Occupational Acroosteolysis

II. An Industrial Hygiene Study

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An industrial hygiene survey was conducted in respect to occupational acroosteolysis (AOL) in 32 plants engaged in production and compounding of polyvinyl chloride. This survey was limited to inspection of facilities, interrogation of technical personnel, and statistical analyses. All manufacturing processes and chemicals utilized were explored. A major objective was the identification of variables in processes and chemicals that were peculiar to those plants affording known cases of AOL. No such processes or chemicals were found. The survey brought to light a number of situations suspected of relationship to the precise cause of AOL, some of which require additional exploration. Most positive of these was the finding that essentially all of the persons who developed AOL had served as reactor cleaners using manual methods.

POLYVINYL chloride (PVC) has been in production and widespread use for more than 30 years. An extensive account of the chemistry, methods of production, materials utilized, properties, and uses of the PVC resins was recently published in a series of technical articles by Albright.[1-5] Uses include such diverse products as floor tiles, films for food wrappings, sheeting for shower curtains, phonographic records, and coatings for cables.

As an indication of the magnitude of the PVC industry, the average operating capacity in this country for the year 1969 was about 3 billion lb.[6] Much PVC is produced in other countries. Even with this extensive production involving thousands of operators, the occurrence of occupational acroosteolysis (AOL) among these workers was not recognized until about 1961.[7]

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The clinical and epidemiological aspects of this condition are discussed in separate papers in this issue of the ARCHIVES.[8,9]

Industrial Hygiene Survey

Surveys were made of 32 plants by the authors of this paper, most of the plants being visited by a team of one physician and one industrial hygienist. Twenty-six of these were polymer production plants. Vinyl chloride monomer production plants and plants engaged in compounding and fabricating of the polymerized resin were a part of the manufacturing complex at a number of these locations. Five plants conducted compounding and fabricating operations only, and one plant produced only the vinyl chloride monomer. These plants were located throughout the United States and one in Canada.

This survey was designed to obtain information on equipment used, procedures followed, materials involved, extent of exposure to these, and names and descriptions of jobs in order to compare practices in the plants where cases of AOL occurred with those in plants experiencing no cases.

The extent of exposures was estimated on the basis of general observation, a knowledge of the physical, chemical, and physiological prop-

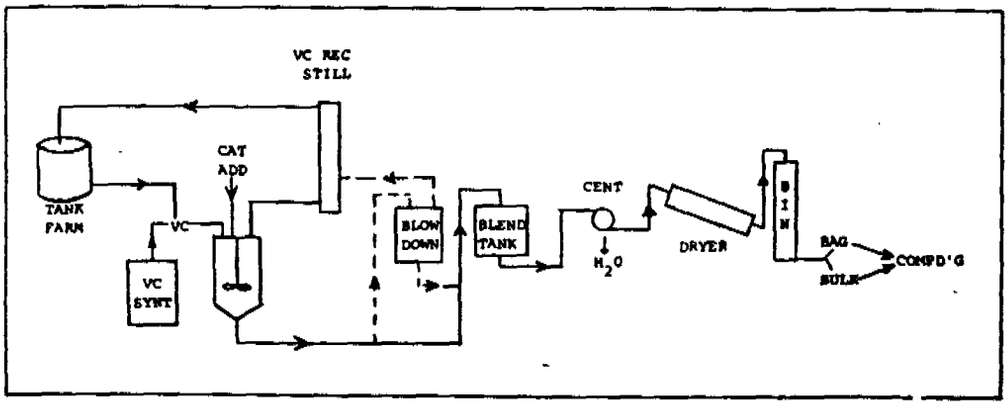

Fig 1.—Flow diagram for production of PVC from vinyl chloride monomer.

erties of the materials, and discussion with technically informed persons at the plants. By setting up three broad categories of duration and of relative severity of the exposure, semiquantitative estimates were made. Since materials responsible for causing AOL might be absorbed either through the respiratory tract or through the skin or both, such estimates were made for each of these avenues of absorption.

Production Operations

Vinyl Chloride Production.—The two processes for production of vinyl chloride described by Albright[1,2] were found to be in current use. One of these involves the reaction of hydrogen chloride with acetylene in the presence of a mercuric chloride catalyst. In the other process, 1, 2-dichloroethane is pyrolyzed in the presence of chlorine as a catalyst for the production of vinyl chloride and HCl. In some plants, both methods were used, with the HCl produced in the latter of these processes being used in the former.

Polyvinyl Chloride Production.—Polyvinyl chloride can be produced in accordance with four processes, each with many variations among different plants. The final polymer may have a molecular weight varying from 50,000 to 150,000, depending on conditions under which it is produced. The production processes are designated as suspension, emulsion, bulk (or nonsolvent), and solvent. A typical procedure is presented in the flow-sheet (Fig 1). The essential steps of these operations are outlined in this paper. For more complete details, reference may be made to the papers by Albright.[3-5]

In the widely used suspension process, deionized water is first introduced into a large autoclave, usually glass-lined, followed by a wide variety of additives. These include suspending agents such as polyvinyl alcohol, methyl cellulose, and gelatin, emulsifying agents such as sulfonated oils, surfactants such as sorbitan monolaurate, and buffers such as sodium bicarbonate. Trichloroethylene may be added to produce the lower molecular weight polymers. Catalysts are added to initiate the polymerization. These are nearly all organic peroxides, with lauroyl peroxide and diisopropylperoxydicarbonate (IPP) being used at the greater number of plants. The reactor is then closed, evacuated to remove oxygen, and vinyl chloride, normally a gas, is piped in as a liquid under pressure from the tank farm or the vinyl chloride plant. In some plants, the catalyst is added to a charge tank from which it is introduced into the closed reactor following addition of the vinyl chloride.

The mixture is agitated with rotating propeller blades, and steam initially is directed into the reactor jacket to raise the temperature to 50 or 55 C. Since the polymerization reaction is exothermic, cooling water must be run into the jacket after the reaction has begun to avoid excessive heating. After ten to 16 hours, the polymerization is essentially complete, and the reactor is brought down to atmospheric pressure. In most plants, it is placed under vacuum for removal of unpolymerized vinyl chloride monomer and transfer to the monomer recovery area. The suspension of PVC is then discharged into a blowdown tank below the reactor. This tank is placed under vacuum for transfer of remaining vinyl chloride to the recovery area. In some plants, the blowdown tank is eliminated. The general appearance of the charging floor of a polymer plant is shown

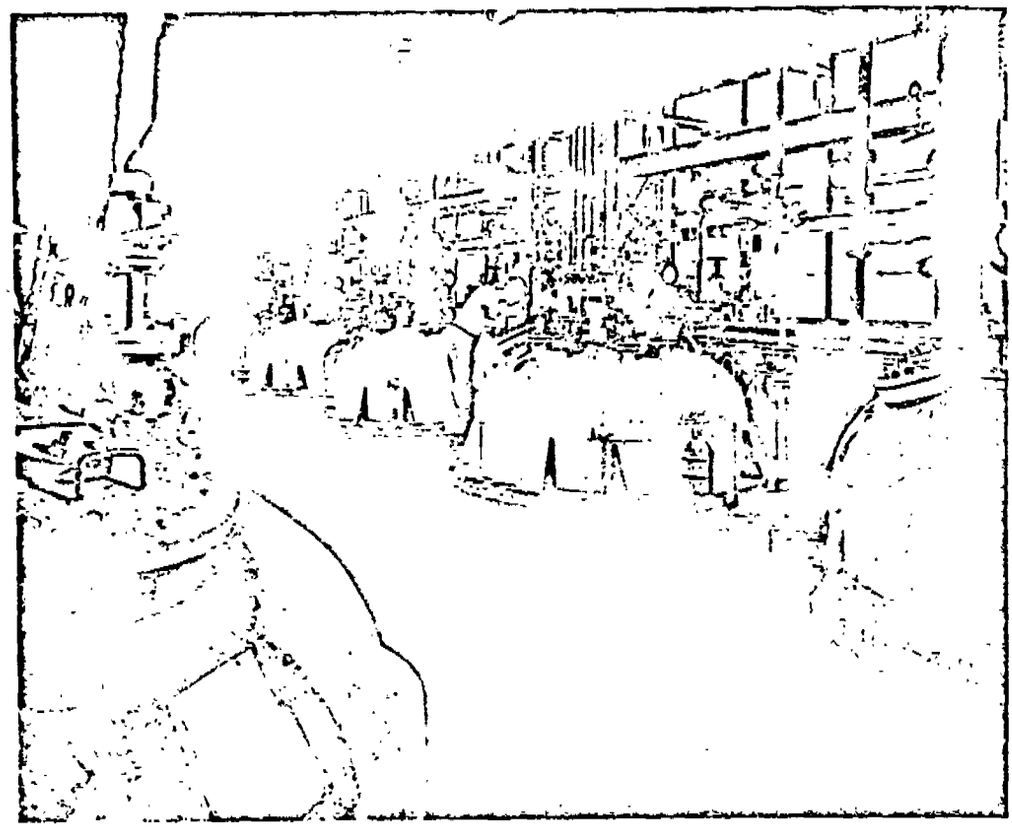

Fig 2.—Charging floor of PVC production plant showing top portion of reactors.

in Fig 2. The reactors extend for ten feet or so down to the floor below.

The polymer slurry is pumped to blend tanks, then to centrifuges for removal of much of the water. The dewatered polymer is passed through a rotary dryer with heated air, the temperature of the polymer being kept below 140 F to avoid degradation. The dried granular polymer is pneumatically conveyed into a cyclone separator, with finer particles being removed from the air stream by means of a filter-type collector. The polymer particles are sized by vibrating screens, then bagged for transfer to compounding and fabricating plants or shipped in bulk. In some plants, the polymer is stored in bins prior to being shipped.

In the emulsion process, the equipment and process is essentially the same as in the suspension process up to the drying operations. In order to produce the finer polymer particles characteristic of the emulsion process, a wide variety of emulsifying agents is used. These may be soaps such as ammonium or sodium laurate, surfactants such as salts of naphthalene sulfonic acid, or various synthetic detergents. Water-soluble initiators such as ammonium persulfate and hydrogen peroxide are used as catalysts. Since the fine polymer particles cannot be readily separated from the emulsion by centrifuging or filtering, a spray dryer is employed in this process.

The bulk process is similar to suspension polymerization but is characterized by the precipitation of the polymer from the liquid phase, as about 10% of the vinyl chloride becomes polymerized.

Solution polymerization is much the same as suspension polymerization, but no water is introduced. Instead, the polymerization is conducted in such solvents as cyclohexane, acetone, or *n*-butane.

Copolymer and Terpolymer Production.—In addition to the production of the homopolymer PVC, many of the plants also produce copolymer and terpolymers, including vinyl chloride. The greater percentage of the monomer tends to be the vinyl chloride in all of these. The copolymer vinyl chloride-vinyl acetate is in highest production

among this group but is a minor product in comparison to the homopolymer. Other copolymers are vinyl chloride-vinylidene chloride and vinyl chloride-laurylvinyl ether. An example of a terpolymer is vinyl chloride-*n*-butyl maleate-dibutyl maleate.

Processes, additives, and catalysts essentially identical to those used for the homopolymer are employed in the production of the copolymers and terpolymers with the addition to the reaction mixture of the additional monomers.

Vinyl Chloride Recovery.—The unpolymerized vinyl chloride removed from the batch following completion of polymerization is conveyed to a vinyl chloride recovery area by the suction pump that places the reactor and the stripping tank under reduced pressure. Here the vinyl chloride gas that is removed is placed under pressure to condense it together with water vapor to a liquid. The water and the vinyl chloride are immiscible, permitting their separation. In some plants, an inhibitor, usually phenol, is added to the vinyl chloride to prevent spontaneous polymerization during its distillation, the method used for its purification. The recovered vinyl chloride, with the higher boiling phenol remaining in the still, is then pumped to storage for reuse.

Table 1.—*Absolute Pressure-Time Values*

Absolute Pressure-Time Values Below 10			Absolute Pressure-Time Values of 10 or Above		
Plant Code	No. of Reactor Cleaners	No. of Expected AOL Cases	Plant Code	No. of Reactor Cleaners	No. of Expected AOL Cases
Plants With AOL Cases					
EE	31	0.8	B	216	5.8
			E	165	4.5
			F	16	0.4
			R	39	1.1
Plants With Possible AOL Cases					
CC	32	0.9			
Totals	63	1.7		436	11.8
Plants With No AOL Cases					
P	30	0.8	D	27	0.7
Q	22	0.6	H	26	0.7
V	91	2.5	L	28	0.8
W	50	1.4	S	17	0.5
			T	9	0.2
			Z	17	0.5
			AA	8	0.2
Totals	193	5.3		132	3.6
Plants Started in Operation in 1965 or 1966					
DD	21	0.6	C	54	1.5
			J	13	0.4
Totals	21	0.6		67	1.9

Table 2.—*Classification of Standard Job Titles*

Job Title	Code	Job Title	Code
Additive makeup (other than catalyst)	1	Monomer recovery operator	14
		Monomer supervisor	15
Bagging and shipping operator	2	Plant guard, security officer	16
Catalyst makeup man	3	Reactor cleaner	17
Clerical, other office, staff	4	Reactor cleaner, solvent	18
Compounding and fabricating	5	Reactor operator	19
Dryer operator	6	Slurry blender	20
General laborer, custodial	7	Supervisor, polymer	21
Laboratory supervisor	8	Tank farm operator	22
Laboratory technician	9	Utilities area operator (water treatment, etc)	23
Maintenance, electrical	10		
Maintenance, mechanical	11	Warehouse operator	24
Monomer maintenance operator	12	Transfer operator	25
Monomer operator	13	Other than PVC	30

Reactor Cleaning Operations.—After the polymer has been discharged from the reactor and the pressure brought to atmospheric, the reactor is aerated. This is accomplished by dropping a flexible duct connected to a portable blower to the bottom of the reactor, with discharge normally through the open manhole at the top of the reactor into the charging-floor area. The loose residue is washed out with water, after which one or two men enter the reactor to remove the skin of polymer remaining on the reactor surfaces. The usual method is by manual scraping with putty knives. Residue on the agitator blades may require hammer and chisel for removal and sometimes even axes.

Four plants use water jets with pressures of from 300 to 3,000 lb/sq in for the cleaning operation. One of these used water jets only in one of two production buildings, as the structional features interfered with movement of the portable high-pressure water unit about the building. Three other plants have been using solvents for reactor cleaning. One of these started to use this method late in 1964, a second in 1966, and the third from the beginning of plant operation in 1966. The reactor is filled with the solvent which must be heated and agitated for a prolonged period, as the PVC is difficulty soluble.

Polyvinyl Chloride Compounding.—Com-

Table 3.—*Magnitude of Dosage Expressed as Single Concept*

Magnitude* of Dosage	Severity/Duration Exposure Parameters†		
	Less Than 1 hr/Week	1-8 hr/Week	More Than 8 hr/Week
Slight			
1	Negligible	None	None
2		Negligible	None
3			Negligible
4	Moderate	None	None
5	Moderate	Negligible	None
6	Moderate		Negligible
Intermediate			
7	Appreciable	None	None
8	Appreciable	Negligible	None
9	Appreciable		Negligible
10		Moderate	None
11		Moderate	Negligible
12			Moderate
Major			
13	Appreciable	Moderate	None
14	Appreciable		Moderate
15		Appreciable	None
16		Appreciable	Negligible
17		Appreciable	Moderate
18			Appreciable

* Expressed in order of increasing dosage received from exposure, which is tha summation of the three columns to the right.
† Severity of exposure is estimated as none, negligible, moderate, or appreciable for indicated durations.

pounding consists of mixing PVC with a multiplicity of plasticizers, antioxidants, pigments, emulsifiers, stabilizers, and other special compounds in ribbon blenders and mills. The mixtures are then passed through roll mills or mixers, such as are used in the rubber industry, where the temperature may rise sufficiently to vaporize some of the plasticizer and other volatile constituents. The compounded polymer is then extruded through rolls or dies to form sheets, films, or pellets. These are used in fabricating operations.

Job Classification

Many variables were introduced in the plants surveyed and even in different units of the same plant in regard to nearly every phase of the operations. Investigation of unit jobs in the plants disclosed a wide assortment of job titles. In fact, a job title as used by the technical supervisors often differed from that for the same job in the same plant as listed by the personnel department.

Furthermore, a job assignment in one plant might include a different group of unit operations than in another plant. Also, the proportion of time devoted to the several unit operations often differed. To compound the difficulties of classification, workers would frequently rotate through several jobs at a weekly, monthly, or other period.

A classification of 26 job titles for the statistical purposes of this study was prepared (Table 1). These job titles corresponded to comparable operations in all the plants and to a common group of types of exposures to production materials. Every job in each of the plants was given its fraction of time related to the job title as defined for the study. Details of the manner in which this was done are discussed in the accompanying paper on epidemiologic aspects of AOL.[3]

Job Progression.—Often the first job assignment of the new employee is that of reactor cleaner. Unless there are many reactors, this work does not require the entire time of the employee. Part of his time may be spent in bagging or shipping finished polymer or in the handling of catalysts and other additives.

As job openings arise and with accretion of seniority, this employee may progress to higher skilled jobs such as reactor, monomer recovery or dryer operator, or any combination of these at any one time.

In plants producing other products in addition to vinyl chloride polymers, employees may transfer between these product areas either as full time for a period of months or dividing their time within a given week or even day. The latter occurs particularly among maintenance personnel.

Where production of vinyl chloride is part of the operation, operators may rotate between jobs in the production of the monomer and those associated with the production of the polymer.

The length of time spent at various jobs is a function of production needs, economic conditions, plant growth rates, and activity of other product lines.

Occupational Exposures to Materials

Extent of Exposures.—Information was obtained not only on each of the materials

used or produced but also on the extent of exposure to each. Since this is a function of both duration and severity, each of these factors was estimated. The duration of exposure was recorded as less than one hour a week, from one to eight hours a week, or more than eight hours a week; the severity as negligible, moderate, or appreciable. Since it was not known whether the materials might be absorbed through the respiratory tract, through the skin, or both, the extent of exposure as related to each of these avenues of absorption was recorded.

For statistical purposes, it was desirable to combine these two factors of exposure into a single dose value. Although admittedly the effect of exposure to materials with differing physiological responses would vary somewhat with different combinations of degrees of duration and severity, the 18 possible combinations of duration and severity were listed in increasing order of dosage and classified in three groups of dose values designated as slight, intermediate, or major. These combinations are presented in Table 2.

Materials Involved.—A total of 227 different materials were used or produced in the formation of PVC, the copolymer vinyl chloride-vinyl acetate, and other copolymers and terpolymers incorporating vinyl chloride. These materials included monomers, polymers, catalysts, dispersants, inorganic compounds for coalescence regulation, emulsifying agents, surfactants, and organic solvents (including hydrocarbons, both aliphatic and aromatic, ketones, esters, and chlorinated hydrocarbons). This total of 227 materials does not include the many more used in the compounding and fabricating plants.

A computer analysis of exposures to these materials was undertaken, but up to the present time, this has disclosed no constellation of materials introduced into the batch at the plants exhibiting cases of AOL that was not used in plants without cases. However, special consideration was given to certain suspect materials and also to certain details of procedure.

Vinyl Chloride Exposures.—In evaluating the role of vinyl chloride as a possible influence in the causation of AOL, the estimates of the extent of the exposure of reactor cleaners and reactor operators were reviewed. Since the authors conducted no air analyses, they had to judge the presence of vinyl chloride in the charging floor area principally on the basis of general ventilation provided and odor observed. The odor of vinyl chloride could be detected in the immediate vicinity of reactors as they were first opened and also when they were first being vented into the charging room area. Air analyses conducted by others have shown vinyl chloride concentrations in the reactor prior to ventilating to be in the order of 3,000 ppm. The lower limit of detection of vinyl chloride by odor is accepted as 400 ppm. Except under the foregoing conditions, the odor of vinyl chloride was not observed in the general room air.

Table 4.—*Use of Inhibitors With Vinyl Chloride*

	Use of Inhibitors	
	In Virgin Vinyl Chloride	In Vinyl Chloride Recovery
Plants with AOL cases or possible cases	2	2
Plants without AOL cases	3	4

The reactor cleaner enters the reactor after the aeration has reduced the vinyl chloride exposure to what is considered satisfactory limits, normally 15 or 20 minutes. The test is either by sniffing at the manhole opening or by use of a flammable vapor indicator. With the lower explosive limit of vinyl chloride at 4%, it requires 400 ppm for the usual type of flammable vapor indicator to give a positive reading.

Where air analyses have been made in a small number of plants with more sensitive instruments, such as the gas chromatograph, it has been found that the vinyl chloride concentration inside the reactor during scraping operations tends to be below 100 ppm and usually about 50 ppm. With the residue containing some unpolymerized vinyl chloride, small amounts of this gas are released as scraping is carried on. Air analyses have shown vinyl chloride concentrations close to the hand during scraping in the range of 600 to 1,000 ppm.

Although this study provided no evidence to suggest that vinyl chloride per se is the etiological agent, the measurement of vinyl chloride concentrations may serve as a useful index to the adequacy of reactor ventilation.

Inhibitors in Vinyl Chloride.—An inhibitor, usually phenol, may be added to the

Table 5.—*Reactor Cleaning Procedures*

Plant Code	Hand Scraping: After Every Batch	Hand Scraping: Less Than Every Cycle	Cleaning by Water Jet	Cleaning by Solvent
Plants with AOL cases				
B	X			
E	X			
F	X			
K	X (through 1964)		From 1965	
R	X			
U		Every 5-12 cycles (building A)	From 1962 (building B)	
EE	X			
Plants with possible AOL cases				
BB		Every "several" cycles		On glass-lined, intermittently in 1966, entirely by December 1966
Plants with no AOL cases				
A	X (to September 1964)			From September 1964
C	X			
D			From 1962	
H	X			
J		Every 2½ cycles		
L		Every 4-8 days		
N	X			
P		Weekly through 1964, every 2 weeks 1965-1966	From 1965	
Q	X			
S	X			
T	X (emulsion)	Every 1-3 cycles (suspension)		
V		Every 10 cycles		
Z	X			
AA		Every 4 or more cycles		
DD	X			
GG				From start of operations

vinyl chloride to prevent spontaneous polymerization in storage. An inhibitor may also be added to the vinyl chloride recovered from the reactor. The phenol is removed by treatment with caustic soda prior to its transfer to the reactor. The practice over the years covered by the study is presented in Table 3. The use of the inhibitor in the virgin vinyl chloride at two of the positive plants and three of the negative plants, with inhibitor being added in the vinyl chloride recovery operation in two positive plants and four negative plants, leads to the conclusion that inhibitors probably are not a factor in AOL causation.

Catalyst Exposures.—Since the catalysts are all active compounds, they were suspect as a possible factor in the causation of AOL. Contact with these inorganic and organic peroxides occurs as they are handled prior to their introduction into the reactor and also during reactor cleaning if any unreacted catalyst remains in the residue. Twenty-two of the 26 plants used lauroyl peroxide. Eight of these were plants with AOL cases or possible AOL cases, and 14 were plants without AOL cases. The next most common organic peroxide was the IPP, and it, too, was in use in both the positive and the negative plants, in four of the former and in eight of the latter. No catalyst or group of catalysts was used in all positive plants and in no negative plants.

Constituents of Scrapings.—Other suspect materials are constituents of scrapings removed from the reactors during manual cleaning. These are believed to include some partially polymerized resins, along with some unreacted catalysts and additives, and unpolymerized vinyl chloride. Little specific information is currently available concerning these constituents. It has been reported that lauroyl peroxide is definitely associated with residual PVC particles, whereas little of the IPP remains unreacted in the polymer.[4]

Further investigation of the scrapings from the reactor may be expected to furnish information that may lead to a better understanding of the factors involved in causation of AOL. A difficulty in such investigation is that the composition of the scrapings is continually changing from the time they are removed from the surfaces of the reactor. It is obvious that comparatively small molecules of partially polymerized vinyl chloride are increasing in size with passage of time, and active constituents such as residual cat-

Table 6.—*Reactor Cleaning Procedures*

Method	Positive Plants	Negative Plants
Manual scraping after every reactor cycle	7	9
Manual scraping after 2-3 cycles	0	2
Manual scraping after 4-12 cycles	2	4
Water-jet cleaning	2	2
Organic-solvent cleaning	1	2

alyst and vinyl chloride monomer are decreasing or may no longer be present.

Procedures Affecting Exposures of Reactor Cleaners

Since all but one of the 25 operators diagnosed as positive for AOL had worked as reactor cleaners and the one exception had cleaned laboratory reactors,[8] additional inquiry was made of procedures that might affect the exposures of this group of workers.

Reactor Cleaning Procedure.—The number of man hours required to clean the reactors depended not only on the number of reactors but also on the frequency of cleaning. In 16 of the 26 production plants, reactors were manually cleaned after every batch. This was true of six of the seven positive plants and one of two plants with possible AOL cases. In only nine of the 17 plants with no AOL cases were reactors manually scraped after every batch.

The procedures followed in each of these plants appears in Table 4 and an analysis of the type of procedure by positive and negative plants in Table 5.

Procedures Following Completion of Polymerization.—Since vinyl chloride and other volatile components of the residue remaining on the reactor surfaces following discharge of the batch might be factors in AOL causation, information was obtained concerning the degree of vacuum applied to the reactor prior to opening it and the length of time that the reactor was under this reduced pressure. The amount of volatile materials remaining in the residue on the reactor surfaces was considered to be roughly proportional to the absolute pressure and inversely proportional to some function of the time. Since the rate of removal of volatile material would tend to decrease with time, the logarithm of this factor was used in calculating an absolute pressure-time (AP-T) value. It was hypothesized that the relative amount of volatile materials remaining in the residue following application of vacuum would approximate a nondimensional value obtained by dividing the absolute pressure in inches of mercury by the logarithm of the time in minutes during which the vacuum was applied. Thus, the lower the AP-T value the less is the amount of volatile materials remaining in the residue.

Another factor affecting removal of volatile materials is the temperature range over the period that the reactor is under vacuum. The variables in temperature control were so diverse that this factor defied classification and could not be incorporated in the parameter under consideration. Actually, variations in degree of vacuum and timing of its application were such that meaningful calculation of an AP-T value could be accomplished only for five of the seven positive plants, one of the two with possible cases, and 14 of the 17 negative plants.

In the subsequent discussion of these values, the three plants that started in operation as recently as 1965 and 1966, all with no AOL cases, are not included as it is not known whether sufficient time had elapsed for cases to have developed by the terminal date of the study period. These plants are listed separately in Table 6.

The AP-T values ranged from 0.5 to 21. The AP-T values were 10 or above (an entirely arbitrary division line) for four of the five positive plants and for one of the two plants with possible AOL cases. Four of the negative plants gave AP-T values below 10, and seven gave values of 10 or above.

Consideration is directed to the number of reactor cleaners and the corresponding number of expected AOL cases in the two groups of positive plants as compared with those in the negative plants.

The total number of reactor cleaners at risk in the positive or possibly positive plants with an AP-T value of less than 10 is 63; that in such plants with an AP-T value of 10 or more is 436. The relation of these two totals is to be compared with that of the negative plants in which 193 reactor cleaners at risk are in the four plants with an AP-T of less than 10 and 132 are in the seven plants with an AP-T above that value.

The number of expected cases of AOL for each plant is also listed in Table 6. These values were obtained by dividing the number of reactor cleaners at risk by 38. This

figure derives from the paper on epidemiological aspects of AOL[8] which reports the prevalence of AOL or possible AOL as one case per 37 reactor cleaners at risk.

Of the negative plants with an AP-T value of 10 or more, none of those in operation earlier than 1965 had enough reactor cleaners at risk to expect an AOL case, whereas two of the four plants with an AP-T value under 10 have enough workers to expect cases. Cases would be expected from the total population of reactor cleaners in the entire group of the seven negative plants with AP-T values of 10 or more, but the total number would be 3.6, as compared with 5.3 expected cases from the entire group of four negative plants with an AP-T value of less than 10. This contrasts with expected cases in the group of positive plants with an AP-T value of less than 10 as 1.7, compared with 11.8 in such plants with an AP-T value of 10 or more.

The proportion of the number of reactor cleaners in the negative plants with an AP-T value of less than 10 to the total number in such plants was 193 to 325. This proportion for the positive plants was 63 to 499. A χ^2 test demonstrated that the probability of this difference between the negative and the positive plants occurring by chance is less than 0.001.

In order to make this comparison between the positive and negative plants with AP-T values below and above 10, it was necessary to oversimplify a multiplicity of varying details of operational procedures from the time the polymerization is completed to the time the cleaner enters the reactor. Accordingly, any interpretation of the findings that reduction of the AP-T value below 10 by reducing the absolute pressure or keeping the reactor at reduced pressure for a longer time or both may results in reduction in development of AOL cases should be approached with great caution.

Preventive Measures

The present knowledge as to AOL is such that categoric statements as to preventive measures are not justified. However, on a somewhat speculative basis, some measures are indicated that may be conducive to AOL prevention:

1. Although some manual removal of residue from reactor surfaces may be required when solvents or high-pressure water jets are used for cleaning, the more extensive employment of these methods would greatly reduce the number of man hours required for conducting this operation by manual methods.

2. The adequacy of ventilation of reactors prior to entry should be checked with flammable vapor indicator equipped with a scale of greater sensitivity than 1% of the lower explosive limit of vinyl chloride or with other instruments of such sensitivity.

3. Further investigation of the constituency of the scrapings from the reactor surfaces should be considered, as such information might disclose the factor responsible for the causation of the disease.

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