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FACTORS INFLUENCING PROCESS SELECTION, PLANT SIZE AND LICENCE TERMS IN THE PETROCHEMICAL AND FERTILIZER INDUSTRY 1/

by

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I. FACTORS INFLUENCING PROCESS SELECTION

The object of the present paper is to analyse the factors that influence the selection of a process for a new venture in a company where the target of necessity must be an optimization of plant and product cost, based on local conditions. In the petrochemical industry the classical problems - as compared with other branches of industry - have been:

- ever increasing unit size (e.g. methanol)
- great demand for capital
- new technology
- new- or re-location of plants
- new ways of thinking
- demand for technicians with new and special training
- problems of integration.

In the early part of 1972, planners and decision-makers in the industry began to realise that an increase in the cost of oil was inevitable and would have to be borne in mind when calculating the profitability of new plants. However, the increases in crude oil price levels since the event of October 1973 have had a pronounced effect on the petrochemical industry. In a paper delivered in February of this

year to World Petrochemicals, Mr. T. J. Innies of Essochem Europe illustrated the effects of increased oil costs and inflation on the cracking costs of a plant built to produce 450.000 tons per annum of ethylene on the basis of 1972 and 1974 cost levels. His documentation demonstrated that the three cost elements: feed, fuel and utilities had multiplied in absolute value 5.3 times from 1972 to 1974. This fact, as a matter of course, had the immediate effect that all projects using rawmaterials based on oil at that crucial time had to be reconsidered and other routes - if any - to the end product desired had to be investigated. Had it been possible to foresee this turn of events when the planning of the new vinylchloride monomer plant, that is described in detail in the case under II below, took place, it is likely that the old route from acetylene had been given more weight in the final analysis of which route to choose.

According to all expertise it is prudent to assume that for planning petro-chemical plants in the future we shall have to accept and consequently take into our calculations the present level of oil prices.

An entry into production of petrochemicals is one that places very heavy demands on the investor's capital resources particularly since the tendency - in the last decade, at least - has been towards increasingly bigger units. A methanol-plant of 400.000 yearly tons is nowadays the rule rather than the exception and many of the 100.000 yearly tons plants and under have been moth-balled. There has been talk of macro-plants of over 1 million yearly tons but logistics and capital costs seem to render the realization of such giants impossible. Another problem for scaling up

into these orders of magnitude is the adverse development of capital cost due to inflation at a rate of some 20% per annum during the period 1968 to 1974. This means that the investment cost of a plant that was completed early this year was about twice that of a plant completed in 1968. Economists, however, foresee that the inflation rate is now stagnating and will have come down to 10% per annum toward the end of the present decade. There is no doubt that the two factors: larger units and inflation will very definitely and strikingly influence on choice of process and will also bring with it the healthy effect that designers of petrochemical plants - be it in industry or in engineering firms - will have to devote much time to energy-saving plant concepts if chemicals shall have a chance in the long run to compete with natural products which they have been substituting at an ever increasing rate in the post war period.

A. Plant size - Cost-Capacity relationship

The reason why operators of petrochemical plants have been ordering increasingly bigger plants lies in the known fact of reduced cost per unit produced since e.g. building a plant that shall produce 200.000 yearly tons of a petrochemical product, say ethylene, does not cost twice as much as one for 100.000 tons, et ceteris paribus. This cost-capacity relationship is generally referred to as the "six-tenths factor rule". In a publication by McGraw-Hill Book Co., professor F.C. Jelen, School of Engineering, Lamar State College of Technology, Beaumont, Texas, states in a chapter on cost-capacity factors that cost estimates can be approximated for a plant or for equipment where cost data are available for similar projects but of different capacity than that desired. In general costs do not rise in strict

proportion to size. The relationship can be expressed in the form

$$C_2 = C_1 \left(\frac{Q_2}{Q_1} \right)^X$$

where C_2 = desired cost of capacity Q_2

C_1 = known cost of capacity Q_1

The exponent X in the above equation is known as the cost-capacity factor. On the average, X is about 0.6, and the relationship is referred to as the six-thenths factor rule. Q can be in any consistent units as it enters only as a ratio.

Example: An ethylene plant of 100,000 tons/year capacity costs $8 million. Estimate the cost of a 200,000 ton/year plant.

Using the 0.6 factor rule for Equation,

$$C_2 = 8{,}000{,}000 \left(\frac{200{,}000}{100{,}000} \right)^{0.6} = \$12{,}000{,}000$$

Although 0,6 is an average value for the cost-capacity factor, it ranges from less than 0.2 to greater than 1.0. Many cost-capacity curves are not straight lines on log-log paper and often show sharp breaks. In such cases, two or more cost-capacity factors, each covering a certain range, give better results than an overall factor.

The 0,6 factor should be used only in the absence of other information. The following table gives the magnitude of the error introduced by using the 0,6 factor in place of various actual cost-capacity factors.

Table - Error Introduced by Use of 0,6 Factor

Ratio of Q_2/Q_1	Actual cost-capacity factor 0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
	Percent error								
5:1	+89	+61	+37	+17	0	-16	-28	-39	-48
10:1	+150	+100	+59	+26	0	-21	-37	-50	-60

The attached "Table 1" gives examples of costs and typical cost-capacity factors. Many other cost-capacity factors can be found in the literature or can be calculated by plotting published data.

The same methods of principle as applied above on whole plants are valid for process equipment of various kinds and the sum total of this is of course incorporated in and expressed in the cost-capacity factor for the total plant cost.

B. Licence fees

Whilst discussing the aspect of capital requirements for building a plant, another capital factor, viz. that for technology or the licence fee, should also be taken into account. The pricing of technology is an exercise that

demands much thought and insight on the part of licensor since its outcome can be decisive first of all in the approach to licensee. Too high a licence fee in the outset of negotiations can spoil all possibilities for the bidding company being considered as a potential licensor. Too low a royalty may downgrade -in licensee's eyes - the offered technology and in the final analysis the royalty must be an incentive to both licensor and licensee. Licensor must feel that he is receiving an appropriate consideration for his technology and services and licensee must feel satisfied that his cost for the acquired technology gives him a viable project whereby he takes a lead over competition and at the same time brings in a handsome profit to his company.

There are many ways in which royalties can be determined from the very often used "Rule of thumb" in a given industry to the more sophisticated methods which take recourse to formulas such as [1)]

1) Richard W. Rahn, Department of the Polytechnic Institute of Brooklyn, "The Determination of Reasonable Royalty".

$$EV(X) = r_1 P_1 \left[\sum_{1}^{3} (D/X)_i P_i \right]$$

$$+ r_2 P_2 \left[\sum_{1}^{3} (D/X)_i P_i \right] (1 - P_1)$$

$$+ r_3 P_3 \left[\sum_{1}^{3} (D/X)_i P_i \right] (1 - P_1)\ (1 - P_2)$$

where: r_1, r_2, r_3 = possible royalty rates

P_1, P_2, P_3 = respective probabilities of r_1, r_2, r_3 occurring

$(D/X)P$ = Estimated sales provided licensee "X", times the estimated probability of the sales estimate occurring.

Whichever formula is chosen the underlying principle must always be that the royalty rate be reasonable. The meaning of reasonable is a matter of definititon. The simplest and perhaps most expressive way to define reasonable is to say that it means justifiable. Therefore, to be reasonable, a royalty rate must give licensor compensation for his commercial alternative in a given territory -be it through own sales, joint venture or affiliated company - at the same time as licensee feels and goes on to feel during the life of the agreement that it gets its money's worth for the royalty payment to licensor.

There is an often expressed misconception that there exist fixed royalty rates in the different branches of industry. Accordingly, in the chemical industry royalty rates would never exceed 5% and at the petroleum end would be below 2%. This may be true in many cases and as a statistical average out of representative statistical data but one must bear in mind that each and every licence deal has specific elements in it that motivate a deviation from the average situation. Take for instance the case where a company is contemplating to replace obsolescent technology with a new process that is superior in all respects and whithout which licensee company would not be able to compete and stay in the market. A common practice in that situation is to calculate the advantage -expressed in money - the modern process has over the old one. Licensee's consideration to licensor for the advantage of the new process is then somewhere in the 1/3 or 1/4 bracket of the difference between profits made in the two operations expressed as royalty on current sales over a period of time. There are, as a matter of course, a host of factors that influence on the pricing of technology particularly in situations where

licensee, contrary to the above case, is going into a new field of activity and therefore does not directly dispose of the mechanisms for formulating his opinion on what royalty rate can be qualified as reasonable. In that situation it would be appropriate for the company going to acquire technology to make a list of factors it considers essential for the licence project under discussion, evaluate their interrelationships and rank them in a priority list to find out for itself in which areas of interest it is essential to have licensor make concessions without which the licence would be uninteresting and which areas are non-essential and therefore need not be covered in an agreement. A negotiating modus operandi would then be, during the progress of discussion, to use these factors as a checklist. Mr. Richard W. Rahn, Department of the Polytechnic Institute of Brooklyn has made a study of how to determine royalties under various conditions and has shown (Table 2) how the reference group in his study (some 350 licensing executives) had ranked the most important factors. It appears that great emphasis had been placed on factors such as

- nature and conditions of the licence,
- amount of money return,
- recent company and industry practice,

whereas factors such as potential profit from the sale or rental of equipment to the licensee were considered to be of minor interest and therefore negligable in terms of the exercise.

Many companies and particularly major industrial concerns prefer to pay for technology acquired by a lump sum instead of by running royalty. This mode of payment has

advantages as well as disadvantages. For licensee it means no administration cost for computing and remitting royalties, the cost for the technology is stated as a fixed amount once and for all and can be incorporated in the project's total investment cost for better profitability calculation. It can also - in some countries - bring with it certain tax advantages from the point of view of depreciation and deductability. Some of the advantages cited are identical for licensor - e.g. less administrative burden, but the main advantage is, of course, that licensor received his money at once and can invest it in the company's operation rather than have it trickle in yearly during the life of the agreement, particularly in a situation where the supply of low-interest money for long term investment is scarce and licensor has many high-profitability projects in the pipe-line.

The great disadvantage of a lumpsum payment for royalties is in the case where the agreement foresees mutual exchange of technical information and improvements since the running royalty is the cement that binds together the licensor - licensee realtionship better than anything else. The fact that the consideration for the licence also included one element for exchange of information, where licensor generally is the net donor, is soon forgotten especially by licensor and this can have less desirable effects on his readiness to supply important developments or to allocate resources for meeting at regular intervals with licensee.

II. EVALUATION OF ALTERNATIVE TECHNOLOGIES OFFERED FOR THE SAME PROCESS - A CASE STUDY.

A. Alternatives available

Polyvinyl chloride, PVC, is one of the oldest plastic materials. By virtue of the large number of applications and its low price PVC is now one of the large "volume plastics" in the world with an estimated production of around 10 million tons per year. The intermediate product for PVC - the vinyl chloride monomer - was until around 1960 generally produced from acetylene and hydrogen chloride, an efficient process with yields over 99% "Figure I".

The acetylene was mainly made from calcium carbide although petrochemical processes for a limited production of acetylene from natural gas had been developed after the second world war.

Calcium carbide is produced from limestone and coal at very high temperatures in large electric furnaces (Figure II). In countries where coal and electric power were available at low cost this inorganic route to arrive at the hydrocarbon acetylene was a viable method although the by-product lime sludge was becoming a problem with the rapid increase in demand for i.a. vinyl chloride.

In Sweden there was no oil, no coal nor any salt but plentiful of low cost hydroelectric power. It was on this basis that the Swedish chemical enterprise KemaNord based on its own waterfalls had built up at Stockvik, near Sundsvall in the north of Sweden, a sizeable production of carbide, vinyl chloride and PVC - around 30.000 tons per year of vinyl chloride in 1963. The demand continued to grow at a rate of 15-20% per year and the company had to decide

whether a heavy investment in a new carbide furnace, acetylene and vinyl chloride plants could be justified or if better petrochemical processes were available and that, consequently, a switch in raw material basis would be to KemaNord's benefit also in the long run.

During the -50's the processes for and the production of hydro-carbons from petroleum and natural gas, like ethylene, propylene, butadiene, aromatics and also acetylene had steadily gained ground in Europe, USA and Japan. Natural gas condensates in the USA and refinery naphtha in Europe were in a growing surplus on the energy market and, consequently, an increasingly attractive feedstock for the organic chemicals industry. Thus, around 1960, the price of ethylene in Europe was on level with or already below the carbide acetylene manufacturing cost for many European vinyl chloride producers.

The process for making vinyl chloride from ethylene and chlorine proceeds in two steps: Chlorine reacts with ethylene to 1.2-dichloroethane also called ethylene dichloride (EDC) which is an easily transportable liquid. EDC is then thermally cracked in the second process step to vinyl chloride and hydrogen chloride gas. If there is no immediate use for this hydrogen chloride it is quite a cumbersome and large by-product from this vinyl chloride process.

Different technologies were available for converting hydrogen chloride back to chlorine, but they were expensive and likely to cause operating problems. However, a new process called oxychlorination which comprises a reaction between hydrogen chloride, air and ethylene to form EDC in one step was under commercial development just before the time when KemaNord began its vinyl chloride expansion studies 12-13 years ago. One American company had started granting

licences for this know-how. The operating experience in a large plant was however lacking at the time. The ethylene route to vinyl chloride with oxichlorination is shown in "Figure III.".

For KemaNord the basic factors which were of a long term nature had first to be analysed. The result of this analysis in the beginning of the -60's indicated that the very favourable costs for electric power in the north of Sweden

- because of almost completely exploited water power generation,
- the increasing proportion of oil-fired power stations on the grid - more expensive to build and especially to operate -
- and the still distant hopes for cheap nuclear power,

were bound to go upwards more quickly in the future than in the past. Also coal in Europe was getting more expensive and loosing out to oil on the energy market. Many mines were closed and the miners that were prepared to go back to the mines would be demanding more and more wage increases for working under dirty and hazardous conditions. Also the labour costs for the carbide furnace operation and the costs for handling and transportation of large tonnages of inorganic limestone and lime-sludge would be more significant in the long run. A problem of a rather local character was that iced waterways during the winter in the north of Sweden sometimes could stop shipping to the plant during up to four months. This would become a major problem for a large plant. Thus there were a number of negative factors both of a cost, environment and logistics nature against the building of further carbide acetylene capacity. Basic factors in favour of the carbide route to vinyl chloride comprised

- the existing long proven carbide operating know-how in the company,
- the existing infrastructure including own hydroelectric power stations and
- the strategic-political implications of becoming dependent on petroleum feedstocks which all in one form or the other had to be imported into Sweden.

On the other hand, it was expected that the price of petroleum in Europe would remain fairly constant for a long time to come, the demand for petrochemicals seemed almost insatiable, whereby the naphtha crackers and similar plants for ethylene and possibly acetylene manufacture were growing bigger and bigger. The well-known scale effect would ensure low cost per ton of ethylene for conversion into e.g. vinyl chloride.

These modern plants were automatically operated and controlled to a very high degree and as for location they were usually brought together in large integrated complexes close to deep-water ports easily accessible the year around. Summing up, the odds were much in favour for leaving definitely the carbide acetylene route and for making all vinyl chloride on a petrochemical basis. This strategic decision could of course be influenced by short-term decisions to buy vinyl choride or even the intermediate EDC for an indefinite period of time.

In Sweden, the first petrochemical center with a medium size naphtha cracker of 50.000 tons per year of ethylene, a polyethylene and an ethylene oxide plant had just started at Stenungsund near Gothenburg on the west coast of Sweden in 1963, but it could not be expected that this cracker would have any ethylene left for feeding also a vinyl chloride

plant. However, the choice was open as to whether ethylene should be purchased or an integration backwards to own manufacture of acetylene and/or ethylene from naphtha be undertaken.

The high temperature cracking processes for making both ethylene and acetylene in certain proportions attracted the interest of KemaNord because of the problem with the by-product hydrogen chloride in the ethylene route to vinyl chloride. Thus, hydrogen chloride from the ethylene route could be reacted with acetylene in a traditional process to produce an equal amount of vinyl chloride.

As can be noticed, the choice situation was complicated and the number of factors influencing the process selection very large. The following two tables sum up the situation:

Table 1

Options for vinyl chloride	Location
1. Expand carbide route.	Stockvik
2. Purchase vinyl chloride	Stockvik
3. Purchase EDC, crack EDC and combine hydrogen chloride with carbide acetylene.	Stockvik
4. Purchase ethylene, make EDC,	
a) crack EDC, hydrogen chloride + carbide acetylene	Stockvik
b) crack EDC, hydrogen chloride + ethylene.	Stenungsund
5. Production of only acetylene from naphtha	Stockvik or Stenungsund
6. Production of acetylene and ethylene from naphtha	Stockvik or Stenungsund
7. Own production of ethylene from naphtha	Stenungsund

Calculation and evaluation of the following factors were carried out:

- market
- technical
- economic
- financial
- personnel
- tactical
- strategic
- political

including assessments of the long range future for raw materials, VCM technology and the PVC plastic material.

The next table gives a simplified comparison between the three basic raw materials and their process implications:

Table 2

	Carbide	Naphtha	Ethylene
Ton raw materials/ton VCM	4.5	2.5	1.2
Ton by-products/ton VCM	2-8	1.3	-
Man hours/ton VCM	3.5	2.5	1
Cost of raw materials/ton VCM incl. chlorine and credits for by-products, Sw. Kronor	500	275	450
Investment inside battery limits (BL) Mill. Sw. Kronor	90	80	40

From the analysis shown in table 2 above it became clear that continued operation even with a fully depreciated carbide plant was not a viable solution.

Production of acetylene only from naphtha was from

techno-economical points of view less attractive than the combined production of acetylene and ethylene at a lower reaction temperature.

Therefore, in the final analysis, KemaNord had the choice between

A. building a special naphtha cracker of the X. type, which was then under development and licensed by two very large engineering companies with extensive naphtha cracking knowledge, to make acetylene and ethylene plus two separate vinyl chloride units operating in balance "Figure IV" (at Stockvik the existing vinyl chloride plant could then still be used) or

B. buying ethylene from Stenungsund after expansion of the existing naphtha cracker and build EDC chlorination, EDC cracking and an oxychlorination unit at Stenungsund "Figure V".

Obviously, this latter choice would have the consequence that also future PVC units had to be built at Stenungsund instead of at Stockvik.

For the two remaining options (A and B above) the following factors were analysed and compared:

- capital investment cost
- production cost
- utility consumption
- operating reliability
- logistic effects - operational, market, social, environmental effects, such as pollution of air and water,
- profit expectations of the cracker unit
- chlorine supply
- assessment of the future raw material prices
- ethylene price at Stenungssund.

After about one year of studies and negotiations the final choice of the future raw material and technology for KemaNord's vinyl chloride was for ethylene and the new oxychlorination technology at Stenungssund.

Decisive for this choice were:

1. The X. naphtha cracker was not in large scale operation anywhere, though licences were being granted to other parties.

2. Naphtha cracking to ethylene was advancing rapidly to higher yields, which could mean lower prices.

3. Oxychlorination had advanced significantly during 1963 and 1964 and licences could now be obtained for this technology from more than one licensor.

4. The naphtha cracker enterprise at Stenungsund agreed to build a new much larger cracker to secure supply of ethylene not only for the vinyl chloride plant but also for the expansion of the polyethylene company, in which KemaNord had a 50% interest.

5. Stenungsund is a superior location from the market point of view.

6. KemaNord by this decision would take direct part in the future petrochemical development in Northern Europe.

B. Vinyl chloride from ethylene and chlorine including oxychlorination

After the first evaluation phase described under A. above, and at the outcome of which KemaNord had taken the definite decision to change the raw material basis from own carbide acetylene to purchased ethylene from the naphtha cracker at Stenungsund, the final evaluation and negotiations for the alternative vinyl chloride technologies available came as the second phase.

At the beginning, discussions were held with six different European and American vinyl chloride manufacturers to establish the so-called "state of the art" and especially the various ways to solve the problem of the hydrogen chloride by-product recovery:

- air oxidation to clorine
- electrolysis to chlorine
- oxychlorination to EDC.

During the studies the new oxychlorination technology was confirmed to be commercial and superior to the other recovery processes.

This still left KemaNord with three possible licensors for the licence package on the process steps comprising:

- ethylene chlorination to EDC
- EDC-cracking to VCM
- oxychlorination

The following factors were then evaluated:

1. Plant investment capital, inside and outside BL,
2. Product yields and manufacturing cost,

3. Utility requirements, especially fresh water,
4. Size and number of years of operation of the potential licensor's plant,
5. Documented on-stream time, duration and reasons for shut-downs, maintenance cost, safety aspects,
6. Size and choice of material for vital components like cracking, furnace, reactors, purification units,
7. Requirements on raw material, purity, pressure, etc.,
8. Vinyl chloride product purity,
9. The whole licence package available from one licensor.
10. Would licensor allow a certain choice between engineering firms for competitive bidding as contractor for KemaNord?,
11. Licence fees and modes of payment,
12. Volume and nature of by-products, their treatment,
13. Problems connected with residual streams to air and water environment and
14. Possibilities for future plant expansions.
15. Thorough studies were made of the effects of scale and load on plant economy. The graph in "Figure VI" demonstrates how product unit cost is effected in different-sized plants at various loads.

The outcome of this study and the final negotiations for licence conditions including technical cooperation and exchange of know-how, crystallized into the choice of one of the potential licensing companies following the three crucial points:

1. Capital investment needed for plant and licence,
2. The rights to the whole package of the three process steps was in the hands of only one of the eting

licensors. Further, that same licensor allowed KemaNord to choose between a number of reputable contractors to design and build the plant in Sweden,

3. The operating experience of the licensor.

The licence agreement which has now expired, included an ongoing exchange of know-how and operating experience between the licensor and KemaNord. This worked out very successfully since both parties contributed with significant improvements in i.a. yields, manufacturing costs and environmental control. The capacity of the plant has been trimmed from the original 75.000 to 100.000 tons of vinyl chloride per year and has after the first 1-2 years of normal running-in problems been running like a clock. The troubles typical for vinyl chloride plants are due to the highly corrosive nature of chlorine and hydrogen chloride in mixture with air and water.

Looking back to the first phase and KemaNord's choice between ethylene and oxychlorination on the one hand and own acetylene and ethylene production as the other alternative, it is now well-known among people in the trade that several plants using the latter alternative route were built in Europe during the late 60's, the last plant to be erected was in Brazil. As far as is known most of these plants have been shut down after tremendous operating problems and heavy capital losses.

The experience of the practical case of KemaNord presented in its main features in this paper demonstrates the necessity of a deep and careful evaluation of a large number of technical and economic factors before selecting technology and licensor.

The evaluation costs involved when one is on the buying

side of the licence table can be substantial, but still a well motivated insurance fee to minimize the risk of much higher losses later on. There is an additional advantage that can be derived from an in-depth study like the one presented above, namely that the purchaser of technology will be given the opportunity of familiarizing himself with the knowledge, technological level and experience of the licensor, his continuing R&D efforts and resources - including costly failures - and in the process absorb the most advanced thinking available in the field of process technology under study.

Table 1

Cost of Battery-limits Plants*

Process	Capacity	Unit	Cost,† $/unit	Cost-capacity factor	Capacity range
Acetylene	10	Tons/day	200	0.73	3.5–250
Aluminum (from alumina)	100 M	Metric Tons/yr	900	0.76	20 M–200 M
Ammonia (by steam-methane reforming)	100	Tons/day	26 M	0.72	100–3 M
Butadiene	10 M	Tons/yr	690	0.65	5 M–300 M
Butyl alcohol	100 MM	Lb/yr	0.027	0.55	8.5 MM–700 MM
Carbon black	1	Tons/day	15.3 M	0.53	1–150
Chlorine	100	Tons/day	90 M	0.62	10–800
Ethanol, synthetic	10 MM	Gal/yr	0.36	0.60	3 MM–200 MM
Ethylene	100 M	Tons/yr	91	0.72	20 M–800 M
Hydrogen (from refinery gases)	10 MM	Cu ft/day	0.26	0.64	500 M–10 MM
Methanol	10 MM	Gal/yr	0.36	0.83	5 MM–100 MM
Nitric acid (50–60%)	100	Tons/day	11.4 M	0.66	100–1 M
Oxygen	100	Tons/day	18 M	0.72	1–1.5 M
Power plants, coal	100	Mw(elec)	200 M	0.88	100–1 M
Nuclear	100	Mw(elec)	270 M	0.68	100–4 M
Styrene	10 M	Tons/yr	200	0.68	4 M–200 M
Sulfuric acid (100%)	100	Tons/day	6.2 M	0.67	100–1 M
Urea	250	Tons/day	13 M	0.67	100–250
Urea	250	Tons/day	13 M	0.20	250–500

* From O. T. Zimmerman and I. Lavine, *Cost Eng.*, vol. 6, pp. 16–18, July, 1961; and O. T. Zimmerman, *Cost Eng.*, vol. 12, pp. 12–19, October, 1967.

† Cost-capacity factor = n = cost-capacity factor for unit costs.

McGraw-Hill Book Co., Professor F.C. Jelen, School of Engineering, Lamar State College of Technology, Beaumont, Texas.

Table 2

Richard W. Rahn, Department of the Polytechnic Institute of Brooklyn, "The Determination of Reasonable Royalty"

TABLE

RANKING OF FACTORS RELEVANT TO THE LICENSE PRICING DECISION

Rank	Mean Score	Influencing Factors Formally Evaluated	Always	Usually	Often	Seldom	Never
1	1.5	Degree of exclusivity of the license	63%	27%	3%	4%	3%
2	1.5	The anticipated total money return	58%	33%	7%	2%	0%
3	1.5	The type of license (patent or knowhow)	65%	23%	9%	2%	1%
4	1.5	Term of license contract	63%	25%	8%	3%	1%
5	1.6	The nature and type of obligations assumed by licensee under the agreement (i.e., guarantees, immunity from suit, etc.)	61%	27%	6%	5%	1%
6	1.6	Foreign country's restrictions on remittances	62%	20%	12%	6%	0%
7	1.6	The probability of the license being profitable for the licensee	58%	31%	5%	5%	1%
8	1.6	Recent company licensing rates and practices for similar products and processes	53%	36%	7%	2%	2%
9	1.7	The perceived ability of the prospective licensee to do a high quality job with the licensee	58%	28%	7%	2%	5%

Table 2 (cont'd)

TABLE (Cont.)

Rank	Mean Score	Influencing Factors Formally Evaluated	Always	Usually	Often	Seldom	Never
10	1.7	The amount of expected profit or saving incurred by the licensee	52%	31%	11%	6%	0%
11	1.7	Anticipated sales volume of licensed products	46%	36%	11%	5%	2%
12	1.8	Geographical location of licensee	53%	23%	18%	5%	1%
13	1.9	Recent industry licensing rates and practices for similar products and processes	36%	48%	11%	4%	1%
14	2.0	Alternatives available to licensee	36%	34%	28%	7%	3%
15	2.0	Competitive situation faced by licensee	38%	35%	25%	5%	0%
16	2.1	Licensee's political environment	34%	32%	25%	9%	0%
17	2.2	The life cycle of the product or process being licensed	29%	38%	15%	12%	6%
18	2.3	R&D costs to the licensor for patent or process	29%	34%	20%	13%	4%
19	2.5	Estimated cost of technical services to be provided without charge to prospective licensee	26%	33%	12%	20%	9%

Table 2 (cont'd)

TABLE (Cont.)

Rank	Mean Score	Influencing Factors Formally Evaluated	Always	Usually	Often	Seldom	Never
20	2.5	Estimated costs of training licensee's employees (including time costs)	23%	36%	16%	19%	6%
21	2.6	The GNP or degree of development of the licensee's country	17%	38%	20%	20%	5%
22	2.6	Salary costs of administrative and technical personnel	28%	17%	17%	29%	9%
23	2.7	Estimated costs of adapting product or technology for licensee	23%	19%	31%	21%	6%
24	2.7	Estimated cost of maintaining and obtaining local patent and trademark protection	29%	21%	23%	31%	2%
25	2.8	Estimated value of engineering, construction and plant installation costs contributed	22%	25%	20%	22%	11%
26	2.8	Estimated travel costs of supervisory and technical personnel	28%	14%	19%	31%	8%
27	2.9	Estimated policing costs in connection with the license	16%	21%	16%	40%	5%
28	3.0	The expected markup of the licensee	15%	28%	22%	20%	13%

Table 2 (cont'd)

TABLE (Cont.)

Rank	Mean Score	Influencing Factors Formally Evaluated	Always	Usually	Often	Seldom	Never
29	3.0	Estimated travel costs of company personnel negotiating agreements	19%	13%	23%	30%	16%
30	3.1	Expected value of technical flow-back rights to licensor	16%	28%	27%	37%	6%
31	3.1	Estimated costs of quality supervisory tests, auditing, and inspection	13%	29%	16%	30%	12%
32	3.2	Possibility of licensor deriving useful information about the foreign country from licensee (and having known contact man)	13%	13%	23%	42%	9%
33	3.3	Estimated value of new rights and technology to be supplied during the proposed agreement without charge	30%	23%	10%	10%	6%
34	3.4	Costs of blueprints, drawings and other written technology	20%	23%	19%	30%	9%
35	3.4	Estimated cost of marketing, purchasing and other non-technical assistance to be provided without charge to prospective licensee	13%	13%	11%	30%	23%

Table 2 (cont'd)

TABLE (Cont.)

Rank	Mean Score	Influencing Factors Formally Evaluated	Always	Usually	Often	Seldom	Never
36	3.5	Expected value of possible sales to licensee of components, equipment, supplies, prototypes, etc.	6%	12%	17%	42%	24%
37	3.7	Estimated cost of machines, equipment and inventory to be contributed	11%	16%	16%	38%	20%
38	3.8	Expected value of possible fees from extra technical or managerial assistance and service	5%	6%	14%	50%	26%
39	3.8	Costs of researching markets and market potential for prospective licensee	6%	8%	15%	43%	28%
40	3.9	Expected value of the possibility of increased sales of other licensor products when licensee serves as a distributor	5%	5%	15%	49%	26%
41	3.9	Estimated cost of advertising and merchandising grants or assistance to be provided without charge to prospective licensee	9%	5%	5%	47%	34%
42	3.9	Licensee as a potential low-cost source of products for sale in licensor's country	5%	6%	18%	40%	30%

Table 2 (cont'd)

TABLE (Cont.)

Rank	Mean Score	Influencing Factors Formally Evaluated	Always	Usually	Often	Seldom	Never
43	4.0	Expected value of possibility of licensee supplying ingredient at lower cost to licensor	4%	4%	11%	47%	30%
44	4.1	Expected value of commissions earned on purchases made or sales made for licensee	4%	7%	8%	40%	30%
45	4.2	Expected profit from purchase and resale of goods produced by licensee	3%	4%	6%	40%	40%
46	4.6	Expected value of rental payments on licensor-owned equipment	1%	1%	3%	30%	60%

Figure 1 ACETYLENE ROUTE TO VINYL CHLORIDE

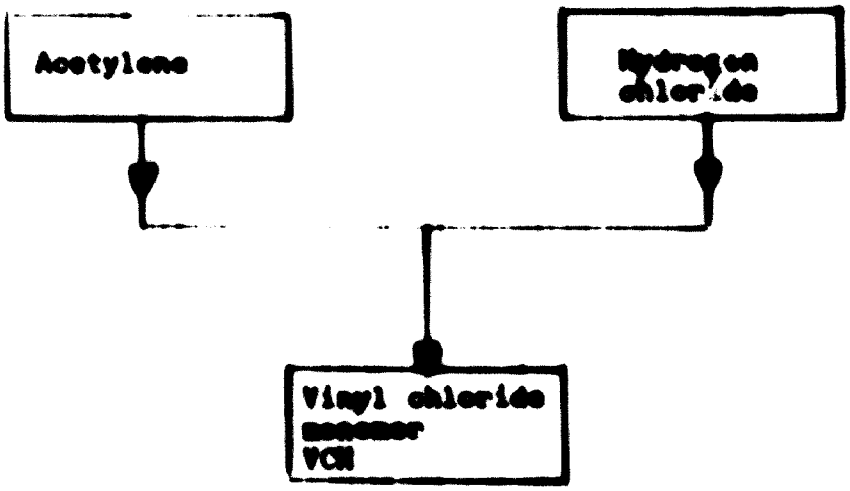


Figure II CARBIDE ROUTE TO ACETYLENE

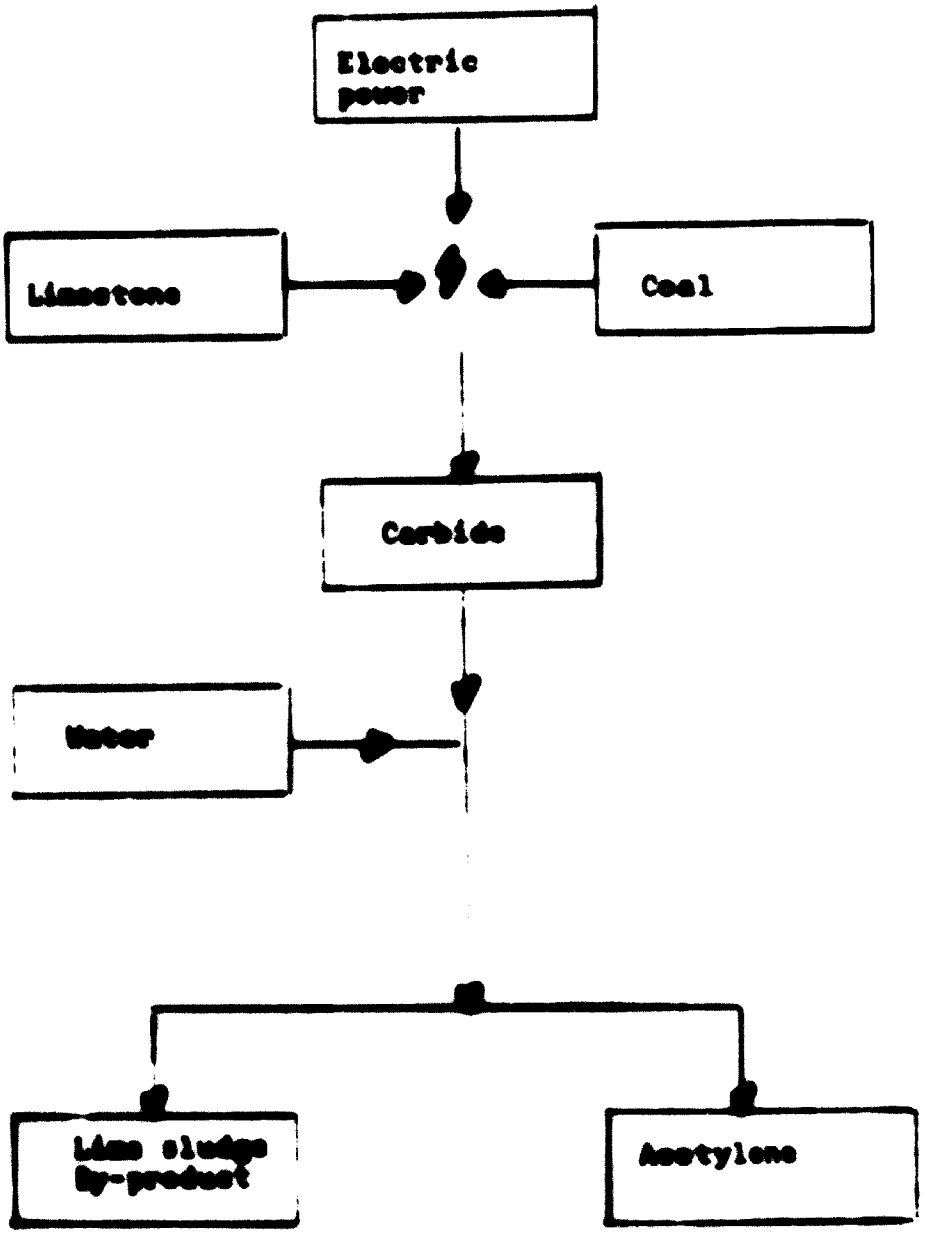


Figure III ETHYLENE ROUTE TO VINYL CHLORIDE WITH OXYCHLORINATION.

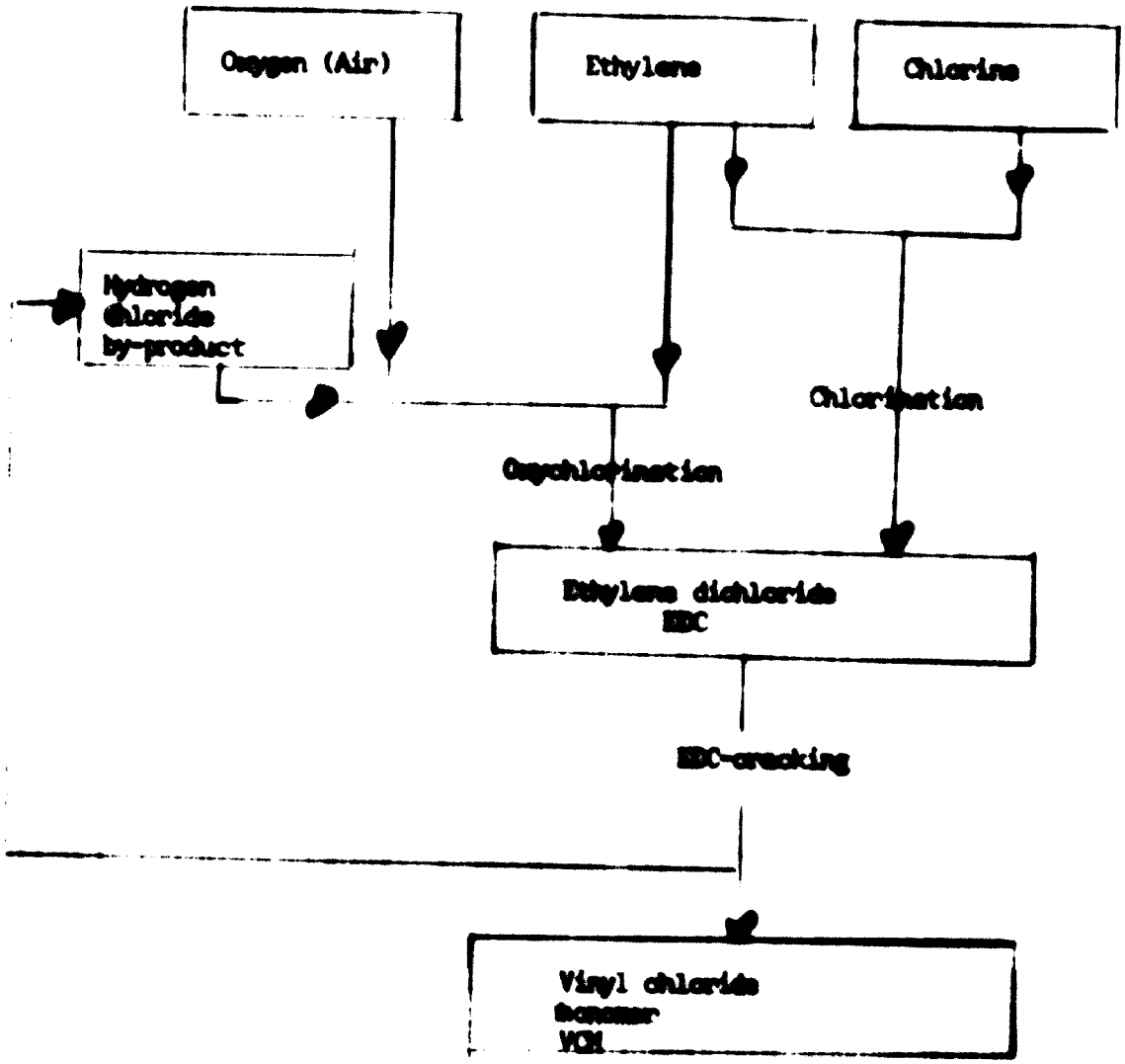


Figure IV PETROCHEMICAL ROUTE TO ACETYLENE AND/OR ETHYLENE

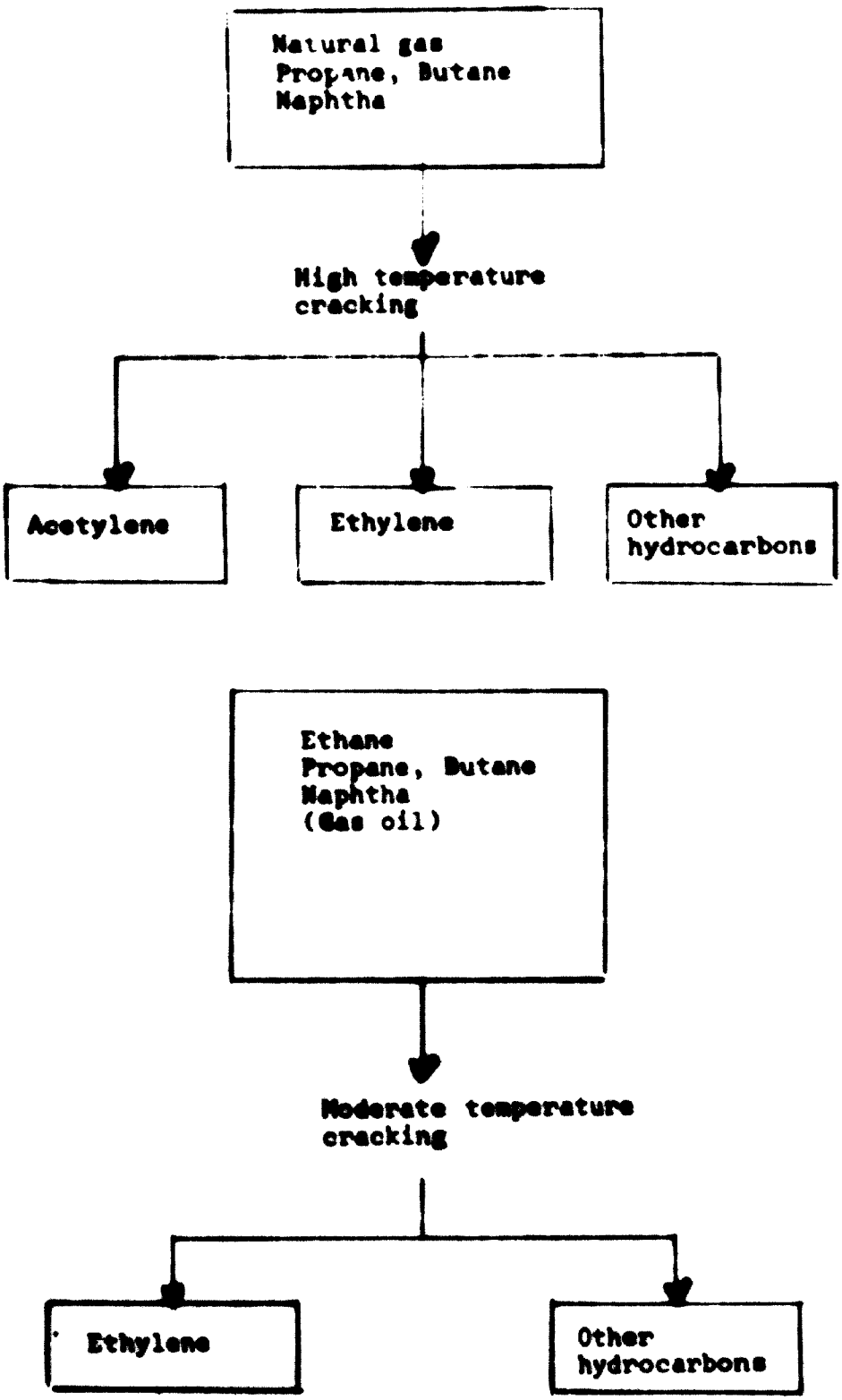
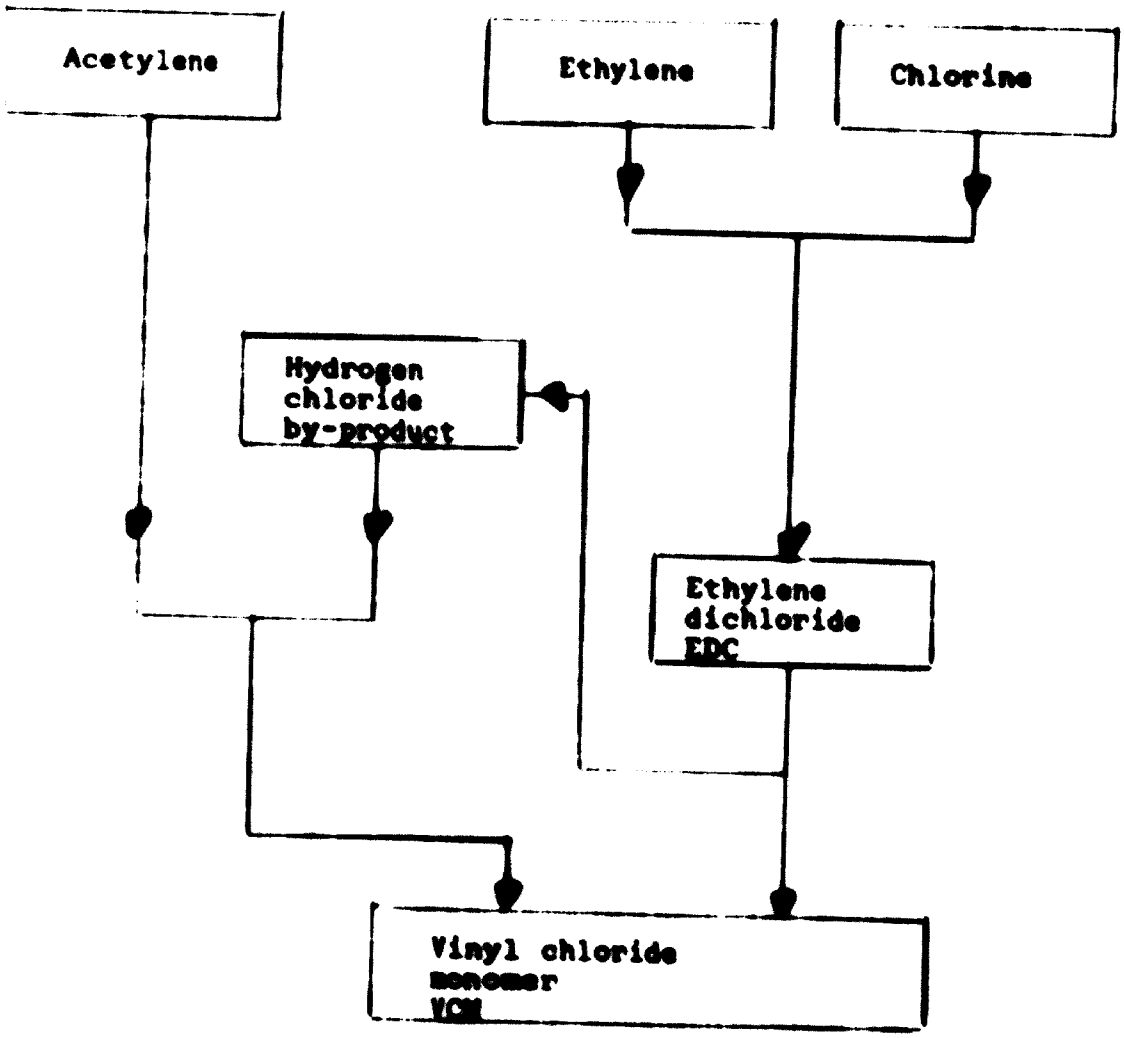
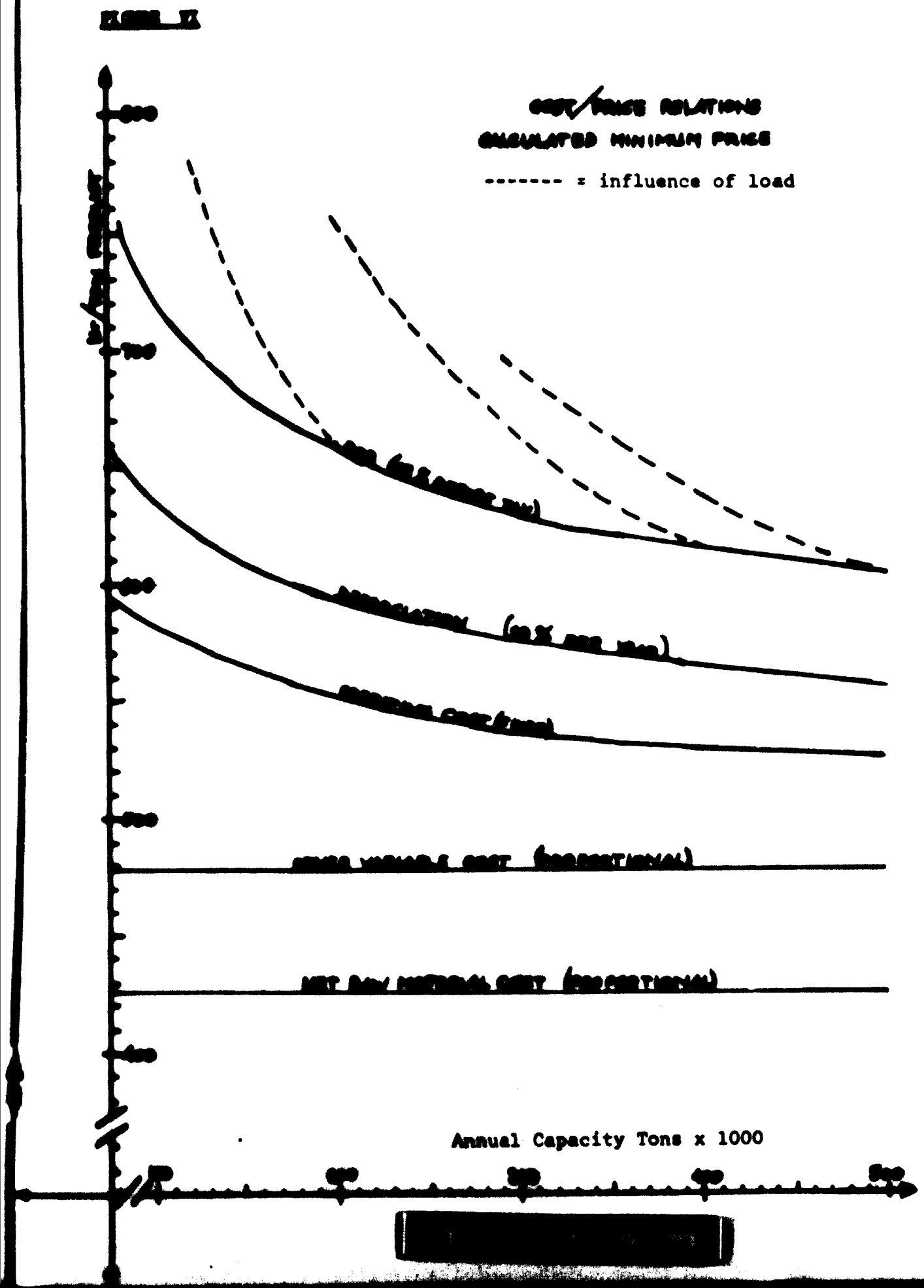
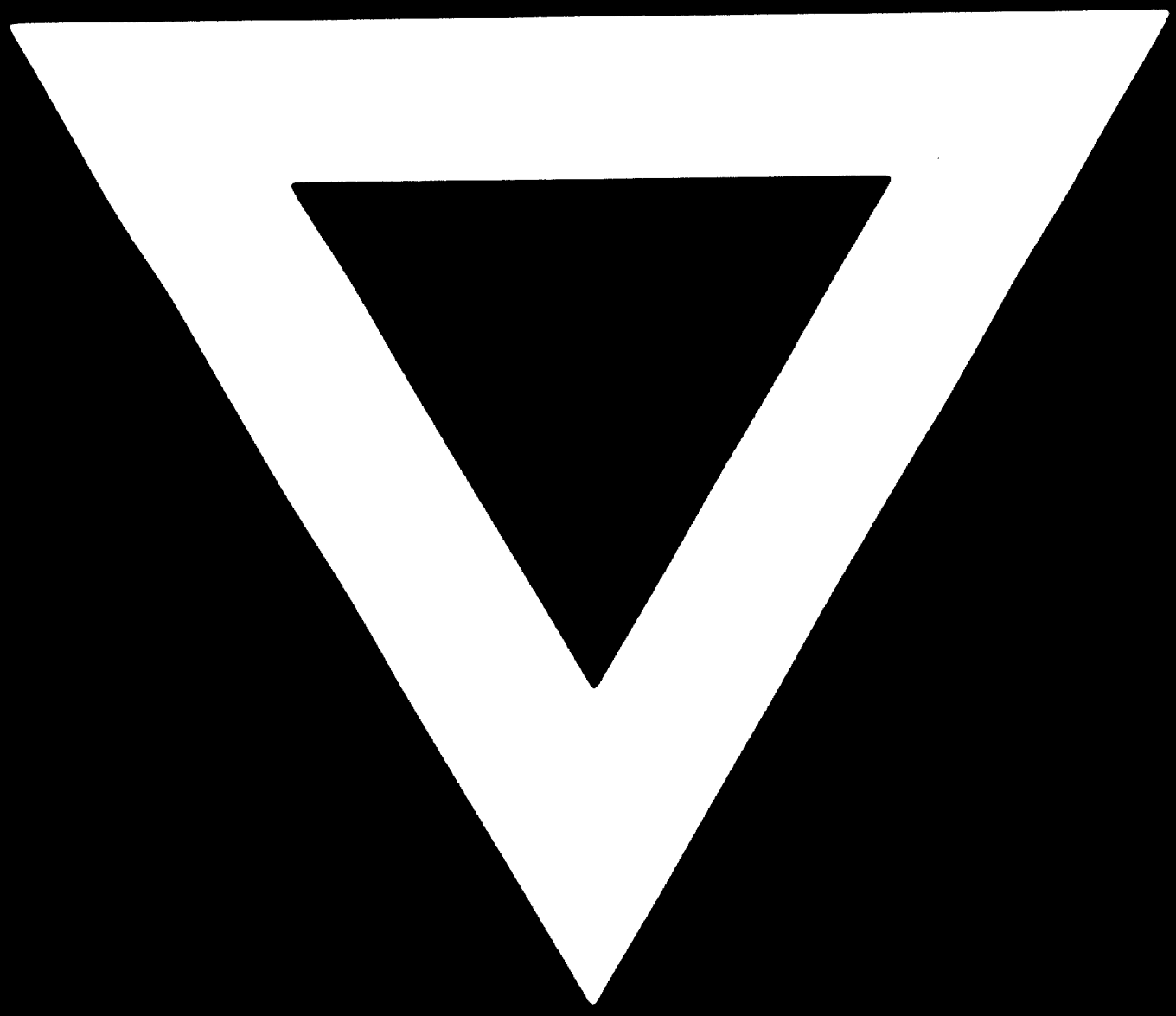


Figure V ETHYLENE ROUTE TO VINYL CHLORIDE BALANCED WITH ACETYLENE ROUTE FOR BY-PRODUCT HYDROGEN CHLORIDE.




COST/PRICE RELATIONS
CALCULATED MINIMUM PRICE
------- = influence of load
Annual Capacity Tons x 1000



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