Blank Rcd Well

EPA-450/3-73-006-i

July 1975

RN Wheeler
fyi HRG
12/3/75

ENGINEERING AND COST STUDY OF AIR POLLUTION CONTROL FOR THE PETROCHEMICAL INDUSTRY

VOLUME 9: POLYVINYL CHLORIDE MANUFACTURE

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

EPA-450/3-73-006-i

ENGINEERING AND COST STUDY OF AIR POLLUTION CONTROL FOR THE PETROCHEMICAL INDUSTRY VOLUME 9: POLYVINYL CHLORIDE MANUFACTURE

by

R.G. Bellamy and W.A. Schwartz

Houdry Division
Air Products and Chemicals, Inc.
P. O. Box 427
Marcus Hook, Pennsylvania 19061

Contract No. 68-02-0255

EPA Project Officer: Leslie Evans

Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

July 1975

UCC
026052

In-Depth Study

of

POLYVINYL CHLORIDE PRODUCTION

Contract No. 68-02-0255

Prepared For

Environmental Protection Agency
Research Triangle Park, North Carolina 27711

Prepared By

Houdry Division
Air Products and Chemicals, Inc.
P. O. Box 427
Marcus Hook, Pennsylvania 19061

Houdry Division
Air Products and Chemicals INC.

UCC
026053

This report is issued by the Environmental Protection Agency to report technical data of interest to a limited number of readers. Copies are available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - as supplies permit - from the Air Pollution Technical Information Center, Environmental Protection Agency, Research Triangle Park, North Carolina 27711; or, for a fee, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

This report was furnished to the Environmental Protection Agency by Houdry Division of Air Products and Chemicals, Inc., Marcus Hook, Pennsylvania 19061, in fulfillment of Contract No. 68-02-0255. The contents of this report are reproduced herein as received from Houdry Division of Air Products and Chemicals, Inc. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of the Environmental Protection Agency. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

Publication No. EPA-450/3-73-006-i

PETROCHEMICAL AIR POLLUTION STUDY

INTRODUCTION TO SERIES

This document is one of a series prepared for the Environmental Protection Agency (EPA) to assist it in determining those petrochemical processes for which standards should be promulgated. A total of nine petrochemicals produced by 12 distinctly different processes has been selected for this type of in-depth study. These processes are considered to be ones which might warrant standards as a result of their impact on air quality. Ten volumes, entitled Engineering and Cost Study of Air Pollution Control for the Petrochemical Industry (EPA-450/3-73-006a through j) have been prepared.

A combination of expert knowledge and an industry survey was used to select these processes. The industry survey has been published separately in a series of four volumes entitled Survey Reports on Atmospheric Emissions from the Petrochemical Industry (EPA-450/3-73-005a, b, c and d).

The ten volumes of this series report on carbon black, acrylonitrile, ethylene dichloride, phthalic anhydride (two processes in a single volume), formaldehyde (two processes in two volumes), ethylene oxide (two processes in a single volume), high density polyethylene, polyvinyl chloride and vinyl chloride monomer.

ACKNOWLEDGEMENTS

The study reported in this volume, by its nature, relied on the fullest cooperation of the companies engaged in the production of polyvinyl chloride. This was given at a particularly difficult time as all the companies were in the midst of an all out effort to reduce all vinyl chloride monomer emissions to a minimum. Without their information this report could not have been written. We, therefore, list the participating companies to acknowledge their cooperation and assistance.

American Chemical Corporation*
Borden, Incorporated
Continental Oil Company
Firestone Plastics Company
General Tire & Rubber Company
B. F. Goodrich Chemical Company
Goodyear Tire & Rubber Company
Great American Chemical Corporation
Hooker Chemical Corporation
Keysor-Century Corporation
National Starch & Chemical Company
Pantasote Company of New York, Inc.
Stauffer Chemical Company
Tenneco Chemicals
Union Carbide Corporation
Uniroyal Chemical Company
Universal PVC Resins, Incorporated
Air Products and Chemicals, Inc.

*Subsidiary of Stauffer Chemical Company

We also acknowledge the help of numerous manufacturers of equipment.

TABLE OF CONTENTS

TABLE OF CONTENTS
(CONTINUED)

I. Introduction

Polyvinyl chloride (PVC) resins cover a great variety of plastic compounds from the pure homopolymer to an almost endless variety of modifications starting with minor (<10%) amounts of copolymers such as vinylidene chloride, vinyl acetate, ethylene, propylene or an acrylate. The resins themselves are modified with plasticizers, stabilizers, inert fillers and many other additives. (In the case of records and many toys the final product may contain less than 45% PVC and in the case of vinyl asphalt tiles much less than 45%.)

Industrial development of PVC resins began some 40 years ago. Production on a full commercial scale began in Germany in 1931 and in the United States in the middle 1930s, aft r the discovery that polyvinyl chloride, when heated in the presence of a suitable high-boiling liquid (a plasticizer), formed a flexible plastic material that resembled rubber or leather. Because plasticized PVC showed itself to be a good insulator, resistant to the weather, and nonflammable, it was put to military uses in World War II. Diversified compounding and processing technology, which developed particularly in the later 1940s and early 1950s, quickly led to many broad-scale commercial uses.

The processing and performance characteristics of PVC r sins can be varied with the molecular weight, which for most commercial PVC resins lies between 50,000 and 120,000. Equally important to the characteristics of the resins is the presence or absence of plasticizer. Most PVC plastics produced in past decades were flexible types, containing plasticizer. While the many processes for plasticized PVC are relatively easy to carry out, the processing of PVC compounds containing essentially no plasticizer (for the production of rigid PVC plastics) is technically more d manding. The properties of plasticized PVC plastics depend greatly on the exact amounts and chemical types of plasticizers used; it is common to employ mixtures to achieve th desired properties.

Although the great majority of PVC resins used in the various processes to manufacture PVC plastics are homopolymers of vinyl chloride, copolymers are still essential in some processes, where they are used alone or in admixture with homopolymers.

The most important commercial copolymers of vinyl chlorid are those with vinyl acetate. The higher molecular weight resins with an acetate content of about 2-8% are used for calendering and extrusion, where somewhat faster processing is possible because of their better flow properties compared with those of conventional homopolymers. Copolymers containing over 8% vinyl acetate flow even more readily under the application of heat and pressure and are, therefore, favored in the production of phonograph records. The copolymers also are capable of binding particularly large amounts of mineral fillers and pigments, a capability utilized in the production of vinyl-asbestos floor tile. Because the solubility in esters and ketones of vinyl chloride copolymers with an acetate content of 10-20% is much greater than that of homopolymers, these resins are used in solution coating.

The commercial copolymers of vinyl chloride with ethylene and propylene contain 1-8% of ethylene or propylene and are predominantly used in the manufacturing of unplasticized (rigid) PVC products. Such copolymers can be processed faster and have better impact strength than comparable homopolymers, without any sacrifice in dimensional stability and other important performance properties.

Copolymers of vinyl chloride with vinylidene chloride are more soluble in solvents than homopolymers and they are good film formers. The few resins of this type that are on the market today are, therefore, mostly used in specialty coatings (in solution and, in some applications, in latex or emulsion form).

A few latex PVCs or copolymers of vinyl chloride and ethyl, n-butyl, or 2-ethylhexyl acrylate are used in the production of wall coverings, nonwovens, and house paint. The latexes are 50 percent solid colloidal dispersions in water.

Postchlorinated PVC homopolymer resins have long been in existence but were of little commercial importance until recently. Products made from them have better heat resistance (and higher densities) than products made from ordinary PVC resins. The main application for these resins is in residential hot water pipe.

In 1973 the production of PVC resins was 4,423,400,000 pounds. As there was a tight supply, this was probably all consumed. Based on production figures since 1962, the growth curve is shown in Figure PV-7 on page PVC-76 and indicates a projection of growth to 1985. However two important factors have interjected themselves recently into the picture which may chang this growth projection. One, is the energy crisis which could curtail the supply of ethylene and discourage projected expansions. (This has actually occurred.) Another factor is the recent discovery (January 1974) of the carcinogenic nature of vinyl chloride and the current uncertainty of how OSHA and EPA regulations will effect the profitability of manufacturing PVC resins. In any case, both factors will probably inhibit the growth of PVC, perhaps very drastically.

A third factor that has reduced the demand for PVC resins is the current temporary slump in the building industry.

It cannot be overemphasized that the emissions shown in this report are based on data obtained by the reporting plants prior to August 1974. Many, if not all, the plants have made considerable progress in reducing emission since that time so that the emissions shown are those of a transition period and do not reflect current emissions. This is true of fugitive losses as well as known streams as the industry has tightened up their losses in all respects.

II. Chemistry of Polymerization

The polymerization of vinyl chloride can occur in two ways, one in a head-to-tail fashion,

$$\{CH_2CHClCH_2CHCl\}_n$$

or head-to-head or tail-to-tail configuration,

$$\{CH_2CHClCHClCH_2\}_n$$

Research has shown that the head-to-tail position is greatly favored and closely represents the actual polymer.

The terminal groups can be saturated, unsaturated or radical fragments from the initiator or solvent, depending on the chain transfer activity of the various groups.

Saturated end groups are formed by chain transfer with monomer and polymer and by termination through disproportionation:

$$\sim\!\sim\!-CH_3;\quad \sim\!\sim\!-CH_2Cl;\quad \sim\!\sim\!-CHCl_2$$

Unsaturated chain ends are due to termination by disproportionation and to chain transfer to monomer:

$$-CH_2CHClCH=CHCl;\quad -CCl=CH_2;\quad -CH_2CHClCH=CH_2$$

Initiator or solvent (chain-transfer agent) fragments, represented by R, can be incorporated in the terminal group:

$$-CH_2R;\quad -CHClR$$

Due to the high transfer activity of the monomer, about 60% of the polymer molecules are estimated to have unsaturated end groups. For the same reason, the percentage of chain ends containing initiator fragments is low; the amount of solvent fragments depends upon its transfer activity.

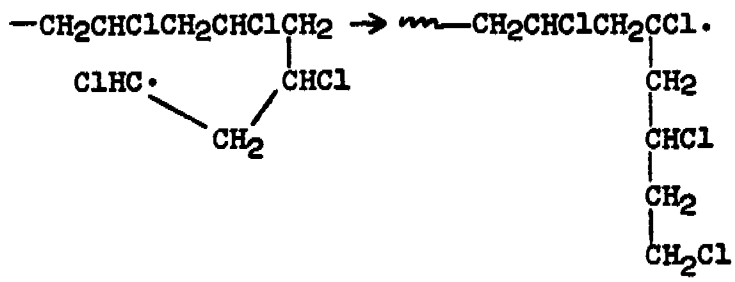
Long-chain branching can be caused by the incorporation of the terminal double bond of a polymer molecule into a growing chain:

$$\sim\!\!-CH_2CHCl\cdot + CHCl=CH-\!\!\sim \rightarrow \sim\!\!-CH_2CHClCHCHCl\cdot$$

or by intermolecular chain transfer to polymer:

$$\sim\!\!-CH_2CHCl\cdot + \sim\!\!-CH_2CHCl-\!\!\sim \rightarrow \sim\!\!-CH_2CH_2Cl + \sim\!\!-CH_2\underset{\wr}{C}Cl\cdot$$

Intramolecular chain transfer (back-biting) leads to the formation of short side chains:



III. Commercial Processes

Polyvinyl chloride is primarily produced by one of the following four processes.

A. Suspension Polymerization

Figure PV-1 persents a simplified flow diagram for the suspension process. This process is by far the most common process used to manufacture PVC resins (78% of total capacity). It is likely to remain so for many years although it may gradually decline as bulk polymerization becomes more common and presumably more economic.

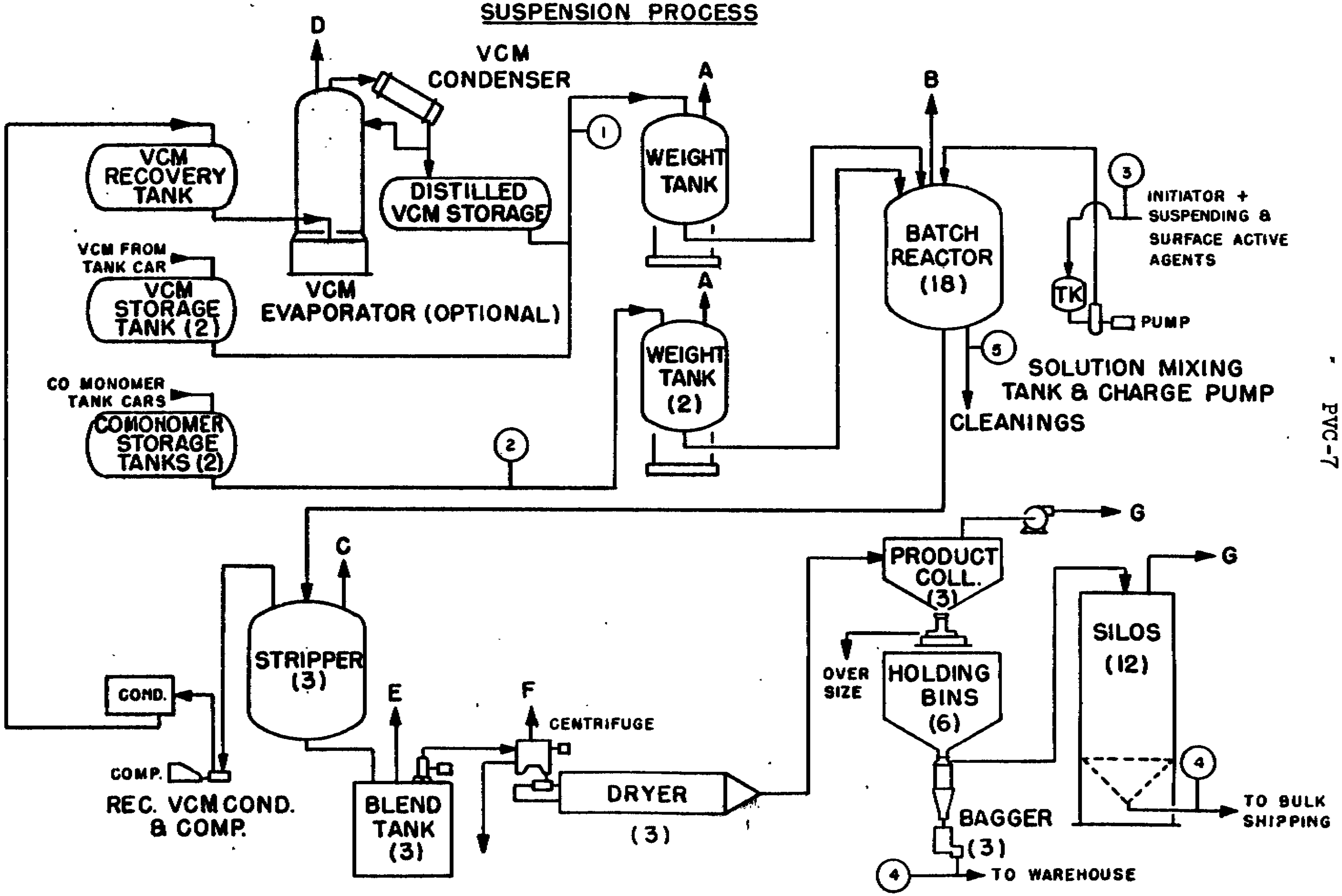
The precise mechanism of suspension polymerization is still being investigated and there is no accepted theory to explain all the observed phenomena. The general overall process involves the suspension of liquid vinyl chloride (requires pressures of 75 to 300 psig) in a continuous water phase. A free radical catalyst is used to initiate the polymerization reaction. This catalyst is dissolved in the VCM feed. Various suspending agents are used along with continuous agitation to keep VCM droplets small and dispersed. The polymerization occurs in the VCM droplets and proceeds to around 85-90% completion. Efforts are being made, with some success, to drive the reaction to near completion (95-99%) using different initiators. Reactor vessel sizes used in older plants were in the 3000-6000 gallons capacity range. The trend in the last three years has been to go to much larger reactors (15,000 to 35,000 gallons) and to switch from glass lined reactors to stainless steel vessels.

The heat of polymerization is removed from the reactor system to maintain the desired operating temperature (about 50°C).

After the polymerization reaction has been completed, the batch may be dropped to a stripper tank where the monomer is stripped from the slurry, although some plants strip in the reactor. The effectiveness of the stripping controls the amount of VCM subsequently lost in all equipment downstream of stripper.

After being stripped, the slurry is then transferred to a blend tank where it is mixed with other batches of slurry to produce a more uniform product. From the blend tank the slurry is passed through a centrifuge to remove as much water as possible and then into a rotary dryer, the discharge of which is classified and stored in silos. Some companies make only the raw PVC resin and sell to companies

FIGURE PV-1
POLYVINYL CHLORIDE PLANT
SUSPENSION PROCESS



PVC-7

that compound the resin, while others do some compounding themselves. Compounding consists of making modifications of the raw resin by the addition of plasticizers, anti-oxidants, ultraviolet stabilizers, colorants, heat stabilizers, etc.

B. Dispersion (Emulsion) Process

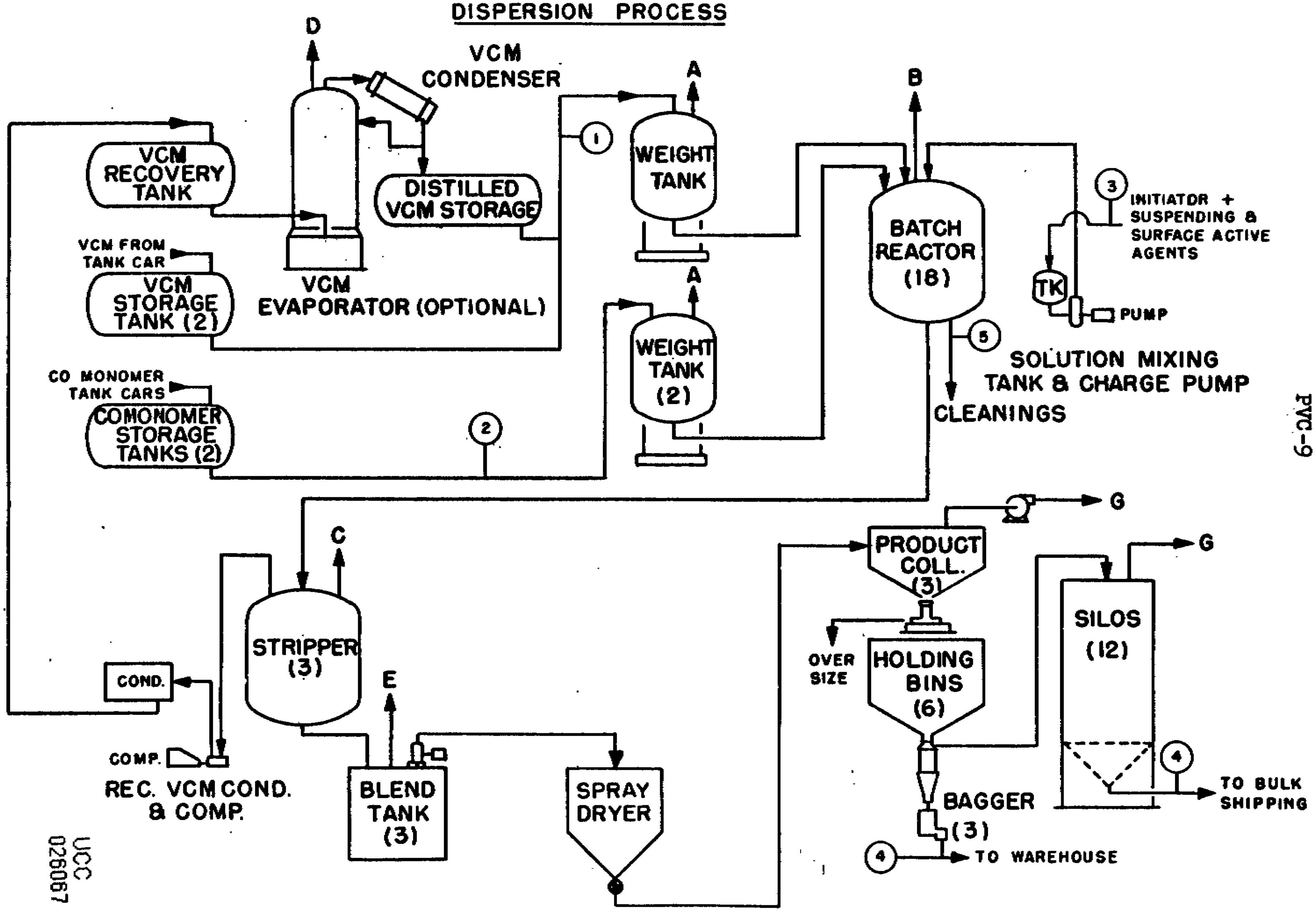
A simplified flow diagram for a typical dispersion polymerization plant is presented in Figure PV-2. This process is basically very similar to the suspension process in that the batch reactor processes liquid vinyl chloride dispersed in a water system. However, in this case the initiator is soluble in either water or VCM. Water soluble emulsifiers are used in high enough concentrations to form micelles which are agglomerates of 20 to 30 emulsified molecules. The initiator either starts a polym r unit from dissolved vinyl chloride or from vinyl chloride picked up by the micelles. In either case the polymer chain reaches its final stage as part of a micelle with the emulsifier molecules clinging to the outside. The particle sizes obtained by dispersion polymerization are much smaller than those obtained by suspension polymerization. For this reason the most commonly employed method for drying is spray drying which ensures maintaining small particle sizes. Approximately 13% of total installed plant capacity is devoted to emulsion process (dispersion) resins. (1)

C. Bulk Polymerization

The commercial method for the bulk polymerization of vinyl chloride is the Pechiney-St. Gobain two step process.[2] This process which currently produces about six (6) percent of United States production will probably increase considerably over the next few years if the economics are as favorable as reported by the licensers. Any significant increase percentage-wise of bulk production would be at the expense of suspension process as the resins from these two processes compete for some of the same markets.

A bulk process flow sheet is shown in Figure PV-3. Th process consists of making seed PVC from liquid VCM in an autoclave using very active initiators at 40° to 70° Centigrade (104° to 158°F) and at a pressure equivalent t the vapor pressure of VCM at the operating temperature (approximately 70 to 170 psi). Conversion is only 7 to 12%. The suspension of PVC in vinyl chloride liquid is then transferred to a larger autoclave (generally horizontal) along with more liquid VCM and more initiator. The agitator in this autoclave is much more rugged in construction as the polymerization reaction is carried out to 85 to 90%

FIGURE PV-2
POLYVINYL CHLORIDE PLANT
DISPERSION PROCESS



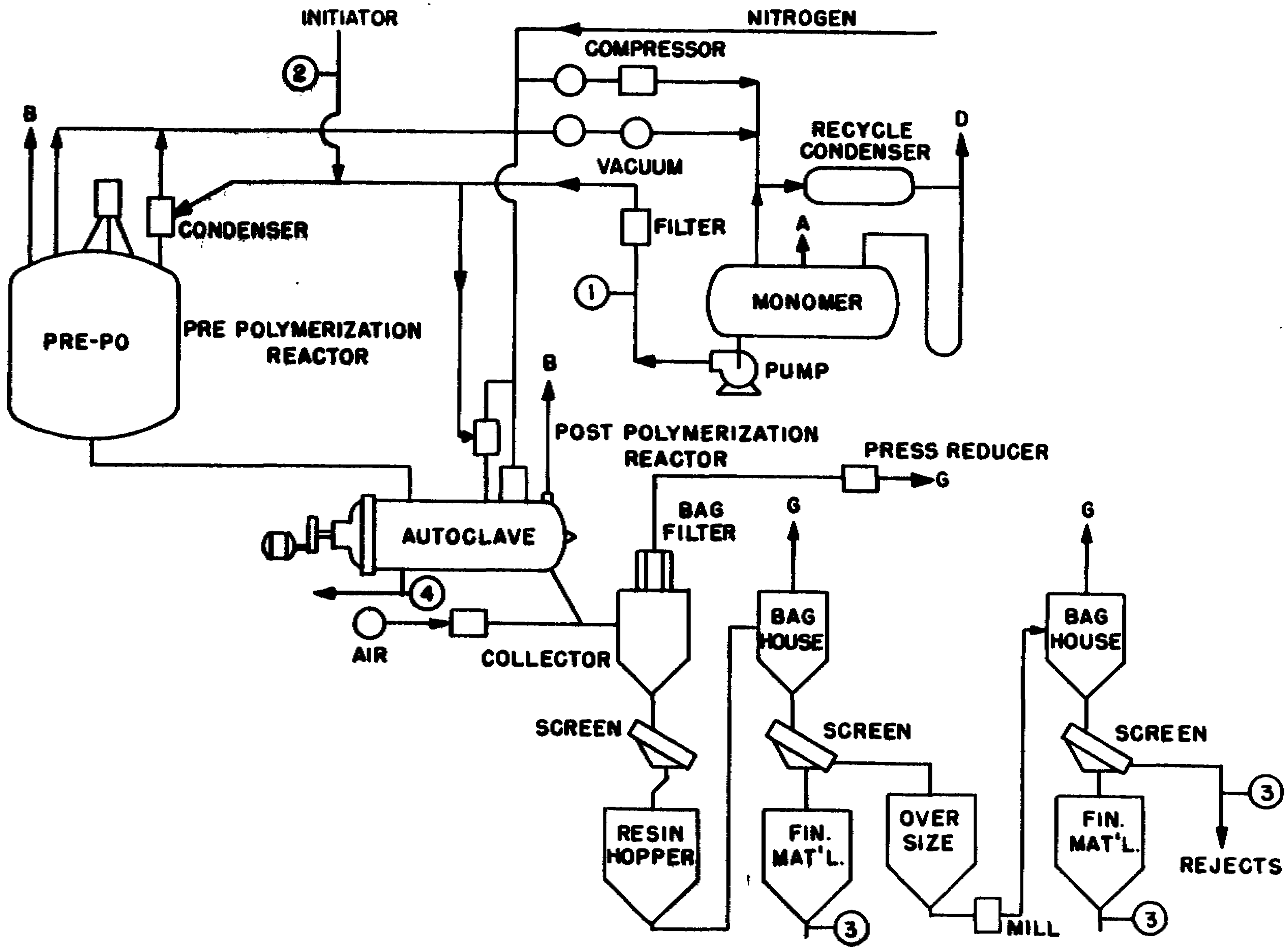
UCC
026067

PVC-9

FIGURE PV-3

FLOW SHEET FOR POLYVINYL CHLORIDE

BULK PROCESS



PVC-10

UCC
026068

EPA-450/3-73-006-i

ENGINEERING AND COST STUDY OF AIR POLLUTION CONTROL FOR THE PETROCHEMICAL INDUSTRY VOLUME 9: POLYVINYL CHLORIDE MANUFACTURE

by

R.G. Bellamy and W.A. Schwartz

Houdry Division
Air Products and Chemicals, Inc.
P. O. Box 427
Marcus Hook, Pennsylvania 19061

Contract No. 68-02-0255

EPA Project Officer: Leslie Evans

Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

July 1975

This report is issued by the Environmental Protection Agency to report technical data of interest to a limited number of readers. Copies are available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - as supplies permit - from the Air Pollution Technical Information Center, Environmental Protection Agency, Research Triangle Park, North Carolina 27711; or, for a fee, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

This report was furnished to the Environmental Protection Agency by Houdry Division of Air Products and Chemicals, Inc., Marcus Hook, Pennsylvania 19061, in fulfillment of Contract No. 68-02-0255. The contents of this report are reproduced herein as received from Houdry Division of Air Products and Chemicals, Inc. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of the Environmental Protection Agency. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

Publication No. EPA-450/3-73-006-i

completion. Temperature is controlled in both reactors by transferring heat to or from the jacket and by refluxing part of the vinyl chloride.

After the desired yield has been reached the remaining monomer is stripped by vacuum and returned to the monomer recovery system. As there is not water or water vapor involved, it is possible to use a low temperature condenser (-35°C) to recover most of the VCM. However, off-setting this particular advantage, is the fact that the autoclave reactor for the final polymerization must be cleaned after every run. The final classification, storage and shipping operations are similar to those employed in the preceeding two processes. It should be noted that since there is no water step there is no VCM carried off in water effluents.

D. Solvent Polymerization

Only one company manufactures PVC by the solvent process in this country. Most resins produced by this process are copolymers of PVC (75-90%) and polyvinyl acetate (10-25%). The basic process consists of a mixture of the solvent, most generally n-butane, and the comonomers, VCM and VAM, being charged continuously to an autoclave along with the appropriate amount of initiator (0.01 to 0.5%) at 40°C (104°F). Slurry is continuously drawn off and the PVC filtered from the slurry. The filter cake is dried by flash evaporation and the recovered monomers and solvent returned to the system. The PVC resin is remarkably pure as no emulsifier or suspending agents are required. The resin is used to make high clarity films for use where a water white product is desirable. The cost is higher than other processes and so is limited to those products that justify a higher cost.

There is a possibility that solvent polymerization could become more important because of a solvent process used in France employing 100% VCM and producing a resin of much higher syndiotacticity (stereo specificity) suitable for fiber manufacture. This is a low temperature process (-20°C or less).

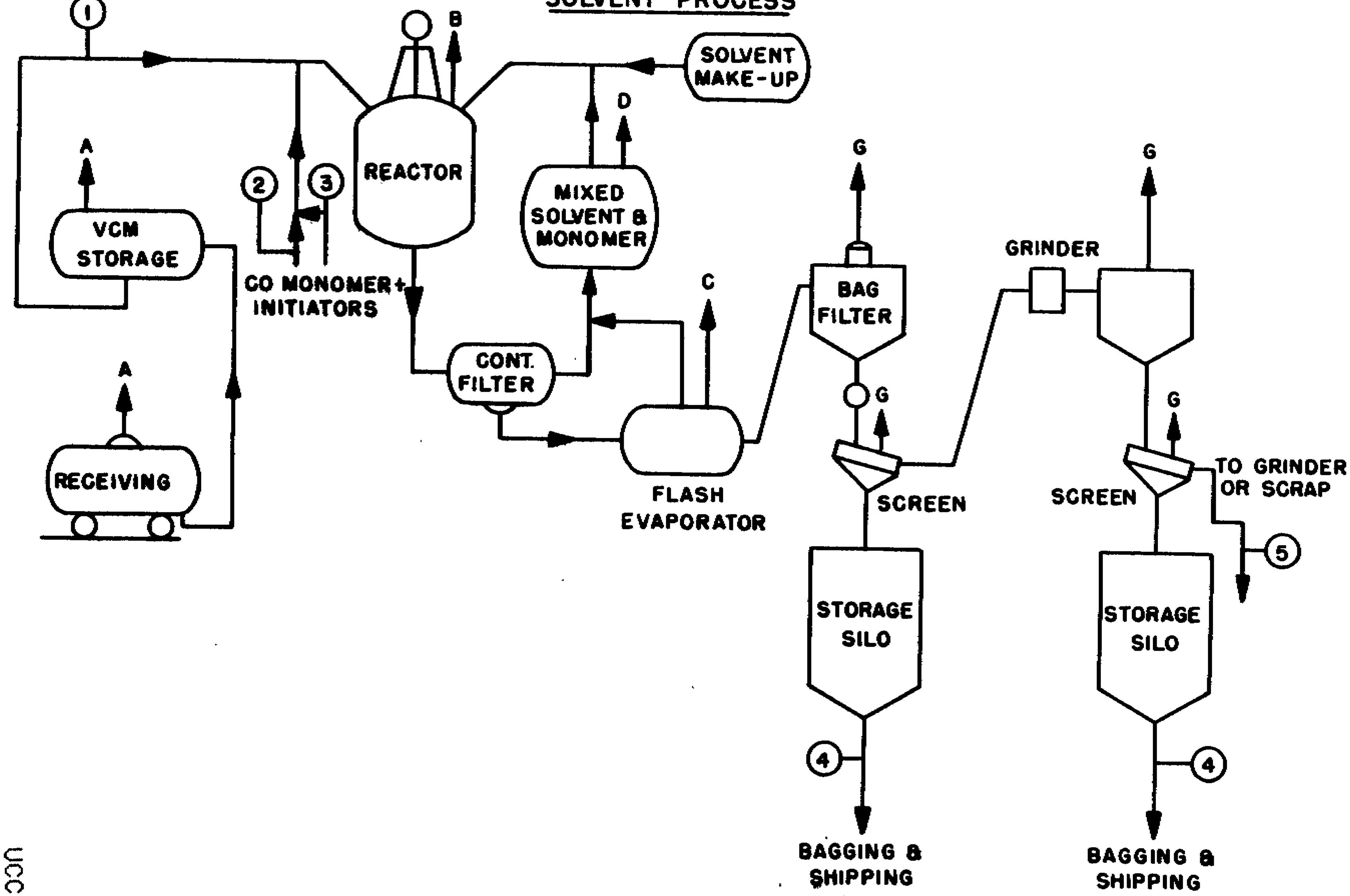
A flow sheet for a typical solvent polymerization plant is shown in Figure PV-4.

Tables PV-1 thru PV-4 present typical net material balances for the four major processes used to produce PVC. These material balances depict plants without major air emission

FIGURE PV-4

POLYVINYL CHLORIDE

SOLVENT PROCESS



PVC-12

UCC 026072

control devices and in general represent an average of data provided by the plants surveyed in May of 1974.

In many cases the survey data was incomplete and the reported flow quantities varied over a wide range. This plus the limited data from the few plants using the dispersion, bulk and solvent polymerization processes has made it difficult to produce firm material balances for these three particular processes.

Tables PV-1 thru PV-4 show that feedstock requirements and air emissions of VCM are lowest for the solvent polymerization process whereas the opposite appears to be true for the dispersion process.

It should be noted that the solvent process material balance is based on one set of data from only one plant and for this reason may not be truly representative of the process. However, since this is a continuous process it is conceivable that VCM emissions would be lower than for the other three batch type processes. (Continuous processes are easier to control from an emission standpoint as there is no hourly or daily opening up of reaction vessels so that emissions are from leaks primarily.)

The high feedstock requirements attributed to the dispersion process may help account for the reported 8-10¢/lb. higher selling price[5] for PVC produced by this process over that for the suspension process.

Table PV-5 presents a list of U.S. plants producing PVC. This table also shows published[1] capacity figures for these units.

TABLE PV-1
POLYVINYL CHLORIDE
NET MATERIAL BALANCE
FOR SUSPENSION PROCESS
(TONS/TON OF PVC CAPACITY)

32.2#/TON

INPUT	Stream I.D. on Simplified Flow Diagram	Polymer Ingredients	Other
Vinyl Chloride Monomer (VCM)	1	0.98-1.05	
Comonomer	2	0.01-0.08	
Initiators	3		0.0009
Suspending Agents	3		0.0010
Surface Active Agents	3		0.0003
Total Input		1.0598	0.0022
OUTPUT		**PVC**	**VCM**
PVC Homopolymer and Co-Polymer	4	1.0000	
Waste Solids and Liquids	5	0.0100	0.0020
Fugitive Emissions		0.0080(1)	0.0081(1)
Reactor Vent	B	0.0009	0.0014
Stripper or Slurry Tank Vent	C	0.0010	0.0032
Monomer Reclaim Vent Condenser	D		0.0048
Blend Tank	E	0.0027	0.0042
Centrifuge Vent	F	0.0006	0.0013
Effluent From Dryer Collectors	G	0.0037	0.0070
Fines From Silo Collectors	G		
Fines From Baggers Collectors	G		
Fines From Bulk Loading Collectors	G		
Monomer Storage	A		0.0005
Safety Valve Vents	B	0.0006	0.0020
Total Output		1.0275	0.0345

(1) Assumed split on total fugitive emissions.

23.4%
1.062
0.76%
1.52
3.24

UCC
026074

TABLE PV-2
POLYVINYL CHLORIDE
NET MATERIAL BALANCE
FOR DISPERSION PROCESS
(TONS/TON OF PVC CAPACITY)

INPUT	Stream I.D. on Simplified Flow Diagram	Polymer Ingredients	Other
Vinyl Chloride Monomer (VCM)	1	0.89-1.00	
Comonomer	2	0.01-0.12	
Initiators	3		0.0009
Suspending Agents	3		0.0020
Surface Active Agents	3		0.0003
Total Input		1.1039	0.0032
OUTPUT		**PVC**	**VCM**
PVC Homopolymer and Co-Polymer	4	1.0000	
Waste Solids and Liquids	5	0.0200	
Fugitive Emissions			0.0106
Reactor Vent (1)	B	0.0013	0.0015
Stripper or Slurry Tank Vent	C	0.0180	0.0123
Monomer Reclaim Vent Condenser	D		0.0050
Blend Tank	E	0.0020	0.0034
Effluent From Dryer Collectors	G	0.0053	0.0241
Fines From Silo Collectors	G		
Fines From Baggers Collectors	G		
Fines From Bulk Loading Collectors	G		
Monomer Storage	A		0.0005
Safety Valve Vents (1)	B	0.0009	0.0022
Total Output		1.0475	0.0596

(1) Assumed split based on data received for suspension pr cess.

TABLE PV-3
POLYVINYL CHLORIDE
NET MATERIAL BALANCE
FOR BULK POLYMERIZATION
(TONS/TON OF PVC CAPACITY)

INPUT	Stream I.D. on Simplified Flow Diagram	Polymer Ingredients	Other
Vinyl Chloride Monomer (VCM)	1	1.0372	
Initiators	2		0.0009
Total Input		1.0372	0.0009
OUTPUT		**PVC**	**VCM**
PVC Homopolymer	3	1.0000	
Waste Solids and Liquids	4	0.0050	
Fugitive Emissions(2)		0.0047	0.0047
Reactor Vent (1)	B		0.0008
Monomer Reclaim Vent Condenser	D		0.0150
Safety Valve Vents (1)	B		0.0010
Fines From Silo Collectors	G	0.0041	0.0023
Fines From Baggers Collectors	G		
Fines From Bulk Loading Collectors	G		
Monomer Storage	A		0.0005
Total Output		1.0138	0.0243

(1) Assumed split based on data received for suspension process.
(2) Assumed split to be 50% VCM and 50% PVC.

UCC
026076

TABLE PV-4
POLYVINYL CHLORIDE
NET MATERIAL BALANCE
FOR SOLVENT POLYMERIZATION
(TONS/TON OF PVC CAPACITY)

INPUT	Stream I.D. on Simplified Flow Diagram	Polymer Ingredients	Other
Vinyl Chloride Monomer (VCM)	1	0.93-1.00	
Comonomer	2	0.01-0.08	
Initiators	3		0.0009
Total Input		1.0169	0.0009
OUTPUT		**PVC**	**VCM**
PVC Homopolymer and Co-Polymer	4	1.0000	
Waste Solids and Liquids	5	(1)	0.0001
Fugitive Emissions		(1)	0.0003
Reactor Vent (3)	B		0.0050
Stripper or Slurry Tank Vent	C		0.0005
Monomer Reclaim Vent Condenser	D		0.0031
Effluent From Dryer Collectors	G	0.0044(2)	0.0083
Fines From Silo Collectors	G		
Fines From Baggers Collectors	G		
Fines From Bulk Loading Collectors	G		
Monomer Storage	A		0.0001
Safety Valve Vents (3)	B		0.0006
Total Output		1.0044	0.0134

(1) No information available.
(2) Assumed value.
(3) Assumed split based on data received for suspension process.

UCC
026077

TABLE PV-5

SUMMARY OF U.S. POLYVINYL CHLORIDE PLANTS (1)

Company	Location	Published Capacity, MM Lbs./Yr.
Air Products and Chemicals, Inc. (Plastics Division)	Calvert City, Ky. Pensacola, Florida	150 50
American Chemical Corp. (owned by Stauffer Chemical Company)	Long Beach, California	150
Borden Inc. Borden Chemical, Division	Illiopolis, Illinois Leominster, Mass.	140 180
Continental Oil Co. Conoco Plastics Division	Aberdeen, Miss. Oklahoma City, Okla.	285 240
Diamond Shamrock Corp. Diamond Shamrock Chemical Co., Subsidiary Plastics Division	Delaware City, Del. Deer Park, Texas	100 270
Ethyl Corporation Industrial Chemicals Div.	Baton Rouge, La.	180
The Firestone Tire & Rubber Co., Firestone Plastics Co. Division	Perryville, Maryland Pottstown, Pa.	230 270
The General Tire & Rubber Co., Chemical/ Plastics Division	Ashtabula, Ohio Point Pleasant, W. Va.	125 50
The B.F. Goodrich Co. B.F. Goodrich Chemical Co., Division	Long Beach, Calif. Henry, Illinois Louisville, Kentucky Avon Lake, Ohio Pedricktown, N.J.	140 140 340 140 170
The Goodyear Tire & Rubber Co., Chemical Division	Plaquemine, Louisiana Niagara Falls, N.Y.	100 100
Great American Chemical Corporation	Fitchburg, Mass.	40

TABLE PV-5

SUMMARY OF U.S. POLYVINYL CHLORIDE PLANTS(1)

(CONTINUED)

Company	Location	Published Capacity, MM Lbs./Year
Keysor-Century Corp.	Saugus, Calif.	35
Monsanto Company, Monsanto Polymers & Petrochemicals Company	Springfield, Mass.	70
National Starch & Chemical Corporation	Meredosia, Illinois	10
Occidental Petroleum Corp. Hooker Chemical Corp., Subsidiary Ruco Division	Burlington, N.J. Hicksville, N.Y.	180 15
Olin Corporation, Thompson Plastics Co. Div.	Assonet, Mass.	150
Pantasote Company	Passaic, N.J. Point Pleasant, W. Va.	60 90
Robintech	Painesville, Ohio	250
Stauffer Chemical Co. Plastics Division	Delaware City, Del.	175
Tenneco Chemicals, Inc. (A major component of Tenneco Inc.), Tenneco Plastics Division	Burlington, N.J. Flemington, N.J.	165 70
Union Carbide Corp. Chemicals & Plastics Div.	Texas City, Texas South Charleston, W. Va.	240 160
Uniroyal, Inc., Uniroyal Chemical Division	Painesville, Ohio	140
	TOTAL CAPACITY	5,400

IV. Commercial Products

PVC resins are compounded into a wider variety of products than most any other plastic. They range from emulsions and caulks to clear films and rigid structural shapes. PVC resins are used to make both flexible and rigid foams with a wide range of density. They have one big advantage over most foams as they are generally rated "self-extinguishing" in fire ratings while other foams need considerable "doctoring". The chemical inertness of PVC makes it an excellent material for pipe and exterior building forms and coatings (on steel and aluminum). It can be made flexible as leather or as rigid as glass. It can be made clear or most any color desired.

Compounded PVC resins are converted to end products by several processes. Extrusion is used to produce both rigid extrusions (e.g., pipe and conduit, siding and window sashes) and flexible extrusions (e.g., electrical wire insulation, garden hose, and packaging film).

Rigid vinyl sheets are generally produced on calendars which produce more than eight million pounds per year of film and sheet products.

Dispersions or plastisols are used for fabric coating (either on knife machines, roller coaters, or casting machines), and in the production of low-cost type of vinyl floor tile in which plastisol is cast on a felt base. Plastisols are also used in rotational molding (e.g., for toys and traffic cones) and in the dipping and hot-spraying of tool handles and appliance parts.

The use of compression molding for PVC resins is restricted to the production of phonograph records. Injection molding of rigid PVC has been developed largely in the 1960s and is mostly employed in the production of pipe fittings, and to a much smaller extent in the production of parts for communications equipment, business machines and toys.

A complex and still emerging technology in the processing of compounded PVC resins is the blow-molding of containers.

V. Plant Emissions

Table PV-6 shows individual plant capacity figures and emission data for most of the major U.S. plants producing PVC. Emissions from these plants are as follows:

A. Continuous Air Emission

1. VCM Recovery System Inerts Vent (Source Area D)

The VCM recovery system is where all the VCM vapors drawn off the stripper (and at times from the reactor) are compressed and condensed to recover most of the unreacted monomer for recycling to the polymerization reaction. This is a major emission stream for most plants, not because of total stream volume which is low, but because of high concentration of vinyl chloride. It results from the necessity to purge inerts from the monomer recovery system. Emissions can be reduced by condensing under pressure and low temperature cooling (10^{o} to $-30^{o}F$). It can be even more effectively reduced by using a vent scrubber or carbon adsorber. The reported vent streams in this category are shown as source area D in Figures PV-1 through PV-4 and Tables PV-1 through PV-6. Losses range from 0.0001 to 0.01 lbs. VCM/lb. product.

2. Dryer Stacks and Miscellaneous Solid Handling Vents (Source Area G)

The dryer vent is continuous but the amount of VCM emission varies widely from plant to plant. If the stripping of VCM at the strippers is done effectively then the emission at the dryer stack is less. However if the stripping is done poorly over 20% of the total emission can occur here. It is a difficult stream to control with add on devices because the volume of air (13,000 to 25,000 ACFM per 5,000-10,000 pounds per hour of dry PVC product) is large, the concentration of VCM low (less than 0.1%) and the air is at $150^{o}F$ with a high moisture content. These figures are typical for rotary dryers which are used in most suspension type plants. Losses range from 0.0005 to 0.006 lbs. VCM/lb. product.

Spray dryer exhaust gas flow is similar to that of a rotary dryer except the stream is generally larger, hotter and more nearly saturated with moisture. Spray dryers are generally used in dispersion plants although a few are also used in suspension plants.

After the PVC solids are dried, they are most often transported in the plant via pneumatic conveying systems. The air conveying streams are not laden with moisture and are at ambient temperatures but their volumes are very high and the VCM concentration much lower than in the dryer stream (0-15 PPM VCM).

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

Plant Code Number: A-1
Plant Capacity, Million Lbs./Yr.: 95
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
A	RR Car Unloading			.0003		14.25	
A	Barge Unloading			.0006		28.5	
A	Transfer Pumps, Valves, Etc.			.0007		33.25	
D&H	Reactor Vacuum System (1)	(3)		.0605		2873.75	
B	Reactor Ventilating System			.0008		38.0	
D	Recovery System	(3)		.0027		128.25	
E	Slurry Tanks			.0112		532.0	
G	Dust Collector			.0055	5×10^{-5}	261.25	2.37
G	Silos			.001	4.6×10^{-6}	47.5	0.22
	Total			.0833	5.46^{-5}	3956.75	2.59
	Loss To Water Systems (2)						
	Reactors			1.85×10^{-8}		8.79×10^{-4}	
	Strainers			1.85×10^{-8}		8.79×10^{-4}	
	Slurry Tanks			1.85×10^{-9}		8.79×10^{-5}	
	Centrifuges			1.5×10^{-5}		0.7125	
				1.5×10^{-5}		0.714	

PVC-22

Notes:
(1) Loss very high here. Have just installed improvements that should reduce VCM emissions by one-third. This would bring it down to about .04 lbs./lb. prod. which is still high. This also includes fugitive losses.
(2) Loss to water systems so low that they have insignificant impact on total VCM loss.
(3) Standard vacuum, compression and condensing system used to recover VCM for economic reasons.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-2
Plant Capacity, Million Lbs./Yr.: 58.4
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
A	RR Car Unloading			.0003		8.76	
A	Transfer Pumps, Valves, Etc.			.0009		26.28	
D	Reactor Vacuum System (1)	(2)		.026		759.2	
B	Reactor Ventilation System			.0013		37.96	
D	Recovery System	(2)		.0027		78.84	
E	Slurry Tanks			.0112		327.04	
G	Dust Collector			.0055	5×10^{-5}	160.6	1.46
G	Silos			.001	4.5×10^{-6}	29.2	0.13
	Total			.0489(2)	5.5×10^{-5}	1427.88	1.59
	Loss To Water Systems						
	Reactor			1.95×10^{-8}			
	Strainers			1.95×10^{-8}			
	Slurry Tank			1.95×10^{-8}			
	Centrifuge			1.53×10^{-5}			

Notes: (1) This is main point of VCM emission. They are looking for improvements to reduce the loss. Could also stand improvements in slurry tank vent losses. Fugitive emissions included here.
(2) Standard vacuum, compression and condensing system used to recover VCM for economic reasons.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-3
Plant Capacity, Million Lbs./Yr.: 175
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
B	Upset Losses Avg. on Cont. Basis			.0006	*	52.56	
D_1	Recovery System Condenser Vent (1)	(3)		.0075		657.0	
D_2	Recovery System Condenser Vent (1)	(3)		.0003		26.28	
E	Tank Vent			.0025		219.0	
G_1	Dryer Vent			.0035		306.6	
G_2	Silo Vents			.0002		17.52	
H	Fugitive			.0088 (4)		770.00	
	Total			.0234		2048.96	

* No PVC loss data are given.

Notes:
(1) Major emission control device is monomer recovery system (vacuum stripper) which was just installed in May 1974. It is not clear if above emission figure is before or after this device was installed. (Presumably "after")
(2) Considering installation of gas holder for collection of emissions at D_1 and possibly B and E followed by a scrubber system. G_1 and G_2 emissions would be reduced with improved vacuum system at D_1.
(3) Standard vacuum, compression and condensing system used to recover VCM for economic reasons.
(4) Assumed 50% VCM, 50% PVC.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-4
Plant Capacity, Million Lbs./Yr.: 120
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
G	Dust Collector			.00021 (1)	.00026	12.6	15.7
G	Dust Collector				.00006		3.7
G	Dust Collector				.00018		11.0
G	Dust Collector			.00032	.00017	19.3	10.2
G	Dust Collector			.00001	.00003	0.7	1.8
G	Dust Collector				.00008		5.1
G	Dust Collector				.00010		5.8
G	Dust Collector			.00038	.00048	23.4	29.6
G	Dust Collector				.00004		2.6
G	Dust Collector				.00005		2.9
G	Dust Collector			.00036	.00001	22.3	0.4
G	Dust Collector				.00004		2.6
G	Dust Collector			.00489	.00026	299.3	16.1
E	Blend Tank Vent			.00036		22.3	
E	Blend Tank Vent			.00033		20.2	
E	Blend Tank Vent			.00021		12.6	
C	Slurry Tank Vent (3)			.00489		299.3	
	Total			.01196 (2)	.00176	732.0	107.5

Notes: (1) All losses are computed from total throughput (120 M/year).
(2) No fugitive losses are estimated or even implied which could explain the low total emission.
(3) No VCM recovery system vent losses given, they could be included in this emission loss.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-5
Plant Capacity, Million Lbs./Yr.: 75
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
G	Exhaust From Dust Collector			.00400		150.0	
F	Centrifuge			.000003	.00009	-	3.4
-	VCM In Resin			.00090		33.8	
D	Vent Condenser	(1)		.00600		225.2	
E	Slurry Tank Vent			.00005		1.9	
B	Reactor Vent			.000003		-	
E	Blow Down Tank Vent			.0000008		-	
B	Reactor Cleaning				.00030		11.3
F	Slurry Filtration				.00006		2.3
	Total (2)			.010957	.000450	410.9	17.0

Notes: (1) Standard vacuum, compression and condensing system used to recover VCM for economic reasons.

(2) No fugitive losses given and report admits that losses given are only a part of total losses.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-6
Plant Capacity, Million Lbs./Yr.: 75
Pr cess: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC(1)	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC(1)
B	Reactor Safety Valves(3)			.0032		120.0	
B	Reactor Jets			.0003		11.25	
D	Stripper Jets			.0015		56.25	
D	Recovery Condenser Vent	(3)	VCD-1&2	.0015		56.25	
E	Blend Tank Vent			.0018	.0144	67.5	540.0
G	Dryer Vents			.0020		75.0	
D	Purification Condenser Vent			.0019		71.25	
B	Reactor Exhaust System			7.45×10^{-6}		0.28	0.
B	Reactor Purge System			.00015		5.63	
H	Fugitive(4)			.0091(2)	.0091	341.3	341.3
	Total			.02145	.0235	804.7	881.3

Notes: (1) Total PVC loss from material balance and known losses is .0308 lbs./lb. prod. or 1155 tons per year.

(2) Considerable improvement is envisioned here when they switch to much larger reactors. Their estimate is about a 40 to 50% total drop in VCM emissions.

(3) Extra cooling used to condense VCM vapors beyond normal system. This is an emission control device to control emissions as well as for economic reasons.

(4) Assumed 50% VCM, 50% PVC.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-7
Plant Capacity, Million Lbs./Yr.: 135
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
D	Recovery Condenser Vent	(4)	VCD-1&2	.0015(2)	(1)	101.25	(1)
E	Blend Tank Vent Blower			.0060	-	405.0	-
D	Reactor Jets			.0067	-	452.25	-
D	Stripper Jets			.0018	-	121.5	-
G	Dryer Discharge (3)			.0009	.0063	60.75	425.25
G	Silos			-	.00055	-	37.125
G	Bagging Machine			-	.00022	-	14.85
G	Bulk Loading			-	.00034	-	22.95
B	Safety Valves			.0040	-	270.0	-
H	Fugitive			.0089(5)	.0089	600.75	600.75
	Total			.0297	.01631	2011.5	1100.925

Notes: (1) Known losses plus fugitive losses from material balance indicate 0.0389 lbs./lb. PVC prod. or a total of 2626 tons of solid loss per year.

(2) Now equipment on order (delivery late 1974) to improve efficiency from 99.5% to 99.9%. This will reduce total VCM loss to .0003 at this point.

(3) Considerable improvement will result from installation of new type cyclones of 99.9% efficiency as compared to present 99.5%. Equipment is on site and will be installed shortly.

(4) In addition to standard vacuum, compression and condensing system a two-stage low temperature condensing system is used (40°F water and 0°F freon or glycol). This is an emission on control device as well as an economic device.

(5) Assumed 50% VCM, 50% PVC.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-8 (1)
Plant Capacity, Million Lbs./Yr.: 225
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
B	Safety Relief Devices			.0024	.0012	270.0	135.0
D	Reactor Evacuator			.0043		483.75	
E	Blending Tanks			.0054		607.5	
D	Recovery System Vent (3)		VCD-2	.0041		461.25	
G	Cyclones & Bag Filters			.0027	.0047	303.75	528.75
-	Solid & Liquid Wastes				.0141		1586.25
H	Fugitive (2)			.0134 (4)	.0134	1507.5	1507.5
	Total			.0323	.0334	3633.75	3757.5

Notes:
(1) All plants at location have a standard section covering control devices. Only parts of this section apply to each individual plant.
(2) The only indication that fugitive emissions are being reduced is in the standard section on control devices that says an organic vapor detection device is being used to locate VCM leaks. It is stated that it can detect VCM levels below odors detection but does not indicate how sensitive it is.
(3) Standard vacuum, compression and condensation system used to recover VCM for economic reasons.
(4) Assumed 50% VCM, 50% PVC.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-9
Plant Capacity, Million Lbs./Yr.: 175
Process: Suspension

Source Area	Description	Type Of Emission Control Device (1)	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
B	Safety Relief Devices			.0012	.0001	104.7	7.4
B	Reactor Evacuator			.0072		636.4	
E	Blending Tanks			.0048		420.5	
D	Recovery System Vent	(3)	VCD-2	.0003		30.2	
G	Cyclones & Bag Filters			.0071	.0015	626.8	131.4
H	Fugitive (2)			.0077 (4)	.0077	673.8	673.8
	Total			.0283	.0093	2492.4	812.6

PVC-30

Notes: (1) All plants at location have a standard section covering control devices. Only parts of this section apply to each individual plant.

(2) The only indication that fugitive emissions are being reduced is in the standard section on control devices that says an organic vapor detection device is being used to locate VCM leaks. It is stated that it can detect VCM levels below odors detection but does not indicate how sensitive it is.

(3) In addition to standard vacuum compression and condensing system, low temperature cond nsing is used which makes this an emissión control device as well as an economic one.

(4) Assumed 50% VCM, 50% PVC.

UCC
026090

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-10
Plant Capacity, Million Lbs./Yr.: 120
Process: Suspension

Source Area	Description	Type Of Emission Control Device(1)	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
B	Safety Relief Devices			.0016	.0009	98.6	55.2
B	Reactor Evacuators			.0067		412.2	
E	Blend Tank			.0053		325.9	
D	Recovery System Vent	(4)	VCD-3	.0087		535.2	
G	Cyclone & Bag Filters			.0002	.0013	12.3	79.7
-	Solid & Liquid Losses			.0053	.0053	325.4	325.4
H	Fugitive (2)			.0275 (3)(5)	.0275	1650.0	1650.0
	Total			.0553	.0350	3359.6	2110.3

PVC-31

Notes:
(1) All plants at location have a standard section covering control devices. Only parts of this section apply to each individual plant.
(2) The only indication that fugitive emissions are being reduced is in the standard section on control devices that says an organic vapor detection device is being used to locate VCM leaks. It is stated that it can detect VCM levels below odors detection but does not indicate how sensitive it is.
(3) High fugitive emission.
(4) Standard vacuum, compression and condensing system used to recover VCM for economic reasons.
(5) Assumed 50% VCM, 50% PVC.

UCC
026091

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-11
Plant Capacity, Million Lbs./Yr.: 80
Pr cess: Suspension

Source Area	Description	Type Of Emission Control Device(1)	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
B	Safety Devices			.0043	.0006	164.25	22.3
B	Reactor Evacuations			.0024		92.0	
E	Blend Tanks			.0012		45.6	
D	Recovery Condenser Vent	(3)		.0052		197.5	
G	Cyclones & Bag Filters			.0052	.0024	200.2	90.7
-	Solid & Liquid Losses			.0090	.0090	344.7	344.7
H	Fugitive (2)			.0061(4)	.0061	233.5	233.5
	Total			.0334	.0181	1277.8	691.2

PVC-32

Not s: (1) All plants at location have a standard section covering control devices. Only parts of this section apply to each individual plant.

(2) The only indication that fugitive emissions are being reduced is in the standard section on control devices that says an organic vapor detection device is being used to locate VCM leaks. It is stated that it can detect VCM levels below odors detection but does not indicate how sensitive it is.

(3) Standard vacuum, compression and condensing system used to recover VCM for economic reasons.

(4) Assumed 50% VCM, 50% PVC.

TABLE PV-6
NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE
(CONTINUED)

Plant Code Number: A-12
Plant Capacity, Million Lbs./Yr.: 113 (1)
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
B	Safety Relief Devices			.0004	.0002	23.6	11.8
B	Reactor Evacuators			.0022		124.8	
E	Blending Tanks			.0060		337.3	
D	Recovery Condenser Vent (3)		VCD-2	.0007		41.2	
G	Cyclone & Bag Filters			.0093	.0012	525.6	64.8
-	Solid & Liquid Losses			.0046	.0046	261.5	261.5
H	Fugitive (2)			.0052 (4)	.0052	294.1	294.1
	Total			.0284	.0112	1608.1	632.2

PVC-33

Notes:
(1) All plants at location have a standard section covering control devices. Only parts of this section apply to each individual plant.
(2) The only indication that fugitive emissions are being reduced is in the standard section on control devices that says an organic vapor detection device is being used to locate VCM leaks. It is stated that it can detect VCM levels below odors detection but does not indicate how sensitive it is.
(3) Standard vacuum, compression and condensation system used to recover VCM for economic reasons.
(4) Assumed 50% VCM, 50% PVC.

TABLE PV-6
NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE
(CONTINUED)

Plant Code Number: A-13(1)
Plant Capacity, Million Lbs./Yr.: 42
Pr cess: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions: Lbs./Lb. Prod. VCM	Emissions: Lbs./Lb. Prod. PVC	Emissions: Tons/Yr. VCM	Emissions: Tons/Yr. PVC
D	Recovery System Vent			.00203	*	42.9	
G	Bag Filters			.0002		4.2	
H	Fugitive			.0086(2)	.0086	181.7	181.7
	Total			.01083	.0086	228.8	181.7

* No data are given for PVC losses. Fugitive loss noted is assumed.

Notes: (1) No emission devices installed at this plant now but all being considered for future. No mention of type.
(2) Assumed 50% VCM, 50% PVC.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-14
Plant Capacity, Million Lbs./Yr.: 150
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC

NO SATISFACTORY DATA

UCC
026095

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Cod Number: A-15 (1)
Plant Capacity, Million Lbs./Yr.: 175
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
D	Recovery System Vent (2)			.001086	-	95.0	-
G	Primary Dust Collector			.00395	.000429	345.6	37.5
G	Primary Dust Collector			.00528	.000573	462.0	50.1
G	Secondary Dust Collector			.000049	.000429	4.3	37.5
G	Secondary Dust Collector			.000049	.000573	4.3	50.1
G	Silo Collectors			.000025	.00100	2.2	87.5
G	Bag Filters			-	.000213	-	18.6
G	Bag Filters			.000025	.000068	2.2	5.9
G	Bag Filters			-	.000213	-	18.6
G	Bag Filters			.000049	.000049	4.3	4.3
G	Bag Filters			-	.000053	-	4.6
G	Bag Filters			-	.000034	-	3.0
A	Transfer System			-	.000018	-	1.6
A	Transfer System			-	.000049	-	4.3
B	Vacuum Jet Steam			.000049	-	4.3	-
D	Recycle on VCM Recovery System			.002122	-	185.7	-
G	Conveying Losses			.003800	-	332.5	-
-	Transfer Losses			-	.000049	-	4.3
G	Emission from Hood Over Callender			.000035	-	3.1	-
-	Transfer Losses to Trucks & RR Cars			-	-	-	-
H	Building Emissions			.001135	-	99.3	-
H	Fugitive			.000667(3)	.000667	58.3	58.3
	Total			.018320	.004417	1603.1	386.2

PVC-36

Notes: (1) Data are complete and coverage of control devices excellent. Should discuss as exemplary report.

(2) Lower vacuum used than normal, no data are given for condensing conditions but the low emission indicates that some cooling or chilling is involved.

(3) Assumed 50% VCM, 50% PVC.

UCC 026096

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-16
Plant Capacity, Million Lbs./Yr.: 40
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
B	Reactor Vents			.0056	*	112.0	
C	Stripper Vents During Evacuation(2)			.0018		36.0	
C	Stripper Vent(1)			NA			
E	Slurry Storage Vent			NA			
D	Recovery System		VCD-3	.0008(1)		16.0	
G	Bag Filters			.0046		92.0	
H	Fugitive			.0070 (3)	.0070	140.0	140.0
	Total			.0198	.0070	396.0	140.0

* No data for PVC losses are given.

PVC-37

Notes:

(1) This VCM loss is low compared to most recovery system losses. May be due to use of scrubber system.

(2) Slurry tank (actually blend tank) is air evacuated continuously to keep concentration of VCM vapors low.

(3) Assumed 50% VCM, 50% PVC.

UCC 026097

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-17-1, A-17-2, A-17-3 (1)
Plant Capacity, Million Lbs./Yr.: 125
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
A	RR Car Unloading			.0002	*	12.5	
A	Storage Vent			.0001		6.75	
A	Charge Line Filter			.0002		12.5	
B	Reactor			.00474		296.25	
B	Reactor Vent & Fouling		VCD-9	.0042		262.5	
D	Recovery System, Seal Water			.0004		25.0	
D	Recovery System Tank Vent			.0001		6.75	
D	Recovery System Drain			.0001		6.75	
E	Blend Tank Vent & Drain			.0004		25.0	
F	Cyclones & Bag Filters			.00425		265.6	
D	Recovery System Vent (2)			.00066		41.25	
D	Recovery System Degassing (2)			.00544		340.0	
	Total (3)			.02079		1300.9	

* PVC data not determined for this composite tabulation.

Notes: (1) This is a composite tabulation of three (3) suspension systems at one plant.
(2) These recovery system losses were noted for only one of the suspension systems (A-17-2). The losses for that system (A-17-2) are inordinantly high while the losses for the other two systems (A-17-1 and A-17-3) are low. Normal vacuum, compression and condensation system used for economic reasons.
(3) No fugitive losses noted.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-18 (1)
Plant Capacity, Million Lbs./Yr.: 117
Process: Suspension

S urce Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
D&H	Monomer Recovery Vent & Fugitive (2)			.01407	-	823.1	-
G	Bag Filters (3)			.01134	.00100	663.4	58.5
B	Reactor Vent			.00250	.00353	146.3	206.5
E	Blend Tank Vent			.00350	.00087	204.8	50.9
C	Stripper			-	.00102	-	59.7
F	Centrifuge			-	.00048	-	28.1
-	Sampling			-	.00020	0	11.7
	Total			.03141	.00710	1837.6	415.4

Notes: (1) This is a composite tabulation of two (2) suspension systems at one plant.
(2) Fugitive emissions are included with monomer recovery system losses as the material balance for the whole process is made here.
(3) High loss here indicates high VCM content of slurry to centrifuge and dryer.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-19
Plant Capacity, Million Lbs./Yr.: 82
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
D&H	Monomer Recovery Vent & Fugitive(1)			.0190	-	779.0	-
G	Bag Filters			.0080	.0010	345.1	43.1
B	Reactor			.0025	.0055	107.8	237.2
E	Blend Tank			.0035	.0015	151.0	64.7
C	Stripper			-	.0008	-	34.5
F	Centrifuge			-	.0007	-	30.2
-	Sampling			-	.0002	-	8.2
	Total			.0330	.0097	1382.9	417.9

Notes: (1) Fugitive emissions are included with monomer recovery system losses as the material balance for the whole process is made here.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-20
Plant Capacity, Million Lbs./Yr.: 225
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
D	Monomer Recovery Vent			.00119	-	133.9	-
B	Reactor Vent			.00311	-	349.9	-
B	Reactor Effluent, Water Stream			.00032	.00319(3)	36.0	358.9(3)
E	Slurry Tank Vent (1)			.00681	.00010	766.1	11.3
G	Dryer Vent			.01317	.00037	1481.6	41.6
F	Centrifuge, Water Stream			.00149	.00081(3)	167.6	91.1(3)
G	Bag Filters (2)			-	.00037	-	41.6
G	Bag Filters			-	.00001	-	1.1
G	Bag Filters			-	.00001	-	1.1
H	Fugitive			.00541(4)	.00541	608.6	608.6
	Total			.03150	.01027	3543.7	1155.3

PVC-41

Not s: (1) Improved degassing system proposed which should help to reduce VCM loss, a slurry tank vent and also from dryer vent, in fact all downstream VCM emissions from the slurry tank.
(2) No VCM emissions are indicated for bag filters and so are probably reflected in fugitive emission.
(3) Not a potential air emission, therefore excluded from total.
(4) Assumed 50% VCM, 50% PVC.

UCC 026101

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-21
Plant Capacity, Million Lbs./Yr.: 115
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
A	RR Car Unloading			.0010	-	60.0	-
B	Reactor Vent		VCD-4&10	.0020 (2&3)	-	120.0	-
C	Stripper Vent (4)		VCD-4	.0040	.0010	235.6	60.0
D	Monomer Recovery		VCD-1,2&4	.0001	-	8.8	-
E	Slurry Vent		VCD-4	.0005	.0020	27.6	120.0
G	Dryer			.0030	.0035	180.0	210.0
F	Centrifuge			-	.0005	-	30.0
F	Sifter			-	.0040	-	240.0
	Total			.0106	.0110	632.0	660.0

Notes: (1) VCM emissions have been shown by areas and include fugitive losses.
(2) This plant has a gas holder for miscellaneous VCM vapors and contains them extremely well.
(3) They are going to a solvent cleaning system which will eliminate normal opening and closing (3-6 batches) of reactor to one or two per year.
(4) This loss is due to losses inherent in the evacuation system.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-22
Plant Capacity, Million Lbs./Yr.: 108.6
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
A	RR Car Unloading			.000080	-	4.34	-
H	Emission From Storage Building			.000066	-	3.58	-
A	Transfer Pump			.000722	-	39.21	-
B	Reactor Vent			.000200	-	10.86	-
B	Reactor Vacuum System			.012258	-	665.76	-
D	VCM Recovery Condenser			.001661	-	90.21	-
H	Polymerization Building Vents			.001252	-	68.00	-
H	Storage Tank Vent Building			.000099	-	5.38	-
H	Vent Fan			.000795	-	43.18	-
C	Reactor Safety Valve & Rupture Disc			.004302	-	233.65	-
D	Condenser Vent			.000675	-	36.66	-
H	Building Vent			.000784	-	42.58	-
G	Bag Filters			.000042	.000649	2.28	35.25
G	Bag Filters			.000042	.000157	2.28	8.53
G	Bag Filters			.000009	-	0.49	-
G	Apron Dryers			.001770	.000102	96.13	5.54
G	Apron Dryers			.000127	-	6.90	-
G	Bag Filters			.001610	-	87.44	-
E	Slurry Tank Vent (1)			.000907	-	49.26	-
G	Rotary Dryer			.001641	.000079	89.13	4.29
E	Slurry Tank (1)			.000062	-	3.37	-
F	Centrifuge			.000039	-	2.12	-
G	Bag House Dryer			.000579	.001282	31.45	69.63
G	Bag House			.000343	.000171	18.63	9.29
G	Bag House			.000090	.000039	4.89	2.12
G	Bag House			.000016	.000520	0.87	28.24
H	Fugitive			.005363 (2)	.005363	291.28	291.28
	Total			.035534	.008362	1929.93	454.17

Notes: (1) These so-called "slurry tanks" are actually blend tanks.
(2) Assumed 50% VCM, 50% PVC.

PVC-43

UCC 026103

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-23
Plant Capacity, Million Lbs./Yr.: 235
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
A	VCM Receiver, Fresh			.00003	*	3.9	*
D	VCM Receiver, Recovered (1)			.00005		5.7	
D	VCM Receiver, Mixed			.00005		6.1	
A	VCM Receiver, Fresh			.00015		17.1	
D	VCM Receiver, Recovered (1)			.00007		8.8	
D	VCM Receiver, Mixed			.00030		35.9	
A	Strainer			.00020		23.7	
E	Blend Tank			.00044		52.6	
E	Blend Tank			.00388		459.9	
G	Bag Filters			.01399(2)		1659.6(2)	
G	Resin Silos			.00002		2.7	
G	Resin Silos			.00001		1.3	
G	Resin Silos			.00001		0.9	
G	Exhaust From Compounding Lines			.000015		1.8	
H	Fugitive			.01012(4)		1200.7	
	Total			.02936		3480.7	

No data are given for PVC losses.

Notes:
(1) New refrigerated condenser system to be installed this year will reduce these losses about 85%.
(2) Ineffective stripping of VCM from latex causes high VCM emission here. Also makes fugitive losses greater.
(3) Emission control procedure section identical for both plants A-23 and A-24.
(4) Assumed 50% VCM, 50% PVC.

PVC-44

UCC 026104

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-24
Plant Capacity, Million Lbs./Yr.: 220
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
D	Recovery System Vents			.000005	*	0.4	*
B	Reactor Dump Screen			.001022		113.9	
C	Slurry Tank Vent (3)			.002492		275.9	
B	Reactor Cleaning Exhauster (1)			.002250		245.3	
G	Dryer Exhaust (1)			.005388		595.7	
G	Silos			.000103		11.4	
H	Fugitive			.006255(4)		688.5	
	Total			.017515		1931.1	

* No data are given for PVC losses.

Notes:
(1) Less losses here than sister plant (A-23) perhaps due to higher temperature used to eliminate VCM from latex.
(2) Emission control procedure section identical for A-23 and A-24.
(3) Continuous exhauster on both slurry and blend tanks to prevent VCM buildup in vapor space.
(4) Assumed 50% VCM, 50% PVC.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-25
Plant Capacity, Million Lbs./Yr.: 120
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
B	Reactor Fouling			.000015	.002657	0.9	159.4
B	Course Material & Lost Batches			.000022	.004015	1.3	240.9
D	VCM Recovery Vent (1)			.013432	-	805.9	-
B	Spillage			.000003	.000650	0.2	39.0
H	Process Leaks			.000650	-	39.0	-
E	Slurry Tank Vent			.000204	-	12.3	-
F	Centrifuge			.000058	.000752	3.5	45.1
G	Dryer Spillage			.000029	.026025	1.8	1561.5
G	Dryer Exhaust			.003351	.000767	201.0	46.0
G	RR Car Spillage			.000001	.002227	0.1	133.6
	Total			.017765	.037093	1066.0	2225.5

Notes: (1) The loss at this point is 75% of total loss noted.

PVC-46

UCC
026106

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-26
Plant Capacity, Million Lbs./Yr.: 175
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM*	Emissions Lbs./Lb. Prod. PVC*	Emissions Tons/Yr. VCM*	Emissions Tons/Yr. PVC*
B	Reactor Vents			.0012	-	105.1	-
D	VCM Recovery System (1)			.0013	-	113.9	-
C	Stripper Vents (2)			.0048	-	420.5	-
E	Slurry Vent			.0042	-	367.9	-
G	Dryer			.0058	.0011	508.1	96.4
G	Product Transfer			.0025	.0001	219.0	8.8
H	Reactor Room Vents, Fugitive			.0017	-	148.9	-
H	Misc. Fugitive (Matl. Balance)			.0042	-	367.2	-
	Total			.0257	.0012	2250.6	105.2

*Emissions to air only.

Notes: (1) We have no information regarding system used but as emission is very low, system must be considered excellent.
(2) Exhauster reducing VCM vapor accumulation in vapor space.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-27
Plant Capacity, Million Lbs./Yr.: 220
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM*	PVC*	Tons/Yr. VCM*	PVC*
B	Reactor Vents			.00119	-	131.9	-
D	VCM Recovery System (1)			.00150	-	166.2	-
C	Stripper Vents (2)			.00154	-	170.7	-
E	Slurry Vents			.00561	-	621.7	-
G	Dryer			.00711	.00115	787.9	127.4
G	Product Transfer			.00158	.00012	175.9	13.3
H	Reactor Room Vents, Fugitive			.00170	-	188.4	-
H	Misc. Fugitive (Material Balance)			.00520	-	587.3	-
	Total			.02553	.00127	2830.0	140.7

* Emissions to air only.

Notes: (1) We have no information on system used but as the emission is very low, system must be considered excellent.
(2) Exhauster reducing VCM vapor accumulation in vapor space.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: A-28
Plant Capacity, Million Lbs./Yr.: 23
Process: Suspension

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
B	Reactor Vents			.0017	*	19.5	
C	Stripper Clean Out (2)			.0016		18.4	
C	Stripper Operation (3)			.0199		228.8	
G	Bag Filters			.0030		34.5	
H	Fugitive			.0105		120.7	
	Total			.0367(1)		421.9	

* No loss data for PVC are given.

Notes: (1) Overall loss is high due mainly to high loss from stripping operation and fugitive losses. From brief description of process it appears that vacuum and condensing equipment is minimal.
(2) Evacuation to keep VCM vapor concentration low.
(3) Includes VCM recovery system.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: B-1
Plant Capacity, Million Lbs./Yr.: 40
Process: Dispersion

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
B	Operating Upset(1)			.00300	--	57.8	--
B	Reactor Vent			.00060	--	12.0	--
D	Recovery System Vent (4)		VCD-2	.00469	--	93.7	--
B	Filter Cleaning			.00020	--	4.0	--
E	Blend Tank Vents			.00500	--	99.9	--
G	Dryer Filter Cleaning			.00005	.00320	1.0	65.7
G	Dryer Vent(2)			.01774	.00 020(2)	354.8	4.4
H	Fugitive Losses(3)			.01000	--	199.7	--
	To Sewer			--	.10000	--	2001.7
	To Landfill			--	.05290	--	1055.6
	To Landfill			--	.10000	--	2001.7
	TOTAL			.04128	.25612	822.9	5129.1

Notes:
(1) These losses seem unusually high.
(2) These losses are very high and indicate a poor stripping system or lack of heat in final VCM removal cycle.
(3) Fugitive losses somewhat high.
(4) Along with normal vacuum and compression system, a low temperature Brine cooling system is used to keep emission at this point low.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: B-2
Plant Capacity, Million Lbs./Yr.: 7.7
Process: Dispersion

Source Area	Description (1)	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
B	Reactor Blowdown			.00205	*	7.9	--
B	Reactor Evacuation			.00068	--	2.6	--
E	Hold Tank Displacement			.00011	--	0.4	--
	TOTAL (2)			.00284		10.9	

* No data on product loss are given.

Notes: (1) Material balance closed without any report of fugitive emissions.
(2) Total emissions extremely low but all products are sold as liquid latices so no drying is involved which may account for such low emissions.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: B-3
Plant Capacity, Million Lbs./Yr.: 27
Process: Dispersion

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
B	Reactor Vent			.0056(1)	*	75.6	
C	Stripper Vent			.0018		24.3	
E	Slurry Storage Vent (4)			.0015		20.3	
D	Recovery System Vent		VCD-3	.0008		10.8	
G	Bag Filters			.0350(2)		472.5	
H	Fugitive			.0116(3)		156.6	
	TOTAL			.0563		760.1	

No data are given for PVC losses.

Notes: (1) This figure does not agree with #/Hr figures even allowing for hours in operation.
(2) Loss of VCM through bag filters is extremely high, indicating poor stripping of VCM in stripper.
(3) Fugitive emission somewhat high and no mention is made of how calculated.
(4) Continuous air evacuation from blend tank (here called slurry tank) to keep VCM vapor concentration from building up.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: B-4
Plant Capacity, Million Lbs./Yr.: 40 (1)
Process: Dispersion

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
D&H	Recovery System and Fugitive			.0246 (2)	--	492.0	--
B	Reactor Vent			.0025	.0050	50.0	100.0
C	Slurry Tank Vent (3)			.0002	.0195	4.0	390.0
G	Bag Filter From Dryer			.0094	.0018	188.0	36.0
G	Micropulverizer			--	.0050	--	100.0
G	Bag Filters-Silos-Shipping			--	.0018	--	36.0
	Sampling			--	.0026	--	52.0
	TOTAL			.0367	.0357	734.0	714.0

Notes: (1) Based on 350 Day/Yr.
(2) Based on a material balance. While heat and vacuum are used in this recovery system the loss is very high, perhaps refrigerated cooling would help.
(3) Change over losses only.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: B-5
Plant Capacity, Million Lbs./Yr.: 11
Process: Dispersion

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
A	Tank Car Unloading			.0003	--	1.4	--
A	VCM Storage Vent			.0001	--	0.7	--
A	Charge Filter			.0003	--	1.4	--
B	Reactor Vent and Waste			.0060	.0129	32.9	69.5
D	Seal Water			.0005	--	2.8	--
B	Accumulated Vapor			.0001	--	0.7	--
C	Latex Transfer Screen(4)			.0574	.0753	315.7	414.0
E	Blow and Blend Tanks			.0039	.0001	21.8	0.7
E	Blend Tank Heel			--	.0026	--	14.0
G	Bag House			.0536	.0008	294.7	5.6
B	Degassing Jet			.0395	--	217.5	--
	Misc. Spillage, Waste, Etc.			--	.0222	--	122.0
	TOTAL			.1610(1)	.1137(2)	889.6	625.8

Notes:
(1) This is an abnormally high VCM loss.
(2) Very high PVC loss.
(3) Combining the two losses indicates that about one-quarter (25%+) of the initially charged VCM is loss to atmosphere and solid waste. Although this is a small plant it is hard to believe such high losses.
(4) Evidently there is no VCM recovery system used.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: B-6
Plant Capacity, Million Lbs./Yr.: 3.5
Process: Dispersion

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
A	Tank Car Unloading			.0003	--	0.5	--
A	VCM Storage			.0001	--	0.3	--
A	Charge Filter			.0003	--	0.5	--
B	Reactor			.0066	.0238	11.4	41.2
D	Seal Water			.0007	--	1.2	--
C	Latex Screen and Blow Tank			.0914	.0001	158.7	0.3
E	Blend Tank			.0042	.0885	7.3	153.5
G	Bag House			.0871	.0011	151.1	2.0
B	Reactor Degassing Jet			.0716	--	124.3	--
	Solid and Liquid Wastes			--	.0287	--	49.8
	TOTAL			.2623	.1422	455.3	246.8

Notes: This plant is the same as B-5 only this operation is a co-polymer dispersion rather than a homo-polymer dispersion. Losses are abnormally high even for a small operation. The emission figures indicate that close to one million pounds of VCM is loss to the air to produce three and a half million pounds of PVC.

Same notes apply as B-5

PVC-55

UCC 026115

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: B-7
Plant Capacity, Million Lbs./Yr.: 24
Process: Dispersion (1)

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
A	Storage Tank Vent			.0007	*	8.8	
D	Scrubber Vent		VCD-3	.0021		26.3	
H	Fugitive			.0009		10.8	
C	Flash Pot Vents (2)			.0112		134.9	
G	Dryer Exhaust			.0008		10.1	
	Total			.0157		190.9	

* No product losses reported.

Notes: (1) This is a unique product and can be considered a dispersion process.
(2) Atmospheric vent to stack.

PVC-56

UCC
026116

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: B-8
Plant Capacity, Million Lbs./Yr.: 26
Process: Dispersion

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
B	Reactor Vent			.0074	*	96.2	
C	Stripper Clean Out (4)			.0035		45.5	
C	Stripper Operation (5)			.1061 (1)		1379.3	
E	Slurry Vent			.0024		31.2	
D	Recovery System			.0008		10.4	
G	Bag Filters			.0313 (2)		406.9	
H	Fugitive			.0127		165.1	
	Total			.1642 (3)		2134.6	

* No data for PVC losses are given.

Notes:
(1) Very high VCM loss (see E-2).
(2) Higher loss than most plants.
(3) Hard to believe that 1/6th of total vinyl chloride is emission to atmosphere.
(4) Evacuation to keep VCM vapor concentration low.
(5) No VCM recovery, just vacuum jet steam evacuation.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: B-9
Plant Capacity, Million Lbs./Yr.: 15
Process: Dispersion

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
H	Fugitive (1)			.0436	*	327.1	
	Total			.0436		327.1	

* No solid PVC waste data are given.

PVC-58

Notes: (1) All emissions are considered fugitive. Indicated figure (0.0436) obtained from ov rall material balance (4.1% VCM emission: 4.1/94.0 = .0436 lbs. VCM emission per pound of product produced). Only latices made, no drying systems involved.

UCC 026118

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: B-10 (1)
Plant Capacity, Million Lbs./Yr.: 15
Process: Dispersion

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod.(2) VCM*	Emissions Lbs./Lb. Prod.(2) PVC*	Emissions Tons/Yr. VCM*	Emissions Tons/Yr. PVC*
C	Stripper Vents			.02314	(3)	173.6	(3)
G	Plastic System Vent			.00030		2.2	
B	Reactor Room Vents			.00220		16.5	
H	Misc. Fugitive (Material Balance)			.00220		16.5	
	Total			.02784		208.7	

* Air emissions only.

Notes:
(1) This unit makes latices only.
(2) Product averages 83% PVC, figures based on total pounds of product.
(3) No PVC losses to atmosphere.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: C-1
Plant Capacity, Million Lbs./Yr.: 32
Process: Bulk

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
B	Safety & Relief Valves(1)			-	-	-	-
B	Reactor Vents			.002784	-	45.1	-
D	Recovery System Vent (2)			.007865	-	127.5	-
G	Bag Filters			.002000	.002784	32.4	45.1
H	Scrap & Waste			.000716	.006446	11.6	103.6
H	Fugitive			.003973(3)	.003973	64.4	64.4
	Total			.017338	.013203	281.0	213.1

PVC-60

Notes: (1) No values given, assumed to be negligible.
(2) Emission high considering they used refrigerated cooling for the vent condenser. However, no conditions are given.
(3) Assumed 50% VCM, 50% PVC.

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: C-2
Plant Capacity, Million Lbs./Yr.: 105
Process: Bulk

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
D	Recovery System Pump Vent[1]			.01502	-	788.4	-
D	Recovery System Tank Vent			.00184	-	96.4	-
D	Recovery System Pump Seal Water			.00029	-	15.3	-
G	Bag Filters			.00018	-	9.6	-
B	Reactor Vents			.00104	-	54.8	-
-	Reactor Cleanings			-	.01168	-	613.2
-	Spillage & Scrap			-	.00083	-	43.8
H	Fugitive			.00823[2]	.00823	431.9	431.9
	Total			.02660	.02074	1396.4	1088.9

PVC-61

Notes (1) Recovery system has high emission losses. Improvement in condensing and degassing system might help and is proposed for near future.
(2) Assumed 50% VCM, 50% PVC.

UCC
026121

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: C-3
Plant Capacity, Million Lbs./Yr.: 168
Pr cess: Bulk

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
D	Recovery System Vent		VCD-2	.001564		131.4	
A	Storage Vent			.000068		5.7	
D	Recovery System - Caustic Scrubber			.000052		4.4	
A	Transfer Filter			.000016		1.3	
B	First Stage Reactor Vent			.000008		0.7	
D	Transfer Filter			.000026	.000104	2.2	8.8
B	Vacuum System on Reactors			.001669		140.2	
G	Bag Filters Before Screening			.001251	.002034	105.1	170.8
G	Bag Filters to Silos			.000991		83.2	
G	Bag Filters to Screen			.000417	.001043	35.0	87.6
G	Powder Blender			.001043	.000417	87.6	35.0
G	Silos			.000010	.000209	0.9	17.5
G	Bagging Hopper			.000005	.000502	0.4	43.8
G	RR Car Loading			.000005	.000104	0.4	8.8
H	Fugitive			.002529 (2)	.002529	212.4	212.4
B	Emergency Venting			.000443		37.2	
	Total			.010097	.006942	848.1	584.7

PVC-62

Not s: (1) This plant seems to be an exemplary one with excellent emission controls.
(2) Assumed 50% VCM, 50% PVC.

UCC
026122

TABLE PV-6

NATIONAL EMISSIONS INVENTORY FOR PVC MANUFACTURE

(CONTINUED)

Plant Code Number: D-1
Plant Capacity, Million Lbs./Yr.: 24
Process: Solvent

Source Area	Description	Type Of Emission Control Device	Control Device Catalog I.D. No.	Emissions Lbs./Lb. Prod. VCM	Emissions Lbs./Lb. Prod. PVC	Emissions Tons/Yr. VCM	Emissions Tons/Yr. PVC
A	Solution Storage			.000001	NO PVC LOSSES REPORTED		
D	VCM Vent Scrubber		VCD-3	.000074		0.9	
F	Centrifuge			.000014		0.2	
A	Solid Feed Tank			.000028		0.3	
B	Precipitation Tank			.001130		13.6	
C	Slurry Tank (2)			.000282		3.4	
C	Slurry Tank			.000212		2.5	
G	Drying Stages			.006532		78.4	
G	Drying Stages			-		-	
G	Drying Stages			.001765		21.2	
-	Vacuum Transfer			-		-	
G	Bin Storage			-		-	
D	Crude Solvent Storage			.001388		16.7	
D	Crude Solvent Storage			.000245		2.9	
D	Crude Solvent Storage			.000011		0.1	
D	Extractor			-		-	
D	-			-		-	
D	Extract Storage			-		-	
D	Vinyl Acetate Still			.000706		8.5	
D	Vinyl Acetate Storage			.000035		0.4	
D	Solvent Still			.000060		0.7	
D	Solvent Storage			-		-	
D	Aldehyde Column			.000056		0.7	
D	Non-Solvent Still			-		-	
D	Non-Solvent Storage			-		-	
H	Fugitive			.000247		3.0	
	Total			.012786		153.5	

Notes: (1) Low emissions but there is no other solvent process to compare with it to indicate if this is normal for this type process.
(2) Atmospheric v nts to keep tanks at atmospheric pressure.

Particulate PVC emissions ar also associated with these vent streams. However, with cyclones and bag filters the particulate emissions are relatively small in amount (approximately 0.004 lbs./lb. of product).

3. Centrifuge Vent (Source Area F)

In many cases there is a centrifuge vent associated with the suspension process. The magnitude of the VCM emission in this vent depends on the efficiency of upstream stripping. Reported values range between 0.00001 and 0.004 lbs. of VCM/lb. of PVC product.

4. Blend Tank (Source Area E)

The blend tank emissions vary widely from plant to plant and depend markedly on the efficiency of the stripping operation. The volume is very low and it can be tied into the stripping system in order to eliminate any direct emission to the outside air.

Blend tank emissions are only associated with the suspension and dispersion type processes and in these plants the reported VCM losses vary between 0.0001 and 0.007 lbs./lb. of PVC product.

B. Intermittent Air Emissions

1. Unloading and Charging Facilities (Source Area A)

There is a certain amount of VCM emission at virtually all unloading facilities. Most plants unload under pressure and most vapors are kept enclosed, but there is always some emission plus losses at pumps, valves, meters, etc. The same is true for weigh tanks, meters and pumps used to charge reactors. None of these emissions are controlled other than using good practices consistent with handling of a toxic liquified gas. Reported VCM losses from these sources range from 0.0004 - 0.001 lbs./lb. of PVC product.

2. Reactors (Source Area B)

There are several possible emission streams from the reactors. During operation, if a run-away reaction occurs, it is generally stopped by releasing the pressure and venting to stacks (one company uses a gas holder). This vent contains a high concentration of VCM but only lasts for 5 to 15 minutes and occurs infrequently. Several companies are working on (may have it worked out by now) a "short stopping reaction" that would mak "blow down" unnecessary.

A more frequent reactor emission occurs when the vessel is purged and during cleaning. Normally after the polymerization reaction is completed and the batch is removed, VCM vapors are pulled from the reactors by a vacuum system and a new charge is added. However, the reactors must be cleaned periodically (every two to six batches). This means each reactor is opened every one to three days for about three hours for cleaning. This causes emissions which are normally kept down by pulling a vacuum on the reactor and compressing and condensing the removed vapors. During the actual cleaning operation, a substantial air stream is blown through the vessel to help protect the worker(s) in the reactor from VCM exposure. The amount of VCM in the vented air stream is very low (5 to 50 ppm) and would present the same problems of emission control as do the dryer and conveying air systems. New improved methods of cleaning reactors such as water jet or solvent cleaning systems greatly reduce these emissions or a water purge can be used to push the VCM remaining after the reaction is over to the recovery system.

Total reported VCM emissions from the reactors normally varies between 0.001-0.01 lbs./lb. of PVC product, with the lowest values (0.001-0.003 lbs./lb. associated with the bulk and solvent polymerization processes. If no equipment is provided to recover VCM from the reactor vent the VCM emissions can be as high as 0.04-0.08 lbs./lb. of PVC product.

3. Safety Valves (Included in Source Area B)

Occasionally a run-away condition in the reactor can cause the relief valves to open resulting in VCM emissions. Most of the surveyed plants did not report emissions from this source. However, the few plants that did report these losses showed VCM emission figures of 0.0004-0.004 lbs./lb. of PVC product. Since these emissions are for a short period on a very infrequent basis they represent a rather large instantaneous rate.

4. Strippers (Source Area G)

The emissions from a stripper are generally completely contained in the overall vacuum, compression, condensation cycle of the VCM recovery system and present no particular problem. However in some plants the stripper is opened to the atmosphere following the vacuum step in order to repressure the vessel and dump the batch to the blend tank. This can result in some VCM emission. In plants employing a monomer recovery system the reported VCM emissions associated with the stripping operation vary between zero and 0.005 lbs./lb. of PVC. If no recovery system is used these losses can be as high as 0.1 lbs./lb. of PVC. All but one of the few plants that do not have monomer recovery systems are small capacity units (3-11 million PPY PVC).

C. Fugitive Emissions

It has been assumed that "Fugitive Emissions" cover all air emissions that are not diverted to a simple vent or stack from the equipment itself. They are caused by leaks at pumps, flanges, filters, strainers, seals, etc., and can be reduced greatly by "good housekeeping". It would be possible to eliminate pump packing or seal leakage by the use of "canned pumps" at some expense in old plants but with less expense in new units. The principal problem with "fugitive emissions" is to keep them low at all times. These emissions can be reasonably under control one minute and suddenly increase greatly. Only good maintenance, with the accent on preventive maintenance, can keep fugitive emissions at a reasonable low level.

Table PV-7 lists all the reported fugitive VCM emissions for the various PVC plants. The only truly meaningful "fugitive emission" is one that is arrived at from a material balance after accounting for all known emissions and discharges. It is difficult to be certain that all wastes (solid, liquid and dissolved) have been included in the overall material balance. If some of these losses are omitted, the reported fugitive air emissions are high. It is also difficult to determine the exact composition of these air emissions. In most of the survey reports these losses are shown as VCM. Based upon the "snow field" appearance around the plants undoubtedly some of these emissions are particulate PVC. For this study an arbitrary assumption has been made that material balance losses are 50% VCM and 50% PVC waste. This was assumed by the producers of Plants A-6 through A-13 and considered reasonable by several other manufacturers.

While the reported fugitive emissions (VCM) for the individual plants vary over a wide range, Table PV-7 shows that the average VCM fugitive emission for the suspension, dispersion and bulk processes are similar (0.005-0.01 lbs./lb. of PVC). As might be expected, fugitive emissions for the solvent process appear to be much lower (0.00025 lbs./lb. of PVC).

TABLE PV-7
SUMMARY OF FUGITIVE EMISSIONS

Plant	Method Determined	VCM Emissions	
		Lb/Lb of Prod.	Tons/Yr
Suspension Process			
A-1	Quantity not specified separately	-	-
A-2	Quantity not specified separately	-	-
A-3	Material balance	0.0088 (1)	770.0
A-4	No indicated fugitive loss, but there is material balance	-	-
A-5	No fugitive losses reported - no material balance	-	-
A-6	By difference - assumed 50% VCM, 50% PVC, By Mfgr.	0.0091	341.3
A-7	By difference - assumed 50% VCM, 50% PVC, By Mfgr.	0.0089	600.7
A-8	By difference - assumed 50% VCM, 50% PVC, By Mfgr.	0.0134	1,507.5
A-9	By difference - assumed 50% VCM, 50% PVC, By Mfgr.	0.0077	673.8
A-10	By difference - assumed 50% VCM, 50% PVC, By Mfgr.	0.0275	1,650.0
A-11	By difference - assumed 50% VCM, 50% PVC, By Mfgr.	0.0061	233.5
A-12	By difference - assumed 50% VCM, 50% PVC, By Mfgr.	0.0052	294.1
A-13	By difference - assumed 50% VCM, 50% PVC, By Mfgr.	0.0086	181.7
A-14	No emission data given	-	-
A-15	Close check on all emissions	0.0018	157.6
A-16	Close check on all emissions	0.0070 (1)	140.0
A-17	No specific value given	-	-
A-18	Quantity not specified separately	-	-
A-19	Quantity not specified separately	-	-
A-20	Unidentified losses from material balance	0.0054 (1)	608.6
A-21	Quantity not specified separately	-	-
A-22	Fugitive emissions are "guesstimate"	0.0083	450.4
A-23	Fugitive by material balance	0.0101	1,200.7
A-24	Fugitive by material balance	0.0063	688.5
A-25	Process leaks (method not given)	0.0006	39.0
A-26	Material balance	0.0059	516.1
A-27	Material balance	0.0069	775.7
A-28	Material balance	0.0105	120.7
	Subtotal		10,949.9
	Wt. Average	0.0081	

Note: (1) Assumed to be 50% VCM and 50% PVC.

TABLE PV-7

SUMMARY OF FUGITIVE EMISSIONS

(CONTINUED)

Plant	Method Determined	VCM Emissions Lb/Lbs of Prod	VCM Emissions Tons/Yr
Dispersion Process			
B-1	Material balance	0.0100	199.7
B-2	None reported - produce liquid latex only	-	-
B-3	Method not specified	0.0116	-
B-4	Quantity not specified separately	-	-
B-5	Not specified	-	-
B-6	Not specified	-	-
B-7	Unusual product and process	0.0009	10.8
B-8	Material balance	0.0127	165.1
B-9	All emissions considered fugitive - no effective control device	0.0436	327.1
B-10	Material balance, manufacture latices only	0.0022 (1)	16.5
	Subtotal		875.8
	Wt. Average	0.0119	
Bulk Process			
C-1	Material balance	0.0047 (1)	76.0
C-2	Material balance	0.0082 (1)	431.9
C-3	Material balance	0.0025 (1)	212.4
	Subtotal		720.3
	Wt. Average	0.0047	
Solvent Process			
D-1	Material balance	0.00025	3.1
	Total VCM Emissions		12,549.1
	Wt. Average Emissions (2)	0.0079	

Notes: (1) All fugitive emissions have been considered 50% VCM and 50% PVC waste.

(2) For all plants listing fugitive emissions.

Total reported air emissions for the various PVC plants vary over a wide range. Part of this variation can be explained by the differences in processing schemes and the amount of emission control equipment employed. However, there are many apparent inconsistencies in the data. These are possibly caused by not including all sources of emission in the survey reports and also distributing material balance losses to the incorrect source. It is usually difficult to ascertain average emission rates for batch type processes especially if there are many vent streams involved and some of these represent large volume flow rates with variable low concentration emissions.

Table PV-8 and Figure PV-5 show the distribution of reported total VCM emissions in the various suspension type PVC plants. Table PV-9 and Figure PV-6 show the same information for the dispersion type plants. The statistical data shown in these tables and curves is completely random and merely indicates the wide variations from plant to plant at this time. Since we are not at all certain that all emissions have been reported and we know that some plants have admittedly only reported a part of their emissions, we cannot even obtain a reliable average or mean.

D. Solid and Liquid Waste

These waste products arise from such operations as vessel cleaning, screening and spillage. The solid material is disposed of via landfill or contract haulage. These losses normally are between 0.001 to 0.03 lbs. of PVC per lb. of PVC product with the associated VCM losses about one-tenth of these values.

E. Waste Water

Process waste water arises from sources such as centrifuging and VCM stripping. Only a few plants reported information regarding waste water. The VCM emissions associated with this water reject range from 0.00001 to 0.001 lbs./lb. PVC.

TABLE PV-8

STATISTICAL EVALUATION OF PVC MFGR'S EMISSIONS FOR SUSPENSION PLANTS

Code No.	Total VCM Emission	Rank No.	Rank No.	Code No.	Total VCM Emission	χ^2 (1)	Percentile (2)
A-1	.0833	27	1	A-21	.0106	.00011236	3.57
A-2	.0489	25	2	A-13	.01083	.00011729	7.14
A-3	.0234	11	3	A-5	.01096	.00012012	10.71
A-4	.01196	4	4	A-4	.01196	.00014304	14.29
A-5	.01096	3	5	A-24	.01752	.00030695	17.86
A-6	.02145	10	6	A-25	.01777	.00031577	21.43
A-7	.0297	17	7	A-15	.01832	.00033562	25.00
A-8	.0323	20	8	A-16	.0198	.00039204	28.57
A-9	.0283	14	9	A-17	.02079	.00043222	32.14
A-10	.0553	26	10	A-6	.02145	.00046010	35.71
A-11	.0334	22	11	A-3	.0234	.00054756	39.29
A-12	.0284	15	12	A-27	.02553	.00065178	42.86
A-13	.01083	2	13	A-26	.0257	.00066049	46.43
A-14	--	--	--	--	--	--	--
A-15	.01832	7	14	A-9	.0283	.00080089	50.00
A-16	.0198	8	15	A-12	.0284	.00080656	53.57
A-17	.02079	9	16	A-23	.02936	.00086201	57.14
A-18	.03141	18	17	A-7	.0297	.00088209	60.71
A-19	.0330	21	18	A-18	.03141	.00098659	64.29
A-20	.03150	19	19	A-20	.03150	.00099225	67.86
A-21	.0106	1	20	A-8	.0323	.00104329	71.43
A-22	.03553	23	21	A-19	.0330	.00108900	75.00
A-23	.02936	16	22	A-11	.0334	.00111556	78.57
A-24	.01752	5	23	A-22	.03553	.00126238	82.14
A-25	.01777	6	24	A-28	.0367	.00134689	85.71
A-26	.0257	13	25	A-2	.0489	.00239121	89.29
A-27	.02553	12	26	A-10	.0553	.00305809	92.86
A-28	.0367	24	27	A-1	.0833	.00693889	96.43
					.77173	.02817105	

Notes:

(1) χ^2 = VCM emissions squared; used to calculate variance and standard deviation.

(2) Percentile used to space data correctly on Probability of Occurrence Curve.

Mean = 0.02858
Variance = 0.00023512
Std. Dev. = 0.01533

PVC-70

UCC 026130

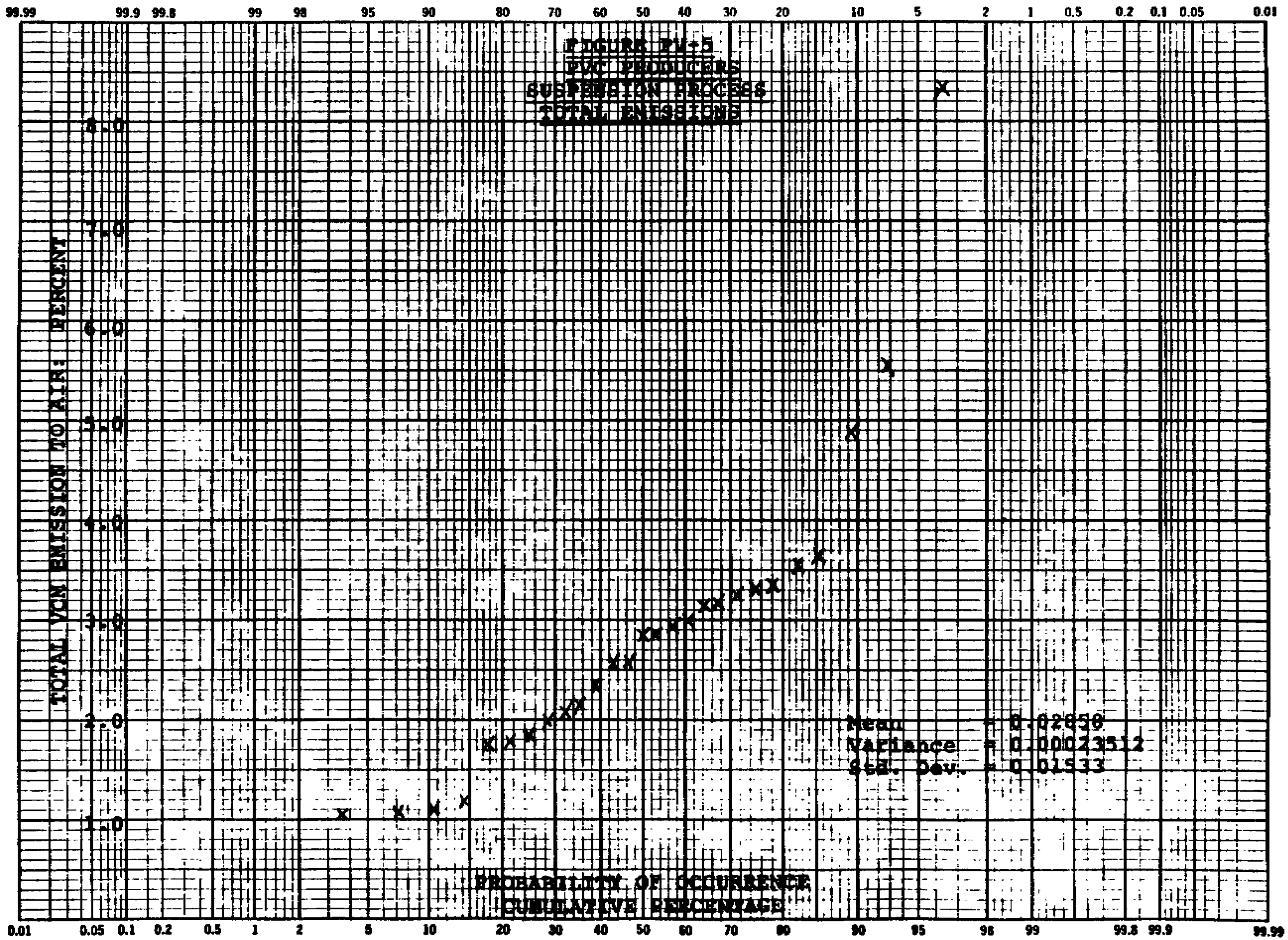


FIGURE PV-5
PVC PRODUCERS
SUSPENSION PROCESS
TOTAL EMISSIONS
TOTAL VCM EMISSION TO AIR: PERCENT
PROBABILITY OF OCCURRENCE
CUMULATIVE PERCENTAGE
Mean = 0.02858
Variance = 0.00023512
Std. Dev. = 0.01533
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0

UCC
026131

TABLE PV-9
STATISTICAL EVALUATION OF PVC MFGR'S EMISSIONS FOR DISPERSION TYPE PLANTS

Code No.	Total Emissions	Rank No.
B-1	0.04128	5
B-2	0.00284	1
B-3	0.0563	7
B-4	0.0367	4
B-5	0.1610	8
B-6	0.2623	10
B-7	0.0157	2
B-8	0.1642	9
B-9	0.0436	6
B-10	0.02784	3

Rank No.	Code No.	Total Emissions	x^2	Percentile
1	B-2	0.00284	.00000807	9.091
2	B-7	0.0157	.00024649	18.182
3	B-10	0.02784	.00077507	27.273
4	B-4	0.0367	.00134689	36.364
5	B-1	0.04128	.00170404	45.455
6	B-9	0.0436	.00190096	54.545
7	B-3	0.0563	.00316969	63.636
8	B-5	0.1610	.02592100	72.727
9	B-8	0.1642	.02696164	81.818
10	B-6	0.2623	.06880129	90.909
		0.81176	.13083513	

Mean = 0.08118
Variance = 0.00721552
Std. Dev. = 0.0849

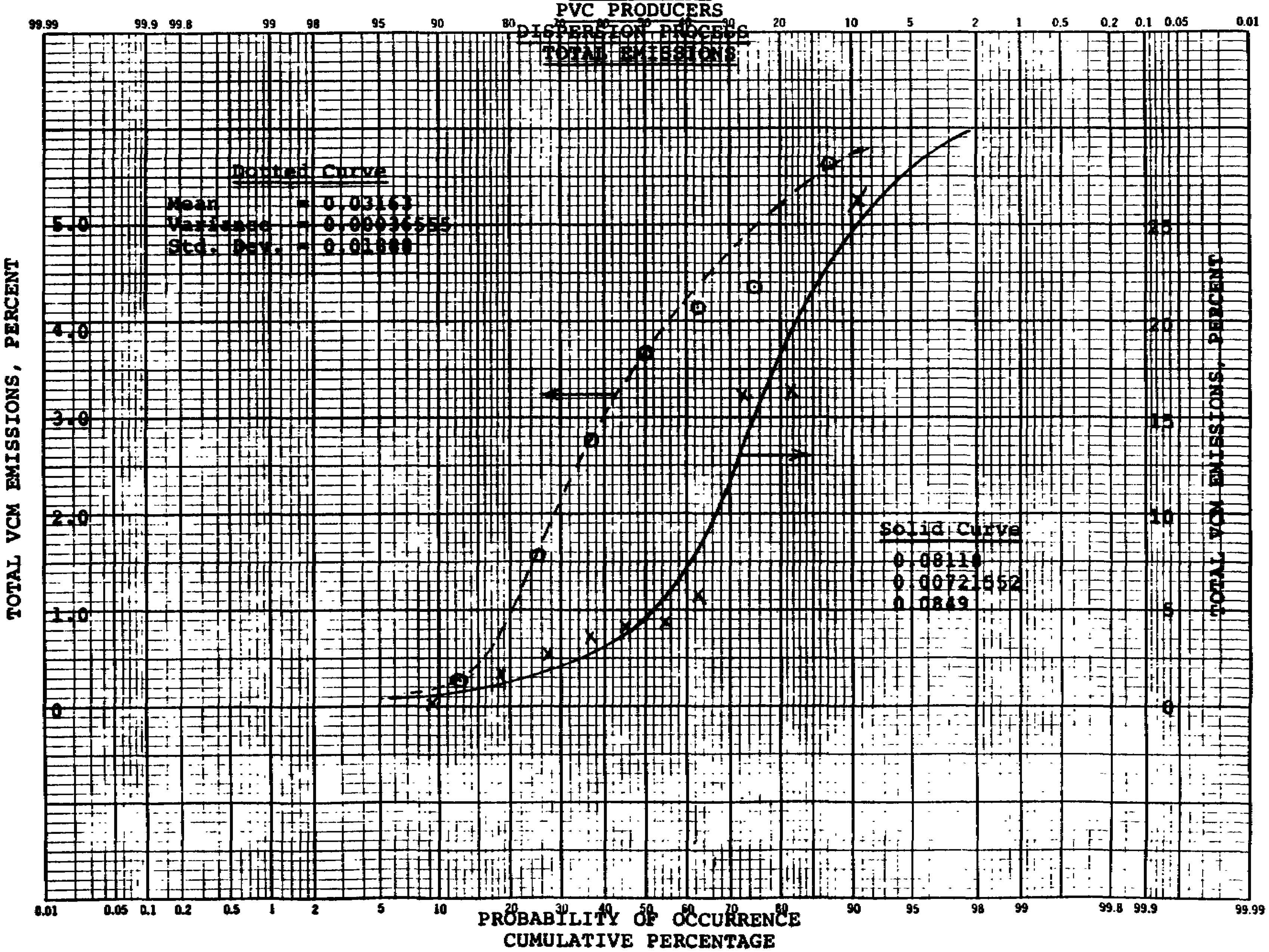
Note: If we eliminate B-5, 6 and 8 because of abnormally high values, the statistical numbers are:

Mean = 0.03163
Variance = 0.00035655
Std. Dev. = 0.01888

PVC-72

UCC 026132

FIGURE PV-6
PVC PRODUCERS
DISPERSION PROCESS
TOTAL EMISSIONS



VI. National Emission Inventory

Based upon the emissions shown in Table PV-6, total approximate VCM air emissions from the surveyed PVC manufacturing plants (approximately 4.0 billion Lbs/Yr PVC capacity) are as follows:

	VCM Emissions	
Process	T/T of PVC	T/YR
Suspension	0.0280	48,599.6
Dispersion	0.0625	6,534.1
Bulk	0.0166	2,525.5
Solvent	0.0128	153.5
	0.0288	57,812.7

Based on an estimated 4.9 billion Lbs/Yr PVC production rate in the U.S. during 1974, the total VCM emissions from PVC manufacturer are estimated to be approximately 70,000 Tons/Yr.

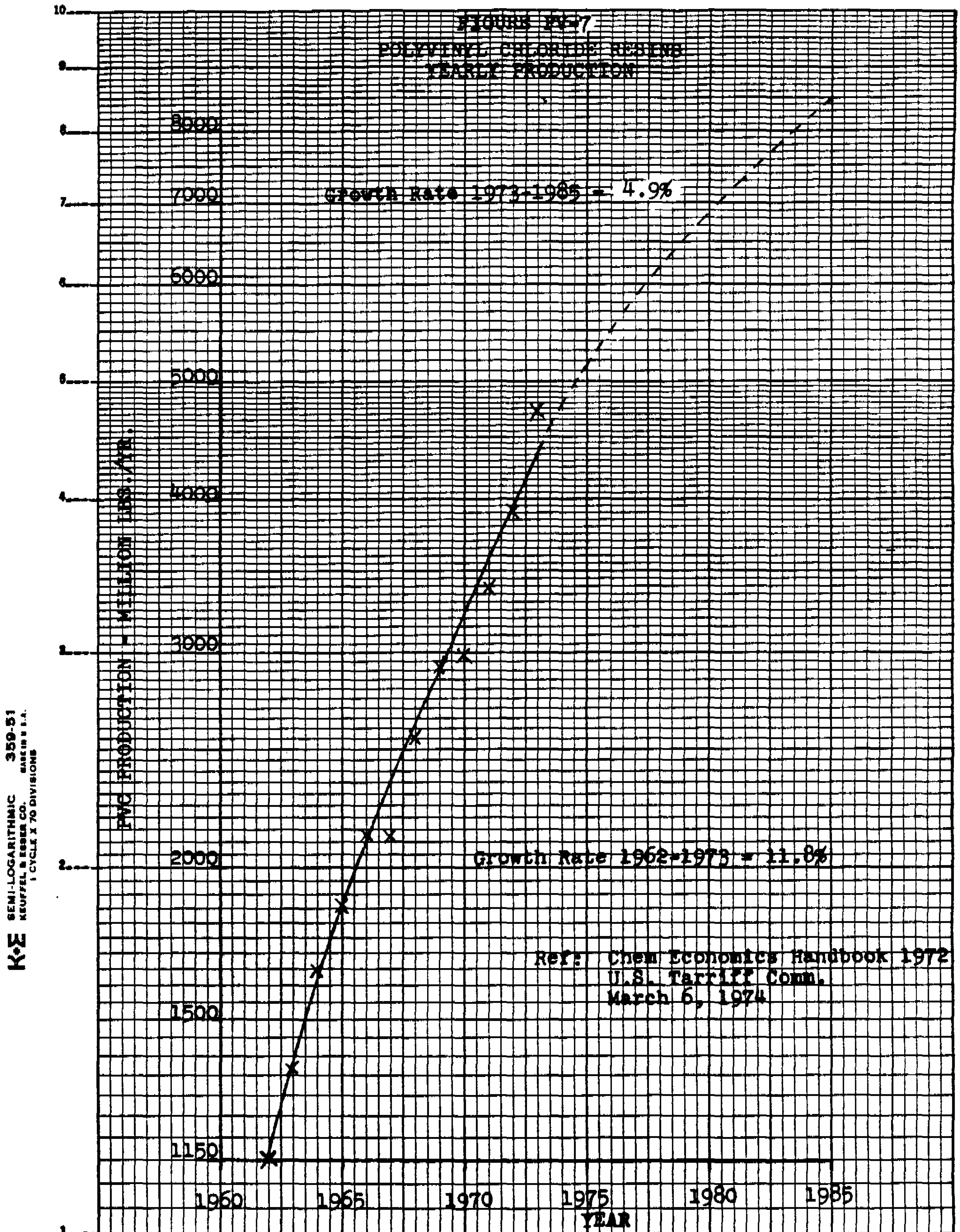
It should be noted that most PVC plants are run at near maximum capacity throughout the year which tends to stabilize emissions. However, because of higher cooling water and air temperatures during the summer months, VCM emissions are somewhat higher at that time of the year.

VII. Industry Growth Potential

The growth of polyvinyl chloride has been fairly steady over the past three decades. The main process used was the dispersion (emulsion) method until the 1950's when the suspension process became predominant. The solvent process has been in existence for a long time (started in the 1930's) but is currently used by only one company so it is unlikely to expand much. The newest commercial process is the bulk process and it will probably expand far more than the suspension process if it proves to be more economic (as claimed by its licensor) and if VCM emissions can be more easily controlled.

Figure PV-7 indicates the growth rate of PVC (all processes) from 1962 to date [3] (1973 last production figure[4] and projects future growth to 1985. As noted on the figure, the growth rate has been 11.8% from 1962 through 1973. A diminished growth rate of 4.9% is projected to 1985. There are several factors that lead one to believe the growth of PVC will slow down significantly. One is the "energy crisis" which could limit the raw material availability, another is the drastic slow down in domestic construction, and the third is the discovery of the carcinogenic nature of vinyl chloride monomer. This last factor has stopped its use as a container material for liquor, food stuffs, etc. It probably has curtailed its use (film form) as a food wrap and could well injure its saleability in other areas. Another factor that is impossible to evaluate at this writing is the future manufacture of PVC with the new OSHA Standard (January 1, 1975). No company would build a new plant if they thought they could not meet the OSHA Standard and most now feel they could not.

Figure PV-8 shows the location of existing PVC manufacturing plants.



RGB 4/30/74

UCC
026136

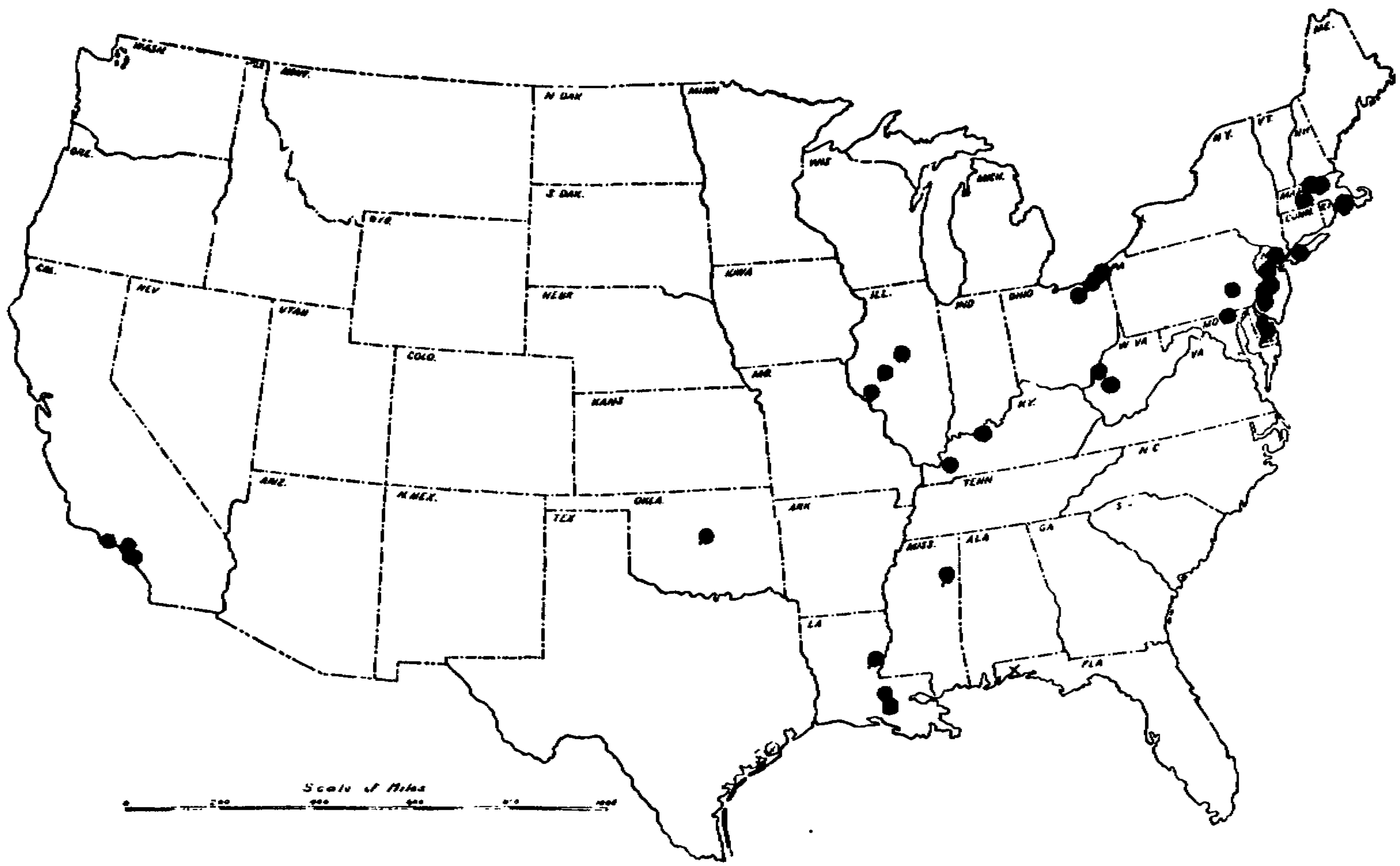


Figure PV-8 - Location of PVC Manufacturing Plants

VIII. Emission Control Devices

Any device used to reduce emissions significantly and is not used for any other reasons (primarily economic) is considered an Emission Control Device. In other words, it can not be profitable or it would be considered a necessary adjunct to the process. In the case of the commercial production of polyvinyl chloride resin there are a remarkably few devices that can be considered truly Emission Control Devices under this definition. However, there are some devices that are used for economic reasons that can be made far more effective than the economics of the process would dictate and such refinements could properly be called Emission Control Devices. This is because the producer is primarily trying to reduce the emission of VCM to a minimum (1 ppm in the working environment).

In addition to devices, there are a number of procedures (real and possible) that are in their entirety an Emission Control Device even though it is a process procedure rather than a specific piece of equipment. In fact in the case of reducing VCM emission to a minimal value, these procedures are more important than the usual control devices.

We will first list equipment and then procedures including known and used methods as well as projected devices and procedures.

A. Control Devices

VCD-1 - Improved Stripping

The stripping of VCM from the latex in the suspension and dispersion processes is the most important procedure in respect to all subsequent downstream emissions. Whatever VCM is not removed here will, in all probability, wind up as an air emission. Most plants have a vacuum system and then compress and condense the VCM vapors to make a substantial recovery of unreacted VCM. Ideally the vacuum pulled should equal the vapor pressure of the water at the temperature used for the polymerization. This would normally be about 25" vacuum (5" Hg absolute pressure) at 135°F. Actual operating pressure is slightly higher in order to minimize foaming. The difference between using a vacuum of 25" Hg vs. 15" Hg vacuum means a reduction of VCM of about 0.0028 lbs VCM/lb product downstream from the stripper. This is with normal cooling water of about 80°F. This does not necessarily reduce the total VCM emissions to the air unless adequate cooling and compression or absorption is used to collect the VCM from this vacuum system.

The vapors from the vacuum pump are compressed to about 75 psig, and condensed (85°F or lower) before being vented. This type of high vacuum (>20" vac.) system is employed by plants A-15, A-18, A-19 and A-22. Probably other plants, which provided insufficient details of their vacuum system, also use this type of low pressure evacuation.

A system suitable for a 200 million pound per year plant, capable of pulling 25" vacuum and compressing to 75 psig can be bought for about $200,000 to $225,000. Installed cost with necessary condenser would be about $750,000. (This is about twice the amount spent for the average system normally used up to now which pull 10" to 15" Hg vacuum.) Power requirement for the low pressure vacuum pump and compressor would be 80 KWH/hr. Approximately 35 GPM of cooling water is required for the condenser.

VCD-2 - Refrigeration for Vacuum Recovery System

In order to increase VCM recovery from the vacuum system some manufacturers (A-6, A-22 and C-3) cool the net vent streams to -15 to -30°F. VCM emission loss (at 25" vac.) without refrigeration would be 0.005 lbs. of VCM/lb. PVC. Cooling the vent to -30°F recovers approximately 80% of this material. For a 200 million pounds per year PVC plant a 5 ton refrigeration unit would be required. This would cost about $70,000 (installed). Power requirements for this unit would be about 15 KWH/hr.

VCD-3 - VCM Recovery System Vent Scrubber

Another effective way to minimize emissions from the VCM recovery system is to pass the compressed vent gases (inerts and VCM vapors) through a scrubber using a liquid having good solvency for VCM and that can be separated from the VCM. This is done at several plants (A-16, A-28, B-3, B-7 and D-1) with resulting low emission losses from this source, see Table PV-10.

For a 200 million pounds per year plant, typical feed to the scrubber would be about 115 lbs./hr. of VCM. Assuming compression and water cooling is used ahead of the scrubber for VCM recovery, the scrubber feed will be available at 75 psig and 85°F and contain a maximum of 70 mol.% VCM (on an instantaneous basis, average composition 10% or less). A 20 ft. by 12 inch diameter packed tower should be able to obtain 96% recovery of VCM from this vent stream. Based on an average emission rate of 0.005 lbs. of VCM/lb. PVC product for a plant without a scrubber approximately one million pounds of VCM will be recovered (at 10¢/lb. equivalent to $100,000 per year). The installed investment cost for the scrubber-stripper system and associated pumps and heat exchangers would be approximately $125,000. Utility requirements for the model plant size scrubber would be 5 KWH/hr., 500 lbs./hr. of 400-600 psig steam and 40 GPM of cooling water.

VCD-4 - Gas Holder

Only one plant is using a gas holder at this time (A-21) and it is interesting to note that it has the lowest total VCM emission of any of the plants where the data can be considered reasonably complete (0.0106 lbs. of VCM/lb. of PVC product). This particular plant vents relief valves and rupture disks from compressors, reactors, strippers, etc.; reactor purge lines, miscellaneous vents from weigh tanks, storage tanks, pumps, condensers, knockout pots, etc.; vacuum pump discharge from stripping tank, and manual reactor vents into the gas holder. The vapors from the gas holder are compressed, chilled and condensed VCM is returned to VCM storage. It is estimated that the installed cost for the gas holder and associated compression and heat exchange system for a 200 million pound PVC plant would be approximately $950,000. Utility requirements would consist of 40 KWH/hr., and 25 GPM of cooling water.

In some cases, safety regulations may prevent sending pressure relief valve vents to the gas holder. In these plants, it would be desirable to provide separate pressure control instrumentation for automatic venting to the gas holder when pressure increases to somewhat below the relief valve set pressure. In this way prsssure upsets can be handled without opening the safety valves.

VCD-5 - Carbon Adsorption

The use of activated carbon has been demonstrated experimentally as a way to reduce VCM emissions. It certainly could be used on the outlet vent of the VCM recovery system where the concentrations are high (over 10% VCM) and possibly prove to be reasonably economic in this service. How effective it would be on the outlet of a rotary dryer is conjecture, as the outlet temperature ranges from 140 to 160°F and the VCM concentration is less than 0.1% with air volumes of 13,000 to 25,000 ACFM per 5,000-10,000 pounds per hour of dry PVC product. The economics would represent a direct added cost as the recovery value of the VCM would be significant. Also, the excess amount of water vapor would limit the adsorption capacity severely. To adsorb 50 ppm of vinyl chloride vapors from a dry air stream of 18,000 ACFM at 150°F and atmospheric pressure requires about 1,200 cubic feet (19 tons) of activated carbon for an 8-hour adsorption cycle.(a) This assumes half of the carbon is in service while the remainder is being regenerated. The regeneration would probably be done with steam at elevated pressure (50 psig) followed by effluent cooling (to 100°F) for VCM condensation and recovery (60 lbs./8-hr. cycle). As indicated, the above carbon requirements are based on processing a dry vent stream. A dryer vent of this magnitude would contain about 16,000 lbs. of water per 8-hour period. This water will undoubtedly increase the amount of activated carbon required.

There is some question as to how many times the activated carbon can be regenerated. Experimentally it has been regenerated at least fifteen times without any loss in adsorptive capacity.[7] However, because of the large volume of activated carbon involved it is important to know the ultimate life of this material.

Because of uncertainties as to the amount of carbon involved and ultimate carbon life it is difficult to develop meaningful economics for this form of emission control device at this time.

VCD-6 - Thermal Incineration

Thermal incineration of the vent stream from a VCM recovery system is impractical compared to other devices as there is nothing to offset the high investment and fuel requirement. Other devices recover VCM for reuse and thereby partially pay for the increased investment and operating cost. The fuel value of the incinerated VCM streams is negligible.

The incineration of the air from a rotary dryer containing 15 to 100 ppm of VCM is possible albeit costly. Fuel requirement is large as the VCM contributes an insignificant amount of combustible and the air is fairly well saturated with water vapor. In addition, a large scrubber system may be required to remove the small amount of hydrogen chloride formed.

The equation for the reaction is:

$$2\ CH_2{:}CH\ Cl + 5\ O_2 \longrightarrow 4\ CO_2 + 2\ H_2O + 2\ H\ Cl$$

(a) Calculated based on published data of Calgon Corp.[7]

In order to conserve energy it would be necessary to employ feed-effluent heat exchange or generate steam with the incinerator effluent. Commercial incinerators with high heat recovery (75-80%) will have an installed cost of 10-15 dollars per cubic foot per minute of feed gas.[6] Therefore, the incineration of the combined vent streams from a 200 million pound per year capacity plant (200,000 SCFM) would take a minimum capital investment of $3,000,000 and consume about 95 million Btu/hr. of fuel (based on 85% heat recovery) and approximately 365 KWH/hr. would be required for induced draft fans.

It should be noted that there is some doubt if the VCM will be completely burned in the incinerator. At the very low concentration of VCM involved combustion efficiency could be low.

VCD-7 - Catalytic Incineration

It is possible to catalytically incinerate to similar levels obtained with a thermal unit. The catalytic facility would operate at lower temperature (800-1000 versus 1800°F) and therefore require less heat recovery and consume less fuel. The somewhat lower initial investment and fuel saving would be offset by catalyst replacement costs and the danger of catalyst fouling and poisoning.

VCD-8 - Canned Pumps

An important source of fugitive emissions is from pump glands and seals on liquid VCM pumps. This source could be eliminated by the use of canned pumps. In a new plant they would increase the capital cost of pumps about 35%. In an established plant, it would be a direct cost increase. They normally reduce maintenance costs but when they go "bad" the pump must be replaced so on an overall maintenance cost basis the canned pump represents little or no advantage. Canned pumps could be installed systematically in a preventive maintenance program and reduce pump emission to "zero". Incremental cost for installing canned pumps in a new 200 million pound per year PVC plant would be approximately $10,000. Replacing pumps in the same size existing plant would cost about $30,000.

B. Procedures

VCD-9 - Solvent Cleaning

One of the principal sources of intermittent emissions is from the opening and closing of the reactors. A method to reduce this emission is to solvent clean the reactors. There are several solvents that are very efficient, such as tetrahydrofuran, dimethyl formamide, and ethylene dichloride. The use of any of these solvents does introduce a possible emission problem but since they are all liquids at normal temperatures, these emissions are much easier to contain and control than VCM.

One company (A-17) does use a solvent system and the following economics have been given, all converted to a 200 million pound per year plant.

Capital Investment	\$300,000
Solvent Purified	6×10^6 Gals/Yr.
Loss 1% (99% Eff.)	6×10^4 Gals/Yr.
$1.253 \times 8.34 \times 6 \times 10^4$	6.27×10^5 Lbs/Yr.
@ 9-1/2¢/Lb.	\$59,600/Yr.
Utilities	
50 PSIG Steam	3.762×10^6 Lbs/Yr.
Cooling Water	12.0×10^6 Gals/Yr.
Electricity	2.5×10^3 KWH/Yr.
Chemical & Misc. Supplies	\$2,500/Yr.
Labor 7% of Battery Limits Capital Investment	\$11,200/Yr.

Plant A-17 uses the solvent system to clean the reactors after every three or four batches.

In addition to reactor cleaning, the solvent should be considered for cleaning pipes, pumps, vessels, etc. As with reactor cleaning, the major problem is associated with separation of the solvent from the PVC resin.

VCD-10 - Water Purge of Reactors

A method used (in conjunction with a gas holder) to reduce VCM emissions from reactors is to thoroughly purge all the VCM vapors to the gas holder by filling the reactor with water. The water is recycled so that there is no VCM loss to water after the initial charge. This purging is only done in preparation for cleaning the reactor (every 3 to 6 batches).

Cost for the water purge system should be less than $200,000 for the model size plant.

VCD-11 - Leak Detection

In order to detect and eliminate leaks as soon as they occur, it is necessary to continuously monitor specific areas for VCM vapors. In a 200 million pounds per year PVC plant, four or five ten-point monitors are required to provide reasonable coverage. These monitors (chromatographs) cost about $20,000 per unit installed. The associated alarm and signal system costs another $30,000 and a data processing system another $40,000 to $90,000. This brings the equipment cost up to $150,000 to $200,000. To follow up on alarms, the part time services of a man and portable VCM detector ($5,000) is required. The system more often than not requires the full time assistance of a pipe fitter to minimize leakage. In addition, the full time services of an instrument man is necessary to keep the chromatographs in operation.

To monitor battery limits and off site VCM concentrations requires personnel and equipment, but the cost varies markedly and indeterminantly due to wide differences in frequency of testing and number of locations tested.

TABLE PV-10

CATALOG OF EMISSION CONTROL DEVICES *

Plant No.	Device No.	Lbs. VCM/Hr. In	Lbs. VCM/Hr. Out	Eff.%	Remarks
A-6	VCD-1&2	1809	13	99.3	-30°F cooling
A-7	VCD-1&2	4620	23	99.5	Conditions not given
A-8	VCD-2	416	104	75	Conditions not given
A-9	VCD-2	-	7	-	Conditions not given
A-10	VCD-2	-	122	-	-70°F cooling
A-10	VCD-3	-	-	75	EDC scrubbing medium
A-12	VCD-2	65	9.5	85	Conditions not given
A-16	VCD-3	-	-	96	30 plate col. 13"Ø 34" high 70 psig
A-17	VCD-9	-	-	-	Use EDC as solvent, closed system
A-21	VCD-1&2	-	53.8	-	No conditions or rates given except discharge
A-21	VCD-4	-	2.0	-	No conditions or rates given except discharge
A-21	VCD-9	-	27.4	-	No conditions or rates given except discharge
B-7	VCD-3	-	-	99.2	No conditions or medium given
C-1	VCD-2	-	29.0	-	No temp. given for refrigeration unit
D-1	VCD-2&3	-	74	-	Cooled to 14°F, acetone is scrubbing medium

PVC-85

Note:

* Most of the respondents are in the process or have plans to reduce VCM emissions. We have only listed those that were in actual service at the time the reports were made.

IX. Model Plant

It should be noted here that most PVC plants have undoubtedly done much to reduce fugitive losses during the past year. This also applies to many procedures where far more care is now exercised to minimize VCM emissions. This takes time and the results are certainly not completely reflected in the emissions reported as of June or July of 1974. For this reason our Model Plant "set up" may indicate higher input VCM content to certain devices or higher fugitive losses than are actually the case today. Table PV-11 presents economics for a typical existing 200 million pound per year PVC plant without VCM emission control devices.

Table PV-12 provides incremental investment, utility and manpower requirements for the same size plant with a moderate amount of emission control equipment. This facility (Model Plant I) employs the following devices and procedures to reduce VCM emissions.

1. VCD-1 Improved Stripping
2. VCD-2 Refrigeration of VCM Recovery System Vent
3. VCD-8 Canned Pumps
4. VCD-11 Leak Detection Program

The best way to reduce VCM losses downstream from the stripper (or the reactor if stripping is done there) is to strip the latex as thoroughly as possible of residual VCM. As the polymerization goes to about 95% completion at best, it is economical to recover most of the VCM. It is possible to recover 99% of the VCM if a vacuum of about 25" Hg (5 in. Hg absolute) can be pulled on the latex and the vapors are compressed and chilled (-30°F) under pressure (70 psig) and care has been taken to minimize leaks into the system. This is not easy to do even with the proper vacuum-compression equipment due to foaming problems. This is particularly true of dispersion latices as they foam far more readily than suspension latices. Considerable work is being done on this problem and our Model Plant devices assume considerable success in this area. The low temperature refrigeration is necessary so that the inerts that must be vented from the system can be discharged with a minimum VCM loss.

The vacuum system should be flexible enough so that it can be used to evacuate VCM vapors from other vessels such as reactors, blend tanks, etc., whenever necessary to minimize VCM emissions to the air.

The replacement of all pumps handling liquid VCM with canned pumps should reduce variable fugitive emissions which occur with some frequency due to packing or seal failures on regular centrifugal pumps.

TABLE PV-11

PVC MANUFACTURING COST FOR A TYPICAL EXISTING 200 MM LB./YR. FACILITY

	¢/Lb. PVC	$/Yr.
Direct Manufacturing Cost		
Raw Material		
Vinyl Chloride @ 10¢/Lb.	10.10	
Vinyl Acetate @ 19¢/Lb.	0.75	
Additives @ 22-1/2¢/Lb.	0.90	
Initiator @ $1.65/Lb.	0.17	
Labor @ 20 X 5.65 X 8/Shift	0.49	
Maintenance (5% of Invest.)	0.55	
Utilities	0.40	
	13.36	
Indirect Manufacturing Cost		
Plant Overhead (110% Labor)	0.54	
Laboratory (25% Labor)	0.12	
	0.66	
Fixed Manufacturing Cost		
Depreciation (10 Yr. Straight Line)	1.10	
Insurance & Property Tax (2.3% Invest)	0.25	
	1.35	
Total Manufacturing Cost	15.37	30,740,000
General Expenses		
Administration (3% of Mfg. Cost)	0.46	
Sales (1% of Mfg. Cost)	0.15	
Research (2.5% of Mfg. Cost)	0.38	
Finance (6% of Investment)	0.66	
	1.65	
Total Cost	17.02	34,040,000
Product Value, PVC	24.00	48,000,000
Profit Before Taxes	6.98	13,960,000
Profit After Taxes (52%)	3.35	6,700,000
ROI (NPAT X 100/Plant Investment)	30.4%	

TABLE PV-12
200 MM LBS/YEAR PLANT
MODEL PLANT I INCORPORATING
MODERATE EMISSION CONTROL DEVICES

Capital Increase for Emission Control Devices

VCD-1 High Vacuum and Compr. for Max. VCM Stripping	$ 750,000
VCD-2 Refrigeration on Condenser to -30°F	70,000
VCD-8 Substitute Canned Pumps	10,000
VCD-11 Monitoring for VCM Emissions	175,000
Total Capital Investment Increase	$1,005,000

Increase in Operating Cost and Energy Requirements	GPM Cooling Water	Electric Power KWH/HR.
Control Device		
VCD-1	35	80
VCD-2		15
VCD-8		
VCD-11	—	—
Total	35	95

Labor 2-1/2 Men/Shift
Annual Cost = 2.5x5.65x8760
= $125,000

Table PV-13 presents incremental economic factors for a facility (Model Plant II) which includes extensive VCM emission control equipment. This plant incorporates the same control devices as Model Plant I except the refrigeration unit is replaced with a lean oil scrubber on the VCM recovery system vent. In addition it includes the use of a gas holder (VCD-4) and solvent cleaning of reactors.

The use of a scrubber to control VCM emissions from a VCM recovery system has proven effective in several plants (A-10, A-16, B-3, B-7, and D-1) and ensures a very low VCM emission to the atmosphere. (Less than .0010 lbs VCM/lb product)

Only one plant (A-21) reported using a gas holder (VCD-4). It is interesting to note that this particular plant has the lowest VCM emission of all the suspension plants that have given reasonably complete emission data. They also use a water purge for reactors (VCD-10). All controllable emissions (to vents, stacks, etc.) are sent to the gas holder. They are then compressed and sent to the VCM recovery system. (Resulting atmospheric vent contains less than 0.005 lbs VCM/lb product.)

Only one plant (A-17) reported the use of solvent cleaning of reactors (VCD-9) as standard procedure. Several plants are experimenting or trying to develop a workable system but are having difficulty separating the solvent from the polymer efficiently and economically. This cleaning system could significantly reduce sporadic VCM emissions caused by frequent openings and cleanings of many reactors. (Less than .002 lbs VCM/lb product emitted with control device.)

The model plants as presented do not include any devices to handle VCM emissions from dryers or downstream processing areas. The use of activated carbon is a possibility but it remains to be proven if it is practical. It might well be of value for dispersion plants where it is difficult to strip the latices effectively at the strippers. However most dispersion plants use spray dryers which means an effluent air stream with more moisture content, higher temperatures and large volumes. All of which increase the quantity of activated carbon requirement. It is also not clear as to how to handle the effluent from the adsorber during regeneration.

Incineration has not been used in the model plants because of the large fuel requirement and the fact that emissions, such as HCl, SO_2 and NO_x, not now emanating from PVC plant, would be formed in significant amounts.

Scrubbing of the large volume air streams with low VCM content has not been considered. There are no data available to indicate that an equilibrium condition exists favorable for a significant reduction of VCM by scrubbing; not to mention the tremendous size of equipment involved with its incumbent high cost.

TABLE PV-13
200 MM LBS./YEAR PVC PLANT
MODEL PLANT II INCORPORATING
EXTENSIVE EMISSION CONTROL DEVICES

Capital Increase for Emission Control Devices

VCD-1	High Vacuum and Compr. for Max. VCM Stripping	$ 750,000
VCD-3	Scrubber for VCM Recovery System Vent	125,000
VCD-4	Gas Holder	950,000
VCD-8	Substituting Canned Pumps	10,000
VCD-9	Solvent Cleaning of Reactors	300,000
VCD-11	Monitoring for VCM Emissions	175,000
Total Capital Investment Increase		$2,310,000

Increase in Operating Cost and Energy Requirements	Steam Lbs/Hr	Cooling Water GPM	Electric Power KWH/Hr	Chemicals $/Yr
Control Device				
VCD-1		35	80	
VCD-3	500	40	5	
VCD-4		25	40	
VCD-8				
VCD-9	500	15	1	62,100
VCD-11				
Total	1000	115	126	62,100

Labor 3 Men/Shift
Annual Cost = 3 x 5 . 65 x 8760
= $150,000

UCC
026150

Tables PV-14 and PV-15 present economics for the Model I and Model II plants.

Table PV-16 presents an estimate of VCM emissions from the suspension PVC process incorporating the emission control devices employed in the model plants. The reduction in emissions shown for the Model II plant can be readily accomplished with present technology. Any substantial further reduction in VCM emissions will require additional research and process development effort.

TABLE PV-14

PVC MANUFACTURING COST FOR A TYPICAL MODEL I PLANT, 200 MM LBS./YR. PRODUCTION

Direct Manufacturing Cost	¢/Lb. PVC	$/Yr.
Raw Materials		
Vinyl Chloride @ 10¢/Lb.	10.10	
Vinyl Acetate @ 19¢/Lb.	0.75	
Additives @ 22½¢/Lb.	0.90	
Initiators @ $1.65/Lb.	0.17	
Labor @ 22½ x 5.65 x 8/Shift	0.55	
Maintenance (5% of Investment)	0.58	
Utilities	0.41	
	13.46	
Indirect Manufacturing Cost		
Plant Overhead (110% Labor)	0.61	
Laboratory (25% Labor)	0.14	
	0.75	
Fixed Manufacturing Cost		
Depreciation (10 Yr. Straight Line)	1.15	
Insurance & Property Tax (2.3% Investment)	0.26	
	1.41	
Total Manufacturing Cost	15.62	31,240,000
General Expenses		
Administration (3% Mfg. Cost)	0.47	
Sales (1% Mfg. Cost)	0.16	
Research (2.5% Mfg. Cost)	0.39	
Finance (6% of Investment)	0.69	
	1.71	
Total Cost	17.33	34,660,000
Product Value PVC	24.00	48,000,000
Profit Before Taxes	6.67	13,340,000
Profit After Taxes (52%)	3.20	6,400,000
ROI (NPAT x 100/Plant Investment)	27.8%	

UCC
026152

TABLE PV-15

PVC MANUFACTURING COST FOR A TYPICAL MODEL II PLANT, 200 MM LBS./YR. PRODUCTION

Direct Manufacturing Cost	$/Lb. PVC	$/Yr.
Raw Materials		
Vinyl Chloride @ 10¢/Lb.	10.10	
Vinyl Acetate @ 19¢/Lb.	0.75	
Additives @ 22½¢/Lb.	0.90	
Initiators @ $1.65/Lb.	0.17	
Miscellaneous Chemicals	0.03	
Labor @ 23 x 5.65 x 8/Shift	0.56	
Maintenance (5% of Investment)	0.61	
Utilities	0.42	
	13.54	
Indirect Manufacturing Cost		
Plant Overhead (110% Labor)	0.62	
Laboratory (25% Labor)	0.15	
	0.78	
Fixed Manufacturing Cost		
Depreciation (10 Yr. Straight Line)	1.22	
Insurance & Property Tax (2.3% Investment)	0.28	
	1.50	
Total Manufacturing Cost	15.82	31,640,000
General Expenses		
Administration (3% Mfg. Cost)	0.47	
Sales (1% Mfg. Cost)	0.16	
Research (2.5% Mfg. Cost)	0.40	
Finance (6% of Investment)	0.73	
	1.76	
Total Cost	17.58	35,160,000
Product Value PVC	24.00	48,000,000
Profit Before Taxes	6.42	12,840,000
Profit After Taxes (52%)	3.08	6,160,000
ROI (NPAT x 100/Plant Investment)	25.3%	

TABLE PVC-16

ESTIMATE OF VCM EMISSIONS FROM MODEL PLANTS (SUSPENSION)

VCM EMISSIONS, TONS/TON OF VCM

Source Area	Plant Without Control Devices	Model Plant I	Model Plant II
A	.0030	.0015	.0005
B	.0030	.0020	.0005
C	.0032	.0010	.0010
D	.0048	.0015	.0003
E	.0042	.0015	.0005
F	.0013	.0002	.0002
G	.0070	.0030	.0010
Fugitive	.0080	.0050	.0030
Total	.0345	.0157	.0070

X. Research and Development Goals

Technological research and development will be concerned with reducing vinyl chloride emissions to very low values as compared with the current emission level. One of the major sources of emissions is the vent to remove inerts from the VCM recovery system. More development should be done on an economical system for scrubbing this vent stream with a liquid from which VCM can be easily stripped and liquified for reuse.

Another important emission source is the reactor, not during polymerization, but when it is being cleaned. All reactors in the suspension and dispersion process tend to build up PVC on the walls and agitator. Most plants still clean by hand, a few of the newer plants (or reactors) are equipped with water jet lances for self cleaning but even these must be mechanically cleaned at times. This means that whenever a reactor is cleaned, it is open and there is some VCM emission regardless of the care taken. A good solvent cleaning system is desirable. There are several solvents that work well (dimethyl formamide, tetrahydrofuran). The problem has been to separate the solvent from the dissolved PVC economically. The development of an economical system would certainly be a big aid towards the reduction of ambient VCM emissions.

One of the difficulties associated with efficient stripping of VCM from the latex is the tendency of latices to foam. Dispersion latices are particularly bad because of their high soap content. The most obvious approach is the addition of foam breakers (silicones, alcohols, etc.). Another approach is the use of mechanical foam breaking devices incorporated into the stripper. Any improvement in this area could result in a marked reduction of VCM emissions downstream of the stripper. Also, there are a number of heat exchangers (falling film, wiped film, multiple effect, etc.) that might make efficient and economically feasible, the removal of 99+% of the VCM from the latex if it were possible to keep the latex from coagulating. Both areas of study, heat exchange devices and stable emulsions, under rigorous conditions are ones that could result in significant reductions of downstream emissions, plus a reduction in the VCM content of the product PVC resin.

REFERENCES

1. "PVC Chemical Profile", Chemical Marketing Reporter, May 20, 1974.

2. Albright, L. F., "Processes for Major Addition - Type Plastics and Their Monomers", McGraw Hill, Inc., New York, N.Y., 1974.

3. "Chemical Economics Handbook", Stanford Research Institute, September 1972 and September 1973.

4. U.S. Tarriff Commission, March 6, 1974.

5. "Current Prices of Chemicals and Related Materials", Chemical Marketing Reporter, November 11, 1974.

6. Private communications with Roy F. Weston, Inc., Consulting Engineers, West Chester, Pennsylvania.

7. "Controlling Vinyl Chloride Emissions with Granular Activated Carbon", Bulletin 23-200, Calgon Corporation, Pittsburgh, Pennsylvania, 1974.

APPENDIX I

BASIS OF THE STUDY

I. Industry Survey

The study which led to this document was undertaken to obtain information about selected production processes that are practiced in the Petrochemical Industry. The objective of the study was to provide data for the EPA to use in the fulfillment of their obligations under the Clean Air Amendments of 1970.

The information obtained during the study includes industry descriptions, air emission control problems, sources of air emissions, statistics on quantities and types of emissions and descriptions of emission control devices currently in use. The principal source for these data was an Industry Questionnaire but it was supplemented by plant visits, literature searches, in-house background knowledge and direct support from the Manufacturing Chemists Association.

More than 200 petrochemicals are currently produced in the United States, and many of these by two or more different processes. It was obvious that the most immediate need was to study the largest tonnage, fastest growth processes that produce the most pollution. Consequently, the following 32 chemicals (as produced by a total of 41 different processes) were selected for study:

Acetaldehyde (two processes)	Nylon 6
Acetic Acid (three processes)	Nylon 6,6
Acetic Anhydride	"Oxo" Alcohols and Aldehydes
Acrylonitrile	Phenol
Adipic Acid	Phthalic Anhydride (two processes)
Adiponitrile (two processes)	Polyethylene (high density)
Carbon Black	Polyethylene (low density)
Carbon Disulfide	Polypropylene
Cyclohexanone	Polystyrene
Ethylene	Polyvinyl Chloride
Ethylene Dichloride (two processes)	Styrene
Ethylene Oxide (two processes)	Styrene - Butadiene Rubber
Formaldehyde (two processes)	Terephthalic Acid (1)
Glycerol	Toluene Di-isocyanate (2)
Hydrogen Cyanide	Vinyl Acetate (two processes)
Maleic Anhydride	Vinyl Chloride

(1) Includes dimethyl terephthalate.
(2) Includes methylenediphenyl and polymethylene polyphenyl isocyanates.

The Industry Questionnaire, which was used as the main source of information, was the result of cooperative efforts between the EPA, Air Products and the EPA's Industry Advisory Committee. After receiving approval from the Office of Management and Budget, the questionnaire was sent to selected producers of most of the chemicals listed above. The data obtained from the returned questionnaires formed the basis for what have been named "Survey Reports". These have been separately published in four volumes, numbered EPA-450/3-73-005a, b, c, and d and entitled "Survey Reports on Atmospheric Emissions from the Petrochemical Industry - Volumes I, II, III, and IV.

The purpose of the survey reports was to screen the various petrochemical processes into the "more" and "less - significantly polluting processes". Obviously, significance of pollution is a term which is difficult if not impossible to define because value judgements are involved. Recognizing this difficulty, a quantitative method for Significant Emission Index (SEI) was developed. This procedure is discussed and illustrated in Appendix II of this report. Each survey report includes the calculation of an SEI for the petrochemical that is the subject of the report. These SEI's have been incorporated into the Emission Summary Table that constitutes part of this Appendix (Table I). This table can be used as an aid when establishing priorities in the work required to set standards for emission controls on new stationary sources of air pollution in accordance with the terms of the Clean Air Amendments of 1970.

The completed survey reports constitute a preliminary data bank on each of the processes studied. In addition to the SEI calculation, each report includes a general introductory discussion of the process, a process description (including chemical reactions), a simplified process flow diagram, as well as heat and material balances. More pertinent to the air pollution study, each report lists and discusses the sources of air emissions (including odors and fugitive emissions) and the types of air pollution control equipment employed. In tabular form, each reports summarizes the emission data (amount, composition, temperature, and frequency); the sampling and analytical techniques; stack numbers and dimensions; and emission control device data (types, sizes, capital and operating costs, and efficiencies).

Calculation of efficiency on a pollution control device is not necessarily a simple and straight-forward procedure. Consequently, two rating techniques were developed for each type of device, as follows:

1. For flares, incinerators, and boilers a Completeness of Combustion Rating (CCR) and Significance of Emission Reduction Rating (SERR) were used.

2. For scrubbers and dust removal equipment, a Specific Pollutant Efficiency (SE) and a SERR were used.

The bases for these ratings and example calculations are included in Appendix III of this report.

II. <u>In-Depth Studies</u>

The original performance concept was to select a number of petrochemical processes as "significant polluters", on the basis of data contained in completed questionnaires. These processes were then to be studied "in-depth". However, the overall time schedule was such that the EPA requested an initial selection of three processes on the basis that they would probably turn out to be "significant polluters". The processes selected in this manner were:

1. The Furnace Process for producing Carbon Black.

2. The Sohio Process for producing Acrylonitrile.

3. The Oxychlorination Process for producing 1,2 Dichloroethane (Ethylene Dichloride) from Ethylene.

TABLE I

EMISSIONS SUMMARY

	ESTIMATED (1) CURRENT AIR EMISSIONS, MM LBS./YEAR						
	Hydrocarbons (3)	Particulates (4)	Oxides of Nitrogen	Sulfur Oxides	Carbon Monoxide	Total	Total Weighted (5)
Acetaldehyde via Ethylene	1.1	0	0	0	0	1.1	86
via Ethanol	0	0	0	0	27	27	27
Acetic Acid via Methanol	0	0	0.01	0	0	0.01	1
via Butane	40	0	0.04	0	14	54	3,215
via Acetaldehyde	6.1	0	0	0	1.3	7.4	490
Acetic Anhydride via Acetic Acid	3.1	0	0	0	5.5	8.6	253
Acrylonitrile (9)	183	0	5.5	0	196	385	15,000
Adipic Acid	0	0.2	29.6	0	0.14	30	1,190
Adiponitrile via Butadiene	11.2	4.7	50.5	0	0	66.4	3,200
via Adipic Acid	0	0.5	0.04	0	0	0.54	30
Carbon Black	156	8.1	6.9	21.6	3,870	4,060	17,544
Carbon Disulfide	0.15	0.3	0.1	4.5	0	5.1	120
Cyclohexanone	70	0	0	0	77.5	148	5,700
Dimethyl Terephthalate (+TPA)	91	1.4	0.1	1.0	53	146.5	7,460
Ethylene	15	0.2	0.2	2.0	0.2	17.6	1,240
Ethylene Dichloride via Oxychlorination	95.1	0.4	0	0	21.8	117.3	7,650
via Direct Chlorination	29	0	0	0	0	29	2,300
Ethylene Oxide	85.8	0	0.3	0.1	0	86.2	6,880
Formaldehyde via Silver Catalyst	23.8	0	0	0	107.2	131	1,955
via Iron Oxide Catalyst	25.7	0	0	0	24.9	50.6	2,070
Glycerol via Epichlorohydrin	16	0	0	0	0	16	1,280
Hydrogen Cyanide Direct Process	0.5	0	0.41	0	0	0.91	56
Isocyanates	1.3	0.8	0	0.02	86	88	231
Maleic Anhydride	34	0	0	0	260	294	2,950
Nylon 6	0	1.5	0	0	0	1.5	90
Nylon 6,6	0	5.5	0	0	0	5.5	330
Oxo Process	5.25	0.01	0.07	0	19.5	24.8	440
Phenol	24.3	0	0	0	0	24.3	1,940
Phthalic Anhydride via O-Xylene	0.1	5.1	0.3	2.6	43.6	51.7	422
via Naphthalene	0	1.9	0	0	45	47	160
High Density Polyethylene	79	2.3	0	0	0	81.3	6,400
Low Density Polyethylene	75	1.4	0	0	0	76.4	6,100
Polypropylene	37.5	0.1	0	0	0	37.6	2,950
Polystyrene	20	0.4	0	1.2	0	21.6	1,650
Polyvinyl Chloride	62	12	0	0	0	74	5,700
Styrene	4.3	0.07	0.14	0	0	4.5	355
Styrene-Butadiene Rubber	9.4	1.6	0	0.9	0	12	870
Vinyl Acetate via Acetylene	5.3	0	0	0	0	5.3	425
via Ethylene	0	0	TR	0	0	TR	TR
Vinyl Chloride	17.6	0.6	0	0	0	18.2	1,460
Totals	1,227.6	49.1	94.2	33.9	4,852.6	6,225.9 (7)	110,220 (7)

(1) In most instances numbers are based on less than 100% survey. All based on engineering judgement of best current control. Probably has up to 10% low bias.
(2) Assumes future plants will employ best current control techniques.
(3) Excludes methane, includes H_2S and all volatile organics.
(4) Includes non-volatile organics and inorganics.
(5) Weighting factors used are: hydrocarbons - 80, particulates - 60, NO_x - 40, SO_x - 20, and CO - 1.
(6) Referred to elsewhere in this study as "Significant Emission Index" or "SEI".
(7) Totals are not equal across and down due to rounding.
(9) Emissions based on what is now an obsolete catalyst. See Report No. EPA-450/3-73-006 b for up-to-date information.

TABLE I
EMISSION SUMMARY

	ESTIMATED ADDITIONAL (2) AIR EMISSIONS IN 1980, MM LBS./YEAR						
	Hydrocarbons (3)	Particulates (4)	Oxides of Nitrogen	Sulfur Oxides	Carbon Monoxide	Total	Total Weighted (5,6)
Acetaldehyde via Ethylene	1.2	0	0	0	0	1.2	96
via Ethanol	0	0	0	0	0	0	0
Acetic Acid via Methanol	0	0	0.04	0	0	0.04	2
via Butane	0	0	0	0	0	0	0
via Acetaldehyde	12.2	0	0	0	2.5	14.7	980
Acetic Anhydride via Acetic Acid	0.73	0	0	0	1.42	2.15	60
Acrylonitrile (9)	284	0	8.5	0	304	596	23,000
Adipic Acid	0	0.14	19.3	0	0.09	19.5	779
Adiponitrile via Butadiene	10.5	4.4	47.5	0	0	62.4	3,010
via Adipic Acid	0	0.5	0.04	0	0	0.54	30
Carbon Black	64	3.3	2.8	8.9	1,590	1,670	7,200
Carbon Disulfide	0.06	0.07	0.03	1.1	0	1.24	30
Cyclohexanone	77.2	0	0	0	85.1	162	6,260
Dimethyl Terephthalate (+TPA)	73.8	1.1	0.07	0.84	42.9	118.7	6,040
Ethylene	14.8	0.2	0.2	61.5	0.2	77	2,430
Ethylene Dichloride via Oxychlorination	110	0.5	0	0	25	136	8,800
via Direct Chlorination	34.2	0	0	0	0	34.2	2,740
Ethylene Oxide	32.8	0	0.15	0.05	0	33	2,650
Formaldehyde via Silver Catalyst	14.8	0	0	0	66.7	81.5	1,250
via Iron Oxide Catalyst	17.6	0	0	0	17.0	34.6	1,445
Glycerol via Epichlorohydrin	8.9	0	0	0	0	8.9	700
Hydrogen Cyanide Direct Process	0	0	0	0	0	0	0
Isocyanates	1.2	0.7	0	0.02	85	87	225
Maleic Anhydride	31	0	0	0	241	272	2,720
Nylon 6	0	3.2	0	0	0	3.2	194
Nylon 6,6	0	5.3	0	0	0	5.3	318
Oxo Process	3.86	0.01	0.05	0	14.3	18.2	325
Phenol	21.3	0	0	0	0	21.3	1,704
Phthalic Anhydride via O-Xylene	0.3	13.2	0.8	6.8	113	134	1,100
via Naphthalene	0	0	0	0	0	0	0
High Density Polyethylene	210	6.2	0	0	0	216	17,200
Low Density Polyethylene	262	5	0	0	0	267	21,300
Polypropylene	152	0.5	0	0	0	152.5	12,190
Polystyrene	20	0.34	0	1.13	0	21.47	1,640
Polyvinyl Chloride	53	10	0	0	0	63	4,840
Styrene	3.1	0.05	0.1	0	0	3.25	225
Styrene-Butadiene Rubber	1.85	0.31	0	0.18	0	2.34	170
Vinyl Acetate via Acetylene	4.5	0	0	0	0	4.5	360
via Ethylene	0	0	TR	0	0	TR	TR
Vinyl Chloride	26.3	0.9	0	0	0	27.2	2,170
Totals	1,547.2	55,9	79,5	80.5	2,588	4,351.9	134,213 (7)

(1) In most instances numbers are based on less than 100% survey. All based on engineering judgement of best current control. Probably has up to 10% low bias.
(2) Assumes future plants will employ best current control techniques.
(3) Excludes methane, includes H_2S and all volatile organics.
(4) Includes non-volatile organics and inorganics.
(5) Weighting factors used are: hydrocarbons - 80, particulates - 60, NO_x - 40, SO_x - 40, and CO - 1.
(6) Referred to elsewhere in this study as "Significant Emission Index" or "SEI".
(7) Totals are not equal across and down due to rounding.
(9) See sheet 1 of 3.

TABLE I
EMISSIONS SUMMARY

	Emissions (2), MM Lbs./Year		Estimated Number of New Plants	Total Estimated Capacity MM Lbs./Year	
	Total by 1980	Total Weighted (5) by 1980	(1973 - 1980)	Current	By 1980
Acetaldehyde via Ethylene	2.3	182	6	1,160	2,400
via Ethanol	27	27	0	900	900
Acetic Acid via Methanol	0.05	3	4	400	1,800
via Butane	54	3,235	0	1,020	500
via Acetaldehyde	22	1,470	3	875	2,015
Acetic Anhydride via Acetic Acid	10.8	313	3	1,705	2,100
Acrylonitrile (9)	980	38,000	5	1,165	3,700 (8)
Adipic Acid	50	1,970	7	1,430	2,200
Adiponitrile via Butadiene	128.8	6,210	4	435	845
via Adipic Acid	1.1	60	3	280	550
Carbon Black	5,730	24,740	13	3,000	5,000 (8)
Carbon Disulfide	6.3	150	2	871	1,100
Cyclohexanone	310	11,960	10	1,800	3,600
Dimethyl Terephthalate (+TPA)	265	13,500	8	2,865	5,900
Ethylene	94	3,670	21	22,295	40,000
Ethylene Dichloride via Oxychlorination	253	16,450	8	4,650	8,250 (8)
via Direct Chlorination	63	5,040	10	3,593	11,540
Ethylene Oxide	120	9,530	15	4,191	6,800 (8)
Formaldehyde via Silver Catalyst	212.5	3,205	40	5,914	9,000
via Iron Oxide Catalyst	85	3,515	12	1,729	3,520 (8)
Glycerol via Epichlorohydrin	25	2,000	1	245	380
Hydrogen Cyanide Direct Process	0.5 (10)	28 (10)	0	412	202
Isocyanates	175	456	10	1,088	2,120
Maleic Anhydride	566	5,670	6	359	720
Nylon 6	4.7	284	10	486	1,500
Nylon 6,6	10.8	650	10	1,523	3,000
Oxo Process	43	765	6	1,727	3,000
Phenol	46	3,640	11	2,363	4,200
Phthalic Anhydride via O-Xylene	186	1,522	4	720	1,800 (8)
via Naphthalene	47	160	0	603	528
High Density Polyethylene	297	23,600	31	2,315	8,500
Low Density Polyethylene	343	27,400	41	5,269	21,100
Polypropylene	190	15,140	32	1,160	5,800
Polystyrene	43	3,290	23	3,500	6,700
Polyvinyl Chloride	137	10,540	25	4,375	8,000
Styrene	7.4	610	9	5,953	10,000
Styrene-Butadiene Rubber	14	1,040	4	4,464	5,230
Vinyl Acetate via Acetylene	9.8	785	1	206	356
via Ethylene	TR	TR	4	1,280	2,200
Vinyl Chloride	45	3,630	10	5,400	13,000
Totals	10,605 (7)	244,480 (7)			

(1) In most instances numbers are based on less than 100% survey. All based on engineering judgement of best current control. Probably has up to 10% low bias.
(2) Assumes future plants will employ best current control techniques.
(3) Excludes methane, includes H_2S and all volatile organics.
(4) Includes non-volatile organics and inorganics.
(5) Weighting factors used are: hydrocarbons - 80, particulates - 60, NO_x - 40, SO_x - 20, and CO - 1.
(6) Referred to elsewhere in this study as "Significant Emission Index" or "SEI".
(7) Totals are not equal across and down due to rounding.
(8) By 1985.
(9) See sheet 1 of 3
(10) Due to anticipated future shut down of marginal plants.

In order to obtain data on these processes, the operators and/or licensors of each were approached directly by Air Products' personnel. This, of course, was a slow and tedious method of data collection because mass mailing techniques could not be used, nor could the request for data be identified as an "Official EPA Requirement". Yet, by the time that OMB approval was given for use of the Industry Questionnaire, a substantial volume of data pertaining to each process had already been received. The value of this procedure is indicated by the fact that first drafts of thes three reports had already been submitted to the EPA, and reviewed by the Industry Advisory Committee, prior to the completion of many of the survey reports.

In addition, because of timing requirements, the EPA decided that four additional chemicals be "nominated" for in-depth study. These were phthalic anhydride, formaldehyde, ethylene oxide and high density polyethylene. Consequently, five additional in-depth studies were undertaken, as follows:

1. Air Oxidation of Ortho-Xylene to produce Phthalic Anhydride.

2. Air Oxidation of Methanol in a Methanol Rich Process to produce Formaldehyde over a Sliver Catalyst. (Also, the subject of a survey report.)

3. Air Oxidation of Methanol in a Methanol-Lean Process to produce Formaldehyde over an Iron Oxide Catalyst.

4. Direct Oxidation of Ethylene to produce Ethylene Oxide.

5. Low pressure catalytic polymerization of Ethylene.

The primary data source for these was the Industry Questionnaire, although SEI rankings had not been completed by the time the choices were made.

In addition separate "In-Depth" studies were made on Polyvinyl Chloride (PVC) and Vinyl Chloride Monomer (VCM) using data obtained from a separate survey made in the summer of 1974.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-450/3-73-006-i	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Engineering and Cost Study of Air Pollution Control for the Petrochemical Industry, Volume 9: Polyvinyl Chloride Manufacture		5. REPORT DATE July 1975 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) R. G. Bellamy, W. A. Schwartz		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Houdry Division/Air Products and Chemicals, Inc. P. O. Box 427 Marcus Hook, Pennsylvania 19061		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. 68-02-0255
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Air Quality Planning & Standards Industrial Studies Branch Research Triangle Park, N.C. 27711		13. TYPE OF REPORT AND PERIOD COVERED Final Report 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This document is one of a series prepared for the Environmental Protection Agency (EPA) to assist it in determining those petrochemical processes for which standards should be promulgated. A total of nine petrochemicals produced by twelve distinctly different processes has been selected for this type of in-depth study. Ten volumes, entitled Engineering and Cost Study of Air Pollution Control for the Petrochemical Industry (EPA-450/3-73-006a through j) have been prepared.

A combination of expert knowledge and an industry survey was used to select these processes. The industry survey has been published separately in a series of four volumes entitled Survey Reports on Atmospheric Emissions from the Petrochemical Industry (EPA-450/3-73-005a, b, c, and d).

This volume covers the manufacture of polyvinyl chloride. Included is a process and industry description, an engineering description of available emission control systems and the cost of these systems.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Polyvinyl Chloride Vinyl Chloride Chlorohydrocarbons	Petrochemical Industry Polymer Manufacture	7A 7B 7C 11G 13B 13H

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

UCC
026163

INSTRUCTIONS

1. **REPORT NUMBER**
   Insert the EPA report number as it appears on the cover of the publication.

2. **LEAVE BLANK**

3. **RECIPIENTS ACCESSION NUMBER**
   Reserved for use by each report recipient.

4. **TITLE AND SUBTITLE**
   Title should indicate clearly and briefly the subject coverage of the report, and be displayed prominently. Set subtitle, if used, in smaller type or otherwise subordinate it to main title. When a report is prepared in more than one volume, repeat the primary title, add volume number and include subtitle for the specific title.

5. **REPORT DATE**
   Each report shall carry a date indicating at least month and year. Indicate the basis on which it was selected *(e.g., date of issue, date of approval, date of preparation, etc.)*.

6. **PERFORMING ORGANIZATION CODE**
   Leave blank.

7. **AUTHOR(S)**
   Give name(s) in conventional order *(John R. Doe, J. Robert Doe, etc.)*. List author's affiliation if it differs from the performing organization.

8. **PERFORMING ORGANIZATION REPORT NUMBER**
   Insert if performing organization wishes to assign this number.

9. **PERFORMING ORGANIZATION NAME AND ADDRESS**
   Give name, street, city, state, and ZIP code. List no more than two levels of an organizational hirearchy.

10. **PROGRAM ELEMENT NUMBER**
    Use the program element number under which the report was prepared. Subordinate numbers may be included in parentheses.

11. **CONTRACT/GRANT NUMBER**
    Insert contract or grant number under which report was prepared.

12. **SPONSORING AGENCY NAME AND ADDRESS**
    Include ZIP code.

13. **TYPE OF REPORT AND PERIOD COVERED**
    Indicate interim final, etc., and if applicable, dates covered.

14. **SPONSORING AGENCY CODE**
    Leave blank.

15. **SUPPLEMENTARY NOTES**
    Enter information not included elsewhere but useful, such as: Prepared in cooperation with, Translation of, Presented at conference of, To be published in, Supersedes, Supplements, etc.

16. **ABSTRACT**
    Include a brief *(200 words or less)* factual summary of the most significant information contained in the report. If the report contains a significant bibliography or literature survey, mention it here.

17. **KEY WORDS AND DOCUMENT ANALYSIS**
    (a) DESCRIPTORS - Select from the Thesaurus of Engineering and Scientific Terms the proper authorized terms that identify the major concept of the research and are sufficiently specific and precise to be used as index entries for cataloging.

    (b) IDENTIFIERS AND OPEN-ENDED TERMS - Use identifiers for project names, code names, equipment designators, etc. Use open-ended terms written in descriptor form for those subjects for which no descriptor exists.

    (c) COSATI FIELD GROUP - Field and group assignments are to be taken from the 1965 COSATI Subject Category List. Since the majority of documents are multidisciplinary in nature, the Primary Field/Group assignment(s) will be specific discipline, area of human endeavor, or type of physical object. The application(s) will be cross-referenced with secondary Field/Group assignments that will follow the primary posting(s).

18. **DISTRIBUTION STATEMENT**
    Denote releasability to the public or limitation for reasons other than security for example "Release Unlimited." Cite any availability to the public, with address and price.

19. & 20. **SECURITY CLASSIFICATION**
    DO NOT submit classified reports to the National Technical Information service.

21. **NUMBER OF PAGES**
    Insert the total number of pages, including this one and unnumbered pages, but exclude distribution list, if any.

22. **PRICE**
    Insert the price set by the National Technical Information Service or the Government Printing Office, if known.

ENVIRONMENTAL PROTECTION AGENCY
Technical Publications Branch
Office of Administration
Research Triangle Park, North Carolina 27711

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
ENVIRONMENTAL PROTECTION AGENCY
EPA - 335

UCC
026165

Return this sheet if you do NOT wish to receive this material , or if change of address is needed ☐. (Indicate change, including ZIP code.)

PUBLICATION NO. EPA-450/3-73-006-i