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TEACHING MARKET ANALYSIS

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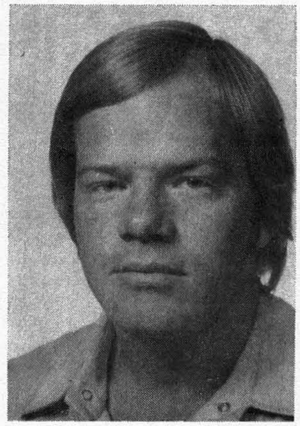

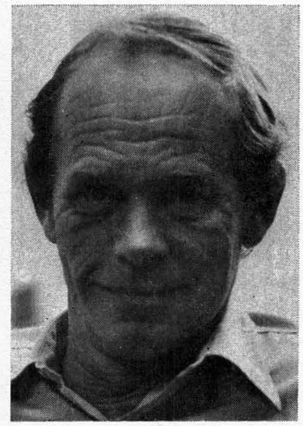

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MARKETING OF CHEMICAL PRODUCTS is a subject which is almost completely ignored in a chemical engineer's university education. This omission is unfortunate since marketing is usually the crucial constraint on the commercial viability of many projects. In spite of its obvious importance, market analysis is not taught to undergraduates; the undergraduate is not trained to analyze a market problem even in a rudimentary fashion. The neglect of the marketing process by the students' professors is understandable since their training emphasizes the scientific aspects of the chemical production process, such as research, development and design. From an academic's view, the estimation of a market size and its location is regarded as a black art best left to someone else.

TABLE I

Capital Costs(1)

	ALBERTA	GULF COAST
Capacity	**1000 T/D** **720 mm lb/yr**	**2000 T/D** **1440 mm lb/yr**
Direct Fixed Cost (excluding working capital)	**66 mm $Can**	**80 mm $US**
Debt(2)	**20.5 mm $Can**	**25 mm $US**
Equity	**45.5 mm $Can**	**55 mm $US**
Interest rate on debt	**Canadian prime + 1½%** (3)	**US prime + 1%**
Term on debt	**15 years**	**15 years**
Yearly debt charge(4)	**$2.2 mm $Can**	**$3.1 mm $US**
Interest rate on equity	**Canadian prime + 4%**	**US prime + 3%**
Term on equity	**15 years**	**15 years**
Yearly charge: equity recovery, return on investment (5)	**5.6 mm $Can**	**7.65 mm $US**
Total Yearly Capital Charges on D.F.C.	**7.8 mm $Can**	**10.75 mm $US**
Unit Capital Charges on D.F.C.	**1.09 ¢Can/lb**	**0.747 ¢US/lb**

(1)Unless stated otherwise, costs are expressed in the currency of the home country.
(2)Debt-equity ratio of 0.45.
(3)Canadian prime interest rate = 8½%, U.S. prime interest rate = 8%.
(4)Both debt and equity charges taken as uniform payment retirement.
(5)Working capital and salvage neglected.

This paper presents a technique which hopefully transforms market estimation from a black art into a dark gray one. Its objective is a quantitative means of estimating a potential market area at a given time for an undifferentiated chemical. An undifferentiated product is one which does not have any unique property that can be attributed to its manufacturer. The manufacturer cannot claim that his product is better than his competitor's since both products are identical within normal engineering specifications. Methanol, fertilizer-grade ammonia and polymer-grade ethylene are examples of undifferentiated products, while almost anything that is advertised as unique or better is a differentiated product. Consequently, the major factor which will govern the sale of this type of chemical is its price, not its quality.

The potential market area for an undifferentiated chemical, produced by a given plant, is defined as that region where the delivered cost of the chemical is equal to or less than other competing producers. The delivered cost of a chemical commodity to a customer is the sum of the production costs, transportation charges, tariffs and currency exchange. The last two expenses are applicable only if the commodity is traded internationally. Rather than analyzing the position of all potential competitors for a market, the technique of estimating a market area can be illustrated more simply by considering only two competitors.

As an example, assume that two hypothetical methanol producers, one located in southern Alberta and the other on the Texas Gulf Coast, are in competition with each other. In recognition of historical precedence, the capacity of the Canadian plant is taken initially as one half that of the Gulf Coast plant. Table I gives the illustrative capital costs and financial charges for each of the two plants. The financial arrangements are simplified in order to make the presentation of the results concise. Unit prices of inputs and associated unit manufacturing costs are shown in Table II. The cost figures in both tables are given in the currency of the home country.

Until recently, the plant gate cost of Gulf Coast methanol was significantly below that of methanol produced in Alberta. In fact, at one time the cost of methanol delivered from the Gulf Coast to Alberta was less than the plant gate cost of Alberta methanol. That situation was due primarily to the economics of scale typical of the American plants and the generally low level of natural gas prices. As is obvious from Table II,

TABLE II

Manufacturing Costs

	ALBERTA		GULF COAST	
Capacity	720 mm lb/yr 1000 T/D		1440 mm lb/yr 2000 T/D	
Direct Fixed Capital	54 mm $Can		80 mm $US	
Working Capital	4.9 mm $Can		5.8 mm $US	
VARIABLE COSTS		Unit Cost ¢Can/lb		Unit Cost ¢US/lb
Natural Gas as Feedstock and Fuel (32 mm Btu/ton)	$1.25/mm Btu	2.05	$1.95/mm Btu	3.28
Power	3¢/KW-hr	.02	3.5¢/KW-hr	.02
Catalyst		.15		.15
Water, misc.		.03		.03
		2.25		3.48
FIXED COSTS				
Labour & Admin.—80 people	$22,000/yr	.244	$20,000	.111
Maintenance & Local Taxes	5% of DFC	.375		.278
Sales	2% of Plant Gate Cost	.078		.09
		.69		.479
CAPITAL COSTS				
Unit debt on D.F.C.		.307		.215
Unit equity on DFC		.779		.531
Interest on W.C.		.03		.036
		1.11		.782
	SUMMARY			
Variable Costs		2.25		3.48
Fixed Costs		.69		.48
Capital Costs		1.11		.78
		4.05		4.74

The potential market area for an undifferentiated chemical, produced by a given plant, is defined as that region where the delivered cost of the chemical is equal to or less than other competing producers.

the situation is now reversed. The plant gate cost of Alberta methanol is below that of the Gulf Coast even though there is a considerable size advantage in favour of the American plant. The reason for the reversal is that the Alberta plant now has a large advantage in natural gas prices. It should be noted these are new gas prices (as of January, 1978) and do not apply to older plants which have long term contracts at lower natural gas prices or to plants that can blend the old and new gas prices.

To estimate the delivered cost at any point, the transportation costs, tariffs and currency exchanges must be added to the average plant gate production costs. The effect of these factors can be illustrated in a simple example. Suppose the two plants attempt to sell methanol in the San Francisco area. The Gulf Coast producer can transport methanol by ship through the Panama Canal while the Canadian producer is restricted to more expensive rail transportation. In addition the American producer will not have to pay a tariff while the Alberta plant must. All of these factors favour the American plant and tend to erode the plant gate cost advantage enjoyed by the Canadian plant. On the other hand, the devaluation of the Canadian dollar relative to the U.S. dollar in effect lowers the plant gate cost of Alberta methanol by about 10%. Table III summarizes all of these effects and shows that the U. S. producer is able to deliver methanol into San Francisco more cheaply than his Canadian competitor. As a consequence, San Francisco is regarded as a potential market area for the U. S. producer.

TABLE III

Cost of Methanol Delivered to San Francisco

	ALBERTA	GULF COAST
Plant Gate Cost	4.05 ¢Can/lb (3.65) ¢US/lb	4.74
Rail to San Francisco 1,324 miles at 2¢/ton-mile	1.32 ¢US/lb	—
Ship to San Francisco 4000 at .5¢/ton-mile		1.0¢
Tariff—7.6 ¢/US gal	1.15 ¢US/lb	—
Delivered cost	6.12 ¢US/lb	5.74 ¢US/lb

The technique used to calculate the delivered costs of the two competitors in the San Francisco area can be generalized to any point of sale. The results of this generalization are best presented on a map as a series of curves of constant delivered costs. These lines will be circles with their centers located at each plant. When a commodity shipment encounters an international border, the "iso-cost" lines will have a discontinuity as a result of tariffs and exchange rates. In general, the magnitude of the discontinuities will not be the same for both competitors.

A further complication arises where there is a possibility of change in mode of transportation. For instance, to market methanol in the U.S. Midwest, the Gulf Coast producer might ship his product via barge to Chicago, then distribute from Chicago either by rail or by truck. The base cost in Chicago would then be the Gulf Coast plant gate cost plus the barge charges to Chicago. Local Midwest costs would be the Chicago cost plus rail or

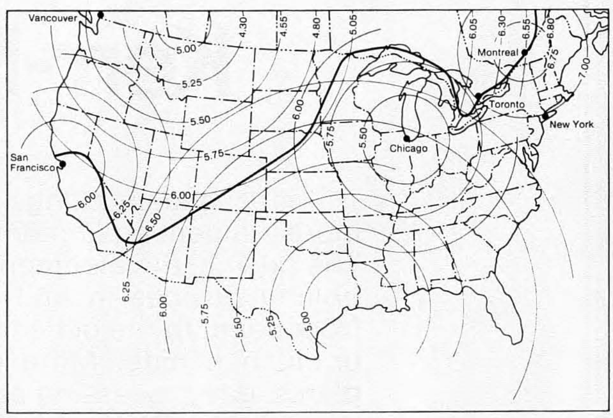

FIGURE 1. Iso-Cost Lines and Market Line for Base Case.

truck transportation charges to the market area. Consequently, the iso-cost lines in the Midwest are again circles, but their origin is at Chicago instead of the plant site. In addition to Chicago, San Francisco and Montreal were chosen as distribution centers.

The technical exercise is to construct the lines of constant cost for each distribution center. A set of these curves is shown in Figure 1. Each of them is labelled with the delivered cost in the currency of the consuming country. These circles are idealizations since the railroads do not run in straight lines. The actual iso-cost lines would be severely distorted, particularly in the west. At this stage of the analysis, this is viewed as a second order effect and is neglected. The potential market

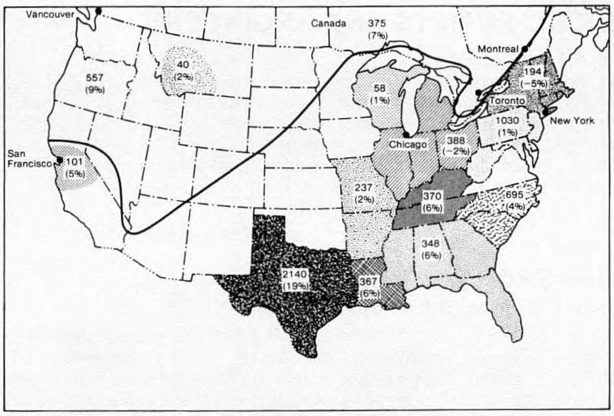

FIGURE 2. Approximate Yearly Consumption and Growth Rate of Methanol by Region.

area for each competitor is found by drawing a line connecting the intersections of the lines of equal constant costs. This, the market line, is also shown in Figure 1. The market area for Alberta methanol is north of the line and the Gulf Coast market is to the south.

As can be seen from the figure, Alberta's market area is all of Canada west of Quebec City and a large portion of the northwest and west central United States. The Gulf Coast producer has a lower delivered cost everywhere else. Once the geographical areas which represent potential markets for the two competitors are established, the objective is to locate customers within those areas. Figure 2 shows the approximate demand for methanol by region. The upper number is the 1977 capacity of chemical plants which use methanol as a chemical feedstock, expressed in mm lb/yr. Below this number is one in parentheses which is the six year net growth in demand for feedstock methanol. The data used to construct this figure were taken from the Chemical Economics Handbook [2] and include only specific plants listed in that publication. These values are somewhat low because they do not take into account demand for methanol as a solvent, gas line antifreeze, etc. Since a large fraction of methanol is used in manufacturing resins for plywood and other wood products, the markets are concentrated in those regions which have a significant harvestable forest. The pacific northwest and southeastern states are examples of this concentration.

By superimposing the market line on the consumption patterns, it is possible to compare the production of the two plants with the requirements of customers potentially available to each. It is clear from Table 2 that the price paid for natural gas is the most significant component of methanol manufacturing costs. The base case natural gas prices were taken as the prevailing new gas prices (1978). Actual prices could be significantly different if old gas was under contract. A number of cases were studied to show the effect of gas prices on the market line. The cases examined are designated on Figure 3 as one through four with line 2 being the base case. When the Alberta producer has a price advantage of $1.00/mm Btu, the change in the market size is fairly small. The only new market penetrated is San Francisco where about 100 mm lb/yr are consumed. Case 3 occurs when both competitors have the same natural gas costs. The Gulf Coast producer can now capture most of the Pacific northwest market as well as the eastern Canadian market. This situation would force the Alberta producer to operate at less than full capacity, further improving the position of the U. S. competitor. Since a small change in any economic or technical variable could cause a large change in market size, competition in the PNW would be intense. Price discounting by both parties would be a definite possibility. Finally, if the Gulf Coast operator enjoys old prices and the Alberta producer pays new gas prices, the Texas plant would capture all of the PNW. The Alberta producer would be left with only the three western Canadian provinces, whose total market is less than his breakeven production rate. The problem is

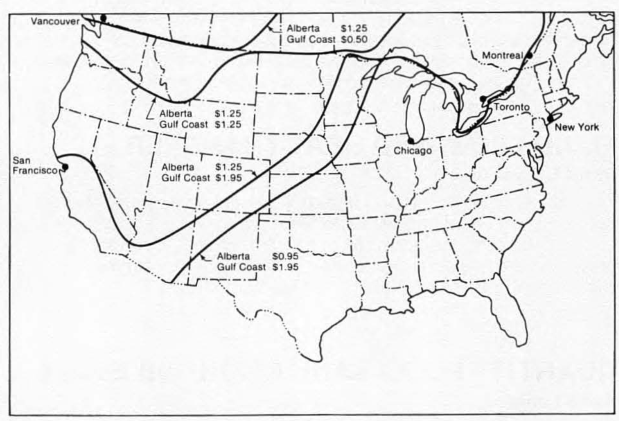

FIGURE 3. Effect of Natural Gas Price on Market Area.

solved since he must then shut down if actually operating or decide not to build a new plant.

Operating under the base case conditions, the Gulf Coast producer has access to a market of approximately 6000 mm lb/yr, while the Alberta manufacturer has a maximum market of 970 mm lb/yr. With the indicated growth rates, these markets will have expanded to 7050 and 1220 mm lbs/yr respectively during the three years taken for planning and construction. To operate at full capacity, the new American producer must capture 20% of the market available to him, whereas the equivalent number for the Alberta plant is 60%. The potential market available to the Alberta producer at start-up is about twice the capacity specified in the base case, i.e. 1000 T/D. As a first step, he might consider doubling the plant capacity to 2000 T/D in order to capture the entire base case market area plus any other market that becomes available as a result of the economics of scale. Figure 4 shows the market

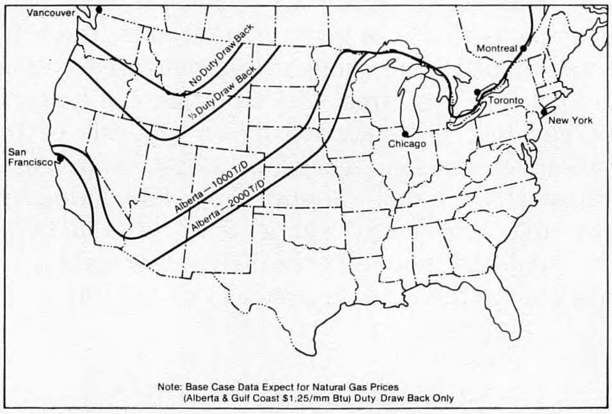

FIGURE 4. Effect of Plant Size and Duty Draw Back on Market Area.

lines for the 1000 and 2000 T/D plants. All other factors were held constant. The interesting feature of the increase in plant size is that, in spite of the reduced unit cost of methanol, not one more major customer was added to the Alberta market. The only effect of the increase was to add sufficient capacity to satisfy the demand of the customers that a 1000 T/D plant could not. It is obvious that the next plant size that should be tried is about 1200 T/D. However, this is too precise a refinement in view of the potential effects of changes in other variables.

On occasion, a commodity is imported into a country, processed, then exported in a different form. When this occurs, the duty or tariff originally imposed on the imported good is forgiven. This is called a duty drawback. In the PNW up to one-third of imported methanol is exported in the form of resin. In effect, the cost of the Alberta produced methanol is reduced by an amount equal to the duty drawback, which improves the competitive position of Alberta methanol in a contested area. The sensitivity of the market line to a change in duty drawback is also shown on Figure 4 for the case of equal natural gas prices of $1.25/mm Btu. With no duty drawback, the Alberta producer should be able to capture virtually all of Washington and half of the Idaho market area. With one-third of the tariff forgiven, he will be able to penetrate one-half of the Oregon market in addition to the states of Idaho and Washington. The incremental increase in geographical area due to the change is relatively small; however, the amount of increased sales should be significant because of the concentration of users located in the area. It should be noted that the line representing the one-third duty drawback is misleading. The line is for drawback based on the average, whereas in reality the drawback is specific for only those plants which exported the processed methanol.

So far it has been assumed that the determination of the market size was undertaken so that both potential competitors can make the capital investment decision of whether to build a plant or not. A more interesting situation occurs when one of the plants is already in production, while the decision to construct the other has yet to be made. For the sake of argument, suppose the Texas plant exists and that the Alberta plant has yet to be built. The Alberta plant must use the average cost of production which includes return on equity to determine its market. On the other hand, the Gulf producer makes his decisions based on the marginal cost of production.

In the short term, the existing plant can sell its production at a cost equal to the variable production cost or breakeven. In the midterm, the producer can sell at a price which includes all manufacturing and debt repayment costs, but excludes equity capital recovery or return on equity. Operating for an extended period under this condition will have adverse effects on either the value of the company's stock or the plant liquidation value. Figure 5 shows the market lines for the Texas plant selling its product under several pricing options. The Alberta producer is assumed to have full equity recovery and return. On this figure, four market lines are shown. The three most southern lines are parametric in the fraction of original anticipated return and recapture of equity. The line designated as 100% corresponds to the original base case and that line marked as 0% is the case where only production and debt costs are met. Finally, the market area outlined

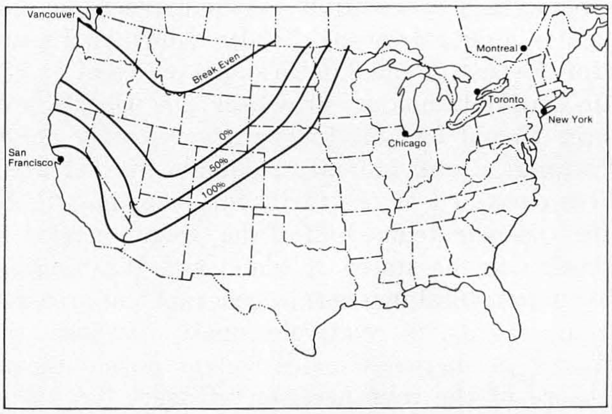

FIGURE 5. Effect on Percent Capital Recovery for Gulf Coast Plant on Western Market Area.

by the breakeven line is the situation where only the variable costs of production are achieved. In the last case there is no allowance made for equity or debt repayment. By selling its product at the marginal cost of production, the northernmost line, the Gulf Coast producer is able to capture most of the PNW market. However, this situation can only be a short-lived phenomenon, since this market is equal to about one-third of the Texas plant's production. Usually, selling at the margin is resorted to when a small fraction of the plant's capacity is under-utilized. In the long run, the Alberta producer does not need to worry about this single competitor capturing a large share of the PNW methanol market. This is certainly not the case if a large number of U. S. producers are operating at less than their capacity. The market line in Eastern Canada was shown only for the base case. The Gulf Coast producer selling into Eastern Canada at breakeven or at the margin would be in violation of Canadian dumping laws, so these lines were not drawn. Dumping occurs when a company sells internationally at a price below its domestic price.

Thus far, the analysis has been used to find the respective market areas for two competitors under a variety of conditions using the concept of delivered cost as the sole criterion. By interpreting the technique in a slightly different manner, the two competitor price can be estimated. Here, a two competitor price at a given point is defined as the higher of the two delivered costs at that point. The concept of this price is best illustrated by a simple example. Suppose the two methanol producers are attempting to sell methanol to hypothetical customers in Pendleton, Washington and Vancouver, B.C. As shown on Figure 6, the cost of Gulf Coast produced methanol in Pendleton is 6.5 U.S. ¢/lb, whereas the Alberta plant cost delivered at the same point is 5.34 U.S. ¢/lb. Given that there are no other suppliers, the Alberta producer can charge slightly less than 6.5 U.S. ¢/lb and still capture the Pendleton market.

By subtracting transportation, tariff and currency conversions from the Pendleton price, the FOB plant gate price of methanol in Calgary is approximately 5.2 Can. ¢/lb. This is shown on the figure as a dashed line. Since the plant gate cost was only 4.05 Can. ¢/lb, the sales into Pendleton will yield a profit of 1.15 Can. ¢/lb in addition to the required profit embedded in the cost calculation. On the other hand, the American plant can set the price in San Francisco at the Alberta delivered cost of about 6.1 U.S. ¢/lb. The basic principle is that in a given market area, the price is set equal to the competitor's delivered cost at any point in that area. The situation can be more complicated, as illustrated by an analysis of the Vancouver market. The Gulf Coast plant could transport methanol via ship from San Francisco and land it in Vancouver at 6.8 Can. ¢/lb. This delivered cost would fix the FOB plant gate price available to the Alberta producer at 6.2 Can. ¢/lb.

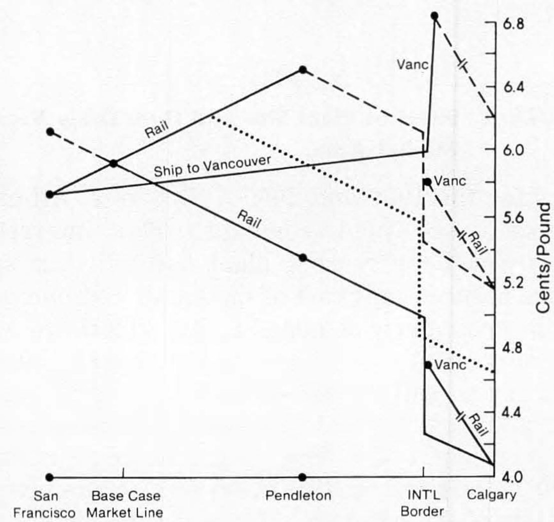

FIGURE 6. Two Competitor Pricing in PNW.

However, the Canadian plant might then be violating American anti-dumping laws by selling to the U.S. at 5.2 Can. ¢/lb FOB plant gate and in the Canadian market at 6.2 Can. ¢/lb. Because the PNW market size is much larger than that in Vancouver, the delivered price of methanol in Vancouver should be set at 5.8 Can. ¢/lb instead of the 6.8 Can. ¢/lb calculated in the absence of anti-dumping laws. Oddly enough, the U.S. anti-dumping law has had the effect of lowering the price to the Canadian methanol consumer while benefitting neither the American methanol producer nor American consumers.

A word of caution is necessary to warn the reader that the actual price will probably not be equal to the one calculated above. Obviously the two competitor model is much too simple to be applicable in the commercial world. The extension of the technique to a multi-competitor one is straightforward in principle and a natural application for a computer simulation. However, even the more complicated model would probably not arrive at a realistic price because of the unavailability of accurate input data. The model would be useful in the commercial world in the hands of someone familiar with the industry. The technique has proven to be a very useful tool in showing students how the technical, economic and regulatory factors influence the potential markets for a chemical commodity. □

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1. Various industry sources.
2. Chemical Economics Handbook, Standford Research Institute, Menlo Park, California, Vol. II, 1977.
3. Brett Haugrud, M.Sc. Thesis, University of Alberta, 1978.

AWARD LECTURE

Kinetics of Coal Processing

Continued from page 18.

Reactant A diffuses through the product layer to the reaction surface where chemical change occurs. As reaction progresses, each pore of the particle has associated with it a growing reaction surface which initially corresponds to the inner surface of the pore. As the various reaction surfaces in the particle grow, it is inevitable that neighboring surfaces will intersect one another as the solid B separating them is consumed and replaced by the product Q.

The growth of the total reaction surface may be followed in terms of the radial growth of a given set of overlapping cylinders, as shown in Figure 12. If the rate of reaction on the actual surface is proportional to the total surface area

$$\frac{S}{S_o} = \frac{1-X}{\left(1-\frac{\tau}{\sigma}\right)^3}\sqrt{1-\Psi ln\left[\frac{1-X}{\left(1-\frac{\tau}{\sigma}\right)^3}\right]} \qquad (2)$$

and the conversion is

$$X = 1 - (1-\frac{\tau}{\sigma})^3 \exp[-\tau(1+\frac{\Psi\tau}{4})] \qquad (3)$$

The surface development predicted by Equation (2) is shown in Figure 13, exhibiting the anticipated maximum, but only for pore structures that

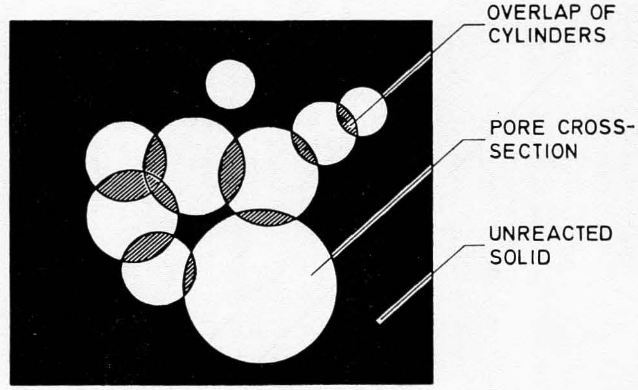

FIGURE 12. Overlapping of cylindrical surfaces. The hatched area shows the overlapped portion. The blackened area represents unreacted solid B. The reaction surface is the interface between the nonoverlapped portion of the cylindrical surface and the unreacted solid. The product layer that is deposited as the reaction surface moves is not shown in this figure. (After Avrami).

provide $\Psi \geq 2$. In this regard the model is more flexible than those based on an order of reaction or a grain model. The Petersen model (1957) can also describe either kind of behavior; but it makes no provision for further pore wall intersections and neglects the distribution of pore sizes. As an example of the use of the above technique, it is worthwhile to return to the data of Hashimoto et al. (1979) on the surface areas produced by steam activation of chars. As $\sigma \rightarrow \infty$, Equation (2) predicts a linear semilog relationship between the group $[S/(1-X)]^2$ and $(1-X)$. This expectation is supported by the data within the limits of experimental error, as shown in Figure 14.

That the subject of coal processing is a complex matter with multiple branches is a commonplace. The emphasis of this paper has been to demonstrate that the newer techniques of experimentation and modeling can shed new light on the old fossil, if the broad problems of practice are disected into manageable parts, each to be digested in its turn. □