DETAILED AREA ANALYSES

COST ANALYSIS (By Manufacturing)

Figure 2 presents the breakdown of unit manufacturing costs from 1957 to mid-1961. It reflects the continuing decrease in raw material prices and shows the results of recent intensive programs for yield improvement and reduction in direct costs. The following table compares "unit costs from raw materials" for this year with those from the same period of 1960.

Manufacturing Costs from Raw Materials

		Jan.-June 1960		Jan.-April 1961
VCM Average Monthly Production, MM lbs		6.84		7.21
Raw Materials	2.970		2.096	
Interdivisional Profit	0.318		0.528	
Acetylene Adjustment	0.262		0.204	
Total Raw Material Cost		3.550		2.828
Wages		0.427		0.419
Other Direct		3.206		2.641
Indirect		1.668		1.905
Shipping		0.082		0.077
TOTAL COST, $/100 lbs		8.933		7.870

The major improvements during this period reflect improved yields due to better control of ethylene impurities, new equipment installed in the expansion, and improved cracker operation with new chlorine meters; a major effort to reduce maintenance costs; and a revised accounting procedure to include the Heyden royalty at an earlier accounting stage.

Raw Material Utilization

	1960	1961 (5 months)	Design
VCM from EDC	93.0%	96.3%	95.0
VCM from Acetylene	95.0%	98.0%	98.5
EDC-Chlorine Yield	94.8%	96.1%	95.0
EDC-Ethylene Yield	93.4%	94.9%	94.0

Further increases in yields depend primarily on achieving split-stream operation for maximum distillation efficiency. The increases in 1961 are due to improved equipment and optimization studies which included:

1. Revised cracker operating conditions with improved chlorine metering to reduce tar production. Ultimate yields in cracking are under study, with 98% not considered impossible (versus the present 96.3%). The overall C_2 yield is currently 94%, and the ultimate is not presently known.

2. Revised conditions on the VCM fractionator (22D7) to remove cracking inhibitors and eliminate vent losses, made possible by added refrigeration and distillation equipment.

3. Definition of the type and sources of ethylene impurities which are detrimental to the chlorination process allowed removal of them from the EDC manufacturing system.

A major study is in progress to optimize the EDC crackers where much of the low-value by-products are formed. The capacity of this equipment could be significantly increased by raising the EDC conversion level, but it would be at the expense of yield losses and increased decoking costs. The study in progress includes developing a kinetic model of the cracker from bench-scale and plant tests on several sizes of cracker tubes. A 3-inch tube replacement is being installed in one plant cracker for full-scale testing. Tests on the effects of feed impurities are in progress so that the EDC purification system can be tied in with cracker performance.

By-Product Recovery and Utilization

Anhydrous HCl supplied to the styrene plant and muriatic acid for power and acrylonitrile plants are the largest current by-product sales. We are selling a small stream of chlorinated solvents at a very low price primarily to save disposal costs. When design operations are achieved, this material will be re-evaluated to determine value of its constituents. Potential sales of EDC are under study at the present time.

Utilities and Energy Requirements

The major utility in VCM is refrigeration, which shows up as a steam cost. Net steam costs for the first five months of 1961 were 0.176¢/lb of VCM, or 2.65% of the total manufacturing cost. This is a 30% increase over 1960, and was partly caused by additional distillation facilities installed in the expansion project. Optimizing this usage will require split-stream operation and IBM computation of heat balances and mathematical expression of point usage against the effect on yields, quality, and operating cost.

Maintenance, Instruments, and Materials of Construction

Repair costs have been reduced to near half the 1960 level by increased efficiency and better planning. This effort is continuing and a recent study of pump repair costs points the way to additional savings. The major item of heat exchanger fouling is under intensive study by Maintenance, Plant Engineering, and Technical Service to minimize both the frequency and cost of cleaning.

Several chromatographic analyzers are installed and planned for the next few months to improve process control in reaction and purification areas. These instruments will allow us to get optimum yield with product quality and to reduce catalyst usage.

9 yr life in 304 SS tubes!!

Mild steel is used successfully throughout the plant by keeping the system dry. The only exception now is in cracker tubes, which are 304 stainless steel. These tubes have given very good service, but retubing will be needed in the next 6 to 12 months, after about nine years of use.

Recent data show severe corrosion to be occurring in a pump and the piping which follow the chlorine injection point for butadiene removal. Extent and nature of this problem is being studied by Plant Engineering to determine the equipment affected and the best means to combat it.

Reactor Catalyst Usage

Catalyst replacement in the acetylene-HCl reactors at design VCM production rate with past reactor performance would cost more than $300,000 per year. The rapid change-out of catalyst required would make it very difficult, if not impractical, to obtain the design 60 MM lbs VCM/year rate from the existing reactors. During early 1961, the acetylene plant ran at very low production rates, resulting in an unusually pure acetylene feed to the VCM plant. The reactor performance has shown an increase in catalyst productivity, especially at high throughput. Current tests show that with pure acetylene, the existing reactors have the capability for design VCM production at considerably reduced catalyst replacement cost. Data from Research studies and Italian (SICE) plant operation indicate a potential catalyst cost reduction of more than $150,000 per year by high-purity feed and optimum reactor conditions.

On-Stream Time

The plant is able to operate well within the design on-stream time. The new refrigeration unit added during the 1960 expansion removed a major cause of lengthy shutdowns. During the first 6 months of this year, the plant was down a total of only 20 hours. Problems which are currently under study are water leaks, reactor charging, and cracker coking.

Since water leakage can occur at many points, with resultant equipment corrosion and rapid heat-exchanger fouling, the need is for a continuous water analysis. Research is evaluating a newly marketed instrument for this use. The reactor recharging and cracker coking problems are part of the Technical Service studies for optimizing these two processes.

Areas for Major Emphasis

1. Split-stream operation: Demonstration with acid scavenger for product cleanup is in progress.

2. Catalyst usage in the acetylene-HCl reactors: Work is in progress for acetylene cleanup process. Reactor optimization studies in plant and slip-stream reactors are continuing.

3. Debottlenecking of EDC manufacturing: Testing of caustic-wash elimination is in progress.

4. On-stream time: Two projects have been planned with the objective of increasing plant on-stream time.

a. Methods for continuously analyzing various process streams for water are being studied by Research. Water cannot be tolerated in the VCM unit because of the corrosive nature of the process streams when wet.

b. Catalyst loading and unloading procedures will be investigated by Technical Service and Plant Engineering to minimize reactor downtime during recharging operations.

5. Maintenance cost reduction: Specific items needing study are reboiler fouling and pump seal repairs.

6. Integration of overall operation: To minimize costs, we must be able to take advantage of the flexibility in raw materials by scheduling the acetylene-to-ethylene feed ratio. At present, maximum acetylene usage is the obvious optimum, since it results in minimum out-of-pocket cost. When Chocolate Bayou comes on stream, the whole picture will change. We should be ready at that time to compute the minimum cost (to Monsanto) feed stock ratio using an economic model of the VCM plant with electronic computers. Preparations for this are now in progress. Analytical methods for reaction and cracking products have been developed for instantaneous yield data as well as future rate versus yield correlations throughout the plant.

CAPACITY ANALYSIS (By Division Engineering)

Capacity Limits of Major Equipment

1. EDC Manufacture -- Department 23 = DC

Design at 130 MM lbs EDC/year equivalent to 78 MM lbs VCM/year at 95% yield. The reaction system has been tested at a higher temperature and pressure that will allow it to handle a rate of 200 MM lbs EDC/year. Bottlenecks to go from 130 to 150 MM lbs EDC/year should be minor, depending upon the success of current tests to eliminate the caustic wash system. Above 150 MM lbs/year, the chlorine and EDC rundown storage will become bottlenecks.

2. EDC Manufacture -- Department 26

This unit is currently idle. It was originally designed as a semi-commercial pilot plant for a capacity of 36.5 MM lbs EDC/year equivalent to 20.8 MM lbs VCM/year. For this unit to operate economically as a producing unit would require some additional capital to reduce losses and increase yield.

3. EDC Purification

70% !

Rated at 130 MM lbs EDC/year equivalent to 78 MM lbs VCM/year at 70% cracking conversion. The capacity can probably be increased to 145 MM lbs/year (86 MM lbs VCM/year) without additional capital and to 160 MM lbs/year with changes in auxiliary equipment. Above 160 MM lbs/year would require major additions.

4. VCM Cracking Plant

2" tubes

3" tubes

Rated at 78 MM lbs VCM/year at 70% cracking conversion. Capability of existing equipment is estimated at 85 MM lbs/year. Capacity of the cracking furnaces could be increased to 115 MM lbs with 60% conversion by enlarging the tubes from 2 inches to 3 inches. One furnace is now scheduled for retubing with 3-inch tubes for plant tests. Additions to the condensing and quenching systems would be required to increase the capacity from 85 to 115 MM lbs/year.

5. VCM-EDC Cracking Separation

Rated at 78 MM lbs VCM/year. The EDC cracker absorber will begin to bottleneck above this capacity; however, it can possibly operate up to 85 MM lbs VCM/year. The HCl stripper, VCM column, and 1,1 DCE column have operated at rates of 105 to 110 MM lbs VCM/year. With modification to the EDC cracker absorber, the capacity of this system can be raised to 115 MM lbs VCM/year.

6. Acetylene-HCl Reaction

Designed at 60 MM lbs/year using series reactors (i.e., one or more reactors feeding into another reactor in series with them). Operational changes and temporarily improved acetylene purity allowed the feed rates to be increased to the existing reactors. Capabilities to reach an ultimate capacity of 72 MM lbs/year depend upon the impurities in the acetylene feed. Feed impurities affect the catalyst life and make series reactor operation beneficial. Research and Engineering work is now under way to study removal of impurities in the acetylene feed. With pure feeds to eliminate series reactor operation and increase catalyst life, a 72 MM lbs/year rate could be reached with no additional capital.

7. VCM Purification

Designed at 138 MM lbs VCM/year and capable of this with good quality when acid-scavenger addition is demonstrated. All major purification equipment is designed for an ultimate capacity of 200 MM lbs VCM/year. Storage will bottleneck at about 160 MM lbs VCM/year.

Areas of Capital Reduction in a New Plant

1. Reducing the number of acetylene-HCl reactors via increased catalyst life and increased throughput. Purified acetylene offers the major improvement foreseeable for increasing catalyst life. Multipoint injection of HCl into the catalyst bed offers the major improvement foreseeable for increasing throughput.

2. Reducing the number of crackers by increasing tube size from 2 inches to 3 inches.

3. Elimination of caustic-washing and azeotropic drying step in EDC manufacture would eliminate capital and reduce caustic.

Ultimate Capacity of Present Plant

The ultimate capacity of the present plant is estimated at about 200 MM lbs VCM/year. Expanded capacity for minimum capital is about 160 MM lbs/year.

The attached Figure 3 summarizes capacity existing now and planned for future expansions.

Major Targets

1. Clean up acetylene feed to improve catalyst yields. This will also allow increased production from the existing equipment.

2. Development work to increase the throughput to the acetylene-HCl reactors.

PROCESS ANALYSIS (By Research)

Process Safety

There are three major hazards in the VCM area:

1. Acetylene: Design and operation of the acetylene-handling facilities in the VCM area are conservative to assure minimum detonation hazard. Research plans to investigate the deflagration characteristics of the mixed HCl-acetylene stream. It is

certainly safer than pure acetylene, but just how much more is unknown. Present operation is conservative.

2. Chlorine facilities: No good way apparently exists to combat a major chlorine spill. Engineering has suggested a number of ways to minimize this hazard (L. B. Bullock to Operating Committee, "Study of Hazards of Chlorine Handling Facilities," Interim Report, 6/5/61). Research intends to investigate better ways to fight a spill than the present best method (soda ash). Additional instrumentation for decreasing possibility of spill at the chlorine storage tanks are being installed presently.

3. Mercury hazard: Technical Service and Research have as a continuing problem the job of preventing toxic pollution due to the use of mercuric chloride catalyst.

Process Weaknesses

1. Raw Materials

Acetylene and ethylene are both upgraded raw materials. We are basic in acetylene and will be basic in ethylene when the Chocolate Bayou project is completed. We have good sales contracts on chlorine.

2. Catalyst Usage in Acetylene-HCl Reactor

Catalyst life has never been satisfactory. Pilot plant work indicated a catalyst yield of about 475 lbs VCM/lb catalyst. Plant yield was about 240 lbs VCM/lb catalyst before the use of series reactors and about 330 lbs VCM/lb catalyst after. The primary reason for this low life is thought to be the impurities present in our Sachsse acetylene. SICEdison reports a catalyst yield of 715 lbs VCM/lb catalyst using carbide-based acetylene. We feel 1,000 lbs VCM/lb catalyst is attainable using pure acetylene with our superior cerous chloride-containing catalyst.

Technical Service has a continuing program to improve catalyst yield through testing in the plant and in their small test reactors. A review of the catalyst problem is scheduled in order to define Research work needed.

Product Quality

The reactivity of Monsanto VCM, as measured by dilatometer polyrate, is the highest in the industry. There has been a great improvement in our VCM quality since the last area analysis was made in 1959. Main factors leading to this improvement were:

a. Chlorination of crude reaction VCM, which has allowed reduction of butadiene and butene content to less than the 1 ppm level.

b. The new VCM fractionator, 22D14, which has resulted in virtual elimination of heavy-ends from our VCM.

c. Use of series reactor, which allowed longer catalyst life while maintaining acetylene impurities in the reactor effluent at low levels.

All competitors are marketing extremely pure VCM. Our VCM compares well except for unusually "large" amounts of the saturated C_4 hydrocarbons. n-Butane normally is running at 20-50 ppm and isobutane at 10-30 ppm. Springfield feels that the butanes are chain transfer agents and desires a reduction. Additionally, VCM purchasers are extremely critical on quality. We feel that sensitive chromatography will become a sales tool, and on a chromatogram, our butane peaks stick out like sore thumbs. Escambia has already questioned us about trace impurities in our VCM. Technical Service is now trying to locate the source of the butanes in our process in order to determine the cost of removing them.

We are presently fighting an acidity problem which does not allow operation of the plant as designed in the expansion ("split system operation") with the chlorination facilities in operation. Solution of this problem is a top-priority project. Addition of a scavenger was successful in a limited test, with further trials and evaluation of monomer at Springfield scheduled for September.

In summary, our VCM is, as far as we can tell, over 99.99% pure, with further improvement necessary before we can make the claim "as good or better than any VCM available".

Competition

All competition use the same processes for VCM that we use. Dow has oxidative chlorination know-how, but we do not know whether they are using it for EDC manufacture. A listing of VCM producers is given below:

Producer	Capacity (MM lbs)	Raw Material
Allied Chemical Moundsville, W. Va.	100	Acetylene

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Producer	Capacity (MM lbs)	Raw Material
American Chemical Watson, Calif.	25	Ethylene
Cumberland Chemical Calvert City, Ky.	50	Acetylene
Diamond Alkali Houston, Texas	50	Acetylene
Dow Chemical		
Freeport, Texas	100	Combined
Placquemine, La.	60	Ethylene
	160	
Ethyl Corporation		
Baton Rouge, La.	150	Ethylene
Houston, Texas	50	Ethylene
	200	
General Tire Ashtabula, Ohio	30	Acetylene
B. F. Goodrich		
Calvert City, Ky.	100	Combined
Louisville, Ky.	100	Acetylene
Niagara Falls, N. Y.	40	Acetylene
	240	
Goodyear Tire Niagara Falls, N. Y.	50	Acetylene
Monsanto Chemical Texas City, Texas	150	Combined
Union Carbide		
Texas City, Texas	100	Combined
S. Charleston, W. Va.	150	Combined
	250	
U. S. Rubber Painesville, Ohio	60	Acetylene
	1,365	

Dow's capacity at Placquemine is expected to be 100 MM lbs/year in 1962. Plans for three other large plants have been announced. Monochem (U. S. Rubber - Borden) is scheduled for 150 MM lbs/year at Geismar, La., by 1962; U. S. Rubber's plant at Painesville, Ohio, would presumably be shut down. Tenneco (Tennessee Gas) has recently announced plans for a 200 MM lbs/year VCM plant in Houston. Diamond plans to have a 90 MM lbs/year expansion on stream in Houston in January 1962. The impact of the drastic 1960-1961 VCM price drop on these projects is unknown.

Monsanto, Diamond, and Carbide (Texas City) now use hydrocarbon acetylene with its associated impurity problems. Diamond, Tenneco, and Monochem all plan integrated plants using acetylene produced by partial combustion of methane.

Alternate Processes

Monsanto has technology in making VCM by cracking of EDC by reaction of acetylene and HCl and by oxidative chlorination of ethylene (to EDC). Exploratory work has been done by Research on oxidative chlorination and high temperature chlorination of ethane. The former gives ethyl chloride as product. The high temperature chlorination (so called sudden chlorination) of ethane can be modified to give a wide variety of products preferentially, including vinyl chloride, vinylidene chloride and 1,1-dichloroethane. Sudden chlorination is new technology using a raw material which has not been upgraded; the technique suffers in that large quantities of HCl (3 moles HCl/mole VCM) are made as by-product. Economics are attractive only if HCl can be moved at a chlorine value.

Areas for Improvement of Present Process

1. Increased catalyst life and decreased catalyst cost. Purified acetylene is the major improvement foreseeable here.

2. Elimination of equipment or process steps. Examples are elimination of the caustic washing and azeotropic drying step in EDC manufacture, or decreased number of crackers in operation if 3-inch cracker tubes are satisfactory.

3. Better plant control by instrumentation. Installation of chromatographs on the cracker absorber (22D5) overhead, on reactor effluent, and on product column (22D14) overhead are examples of such installations accomplished or in progress.

4. Preparation of a mathematical model of the VCM plant for computer optimizing yield and utility costs. This includes work required to develop information to prepare such a model. Reduction of losses is a part of yield improvement.

5. Quality improvements, including control of HCl and reduction of butane content, are necessary to meet competition.

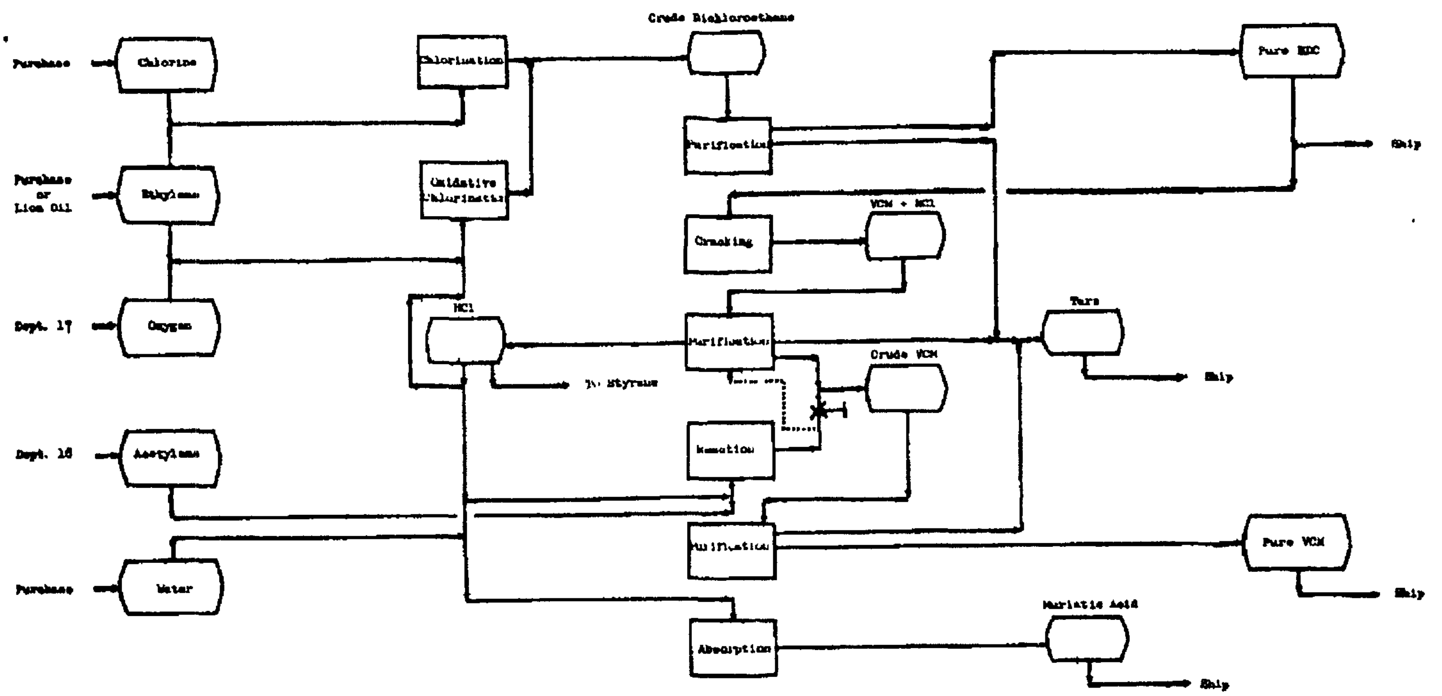
6. Minimizing the hazards resulting from chlorine spills and studies of deflagration in acetylene-HCl mixtures are needed to improve plant safety.

do

8/15/61

FIGURE 1

TEXAS CITY VCM PLANT



1. C_2H_2 + HCl $\xrightarrow[HgCl_2\text{-}CeCl_3 \text{ on } C]{100^\circ}$ $CH_2{=}CH\text{-}Cl$

   Acetylene — M.W. 26; M.W. 36.5; Vinyl chloride — M.W. 62.5

2. $Cl\text{-}C_2H_4\text{-}Cl$ $\xrightarrow[Cl_2]{480\text{-}520^\circ C}$ $CH_2{=}CH\text{-}Cl$ + HCl

   1,2-Dichloroethane — M.W. 99; Vinyl chloride — M.W. 62.5; M.W. 36.5

The 1,2-dichloroethane (EDC) can be produced by two routes:

3. C_2H_4 + Cl_2 $\xrightarrow{Fe, O_2}$ $Cl\text{-}C_2H_4\text{-}Cl$

   Ethylene — M.W. 28; M.W. 71; M.W. 99

4. C_2H_4 + $2HCl$ + $1/2\ O_2$ $\xrightarrow[220\text{-}230^\circ C]{CuCl \text{ on } Al_2O_3}$ $Cl\text{-}C_2H_4\text{-}Cl$ + H_2O

   M.W. 28; M.W 36.5; M.W 32; M.W. 99; M.W. 18

CBY 1040431

RSV0031381

FIGURE 2

VCM UNIT MANUFACTURING COSTS
(COST REPORT DATA)

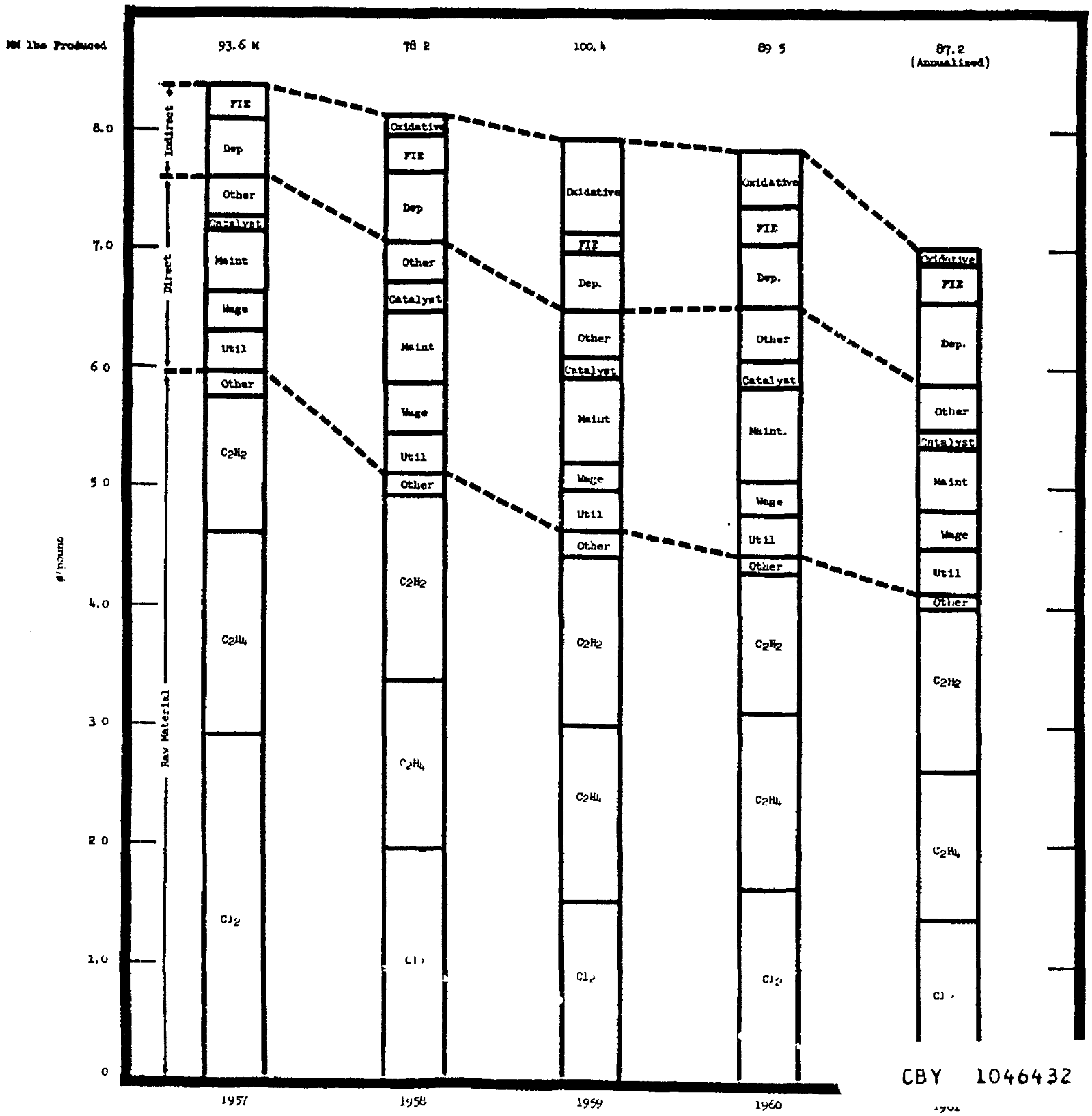
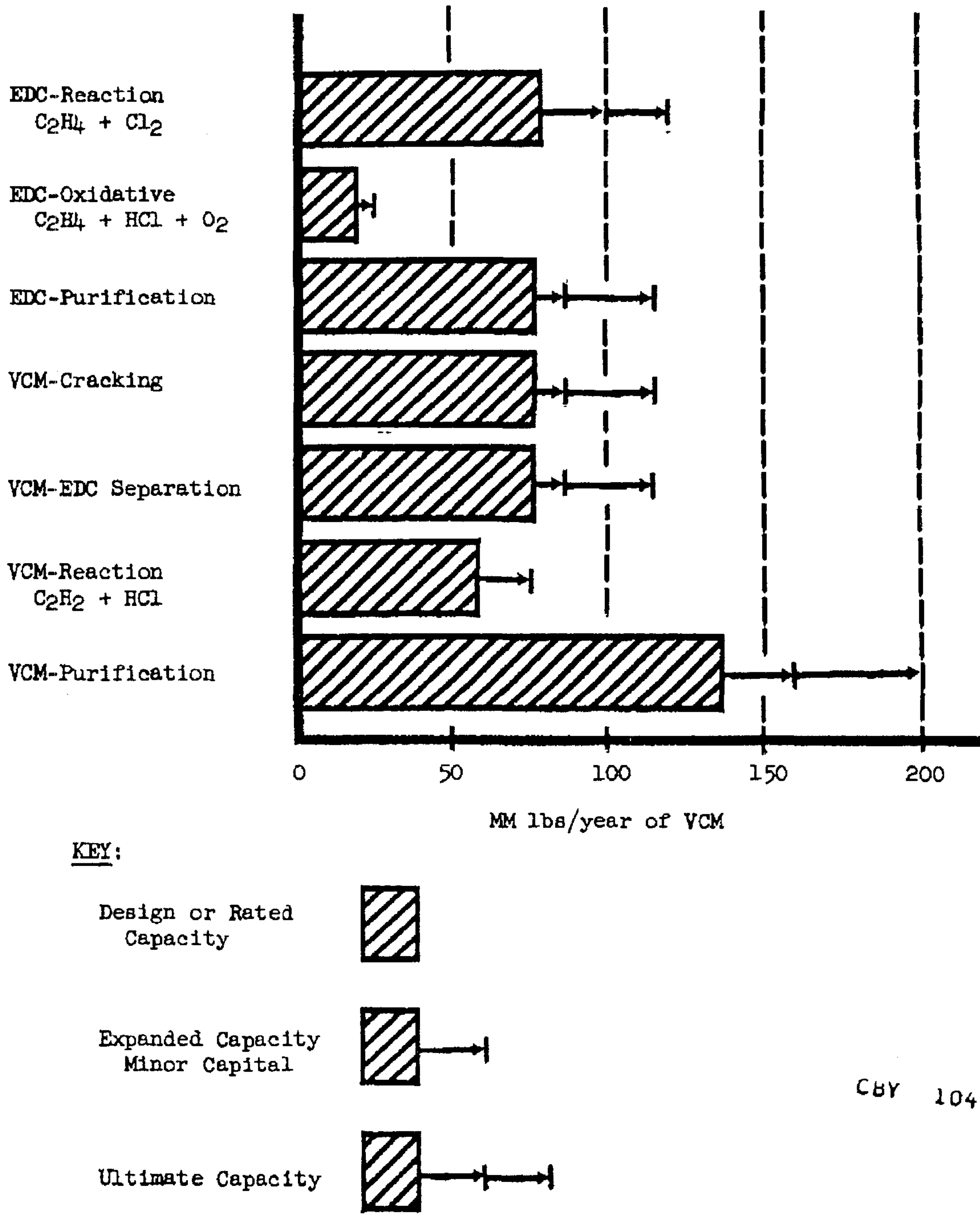


FIGURE 3

CAPACITY ANALYSIS -- VCM PLANT



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