the other locations for each factor.

It is now possible with the ΔC's from Table VIII to define the marketing area. The method is to draw a line between Pryor and the competitor being considered. Several values are chosen for the angle θ between the line to market and line to competitor's plant. Values of r, the distance to the market from Pryor, are then calculated for each angle by use of the following equation:

$$r = \frac{d^2 - \left(\frac{100P\Delta C}{M}\right)^2}{2d\ \cos\theta + 2\left(\frac{100P\Delta C}{M}\right)}$$

These values are plotted as points through which a curve may be drawn that will represent the locations both plants can market the chemical at the same delivered price and make identical profits.

The results of these calculations for each location are shown in Figure 7 and indicate by the intersection of lines of equal profit and equal delivered price what market area Pryor could sell in at an advantage.

TABLE VIII

COMPARISON OF PRODUCT COST FACTORS
FOR LOCATIONS CONSIDERED IN ILLUSTRATION 1

Item		Pryor	Brooklyn	Baltimore	Tipton
Taxes	(Monthly)	$ 5,940	$ 9,120	$ 7,980	$ 7,500
	△C	---	-3,180	-2,040	-1,560
Labor Cost	(Monthly)	$ 5,000	5,270	5,320	5,640
	△L	---	-270	-320	-640
Fuel Cost	(Monthly)	$ 230	1,910	1,320	920
	△F	---	-1,680	-1,090	-690
Water Cost	(Monthly)	$ 130	286	163	286
	△W	---	-156	-33	-156
Electricity Cost	(Monthly)	$ 220	955	865	955
	△E	---	-735	-645	-735
Raw Material Cost	(Monthly)	$24,900	26,848	26,254	26,026
	△R	---	+ 2,348	1,254	1,726
ΔC		---	-3,673	-2,874	-2,055

FIGURE 7
PREFERENTIAL MARKETING AREA

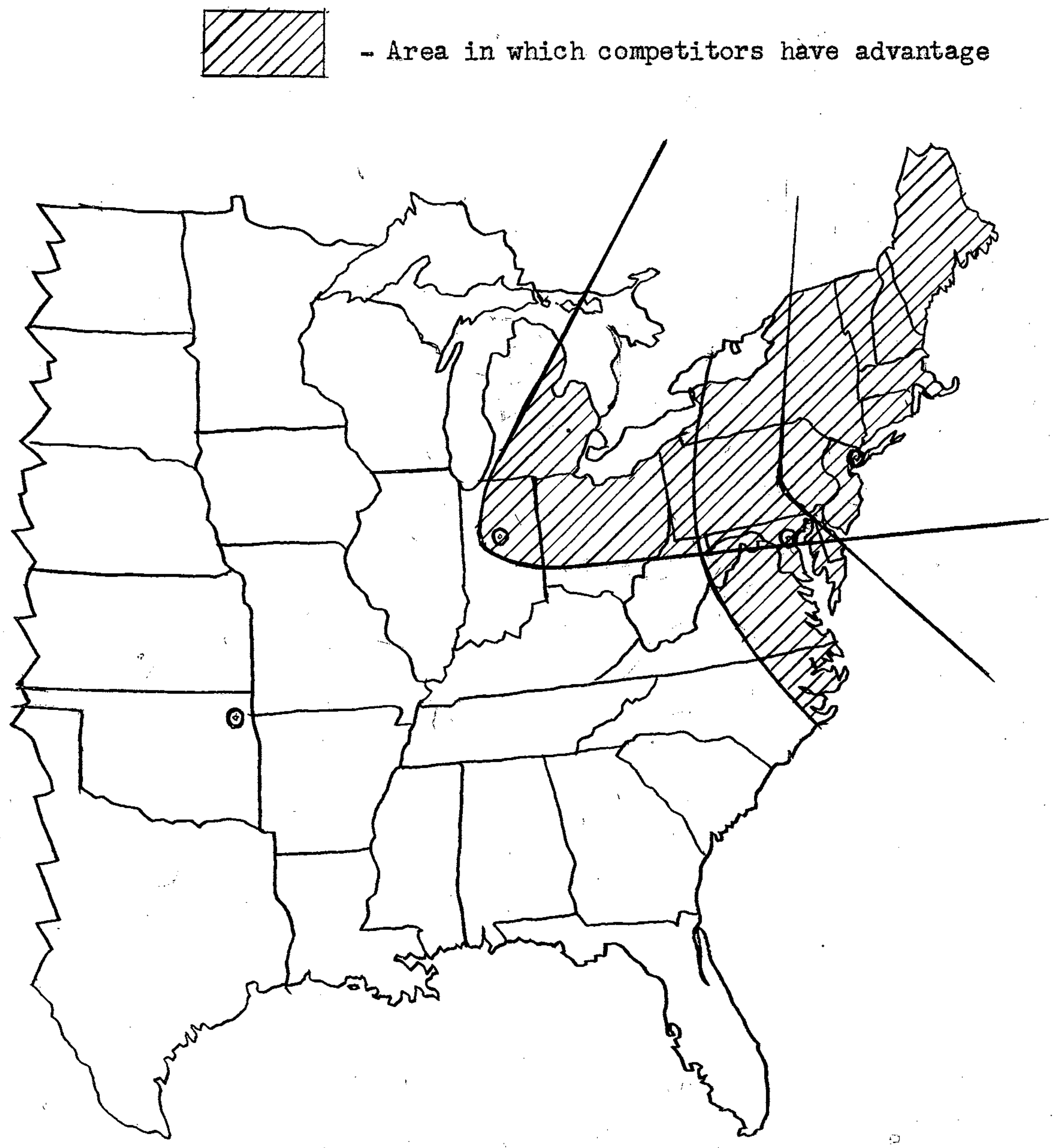


Illustration 2

Given: The town of Pryor, Oklahoma, is being considered as a potential location for a fine chemical plant. The product to be manufactured and its cost have not been as yet determined. It is assumed that it will be an organic chemical having the same distribution of items totalling the selling price as listed in the preceding illustration.

It is desired that any chemical selected might be marketed nationally at either an advantage or on equal basis with all competitors. Locations where competition might be expected are Brooklyn, New York; Tipton, Indiana; and Baltimore, Maryland.

To find: At what price per pound (f.o.b.) could a chemical be manufactured in Pryor, Oklahoma, and sold at the same delivered price as the competitor's at his location and still make the same profit per pound.

Solution: The same assumptions are made as in the preceding illustration. It is obvious that as the price of the chemicals considered decrease, the amount produced must increase in order to achieve the same net annual sales. Increasing the amount of the monthly production decreases the $\triangle C$ or differential cost advantage per pound of product one location has over the other. Since this cost advantage per pound aids in extending the market area by paying additional freight costs, a decrease in the price of the chemicals considered results in a decrease in the marketing area. The following equation permits the calculation of the lowest price per pound product which could be manufactured and delivered to the competitor's location at the same price and profit per pound. As may be seen, it is necessary that a differential cost advantage exists for the location being considered.

$$P = \frac{-d\ (2.52)\ (M)}{100 \triangle C}$$

By use of the foregoing equation, chemicals whose prices are no lower than the following could be considered for manufacture in competition with each of these locations.

	$/lb.
Brooklyn, New York	0.391
Baltimore, Maryland	0.436
Tipton, Indiana	0.331

The above prices allow Pryor to ship to any location on an equal basis with the competitor and should provide an advantage for most markets.

In applying the preceding evaluation method to particular problems, certain limitations should be kept in mind.

1. After a market area is established, it should be determined what percentage of the total existing market lies within this area. Low percentages would require further evaluation.

2. In some cases patent advantages of the competitor might completely nullify all manufacturing advantages at the proposed location.

3. No attempt is made in this method to evaluate differences in labor efficiencies, insurance rates, community attitudes, labor turnover rates, strike records, fringe benefit expenses and other similar items of lesser importance than the factors considered.

4. Since fuel, water and electricity rates decrease with increased consumption, the assumption of equal capacity and production result in a significant error if plants differ greatly in capacity.

It was felt that these limitations do not restrict the use of this method for a rapid evaluation of the advisability of producing a chemical at a particular location. They do indicate a detailed study is required for any chemical which appears attractive.

This method does provide a means of selecting from a large number of chemicals, those which appear to be the most profitable for manufacture.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions:

From this investigation certain important factors were observed which influence the selection of a fine chemical to be considered for manufacture in Oklahoma.

1. The chemical should be manufactured from raw materials available in Oklahoma or surrounding states; but the importance of this diminishes as the ratio of freight cost to product value decreases.

2. If the raw materials are not available nearby, the amount of raw materials required per pound of product should be small.

3. The total cost of the raw materials should be a relatively small portion of the product selling price.

4. The principal contribution to the increase in value of the product should result from the use of labor and utilities.

5. If the market is not nearby, the percentage product freight cost is of product value should decrease with an increase in distance to market.

The investigation of pyrethrum illustrates what might be the result if all the above conditions do not prevail. Pryor, although having the greatest manufacturing advantage, was so penalized by the cost of raw materials shipment, that the majority of the manufacturing advantage was lost.

As an example of a well located manufacturing operation, the manufacture of phenol-formaldehyde resins is suggested--utilizing raw materials which are available locally, producing resins to be sold to a nearby plant which manufactures plastic articles for distribution in the Southwest. Since the preceding requires a joint venture between one group experienced in plastic resins manufacture and another group acquainted with the plastic specialties business, the difficulty of achieving such an association is most probably the reason none exists to date.

The general evaluation procedure, developed for use in making location evaluations similar to the one presented herein, finds utility in the following instances.

1. In determining the effect of market isolation on a location being considered for a chemical plant because of the low labor, tax and utility rates.

2. In establishing areas in which a considered plant location might sell the product at greater advantages than his competitors, thereby establishing a potential market area.

3. In fixing the lowest priced chemical which might be manufactured and sold at advantage nationally over assumed competitors.

From this investigation it was shown that Pryor, Oklahoma, had the lowest fuel, electricity and adjusted tax rates of the nine locations considered and was second lowest in labor and water rates. As a result of the high raw materials freight cost for pyrethrum manufacture, the advantage of lower labor, utilities and tax costs was not utilized to the fullest extent. This investigation indicates a fine chemical which meets the requirements listed on the preceding page should be economically feasible for manufacture in Oklahoma.

Recommendations:

From the results of this study the recommendations are:

1. Alkaloids and botanicals not be considered for manufacture in Oklahoma

2. That the general evaluation procedure established herein be applied to the location of Pryor, Oklahoma, for fine chemicals which meet the criteria set forth on the preceding page

3. That the intangible effect of company name and reputation on selling be investigated since most fine chemicals have restricted markets

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APPENDIX A

The following lists the rate schedules of fuel, electricity and water at locations in increasing order of cost.*

Fuel Rates

1. Pryor, Oklahoma (1109 Btu gas)

   $.01982 per c.c.f.

2. Stillwater, Oklahoma (1050 Btu gas)

First	10	c.c.f./mo.		$1.55	
Next	990	"	@	.0456	per c.c.f.
"	19,000	"	"	.0226	"
"	20,000	"	"	.0186	"
"	60,000	"	"	.0176	"
"	200,000	"	"	.0171	"
Over	300,000	"	"	.0166	"

3. Tipton, Indiana (1000 Btu gas)

First	800	c.c.f./mo.	@	$ .21	per c.c.f.
Next	1,200	"	"	.10	"
"	9,080	"	"	.08	"
"	100,000	"	"	.07	"
Over	300,000	"	"	.065	"

4. Minneapolis, Minnesota (1050 Btu gas)

First	300	c.c.f./mo.	@	$ .10	per c.c.f.
Next	29,000	"	"	.072	"
"	130,000	"	"	.065	"
"	240,000	"	"	.065	"
"	400,000	"	"	.065	"

5. Baltimore, Maryland (1050 Btu gas)

First	2	c.c.f./mo		$1.10	
Next	18	"	@	.175	per c.c.f.
"	180	"	"	.145	"
"	550	"	"	.126	"
"	4,250	"	"	.110	"
"	5,000	"	"	.095	"

*Information obtained from utilities at each location by private communication

6. Lyndhurst, North Bergen,
Metuchen, New Jersey (525 Btu gas)

First	4 c.c.f./mo.			$1.00	
Next	10	"	@	.11	per c.c.f.
"	486	"	"	.095	"
"	500	"	"	.09	"
"	1,500	"	"	.08	"
"	2,500	"	"	.07	"
"	5,000	"	"	.06	"

7. Brooklyn, New York (1040 Btu gas)

First	500 c.c.f./mo			$120	
Next	500	"	@	.175	per c.c.f.
"	500	"	"	.170	"
"	1,000	"	"	.160	"
"	2,500	"	"	.150	"
Over	4,500	"	"	.130	"

Electrical Rates

1. Pryor, Oklahoma

Demand Charge	Energy Charge
100 KW - $ 50	$.004/KWH
200 KW - $100	
300 KW - $150	

2. Stillwater, Oklahoma

Demand Charge	Energy Charge				
100 KW - $ 90	First	100	KWH/mo	@ $.05	per KWH
200 KW - $190	Next	100	"	.04	"
300 KW - $290	"	200	"	.03	"
	"	4,600	"	.02	"
	"	5,000	"	.015	"
	Above	10,000	"	.012	"

3. North Bergen, Lyndhurst,
Metuchen, New Jersey

Demand Charge	Energy Charge				
First 50 KW - $100	First	5,000	KWH/mo	@$.0317	per KWH
Next 50 KW - $ 80	Next	45,000	"	.0117	"
" 500 KW - $725	"	200,000	"	.0107	"
	"	250,000	"	.0097	"
	"	300,000	"	.0077	"
	"	800,000	"	.0068	"

4. Baltimore, Maryland

Demand Charge	Energy Charge			
$1.84 per KW in excess of 60 KW	First	2,650	KWH/mo	@$.0559 per KWH
	Next	2,650	"	.0341 "
	"	6,650	"	.0231 "
	"	15,000	"	.0144 "
	"	275,000	"	.0117 "

5. Brooklyn, New York

Demand Charge	Energy Charge			
First 7 KW - 0				
Next 28 KW @ $2.50 per KW	First	10	KWH/mo	$.80
" 65 " $2.00 "	Next	190	"	@$.0511 per KWH
" 900 " $1.55 "	"	500	"	.0391 "
	"	1,300	"	.0281 "
	"	8,000	"	.0211 "
	"	30,000	"	.0161 "
	"	60,000	"	.0121 "
	"	150,000	"	.0111 "
	"	250,000	"	.0101 "

6. Minneapolis, Minnesota

Demand Charge	Energy Charge			
All energy in excess of 200 KWH demand @ $.017 KWH	First	200	KWH/mo	@ $.0536 per KWH
	Next	300	"	.0457 "
	"	1,500	"	.0356 "
	Excess		"	.0276 "

7. Tipton, Indiana

Demand Charge	Energy Charge			
None	First	250	KWH/mo	@ $.0461 per KWH
	Next	500	"	.0411 "
	"	1,250	"	.0311 "
	"	8,000	"	.0261 "
	"	10,000	"	.0211 "

Water Rates

1. Minneapolis, Minnesota

First	100,000 c.f.	@ $.04 per c.c.f.
Next	200,000 c.f.	" .02 "
Over	300,000 c.f.	" .01 "

2. Pryor, Oklahoma

First	133,700 c.f.	@ $.0748	per c.c.f.
Next	267,400 c.f.	" .052	"

3. Baltimore, Maryland

First	50,000 c.f.	@ $.142	per c.c.f.
Over	50,000 c.f.	" .080	"

4. Stillwater, Oklahoma

First	267 c.f.	@ $.52	per c.c.f.
Next	801 c.f.	" .373	"
"	1,335 c.f.	" .299	"
"	4,005 c.f.	" .262	"
"	10,000 c.f.	" .202	"
Above	16,408 c.f.	" .150	"

5. Tipton, Indiana

First	300 c.f.	@ $.40	per c.c.f.
Next	1,300 c.f.	" .35	"
"	6,400 c.f.	" .30	"
"	12,000 c.f.	" .22	"
"	30,000 c.f.	" .18	"
"	50,000 c.f.	" .15	"
"	100,000 c.f.	" .12	"

6. Brooklyn, New York

$.15 per c.c.f. for industrial users

7. Lyndhurst and North Bergen, New Jersey

First	3,300 c.f.	@ $.28	per c.c.f.
Next	30,000 c.f.	" .24	"
"	300,000 c.f	" .20	"
"	333,000 c.f.	" .162	"

8. Metuchen, New Jersey

First	100,000 c.f.	@ $.24	per c.c.f.
Next	900,000 c.f.	" .19	"
"	1,000,000 c.f.	" .145	"

APPENDIX B

DEFINITION OF SYMBOLS

ΔC - total difference in product costs, proposed location minus competitor's

d - distance between proposed location and competitor's plant (in 1,000 miles)

ΔE - difference in monthly electricity costs, proposed location minus competitor's

ΔF - difference in monthly fuel costs, proposed location minus competitor's

ΔL - difference in monthly labor cost, proposed location minus competitor's

M - average monthly sales in dollars

P - selling price of product, dollars per pound, f.o.b., wks.

ΔR - difference in monthly raw materials cost proposed location minus competitor's

r - distance to market from proposed location (in 1,000 miles)

ΔT - difference in monthly tax costs, proposed location minus competitor's

ΔW - difference in monthly water costs, proposed location minus competitor's

θ - the angle between the line from the proposed location to the competitor's plant and the line from the proposed location to the market

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Master of Science

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