most important starting materials of the plastics industry.

(1) Process Descriptions[1,2,3,5,6,7]

Vinyl chloride is presently produced by 10 companies in 15 plants in the United States (including Puerto Rico),as shown in Table 1. Until the late 1950's, VC was generally produced from acetylene and hydrogen chloride. Since that time, the process involving oxychlorination of ethylene has increasingly replaced the acetylene route in this country, so that presently 13 plants with almost 92 percent of the capacity are using the ethylene route.

Acetylene Route - In this process, vinyl chloride is produced by the catalytic hydrochlorination of acetylene, usually with mercuric chloride as the catalyst. The acetylene and the hydrogen chloride are first passed through a drying tower and then mixed in a chamber packed with activated charcoal. This mixture is then passed through several hundred vertical tubes in which the catalyst is packed. The temperature of these tubes is controlled to ranges which permit the reaction to take place. The product gases are then purified to vinyl chloride by water and alkaline scrubbing, drying, and finally fractional distillation using decreased pressure and permitting the VC to boil. Most of the variations in this process arise from the use of different catalysts or mixtures of catalysts. Use of this route in the United States has been decreasing due to the greater efficiency of large scale plants using the oxychlorination process.

Table 1

Vinyl Chloride Monomer Producers

Company	Location	Nominal Capacity (MM lb.)	Process
Allied Chemical Corporation	Baton Rouge, La.	300	Direct and oxychlorination
American Chemical, Inc.	Watson, Calif.	170	" "
B. F. Goodrich Chemical Company	Calvert City, Ky.	1,000	" "
Continental Oil Company	Lake Charles, La.	625	" "
Dow Chemical Company	Freeport, Texas	180	Direct chlorination
	Oyster Creek, Texas	700	" "
	Plaquemine, La.	340	" "
Ethyl Corporation	Baton Rouge, La.	270	Direct and oxychlorination
	Houston, Texas	150	" "
Monochem, Inc.	Geismar, La.	350	Acetylene
PPG Industries	Lake Charles, La.	300	Direct and oxychlorination
	Guayanilla, P. R.	500	" "
Shell Chemical Co.	Deer Park, Texas	1,200	" "
	Norco, La.	1,000	" "
Tenneco Chemicals, Inc.	Houston, Texas	255	Acetylene
		7,340	

Sources: See Bibliography, references 1, 2, 3, 4.

Ethylene Route - Ethylene can be directly chlorinated to produce vinyl chloride; however, difficulties with that technique have led to VC production from ethylene through the intermediate formation of 1,2-dichloroethane (also called ethylene dichloride). Several plants in the United States, Japan, and Europe use this process, also known as the oxychlorination process. There are several variations of this process which have demonstrated commercial feasibility. Differences among these generally arise in the amount of recycling or in materials used as catalysts. The basic steps involve combining chlorine with ethylene to form ethylene dichloride (EDC), oxyhydrochlorinating ethylene to form EDC, and pyrolyzing EDC to form vinyl chloride and hydrogen chloride.

The EDC thus comes from two sources: chlorine combined with ethylene in a liquid phase reaction with a dissolved catalyst, and ethylene combined with hydrogen chloride and oxygen in a vapor phase reaction with a catalyst. The crude EDC from these two units is combined with EDC recycled from the cracking unit and is then purified by distillation. The second major operation involves thermal cracking in the presence of a catalyst to form vinyl chloride and anhydrous hydrogen chloride from the EDC. The resultant effluent is then separated by fractionation into vinyl chloride. Hydrogen chloride is passed back to the oxychlorination unit, and unreacted EDC is recycled.

(2) Worker Exposure[3, 8, 9, 10, 11]

Vinyl chloride is produced in outdoor plants, and hence the build-up of vinyl chloride in any area is less than what is observed at locations in subsequent processing involving the

monomer or polymer. The job categories of workers at VC production plants are shown in Table 2. No data is currently available to show how many people nationwide are employed in these plants in each category. At the OSHA hearing on February 15, 1974, the Manufacturing Chemists Association estimated that 1,500 people are employed in monomer production. However, information presented by PPG Industries and the Shell Chemical Company gives a substantially different picture. PPG indicated that it employs between 2 and 4 workers per million tons of stated capacity at its plants, while Shell indicated between 26 and 40 workers per million tons of stated capacity at its plants. The difference between the two probably indicates that each type of process (and perhaps each plant) differs in the number and type of workers required.

An estimate of the number of workers of each type is necessary for any characterisation of the total hazard, since data presented to OSHA and at the public hearing indicate different peak and time-weighted-average concentrations for different categories. The major sources of exposure during normal exposure are judged to be:

- o Sampling and analysis of vinyl chloride for quality control;
- o Loading of vinyl chloride for shipping;
- o Entry of vinyl chloride containing vessels for maintenance and repair work; and
- o Leaks of vinyl chloride in the process area.

Table 2

Job Categories of Workers

Vinyl Chloride Plants

Control Operator	Material Controller
Distillation Operator	Millwright
EDC Operator	OXY Operator
Electrician	Pipefitter
Instrument Technician	Quality Control Specialist
Laboratory Technician	Sample Man
Laborer	Shift Supervisor
Loading Operator	Tank Farm Operator
Maintenance Worker	VCM Operator

Some sampling data indicate peak concentrations over 200 ppm for laboratory technicians, over 150 ppm for loading operators, and near 50 ppm for quality control specialists. Time-weighted averages are generally well below 50 ppm. Since no information in sampling time and method or analytical method are given, the data cannot be used to estimate the worker's exposure to VC.

2. Production of Vinyl Chloride Polymer and Copolymer Resins

Virtually all vinyl chloride produced in the United States is used to manufacture vinyl chlorida homopolymers and vinyl chloride copolymerized with such monomers as vinyl acetate, vinylidene chloride, and acrylates. Generically, these homopolymers and copolymers are known as polyvinyl chloride (PVC) resins. They are generally in the form of powders, which, after compounding with a variety of additives, are processed in several ways to produce a large variety of plastic or resinous end products. The resins are produced by 22 companies in 36 plants in the United States, as shown in Table 3, which also indicates the capacity of each plant. As indicated in the references, this list is current to mid-1972; changes in company ownership, additional plant openings, and increased capacities are likely to have occurred since that time.

Most commercial resins have molecular weights between 30,000 and 120,000, the weight being a determinant of the resin's processing and performance characteristics. These characteristics are also affected by the specific additives with which the resins are compounded. Since theoretical results do not definitively indicate

Table 3

Vinyl Chloride Polymer and Copolymer Resin Producers

[illegible]	[illegible]	Nameplate Capacity [illegible]
Air Products & Chemicals, Inc.	Calvert City, Ky.	120
	Pensacola, Fla.	50
American Chemical Corporation	Long Beach, Calif.	125
B. F. Goodrich Chemical Co.	Avon Lake, Ohio	125
	Henry, Ill.	125
	Long Beach, Calif.	125
	Louisville, Ky.	275
	Pedricktown, N.J.	130
Borden, Inc.	Illiopolis, Ill.	285
	Leominster, Mass.	285
Continental Oil Co.	Aberdeen, Miss.	220
	Oklahoma City, Okla.	80
Diamond Shamrock Corporation	Delaware City, Del.	250
	Deer Park, Texas	250
Ethyl Corporation	Baton Rouge, La.	180
Firestone Tire & Rubber Co.	Perryville, Md.	130
	Pottstown, Pa.	140
General Tire & Rubber Co.	Ashtabula, Ohio	100
Goodyear Tire & Rubber Co.	Niagara Falls, N.Y.	100
	Plaquemine, La.	100
Great American Chemical Corp.	Fitchburg, Mass.	40
Hooker Chemical Corporation	Burlington, N.J.	180
	Hicksville, N.Y.	10
Keysor Century Corporation	Saugus, Calif.	35
Monsanto Company	Springfield, Mass.	150
National Starch & Chemical Corp.	Meredosia, Ill.	10
Pantasote Company	Passaic, N.J.	120
	Point Pleasant, W. Va.	120

Table 3 (cont'd)

Vinyl Chloride Polymer and Copolymer Resin Producers

Company	Location	Nameplate Capacity (MM Lbs.)
Robintech, Inc.	Painsville, Ohio	220
Stauffer Chemical Company	Delaware City, Del.	160
Tenneco Chemicals, Inc.	Burlington, N.J.	165
	Flemington, N.J.	60
Thompson Plastics Company	Assonet, Mass.	150
Union Carbide Corporation	South Charleston, W. Va.	120
	Texas City, Texas	200
Uniroyal, Inc.	Painsville, Ohio	140

Sources: See bibliography references 2, 12, 13, 14.

what mixtures will give rise to what properties, formulation and processing is largely a matter of experience.

Four basic processes are employed in polymerization or copolymerization: bulk, suspension, emulsion, and solution polymerization. The bulk process is a dry process requiring no water, suspanding agents, or emulsifiers; the other three processes require water, solvents, or other liquids, but they are similar enough that they can be used in the same equipment. Polymerization of monomers is initiated by free radicals produced from peroxides, azo compounds, and persulfates by thermal decomposition. The rate of polymerization and the molecular weight distribution of the resin are largely determined by the temperature of the reaction and the concentration of initiators.

(1) Process Descriptions [1,12,13,15]

In the United States, approximately 78 percent of PVC resins is produced by suspension polymerization, 13 percent by solution polymerization, 6 percent by bulk polymerization, and 3 percent by solution polymerization. The bulk polymerization process is relatively new and has been taking an increasing proportion of the production of PVC resins in recent years.

Suspension Polymerization - This process is essentially a batch process generally carried out in glass-lined reactors having a capacity of 2,000-6,000 U.S. gallons. Monomer soluable initiators, such as lauroyl, decanoyl, and benzoyl peroxides are

dissolved in liquid monomer dispersed in water to form a suspension. The reactor is first charged with the required amount of deionized water. Then the dispersant, a buffer, and the initiator are added. Oxygen is then evacuated from the reactor, and the vinyl chloride and any comonomer are fed in. Agitation (to increase the degree of dispersion) is begun, and the contents of the reactor are brought up to the polymerization temperature (45-60°C). When the polymerization has been completed (after 10 to 16 hours), the contents of the reactor are dumped into a large vessel where excess vinyl chloride is recovered for distillation and reuse. The PVC slurry is then blended in another vessel with other batches to reduce small variations, and dewatered by a superdecanter or continuous centrifuge to yield a polymer cake containing about 20 percent moisture. The polymer is then dried in a flash dryer, and the polymer particles are separated by passage through a cyclone separator, from which it is screened and sent to storage.

Emulsion Polymerization - This process is very similar to the suspension process, and is used primarily to produce very fine particles. There are two primary differences: (1) Usually two emulsifying agents, one soluble in water and one in the monomer, are used to prevent the coalescence of polymer particles; and (2) the polymer is separated from the water by spray drying. Even though this process is more costly, it is important to users who need PVC in liquid form. This type of polymer has the ability to form a paste when combined with a plasticizer. In some cases, the slurry is not dried, instead it is used subsequently in the latex form.

Bulk Polymerization - In this process, vinyl chloride is polymerized without the addition of other liquids in the presence of a free-radical initiator. The resulting polymer is insoluble in the monomer, and the rate of polymerization increases with increasing conversion. This acceleration can be induced by the addition of preformed polymer. For this reason, a portion of a day's supply of monomer is pumped into a prepolymerizer, a stainless-steel clad vessel. The reaction products from this stage serve as seed for the polymerization continued in a second step. The mixture from the prepolymerizer, together with an equal amount of fresh monomer, are transferred into an autoclave equipped with slowly rotating agitator blades, where the reaction is induced by high pressures. The reaction medium is essentially powdery. After the monomer has been converted, unreacted monomer is removed by a vacuum and recovered in a recycle condenser. The resin is transferred to a resin receiver, and fines are collected in a dust separator and removed through a manhole. The output of bulk processing plants is said to be more than twice that of good suspension plants of comparable size. This factor will probably lead to a greater use of bulk polymerization during ensuring years.

Solution Polymerization - This process is used exclusively for the production of copolymers of vinyl chloride with vinyl acetate. The mixed monomers are dissolved in an organic solvent in a stirred autoclave heated to 40°C. The reaction in the autoclave has the same autocatalytic characteristic as that occurring in bulk

polymerization. In this case, however, the phase separation, arising from the formation of a concentrated polymer base, leads to a decrease in the rate of polymerization. The contents of the autoclave are passed through a filter press to retain the polymer, and the filtrate is recycled. The filtered polymer (in the filter press) is then washed, during which a certain amount of unpolymerized vinyl chloride is recovered by fractional distillation.

(2) Worker Exposure [8, 9, 16]

The total number of workers engaged in all aspects of the production of PVC resins has been estimated as 5,000. The validity of this figure is suspect, since an industrial hygiene survey conducted in 1969 examined over 5,000 workers at a time when PVC production was approximately half of the current level. A small proportion of those workers were engaged in operations other than resin production; in addition, the productivity of these workers has probably increased substantially since 1969 in view of significant technological changes, such as the introduction of the bulk polymerization process. Therefore, the number of workers has probably increased substantially beyond 5,000, but in all likelihood is still significantly less than 10,000. Some of the job classifications of workers involved in resin production with potential exposure to VC are shown in Table 4. Since no estimates of the personnel distribution in these categories is available, and since exposure varies according to job category, no estimate of the total industry exposure to vinyl chloride can be made.

Table 4

Job Categories of Workers

Production of PVC Resins

Bagging and shipping operator	Monomer recovery operator
Catalyst makeup man	Monomer supervisor
Dryer operator	Polymer supervisor
General laborer, custodial	Reactor cleaner
Laboratory technician	Reactor operator
Maintenance personnel	Slurry blender
Monomer maintenance personnel	Utilities operator
Monomer operator	Warehouse personnel

Very little information is available as to the level of exposure faced by different workers. The industrial hygiene survey mentioned above performed no air analyses. However, the information available does tend to indicate that exposure to VC is greater in resin producing plants than in those synthesizing the monomer. The areas of greatest exposure in a PVC plant are judged to be the following:

- o Unloading of incoming vinyl chloride;
- o Reactor cleaning;
- o Entry of vinyl chloride containing vessels for maintenance and repair work;
- o Entry of PVC storage silos;
- o Shipping or packaging of PVC; and
- o Leaks of vinyl chloride in the process area.

No definitive measurements have been made to ascertain the relative exposure in these areas. From the little data available, it appears that reactor cleaners are likely to have the greatest exposure. Operators of the polymerization process equipment, those involved in unloading or transferring the monomer, and maintenance personnel, respectively, have successively lower exposures to VC. Other personnel are likely to be exposed to much lower levels.

Reactor cleaning poses a special hazard. During the reaction, the polymer, with entrapped monomer, builds up on the surface of the reactor, so that cleaning after several batches is usually required. In the past, most of this cleaning was performed by hand

using a scraper and chisel. Air analyses have shown that VC concentrations in the reactor prior to ventilation reach 3,000 ppm. After ventilation has been completed and the worker begins the scraping, concentrations between 50 and 100 ppm may easily be released in the scraping. Air analyses have shown concentrations of 600 to 1,000 ppm of VC close to the hand. Since these studies were completed, the industry has moved to greater use of water-jet or organic-solvent cleaning. The status of the exposure levels when the reactor is opened for cleaning is not known.

3. Compounding of PVC Resins with Additives [1, 12, 15, 17]

In most applications PVC is used with one or more specific additives to enable processing and converting the compound into final products. The additives which are used depend on the initial form of the resin, the type of processing to be used, and the desired application. Resins are classified as general purpose (made by any of the techniques described in the previous section) and dispersion (made primarily by emulsion polymerization). With the addition of a plasticizer, the general purpose resins are further classified into plasticized resins and unplasticized, or rigid, resins. The dispersion resins, or latexes, may also be plasticized for ultimate use as plastisols or organosols, or they may be chlorinated for ultimate processing similar to that used on general purpose resins. To these basic resins, other additives may be compounded according to particular requirements. These

additives are usually categorized as follows:

- o Plasticizers, to increase resin flexibility, softness, and elongation, and in some cases, to extend the basic resin;
- o Heat stabilizers, to prevent discoloration during the processing of resin compounds;
- o Fillers, essentially to reduce costs, but sometimes to produce opacity, specific electrical properties, resistance to ultraviolet light, resistance to blocking, improved dryblending properties, and other properties;
- o Pigments and dyes, to color PVC resin compounds;
- o Processing aids, to facilitate the achievement of certain processing objectives, such as increased processing rates, lower processing temperatures, improved fusion, and reduced surface gloss;
- o Impact modifiers, for rigid resins, to protect against brittle fracture;
- o Lubricants, to reduce friction of melts with the surfaces of processing machinery and molds;
- o Light stabilizers, to prevent PVC degradation from continuous exposure to sunlight;
- o Fungicides, to inhibit the vulnerability of compounded PVC to attack by microorganisms;

- o Flame retardants, to preserve the nonflammability of PVC introduced by the use of flammable plasticizers;
- o Antistatic agents, to improve electrical conductivity;
- o Antioxidants, to provide protection in high-temperature applications; and
- o Foaming agents, to influence cell structure for resins expanded into foams.

Compounding of these additives with PVC resins may take place in a plant producing the basic resin, in a plant designed for the purpose of compounding alone, or in a plant which also processes the compounded resins. Trade publications identify approximately 200 companies supplying chlorinated, plasticized, or rigid PVC or copolymer resins. The accuracy and completeness of these listings cannot be appraised at this time.

The purpose of the compounding stage is to ensure that the additives are fully dispersed in the PVC resins to yield a homogeneous material suitable for further processing. The compound may be in powder or granular form. The latter can be obtained only by heating which converts the compound into granules or pellets. The granulated compound is used as the feedstock for subsequent extrusion and molding processes. The powder

blends can be fed directly into fabrication equipment so that the PVC resin needs to be heated only once and thus requires fewer additives.

(1) Process Descriptions

A wide variety of compounding equipment is currently available; the majority of such equipment accepts the resin and the various additives in dry form. Frequently, the resin is premixed with several additives before being used in processing the compounded PVC. The order in which specific compounding equipment is used depends on the requirements that the PVC must meet.

Two-Roll Mill - The material is fed in the form of a powder blend to two rolls separated by a small gap in which it is kneaded at a temperature of 150-160°C and stripped off as a continuous band after about 10 minutes. The strip of material is then granulated into small cubes suitable for use in an extruder.

Banbury Mixer - The mixer consists of a jacketed mixing chamber fitted with rotors rotating in opposite directions. Material is mixed in batches under pressure and heat to produce a fully fused and kneaded mixture. This mixture is discharged in a doughlike mass which must be converted into sheet form for

granulation. The material is fed into a two-roll mill for this purpose. The use of Banbury mixers may lead to significant variation between batches. This variation is reduced in some cases by the use of automatic weighing and feeding systems for injection of the various materials to be mixed.

Continuous Mixers - This type of mixing is designed to increase consistency between batches by providing a continuous feed operation. These mixers require greater care to ensure that a homogeneous mixture is obtained. The types of equipment used are basically single or twin-screw extruders, modified to increase the working of the material. The compound may be heated, fed directly to calenders, extruded through a die plate for granulation, or extruded through a die with a die-face cutter for granulation.

Multiscrew Compounders - Since a twin-screw extruder is suitable for PVC compounding, this type of equipment has been adapted. The primary variation from extruders is the development of screw sections and kneading discs which can be changed to meet the specific requirements of the material being compounded.

High-Speed Mixers - Injection molding and extrusion equipment has been modified to accept PVC powder blends. To

ensure satisfactory processing, the blends are mixed in a high-speed mixer in which heat is generated by friction. The production of the proper blends must be carried out very carefully using this type of equipment.

Wet Granulation - In this process, the PVC is used directly from the polymerizer while still in an aqueous dispersion. The additives are first introduced into the granulating vessel. The plasticizer, along with some of the stabilizer and lubricants, however, is mixed separately and then fed into the granulator. Finally, the compounded resin particles are rapidly plasticized, and the compound is produced in the form of granules which are easily separated from the suspension. This process is limited to polymer manufacture, since it is not economically feasible to redisperse the polymer once it has been dried out.

Mixing of Plastisols - PVC pastes can be produced using paddle-type mixers, such as the vertical paddle mixer, the vertical planetary mixer, or the horizonal Z-blade mixer. These mixers can be operated under a vacuum. The PVC resin is introduced into the mixer along with sufficient plasticizer to form a paste. Other ingredients are then incorporated slowly and at low temperatures until a smooth homogeneous paste is obtained.

(2) Worker Exposure

The PVC resin and the compounds involved in the processing at this stage contain residual amounts of vinyl chloride in concentrations which may be as high as 3,000 ppm. The basic resin,

if stored for some time in bags or drums, will release an amount of the monomer inside the container which would be released to the air upon the opening of the container. During the compounding, the mixing operations may cause an additional release of the monomer entrained in the polymer. The extent to which the monomer escapes has not been adequately studied, since a significant problem was not known to be present. Some initial environmental studies have shown levels in the workroom air to be below 1 ppm; however, levels inside certain types of mixers have been measured at 460 ppm. These studies do not conclusively establish that workers engaged in compounding are not exposed to concentrations in excess of 1 ppm. No studies have as yet been made to determine the relationship between the concentration in the workplace air and the residual vinyl chloride in the PVC resin or compound.

The numbers and types of workers exposed to vinyl chloride during these compounding operations are not known. It is assumed that the greatest concentrations of vinyl chloride are present in storage rooms where the PVC resins are kept prior to processing. However, industrial hygiene studies have not yet been conducted to determine where the greatest concentrations are to be found.

4. Fabrication of End Products from PVC Compounds[1, 12, 15]

The popularity of polyvinyl chloride arises from its adaptability to many types of processing for the production of a

wide variety of products. These processes have not been developed specifically for PVC, and so, equipment may possibly be employed with a variety of plastics compounds. The importance of PVC lies in the ease with which it is processed and the characteristics of the final products. Through processing, PVC resins are converted after all additives have been introduced into products which are subjected to no further chemical processing. The products of this stage may be final products (such as pipes), components of other equipment (such as wires), or materials for other industries (such as films and sheets for packaging). Thus, products made at this stage may be subjected to further processing, but such products would no longer be designated as PVC. The number of firms engaged in this type of processing is not known, but has been estimated to be between 4,000 and 20,000, ranging in size from a few people with simple equipment to large plants involving many people.

(1) Process Descriptions

PVC compound processing in this stage is marked by heating the compound and subjecting it to pressure in order to put it into the desired form. The types of equipment and the temperature used for these processes depend on the form and the characteristics of the raw material. Thus, for example, plasticized compounds can be processed more easily than rigid compounds, since it is possible to use temperatures between 140 and 160°C rather than between 185 and 190°C.

Extrusion - Both plasticized and rigid PVC formulations can be extruded into a variety of shapes. The compound is generally processed from either powder blends or granulated material using single or twin-screw extruders. Determination of the temperatures and other characteristics such as rate at which the extrusion is carried out can only be accomplished by careful experimentation. Extrusion performance depends quite significantly on the additives, particularly lubricants, combined with the PVC resin. Extrusion is used primarily to produce wire and cable insulation, rigid pipe and tubing, blown film, and unplasticized PVC sheet.

Injection Molding - Generally, low-molecular-weight PVC resins in the form of granular or powder blends may be used in screw-type injection molding machines. The rotation of the screw produces a homogeneous melt which is then injected into a mold at high pressures.

Blow Molding - This process is generally limited to the production of bottles, mostly from powder blends but with some use of granular compounds. Most of the equipment used in this process forms a parison, a partially formed mass of material still in plastic form, by continuous extrusion or by the use of a reciprocating-screw system. The parison is then blown into the proper mold.

Compression Molding - This technique is used primarily for processing rigid PVC compounds into phonographic records. Usually,

a copolymer of vinyl chloride and vinyl acetate is used to produce a low-viscosity melt. This melt is mixed and fused, passed to a two-roll mill from which it is stripped, and then compression molded in a record press at high pressure. The initial compound can also be in pellet form from which a premeasured molten extrudate is pressed in a mold. This technique is also the only method used to manufacture thick, high-quality, rigid sheet.

Calendering - This technique is used extensively for the production of flexible and rigid PVC film and sheeting. It is usually used in conjunction with the mixing of additives rather than as a separate stage in processing PVC. Pellets or powder are fed directly to the hot rolls of the calender. The resulting molten material is carried through finishing rolls to produce rigid sheets or material laminated to a substrate.

Plastisol Processing (Coating) - In this processing, a PVC paste resin is coated on various substrates such as fabrics, sheet steel, and paper. Several types of equipment may be used to accomplish the coating. The paste resin is generally fed to a device which applies the PVC to the substrate, either one or several times to achieve the desired thickness. The material is then passed through a heating oven to produce complete fusion of the PVC.

Plastisol Processing (Molding Methods) - Several methods may be employed to mold a PVC paste resin into a desired shape. A measured amount of paste may be charged into a mold. The mold is rotated to cause the resin to gravitate to its walls where it is fused to form a uniform thickness. The paste resin may also be poured into a mold where it is fused. Low-pressure injection molding is also used to produce PVC shoe soles.

Foams - Flexible or rigid PVC foams can be produced by subjecting PVC resin converted into a plastisol to mechanical or chemical blowing. The plastisol is mixed with an inert gas or air which is then fed through spray nozzles under carefully controlled conditions to produce a slowly expanding foam. The plastisol is whisked and the resulting froth is stabilized. Either of these mixtures is then subjected to heat while being calendered, extruded or molded so that it is fused in the desired form.

(2) Worker Exposure

The numbers and types of workers exposed to vinyl chloride in this fabricating stage are not known. The extent to which vinyl chloride is released from the raw materials used is also not known, although it would seem that the amount released would depend on the amount of the residuum still present in PVC compounds. The products fabricated in this stage also contain some amounts of vinyl chloride, but the rate of migration is deemed to be sufficiently small so that no detectable amount is present in workroom

air. Further studies must be conducted to determine the extent to which workers in fabricating plants are exposed to vinyl chloride.

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V. THE PROPOSED STANDARD

In response to the health hazards of vinyl chloride that have recently become known, the Occupational Safety and Health Administration has developed a proposed standard (Appendix B). This chapter briefly describes the provisions of the proposed standard.

Applicability of Proposed Standard

The proposal applies to any company manufacturing or using vinyl chloride or polyvinyl chloride which releases detectable amounts of vinyl chloride. Detectable levels are defined as those measurable by a method capable of detecting 1 ppm with an accuracy of ± 50 percent.

Raw polyvinyl chloride resin and the many compounds made from this resin specifically for molding, calendering extrusion, or other similar processes are considered to have the potential for releasing detectable levels of vinyl chloride. If the PVC compounded resin contains a large proportion of unreacted monomer, its handling and heating will release some part of that monomer.

Operations handling fabricated products made from polyvinyl chloride, entirely or in parts are specifically exluded from the standard, since the release of monomer from such products has not been demonstrated. The proposed standard specifies that fabricated products include such items as film, sheet, block, bar, and extrusion stock.