INDUSTRYWIDE STUDIES REPORT OF AN INDUSTRIAL HYGIENE SURVEY AT

Monsanto Chemical Company
Decatur, Alabama

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16. Abstract (Limit: 200 words) A walk through survey was conducted at the Monsanto Chemical Company (SIC-2824, 2869), Decatur, Alabama for the purpose of determining worker exposure to acrylonitrile (107131) (AN) during the manufacture of acrylic fibers and nylon intermediates. Acrylic polymers were originally produced using a batch process, but at the time of the survey they were only made by a continuous polymerization reaction. The highest exposure levels were in the old cell house of the Nylon Intermediates site, followed by the operators in the Acrylic polymer manufacturing location, particularly those involved in the old batch operation. Only limited data existed on the influence of specific engineering controls developed at the facility. Two large engineering changes did occur at the site which played a role in lessening exposure levels.

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The cooperation and assistance we received during this site visit from employees, and management representatives was excellent. A special note of thanks to Mr. Roger Evans.

Some of the information contained in this report was extracted from NCI Contract Report No. NCI-CP-41022-60[1], from the project protocols for the NCI/NIOSH AN study,[2,3] and from three NIOSH publications.[4-6]

Purpose of the survey:	To corroborate and to supplement information previously gathered by NCI investigators on plant processes, chemical usage, work areas, job titles, job tasks, and how these items had changed historically. The information collected by NCI and NIOSH researchers will be used to estimate acrylonitrile (AN) exposures for all employees occupationally exposed to AN as part of the NCI/NIOSH Study of Mortality Among Workers Exposed to Acrylonitrile.
Employer Representatives Contacted:	Mr. Roger Evans, Supervisor, Industrial Hygiene Mr. R. J. Kucera, Superintendent, Environmental Health, Safety & Services
Employee Representatives Contacted:	None (non-union)
Standard Industrial Classification of Plant:	SIC 2824 (Synthetic Organic Fibers, Except Cellulosic) SIC 2869 (Organic Chemicals) SIC 2869 (Plastic Production - previously Monsanto's Lustrex, now Polysar)

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ABSTRACT

On July 19-22, 1988, a site visit was conducted at the Monsanto plant in Decatur, Alabama. This site visit was conducted as a part of the National Cancer Institute (NCI)/National Institute for Occupational Safety and Health (NIOSH) Study of Mortality Among Workers Exposed To Acrylonitrile (AN). During the survey a walk-through tour of the plant was conducted and 35 employees from supervisory and line positions were interviewed to identify processes, engineering changes, job titles, job tasks, personal protective equipment, number of workers per area, and documentation of how these items had changed historically. Interviewees reported historical exposure levels of AN were higher in the early days of plant operation, especially prior to 1978. The numerous changes that were instituted between 1978 and 1981 (as a result of the Occupational Safety and Health Administration's 1978 standard on AN) had a marked effect on the potential AN exposure levels. A major process change instituted in the manufacture of certain nylon intermediates (which uses AN as a raw material) in 1972 also had a marked effect on AN exposures in that area of the plant. AN monomer has been used at this plant from its opening in 1952. Monsanto's management personnel did not participate in the employee interviews nor were they allowed to review the field notes taken during the interviews.

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INTRODUCTION

Acrylonitrile (CH_2=CHCN) is a volatile, water-soluble liquid with a normal boiling point of 77°C and a vapor pressure of 80 millimeters at 20°C. Synonyms for acrylonitrile (AN) include carbacryl, cyanoethylene, fumigrain, 2-propenenitrile, VCN, ventox, and vinyl cyanide. AN is used in the manufacture of acrylic fibers, acrylonitrile-butadiene-styrene (ABS), and styrene-acrylonitrile (SAN) resins, nitrile elastomers, acrylamide, adiponitrile, and other organic chemicals. Commercial production of AN in the United States was first reported in 1940; annual production was reported to be approximately two billion pounds in the late 1970s.[7,8]

Principal exposure occurs among workers in AN production and user industries through inhalation of vapors and dermal absorption. Estimates of the total workforce exposed to AN vary; NIOSH estimated in a 1977 Current Intelligence Bulletin (CIB) that 125,000 workers in the United States were potentially exposed and OSHA estimated that 70,000 persons in the United States may have been occupationally exposed in 1978.[4,9] Low exposures may also occur to the general population around industrial sites and, to a lesser extent, from the migration of AN from food and beverage containers.[10]

AN has a characteristic onion or garlic like odor. In a 1989 publication, the American Industrial Hygiene Association lists reported odor thresholds for chemicals with established health standards. Reported thresholds for detecting the odor of AN range from 1.6 to 22 ppm, with a geometric mean air odor threshold of 1.6 ppm.[11]

In the late 1940s the American Conference of Governmental Industrial Hygienists (ACGIH) adopted a Threshold Limit Value (TLV) of 20 ppm as an 8-hour time weighted average (TWA). OSHA adopted the TLV and regulated exposure to AN in 1972 with a permissible exposure level (PEL) of 20 ppm as an 8-hour TWA. NIOSH recommended in the 1977 CIB that AN be handled in the workplace as if it were a human carcinogen.[4] This recommendation was based on preliminary results from an epidemiologic study by E.I. du Pont de Nemours & Company Inc., which indicated an excess risk of lung and colon cancer among acrylonitrile workers, and on a laboratory animal study reported by the Manufacturing Chemists Association (MCA), which indicated an excess risk for a number of different tumors.[4] NIOSH reaffirmed this recommendation in a January 1978 criteria document and recommended that no worker be exposed to AN in excess of 4 ppm.[10] This recommended exposure limit (REL) was revised to 1 ppm during NIOSH testimony at the March 1978 OSHA Hearing.[11] OSHA subsequently promulgated a revised standard with a PEL of 2 ppm (8-hour TWA). OSHA estimated that prior to the 1978 standard, about 66 percent of AN workers were exposed to levels between 2 and 29 ppm (8-hour TWA) with the remaining 34 percent exposed to less than 2 ppm (8-hour TWA).[8]

Background of the AN Study

In response to the suggestive evidence of the human carcinogenicity of AN, an eight-member group of industry scientists representing companies which use or

produce AN met with NCI scientists to discuss the feasibility and desirability of an industrywide epidemiologic study. After determining that a study was warranted and feasible, plant selection was made by NCI by focusing on the three types of manufacturing operations in the United States which produce or use the greatest volume of AN: monomer production, fiber production, and ABS/SAN resin production. The goal of plant selection was to include workplaces that provided a range of exposures.[2] NCI conducted a feasibility study to select plants, to evaluate plant records, and to determine record retention policies. NCI investigators subsequently made two site visits to each of the eight study facilities to conduct personal air monitoring for AN (Appendix-I); and to collect company air monitoring data (Appendix II) and descriptions of job titles and tasks (Appendix III), and to document historical events (e.g. engineering changes - Appendix IV) which may have affected AN exposure levels.[1]

In 1987 NIOSH and NCI entered into an interagency agreement for NIOSH investigators to supplement the industrial hygiene information gathered previously and to estimate AN exposures for all employees in the epidemiological study. The survey conducted at Monsanto's Decatur plant was the third of eight final site visits that NIOSH investigators will conduct.

Methods

Guidelines for conducting interviews during plant site visits were developed at a meeting on March 21, 1988, between plant and union representatives, NIOSH and NCI researchers, and a scientific advisory panel. The key elements developed by consensus were: 1) all interviews would be confidential with only interviewees and NIOSH/NCI researchers present, 2) employees' interviews would be conducted in groups of from two to six employees, 3) NIOSH/NCI researchers and company and union (for unionized plants) representatives would all be involved in selecting the employees to be interviewed, 4) all interviewees would be active employees unless retirees were available, who were thought to have critical information about a specific department.

About one month prior to the site visit, management was given several documents to review. These included partially completed interview forms that would be used during on-site interviews, and a list of employees and supervisors to be interviewed. We had asked that the interview form be reviewed for technical accuracy, and that the interviewee list be reviewed to determine if the persons selected were available and suitable for the work areas identified. Changes to the list of potential interviewees were to be made by management representatives.

NIOSH researchers visited the Decatur, Alabama plant from July 19 through July 22, 1988. On July 19 an opening meeting was held with management representatives to give a brief overview of the project status and discuss our planned activities during the site visit. Subsequently, a walk-through survey of the corresponding AN production or handling areas was conducted. Interviews were conducted with employees and supervisors from Acrylic Fiber Manufacturing, Technical Center, Quality Control (QC), Utilities, Medical and

Environmental Health, Safety and Services, and Nylon Intermediates. During each interview the participants were asked the list of prepared questions which were often supplemented by follow-up questions. Emphasis was placed on collecting information about job titles and the corresponding tasks for the job in question, which areas or tasks involved the highest exposure to AN, how exposures had changed historically, what personal protective equipment was available, and what, if any, events had occurred to increase or decrease employee exposures to AN.

Monsanto Management personnel did not participate in the employee interviews nor were they allowed to review the notes taken during the interviews. This is consistent with Industrywide Studies Branch policies and regulations for conduct of industrywide studies as indicated in its governing regulations (CFR Part 85a).

Area air samples were collected in the baling area to assess if respirable sized fibers were present. Four air samples were collected on 25 millimeter cellulose filters. All samples were collected in the baling area of North Fiber. Samples were analyzed using phase contrast microscopy (PCM) via NIOSH Method 7400, using the "A" rules (400 x magnification). One hundred fields were counted on each sample preparation. All four samples were also analyzed via transmission electron microscopy (TEM) using NIOSH Method 7402 with these modifications:

A. Samples were not etched.

B. One hundred fields were examined on each sample preparation.

The samples were analyzed at a magnification setting of 20,500 x. A plant layout was also obtained.

HISTORY AND DESCRIPTION OF THE PLANT

The site for the Monsanto Decatur plant was purchased in October of 1950 and plant production started in April of 1952. Monsanto produces acrylic fibers and nylon intermediates at this plant. In March 1965, nylon intermediates (adiponitrile, hexamethylene diamine) were added to the product list and later that year, polyester fibers were first manufactured. Other products that have been made at this plant include polyester staple and flake, nylon tire yarn and nylon staple, polystyrene plastic, and chemcoke. The site encompasses 677 acres and currently employs 1200 people. Three different acrylic fibers are produced at this site. The three acrylic fibers are designated as WRC (discontinued in 1989), A16, and modacrylic, and contain approximately 90%, 90%, and 65% AN respectively. The general areas of concern within the plant where the potential for exposure to AN exists (or has existed in the past) include the production areas of Acrylic Manufacturing (includes Intermediates and Fiber areas) and Nylon Intermediates and other areas including Maintenance, Tech Center, Utilities, and Quality Control. A general layout of the plant is given in Figure 1 showing these areas. An overall chronology of major plant changes, particularly those which may have affected exposure to AN, is listed in Appendix II.

PROCESS DESCRIPTIONS AND INTERVIEW RESULTS

Acrylic Manufacturing

A flow diagram of the Acrylic Manufacturing area (from 1952 to present) is shown in Figure 2. Acrylic manufacturing is broken into two major subgroups: Intermediates and Fibers. The Intermediates area includes the North and South Plants which produce polymer, Solvent Manufacturing, and two Solvent Recovery areas. The Fibers area encompasses Dope Prep, Spinning, Cutting and Baling, and Warehousing. In general, the raw materials (which include AN and other monomers) are polymerized in a continuous polymerization reactor, the polymer is then stripped of unreacted monomer, filtered, pelletized, and dried, and then sent to be made into dope (the liquid solution used to spin fibers). Once the dope is prepared, the fibers are formed by extruding the dope through spinnerettes into the spin baths and then the fiber undergoes a series of treatment steps including washing, stretching, drying, crimping, annealing, and recrimping before it is cut and baled.

Acrylic Intermediates

Acrylic Intermediates incorporates six areas at the plant: North Solvent, South Solvent, North CP16, South CP16, CP12, and Tank Farm. The CP designation refers to continuous process. Production of fibers first started in the South plant (April 1952) while the North plant was started in April 1965. Major expansions included one in the South plant in July 1957, the North plant in October 1968, and the start of CP-12 production in January 1977. A complete list of significant historical plant events can be seen in Appendix II. Listed in Appendix IV are the job categories and job duties for each of the areas within Acrylic Intermediates.

Polymerization

Acrylic polymers were originally produced using a batch process, but currently they are only made by a continuous polymerization reaction. The batch process (designated as the VCF-Variable Catalyst Flow process) ran from 1952 to 1978 to first make the precursor polymer for A-1656, A41, and later modacrylic fibers. The batch process was located in the old South Plant. In the batch process, the monomers (AN and vinyl acetate - VA or other comonomers) were blended together in a mix tank and transferred to a feed tank. The monomer mix, water, and inhibitors were added to the reactor over a period of approximately two hours. The slurry was then held for a period of time to complete the polymerization. This is actually a semi-batch process. The product was pumped out of the reactor, coagulated by blending with a second polymer emulsion, centrifuged off, and the cake was transferred to the dryer. The batch sizes averaged about 7600 pounds and could be as large as 8100 pounds. Usual production rate was 2 batches per shift for each of the four reactors which ran three shifts per day, or a total of 24 batches per day if all ran well. Primary exposure sources included leaky pumps and process leaks, tank runovers, general AN vapors from the open venting of the various tanks, maintenance activities on the process, collecting QC samples, line

plugs which resulted in spills, chiseling out scale buildup in reactors (introduction of a jet cleaner in the late 1950s lowered exposures related to this activity), and visual checking of levels in the batch tanks.

There were two major job categories, Senior Operator and Operator. There was generally only one Senior Operator per shift, while there were anywhere from three to ten Operators per shift (total of about 45 workers on all shifts). One supervisor, the Intermediate Supervisor or Foreman, was in and out of the process area.

The interviewees all agreed that except in the early years of the CP process, exposures in the batch process were much higher than in the continuous process. Reportedly, AN could be smelled continuously around the reactor and there were several cases of blistered feet, red/watering eyes, and other symptoms of nausea, headaches, and fatigue. Operators also reported difficulty in seeing when the sun came up after being on the graveyard shift. QC samples were collected and delivered to the lab by the operators. These samples included about eight per batch from the monomer, the reactor slurry, and the wet cake. (According to comments received from Monsanto's Corporate Industrial Hygiene Staff, it took about one-minute to collect an individual QC sample.) Gloves and rubber boots were worn during the batch process, but were usually shared as community property. One air mask was present and respirators were introduced formally in 1975-76, about the time the batch process stopped. (Monsanto's Corporate Industrial Hygiene Staff stated that respiratory protection was available prior to 1975-76.)

A flow diagram of the continuous polymerization process is shown in Figure 3. The South CP16 was started in 1957 and North CP16 started in April 1965. Process lines A, B, C refer to the North plant while lines 1, 2, 3 refer to the South plant. Line 3 has pressurized reactors for CP-12 production and was started in January 1977. AN is transferred from storage to a mix tank where it is mixed with co-monomer(s) used in the process. It is then transferred to a feed tank. The mix is then fed continuously to a reactor where water and an initiator system are continuously added. Polymerization forms a slurry which is continuously removed and sent to a slurry stripping column which removes the excess monomers before drying. The slurry was then filtered, reslurried with water, filtered, pressed into pellets, dried, ground to fine powder, and stored. Waste streams from all phases of polymerization are sent to the water treatment area for disposal.

The interviewees reported that during the early days in the CP area, exposures were much higher than today and were even higher than in the later days of the batch process. The interviewees believed, however, that exposures in CP process were never as high as in the early years of the batch process. One employee who had worked in the plant since startup, estimated that exposures in the early days could have exceeded 100 ppm at times and that by the 1960s the exposures may have been down around 50 ppm and then into the teens just prior to all the engineering changes in the 1978-81 period. (Monsanto's Corporate Industrial Hygiene Staff questioned the accuracy of these estimates.)

The job titles and sources of exposures were similar to those in the batch process. However, there were only six workers per shift in the old CP process (versus 10-12 in the batch). The interviewees reported that other tasks with (potential) higher exposure included changing the monomer filters (which took about 20 minutes, once a day), and cleaning the hold tanks (each tank was cleaned every two months or so and required six to eight hours to complete). Several workers remembered experiencing genital and underarm burning during these cleaning operations. Respirators were usually worn during cleaning operations and were required in the early 1970s.

Quite a number of changes have occurred over the years in the continuous process that have affected exposure to AN. All workers agreed that introduction of slurry stripping was the one major control change that most affected exposures. Slurry stripping was first installed on line 3 in South Plant (CP12) in 1976. By 1980-81 all areas of Acrylic had slurry stripping.

There were a large number of changes instituted in the 1977-78 period, when the AN standard came into effect, which lowered the OSHA allowable concentration from 20 ppm to 2 ppm (8-hour TWA). All interviewees agreed that this had the next largest effect on reducing exposures. Other major changes included installation of scrubbers on filters, hold tanks, and mixer vents (1965), the introduction of water flow on the overflow of the reactor (1975), improvements on agitator and reactor seals, seal pots on the agitators, curtains on the pelletizer, and installation of Strahman valves with good O-ring seals (all of these occurred around 1977-78). In 1980-81, an onstream monitoring system on the mix tanks was installed, thus significantly reducing the number of QC samples required.

The tank farm is also considered part of Acrylic Intermediates. AN is now received by barge, but was historically (e.g., during the early years of production) received in rail or tank cars. The primary duty of the worker in the tank farm is to connect up to the barge/tank car and oversee the unloading. The job is now done by a senior operator (senior process operator) where it once was called operator (field operator) or tank farm operator. Historically, the tank/rail cars were open to the atmosphere while a dip leg was used to unload. All connections now are via a closed system (started about 1975). Likewise, the vents and overflow lines are now closed and scrubbed or piped directly to a hazardous waste handling reservoir (instituted around the late 1970s).

South and North Solvent

Both these areas service the respective Acrylic manufacturing areas to provide the DMAC (N,N-dimethylacetamide) for Dope Prep and cleanup of recycled solvent. Operation of the Solvent plants was from the respective manufacturing area. For example the Solvent Recovery Field Operator in the North plant, worked out of the North polymer plant. In fact, the Solvent Operator also worked in the polymer plant and generally had to be familiar with the solvent plant, CP-polymer area, and the CP control room. Likewise the CP-Polymer Field Operator had to be familiar with the solvent area.

Therefore, all North plant operators probably have had exposure to AN. In the South plant, the South Solvent Field Operator and Control Room Operator were responsible just for the south solvent area and did not cross into the polymer area.

Acrylic Fiber

This area includes the Dope Prep, Spinning, and Cutting and Baling processes. Dope Prep (see Figure 4) starts with the receipt of the dried polymer from the polymerization area where it is fed into the slurry tank along with an organic solvent (DMAC-from Solvent plant) and other additives, e.g., titanium dioxide. This, on heating, forms the "dope" which is a thick, viscous fluid which is placed in a hold tank, filtered to removed any undissolved particles, and fed to the spin tank. The dope then enters the Spinning Department (Figure 5) where it is heated, filtered again, and extruded through thousands of tiny holes in the spinnerettes to emerge in an aqueous coagulation bath. Each hole in the spinnerette produces an acrylic fiber strand. The fibers are gathered together in a "tow" and undergo a series of processing steps including washing, stretching, finishing, drying, crimping, annealing, recrimping, and then it is cut and packaged in bales. The process from annealing on is considered to be part of the Cutting and Baling department (Figure 6). The final product may also be packaged as uncut tow.

The exposures in the Fiber area are now quite low. In fact, it is thought that there is no AN from the spinning area on in the process. Historically this has not always been the case. The advent of slurry stripping reduced the amount of residual AN monomer in the polymer, thus significantly reducing the amount of AN exposure downstream from the polymer area.

Monsanto's Corporate Industrial Hygiene Group questions this statement, by stating that they are unaware of any data that supports the "significant" reductions.

Nylon Intermediates

AN is used to make adiponitrile (ADN) and the ADN is then reacted to produce hexamethylene diamine (HMD), which is shipped to other Monsanto plants or to customers to be used to make nylon fiber. A flow diagram of the overall process can be seen in Figure 7 and the relative location of Nylon Intermediates can be seen in Figure 1. A list of the job descriptions and their major duties is given in Appendix IV. This process was started in March 1965 and the capacity was approximately doubled in December 1968. In general, this process is composed of four distinct areas (and cost centers): 402-ADN Synthesis, 403-Refining (purification of ADN and HMD), 404-HMD Synthesis, and 406-Hydrogen Synthesis. In ADN Synthesis, AN is mixed with water and with organic and inorganic salts and then circulated through electrolytic cells. In the cells, the AN is converted to ADN along with several by-products. The output from the electrolytic cells is sent to a recovery system which recovers unreacted AN and electrolyte, and returns the latter to the process. The recovery system also separates and removes propionitrile (PN), which is formed as a by-product during ADN manufacturing.

The PN is purified for sale; the waste streams from the purification being burned for energy recovery. The crude ADN stream is then refined; the liquid waste streams are burned for energy recovery. During ADN synthesis and refining, various solid wastes are generated. These wastes are disposed of at a regulated disposal site.

Hydrogen is produced from natural gas in the Hydrogen Synthesis area and sent along with the refined ADN to make HMD. Hydrogen and ADN are reacted under pressure and in the presence of a catalyst to form crude HMD via hydrogenation. The HMD is refined in distillation columns. The resulting high and low boiling impurities are burned for energy recovery or sold. The resulting HMD, which is a solid at room temperature, is blended with water and shipped out to other Monsanto plants and outside customers. Although nylon tire yarn was once produced at the Decatur plant, HMD was first sent to other Monsanto plants where it was reacted to form a nylon salt which is used by those plants and also returned to Decatur for nylon manufacturing.

The cell area in ADN Synthesis is the point where the highest potential exposures to AN occurred in the Nylon Intermediate Department. The original cell utilized a Monsanto developed process known as electro-hydro-dimerization (EHD). This process started in 1965, was down for the year 1967, and was shut down in late 1972. These cells were a series of plates separated by membranes and pressed together with the metal cathode on one side connected to the metal anode on the other side. Each plate (cell) was three feet square and there were 31 cells per unit and a total of 16 units. Each cell had 3-inch rubber feed hoses for the catholyte and analyte, for a total of almost 1000 hoses. The catholytic feed consisted of AN, organic salts, water, and ADN product at 80 psi. The analyte was 5% sulfuric acid. The interviewees reported that there were constant problems in the early years of production with these hoses breaking or coming loose. The cell house was a two-story enclosed building with concrete floors. The ADN product was then sent to the extraction/distillation (403) area where separation of the product from the feed material and by-products occurred. Recovered feed was returned to the ADN area while the ADN product was further purified and sent to the HMD area. A centrifuge, in conjunction with extraction filters, was used to separate the crude ADN from other materials. The centrifuge/filter area was reported by the interviewees as another area of high potential exposure to AN.

The consensus among the people interviewed was that during the early years of production the smell of AN could be detected constantly in the cell house despite the 60 air changes per hour in the room. Any time hoses needed to be repaired or replaced, or cells or cell membranes needed to be replaced, exposures for anyone working in the area were quite high. Symptoms reported from the early days of the EHD cell house included nausea, headaches, burning and tearing of the eyes, and vomiting. In general, gloves, goggles, and rubber boots were worn when working with liquids and respirators were also used when changing filters. Workers in these areas were called Field Operators, Nitrile Cell House Field Operators, Relief Operators, or Helpers (term for newly hired employees). The Control Room Operators or Nitrile Cell

Control Room Operators, generally stayed in the air-conditioned control rooms. Workers in the extraction/distillation area were Field Operators, Control Room Operators, Foreman, Utility Operators, Relief Operators, or Helpers. Several Process Engineers were assigned to the ADN unit in the early days - typically there is only one assigned there now. (Per comments from Monsanto's Corporate Industrial Hygiene Staff, several process engineers as a job class are assigned to the ADN unit and have been since the early days.) There were 25 to 28 workers per shift in the Nylon Intermediates area, with as many as 21 field operators at one time. Generally, in the ADN and HMD areas, there were 18 operators (field and control room) per shift, 2 foremen and 4 relief operators. There was frequent rotation within the units and among the jobs. The job descriptions specify that the specific job will also work in numerous other jobs and will "rotate through all ADN Area control room positions" (quote from job description for Nitrile Cell House Control Room Operator - eight specific other jobs are listed that this position will work in). Therefore, it is likely that all workers in the Nylon Intermediate area had opportunity for exposure at one time.

In 1972, a new "Unicell" or EHDM process replaced the old EHD process in the production of ADN. The EHDM process uses an electrolytic cell. In the cell, AN in the presence of certain salts, is dimerized to form ADN. The ADN product then goes through similar separation and purification as in the old EHD process. Reportedly, this new Unicell process resulted in significantly lower AN exposures, particularly after it was in operation for awhile.

One major task of the field operators was the collection of QC samples. Not only did the operators collect the samples but they would analyze them in the ADN control room. Reportedly, this resulted in AN being smelled in the control rooms. Today, the operators do very limited checks on samples and under better controlled hoods. Most of the samples are delivered to the laboratory. Today in the ADN-402 area, there are a total of ten samples collected per shift. This compares with an estimated 30-200/shift in the beginning and 20/shift in the 1970s. There were many more samples taken in the 403 (distillation/extraction) area, with estimates as high as 30 per hour when there were process upsets.

There have been numerous beneficial process changes over time, particularly during the 1978-81 time period, resulting in lowering AN air concentrations and potential exposures to AN. Some of the more significant ones include the installation of recyclable filters in the 403 area so that filters did not have to be changed as often (1977), installation of ISOLOCK sample collection stations (1978-80), 26-point automatic continuous air monitoring (ACAM) system to detect early process upsets and leaks of AN (1981), and dual vent scrubbers on all AN tanks (1981). There were two large process engineering projects in the Nylon Intermediates area which were designed to control emissions/exposure to AN. These were designated projects # 3414 and 3476. These projects were instituted in early 1980 and 1981, respectively. In addition to the changes given above, other items were the task identification of all exposures, increased ventilation in the 402 area, intensified equipment decontamination procedures, instrument purge on all AN streams, covering the AN contaminated

sump in 403, separate clothing and ventilated lockers for workers in Nylon, a computer controlled enclosed filtering system in 402, package decontamination for the reactor cells, an emergency flush system on the distillation unit, a separate hold tank for AN contaminated water, a caustic mobile tank for equipment decontamination, and a reactor flush decontamination system. Most of these changes were added during two large engineering projects, which were designed to lower AN levels as a result of the OSHA Standard for AN, which lowered the allowable limit of AN from 20 ppm to 2 ppm (8-hour TWA). Monitoring data were generated to demonstrate the effectiveness of these changes. These data are summarized in Appendix V.

In addition to the one year shut down of 1967, the old EHD cell house had frequent shut downs due to process upsets. In fact, one interviewee stated that the longest continuous period without any shut downs was for only seven days. The shut downs were due to hose leaks, the need to change cell membranes, etc. (Monsanto's Corporate Industrial Hygiene Staff questions the accuracy of this statement by stating that it is unlikely that a process could have operated with upsets occurring more than once per week.) The current system has a planned annual shut down that lasts 3-14 days, and abbreviated shut downs for 3-5 days every three months.

Maintenance

All maintenance workers came out of a central pool during the years 1952 to 1956. After that time, workers were assigned to specific plant departments. Maintenance workers were assigned to Acrylic Intermediates (both North and South), Nylon Intermediates, Boiler, Utilities, and Technical Center (including pilot plant). Maintenance workers were grouped into millwrights, pipefitters, welders, instrument workers, electricians, and insulators. These jobs are listed in the order of decreasing exposure potential to AN as determined by interviewees from the Acrylic Intermediates area. The insulators category was not included in the ranking. It is an old job category that no longer exists.

Maintenance workers had potential for exposure to AN in all areas where AN existed, but primarily in Acrylics, Nylon Intermediates, and around the pilot plant in the Tech Center. Several of the interviewees from these three areas related being able to smell AN anytime they went in their area. Symptoms reportedly experienced by employees who worked in these areas included skin burning, nausea, and vomiting. Some of the tasks which the interviewees reported resulted in higher than normal exposures, were work during process upsets resulting in stoppages, vessel entry, redressing filters between reactors and dryers (second floor of B and C lines in Acrylic, third floor filter in A line), work on monomer feed filters, pulling of flow indicators from process lines, replacement or repair of control valves, any work in the old EHD cell house including pulling cells or hose replacements, vent checking on all AN tanks, and during scheduled or unscheduled turnarounds. Personal protective equipment included rubber gloves and boots, eye protection, and air supplied respirators for vessel entry. Interviewees related a problem that

occurred during vessel entry, in the early years, was that one could only stay in the tanks so long before they experienced strong genital and underarm burning.

The major problem in assessing exposure to past maintenance workers is that all personnel records list maintenance workers as just that, with no delineation of where they worked. The Personnel Office and Maintenance secretaries were unable to provide additional information. The maintenance employees will be one of the more difficult groups to estimate exposures for. This is true, even though a significant number of maintenance workers had potential AN exposure, and exposure data exists for many workers.

Technical Center

The Technical Center (or Tech Center) is composed of several groups including the Textile Tech, Dye Labs, Acrylic R & D (or just Research and Development), and Acrylic Development (which includes the Pilot Plant). In general, the Tech Center provides technical support or services to the whole plant. Efforts such as product development, process engineering, and product testing are included in the Tech Center. Of main interest for AN exposure is the Pilot Plant which has been used for production of many polymers, the bench research conducted on AN related polymers and fibers, and the R & D Analytical Lab.

The Pilot Plant development is a mirror for the polymer processes in manufacturing. That is, the pilot plant was used to test new process improvements and if they worked, the improvements were then implemented in the full scale manufacturing processes. For example, the Pilot Plant started out as a batch operation and was used to develop the continuous process. Likewise with slurry stripping, which was first tested and refined in the Pilot Plant before being implemented in the plant. So the exposure potentials in the Pilot Plant (PP) were similar to those in the Acrylic area except they were lowered sooner, the PP did not operate all the time, and its personnel carried out other operations, primarily spinning. One interviewee estimated exposures in the PP to be lower than those in the Acrylic area simply because it was not a full-time operation. The scale of the operation was also much smaller. Operators in the Pilot Plant worked interchangeably on spinning and polymerization operations.

The Pilot Plant was started as a batch process in the early days of the plant (1954) and was changed to a continuous process in 1956. Much of the early work involved the AN and vinyl acetate (VA) monomers. In general, the PP operation consisted of a continuous, stirred reactor (production capacity about 100 pounds/hour). The slurry that was formed flowed out the top of the reactor where an inhibitor was added to short stop the reaction. The slurry went to an open primary filter where it built-up and fell into a collection tank. Water was added to this tank and the resultant slurry was pumped to a secondary filter. Spray washing of the polymer was carried out during both filtration operations. The polymer was then pelletized and sent through a dryer. The pellets were then ground to a fine powder. The polymers produced

was used in another part of the Pilot Plant to make fibers. It is estimated that the residual monomer content in the polymer product stream, before slurry stripping, was around 0.5% and that AN concentrations around the polymer filter were as high as 100 to 200 ppm. The interviewees related that in the early days of the Pilot Plant, the odor of AN was smelled constantly and there were several cases of skin burns, headaches, and nausea related to the PP. Interviewees related that all job categories in those days were equally exposed to AN. (Monsanto's Corporate Industrial Hygiene Staff questions the accuracy of this statement, saying that in any department all job classifications are not equally exposed. By the nature of the job function, the potential expsoures will vary for each job classification.) The interviewees also said that exposures were higher in the old batch process than in the continuous one, except for when the continuous process was first started. There were gradual improvements in the control of AN releases up to 1960 when the PP was moved. Along with the move came several improvements such as exhaust hoods over the polymer filters and rotary vacuum filters to filter the polymer. Another area reported to have had high potential exposure was the pelletizer. In 1974-75 curtains were added around the pelletizer and ventilation was added to reduce AN levels. The Spinning Operator would have had opportunity for some exposure to AN since the polymer retained a small amount of residual AN, especially before slurry stripping. The spinning area in the Pilot Plant was some distance away from the Polymer Production area.

The polymer Pilot Plant did not operate 100% of the time. One old-time employee estimated that during the 1950s-60s the Pilot Plant reactor was in operation about 50% of the time. This reduced to about 10% of the time in the early 1960s. There was a major modacrylic fiber project in the late 1960s and early 1970s which increased the PP operation time to 50% and then it decreased to less than 10% usage about 1982. The usage has remained at less than 10% since 1982. When the Polymer Area was not in operation, the workers went to other non-AN areas of the Pilot Plant, e.g., fiber spinning. The job titles in the PP were much the same as those used in the plant, Operators, Foremen, and Helpers. There was a wide number of other job titles used over the years, but Technician, or Acrylic Tech, or Pilot Plant Tech, or Development/Project Technician were some of the more common titles used to describe the operators of the PP. There were also a number of engineers in the PP area who would have had the potential for exposure to AN, but less so than the PP operators. Appendix IV lists the more common job titles and their work duties.

The Acrylic R & D area of the Tech Center also worked with AN, but their work was primarily bench top research where small quantities of AN were handled in hoods (most of the time). The R & D group started at the plant in 1952 and then in 1960 was transferred to Research Triangle Park until 1981 when it was moved back to Decatur. Most likely those people who were working with AN before R & D moved would have continued to have some potential for exposure to AN after the move, but these people would not be identified in the Decatur personnel records. In the early years, there were as many as 350 people in the R & D area at one time and a total of about 2700 over all years of operation. Many of the people who worked in the R & D Plant worked with little or no AN. The R & D group was often referred to as the Research

group. Job titles in R & D are reflective of many of the job titles plant-wide. People in R & D may have moved about in different job titles depending on the special projects that were underway at the time. R & D people would occasionally go out to the plant to observe some modification or some aspect of the process that was being researched. Interviewees reported that AN was rarely smelled and that no incidences of AN overexposure (i.e., health effects, e.g., headaches) could be recalled. Protective equipment worn may have included glasses and gloves when liquids were handled. However, gloves were not routinely worn. The R & D Analytical Laboratory was once called the Pilot Plant Analytical Lab. The primary function of this lab was to support the PP effort and occasionally work for other groups in the R & D area. The lab would do routine analysis of PP process samples, but would also have to develop methods to run special samples. The lab had as many as 15-30 people in it, but it now numbers 6. Job titles include Group Leader, Shift Leader, and General Technician. Other historical job titles included Specialist, Senior or Research Chemist, and Foreman. The interviewees did not think that the potential for exposures in the R & D Lab were very high. Few could ever recall smelling AN except if a spill occurred (which was very rare) or sometimes when a sample was opened or transferred. No one reported ever having any symptoms of AN exposure.

Quality Control

The Quality Control Department includes the Chemical Laboratory, Physical Testing (PT) Lab, Tech Lab (Chemical and Fiber), Fiber Quality (Acrylic and Staple & Tire), Nylon Intermediates Quality, and Industrial Engineering. The Chemical Lab receives and analyzes all the routine process QC samples. This lab has also been called the QC Chem Lab, Control Lab, or General Chemistry Lab. The Tech Lab (Chemical) analyzes all the non-routine or specialty samples. The Fiber Quality, PT Lab, and Fiber Tech Lab are all involved in fibers and as such would not have any exposure to AN.

The Chem Lab receives and analyzes two types of AN related samples: process samples and incoming product samples (100% AN). Today, two to three dozen process samples are received per day, which may contain anywhere from 0.1% to 90% AN depending on where they are from. Currently only one to two pure AN samples are received in a year's time. Historically, there were many more process and product AN samples (up to 10 per week). The increased number of process samples included a higher percentage of monomer mix samples which contain 80-90% AN. The process samples are analyzed by gas chromatography (GC) while the pure AN samples are analyzed using wet chemical methods. The wet chemical methods are more labor intensive and increase the potential for exposure to AN. The GC samples require only that an aliquot be taken from the sample prior to injection (unless dilution is required).

The main job categories in the lab include Technicians, Chemists, and Foreman. There are several subclassifications within these categories. Those interviewed ranked the jobs by exposure potential (high to low) in the following rank: Bottle Washer, Selectivity Job, NSP Technician, Nylon Instrument Tech, Salt Split Tech, Tech Lab Technicians, and Day Crew Tech. From plant start-up to about 1965, the Day Crew Technicians would have had the

highest potential exposure of all job categories in the lab, because they analyzed the pure AN samples. Because there was rotation of jobs within the lab, everyone would have had some exposure potential. The interviewees pointed out several events which occurred over time that may have affected exposure. Basically, the exposure potential would have been about the same from 1952 to 1964 when the new lab was built. The new lab had lab hoods and better ventilation.

In January 1977, the plant switched to a 12-hour shift. It was around this same time that a hazardous chemical materials manual was written and awareness of AN toxicity was greater (due to the new AN standard). Many changes occurred in the next few years which affected exposure potential including installation and expansion of hoods in the bottle wash room, polymer area, and along the east wall. The AN waste was originally poured down the sink and later this was directed to a sump. Today disposal is in a hood sink, which is directed to the water treatment plant.

Until mid 1970, most AN samples were stored and analyzed on an open bench. Interviewees reported being able to occasionally smell AN, but most notably when a spill occurred. Spills were not common events. Three spills were detailed, all had occurred within the last six years. No one reported ever having, or heard of anyone having, any AN related symptoms.

Other major chemicals that have been used in the lab include:

acetone	acetic acid	adiponitrile
alcohol (MeOH, EtOH)	butyraldehyde	chloroform
carbon tetrachloride	carbon disulfide	chlorobenzene
DMSO	dimethylamine	dimethylformamide
ethylene diamine	cyclohexane	hexamethylene diamine
hydrogen sulfide	pyridine	methylene chloride
nitrobenzene	phenol	propionitrile
sulfur dioxide	styrene	vinyl acetate
vinylidene chloride	vinyl bromide	toluene
triethanolamine	lead	cadmium

Utilities

The Utilities Department encompasses many operations including steam generation and distribution, electricity, water treatment and distribution, nitrogen, refrigeration, natural gas, compressed air, coal handling, secondary waste treatment, and chem coke manufacturing. However, it is functionally broken into two main groups, the Boiler House and General Utilities. Those in General Utilities go all around the plant handling utility related operations. The Boiler House is composed of a larger workforce of about 30 workers who are divided into Operators (Control Room and Field - 3 each per shift), Foremen, and 1 Supervisor. Included in the Utilities, Boiler House area is a marine boiler used to incinerate waste process streams from Nylon Intermediates (ADN waste streams containing AN). This boiler installed about 1971, was taken off a WW II navy destroyer, therefore its name - marine boiler.

The waste streams are sent to a storage tank until they accumulate to a certain point. The marine boiler is then fired with natural gas until a certain temperature in attained. Then the waste streams are introduced for incineration. From 1965 to 1977 there was an open air incinerator in operation and AN could be smelled occasionally. The incinerator has been dismantled. There were an estimated six to eight times when overexposure to AN occurred from 1965 to 1971. One problem which occurred was when the burner tip plugged-up and the waste streams backed-up into the steam feed lines and then out the relief vents. This resulted in a cloud of AN being released and two operators being sent to the hospital with vomiting. The other cases were less severe with workers reporting nausea, headache, etc.

The marine boiler runs about 50% of the time now, and there are many new controls to prevent the problem of AN being released into the work area (e.g., separate block and feed lines, extended stacks, ACAM system, etc.). Changes were made around 1985. Operators now say they can rarely smell AN. All the Operators in the Boiler House have rotated through the marine boiler and have had the potential for exposure to AN. The potential for exposure in the Utilities area is estimated to be quite low, except for the few isolated incidences outlined above.

Engineering

Several engineering groups existed throughout the plant including Process Engineering, Project Engineering, and Engineering Development. In general, Process Engineering supported manufacturing by providing engineers for each of the ongoing operations, while Project Engineering helped design and implement new processes or process modifications. Engineering Development was part of the Tech Center and was associated with the Pilot Plant. Therefore, these jobs would have had the opportunity for AN exposure. Likewise, the Process Engineers assigned to AN areas, e.g., Acrylic, Nylon Intermediates, would have had the potential for AN exposure. Many of the Process Engineering staff were actually assigned to particular units, however, their personnel records may not have reflected that assignment. The relative exposure for Process Engineers was estimated by interviewees to be similar to that of the supervisors for the particular area and the only personal protective equipment worn routinely were safety glasses and shoes. The exposure potential for Project Engineering was very low to non-existent. Most of the engineers in this department worked in the administration building. The only exception was to oversee the installation of a job in the plant. Project Engineering was also sometimes referred to as Plant Engineering.

Environmental Health, Safety and Services

Per comments from Monsanto's Corporate Industrial Hygiene Staff, Industrial Hygiene has been a part of the plant's safety program since the start-up of the plant. Safety personnel were responsible for monitoring and evaluating workplace exposures. Site safety also included training on effects of hazardous materials, use of PPE, and proper work practices.

Currently, all Industrial Hygiene, Safety, and Environmental related functions are grouped together in one department. A separate Industrial Hygiene function was started at the plant in 1976. The plant began retaining monitoring results for AN in 1978. (According to Monsanto's Corporate Industrial Hygiene Staff, monitoring for AN was conducted prior to 1977/78, but the results were not systematically recorded or retained due to the lack of any record keeping requirements.) Early monitoring was done with the charcoal tube/pump method, and about 1980 the switch was made to the 3M passive monitor. The results of available past AN monitoring are included in Appendix III, while those data collected by the NCI contractor in 1986 are included in Appendix I. The only continuous monitoring system for AN was installed in 1980 in Nylon Intermediates. Personal protective equipment provided to AN areas has changed over time. Prior to 1970, gloves, safety shoes and glasses were routinely available. Respiratory protection, also available prior to 1970, evolved so that during 1975-79 it was required in certain jobs where the potential for AN exposure was evident. This requirement continues today. Before the mid seventies, respirators of various types were generally available for emergency use, and according to Monsanto's Corporate Industrial Hygiene Staff, available for other situations which were judged to potentially expose individuals to hazardous concentrations of AN.

Other Departments

There are several other departments in the plant, none of which have any known exposure to AN. These include Polystyrene Manufacturing, Polyester Fiber, and Nylon Tire Yarn. The Nylon Tire Yarn operation started in 1974 and was shutdown in 1980. The last Polyester unit was shut down in 1982.

The polystyrene facility started operation in July 1974. The primary chemical used to make polystyrene is styrene monomer, which is injected with other additives into a reactor. The final product is solid polystyrene pellets, which is stored in large silos and then shipped out in hopper cars, bulk trucks, and boxes. The Polystyrene Resin facility was sold to another firm in 1986.

The main products in the Polyester and Nylon Yarn Department include polyester staple fiber, polyester flake, and nylon yarn. Manufacture of the polyester fiber staple begins with the polymer production where ethylene glycol and terephthalic acid are mixed together in a reactor. Once the polymer is in a thick molasses-like state, it is forced through spinnerettes to form tiny fibers. The collection of fibers are gathered together in a tow and then processed in various ways to get the fiber characteristics of interest. The drawn tow is crimped, dried, cut into proper staple lengths, and baled. The polyester polymer, in extruded or flake form, is also processed for shipping in hopper trucks to other plants where it is processed into yarn.

Hexamethylene diamine produced at Decatur was sent to Pensacola where it was converted into a nylon salt and then the nylon salt was returned to the Decatur Tire Cord area, where it was fed to a continuous polymer reactor. The salt was converted to the polymer, which was then spun into fiber and

converted to yarn. Hexamethylene Diamine is still being produced by Decatur and sent to other locations, but is not returned as nylon salt.

Results of Fiber Air Sampling

No fibers were detected on any of the four filter samples collected in the North Cutting and Baling area. What appeared to be fibers via PCM analysis were actually web like and rod structures when analyzed via TEM analysis.

TOXICITY

Acrylonitrile has also been found to produce bilateral adrenocortical hemorrhage and necrosis in rats from a single injection.[15] Damage to the lungs, liver, and kidneys has also been noted in animals from acrylonitrile inhalation.[16,17] AN has also been found to be embryotoxic in mice when administered to pregnant females.[18] Results of animal studies presented by the MCA indicated that acrylonitrile caused the development of central nervous system tumors and zymbal gland carcinomas in test animals. Increased incidence of mammary region masses was also noted.[4]

AN is mutagenic in bacterial test systems and carcinogenic in rats (the only species of experimental animal tested) following inhalation and oral administration, producing increased incidences of tumors of the brain, zymbal gland, small intestine, mammary gland, and forestomach.[19]

AN is considered toxic in man, affecting the central nervous system, gastrointestinal, respiratory, and peripheral blood systems. Acute symptoms of exposure to AN include eye irritation, nausea, vomiting, headache, and diarrhea. Mild jaundice, anemia, and leucocytosis have been reported. Epidemiologic evidence on its carcinogenicity, however, is limited. Excesses of cancers of the lung, prostate, stomach, and lymphatic system have been reported in some studies,[20-25] while other studies have reported no increased cancer risk.[26-28] Most of these studies, however, were limited by their small population sizes, and many included short follow-up periods and potentially confounding chemical exposures. In addition, most have not adequately assessed the effect of smoking habits on the cancer findings. Both the International Agency for Research on Cancer (IARC) and the World Health Organization (WHO) have concluded that further epidemiologic research on AN is needed.[7,10]

APPLICABLE STANDARDS AND RECOMMENDED LIMITS

The current PEL for AN is 2 ppm based on an 8-hour TWA. The standard includes an action level of 1 ppm and a ceiling limit of 10 ppm.[14] NIOSH considers AN to be a suspect occupational carcinogen. The corresponding NIOSH REL is 1 ppm (8-hr TWA) with a ceiling REL of 10 ppm (15-minutes).[13] The ACGIH TLV is 2 ppm (8-hour TWA), and ACGIH designates AN as an A2 carcinogen, which means it is a suspect human carcinogen.[29]

CONCLUSIONS

Estimating employee exposure to acrylonitrile will be conducted using the information collected during the NIOSH visit of July 1988, together with the materials previously collected by NCI investigators. In general, information provided by supervisors and line employees agreed on the relative exposure rankings of jobs and areas and how these exposures may have changed over time. The interviewees believed exposures to AN were highest in the early years of plant operation. The OSHA Standard for AN, promulgated in 1978, was reported as being the most significant event affecting the potential for exposure to AN. The revised standard reduced the exposure limit from 20 ppm to 2 ppm (TWA), and resulted in a number of changes (Appendix II). Two of the most difficult areas and times for estimating exposures include the Nylon Intermediates area during the time period of 1965 to 1972, when the old EHD cells were used to make ADN, and the old batch polymer process located in the South plant which ran from 1952 to 1978. No exposure data are available from the time periods these processes were in operation and the processes are no longer in operation.

Overall, exposures in the old cell house of the Nylon Intermediates were estimated to be the highest experienced in the plant. This would have included the operators and maintenance workers assigned to this area. Next highest would have been the operators in the Acrylic polymer manufacturing, particularly in the old batch operation. After that, the relative rankings will have to be sorted out more closely as they include all field operators in Nylon Intermediates after 1972 and Acrylic Manufacturing after 1976, Maintenance workers assigned to these two areas, etc. Maintenance workers were assigned to specific process areas, but their personnel records only reflected that they were in maintenance and at what grade. Attempts will be made to have a list of maintenance workers classified by the older plant employees as to which process operation they were assigned. In this way, we hope to be able to estimate exposure for maintenance workers. Process Engineers that were assigned to specific AN operations would have had potential exposures similar to the Process Supervisors. However, it is unclear at this time whether all Engineers were classified by personnel into administrative departments or if they were carried under the specific manufacturing cost code (department) where they were assigned.

Limited data exist from the plant on the impact of specific engineering changes on AN exposure. The plant implemented two large engineering projects over the time period from 1979 to 1981 and at the same time generated AN exposure data before and after the specific changes were installed. These data are summarized in Appendix V and illustrate the changes in exposure that occurred as a result of the OSHA AN standard. Other significant plant events which may have influenced AN exposures are summarized in Appendix II.

REFERENCES

1. Flowers ES. Mortality study of acrylonitrile workers and description of plant #3 processes, workforce, and potential exposures. National Cancer Institute (NCI) Contract no. NCI-CP-41022-60. May 8, 1985.

2. Miller BA, Stewart PA, Blair A, Herrick RF, McCammon CS. A study of mortality among workers exposed to acrylonitrile. PROTOCOL. National Cancer Institute (NCI)/National Institute for Occupational Safety and Health (NIOSH). April 1987.

3. Stewart PA, McCammon CS, Herrick RF. Industrial hygiene protocol for the mortality study of acrylonitrile workers. A Joint Protocol of the National Cancer Institute and the National Institute for Occupational Safety and Health.

4. National Institute for Occupational Safety and Health (NIOSH). Current intelligence bulletin 18: acrylonitrile. July 1, 1977. National Institute for Occupational Safety and Health. Cincinnati, Ohio.

5. Brown J, Robinson C. Industry-wide study of workers exposed to acrylonitrile. (NIOSH, DSHEFS, IWSB File No. 84.3). National Institute for Occupational Safety and Health. Cincinnati, Ohio

6. National Institute for Occupational Safety and Health. Criteria for a recommended standard: occupational exposure to acrylonitrile. Cincinnati, Ohio: National Institute for Occupational Safety and Health (DHEW publication no. (NIOSH) 78-116).

7. International Agency for Research on Cancer. IARC monograph on the evaluation of the carcinogenic risk of chemicals to humans. IARC, Lyon, France. 1979;19:73-113.

8. Santodonato J, Bosch S, Meylan S, Neal M, Sorel J. Monograph on the potential carcinogenic risk to humans: Acrylonitrile. Draft. Prepared by the Center for Chemical Hazard Assessment, Syracuse Research Corporation, for the Office of Environmental Cancer, National Cancer Institute, 1983; NO1-CP-26002-03.

9. Occupational Safety and Health Administration. Final Report - economic impact assessment for acrylonitrile. Prepared by Enviro Control, Inc., Rockville, MD. OSHA, Washington, DC. 1978 (contract no. J-9-F-6-0229).

10. World Health Organization. Acrylonitrile. Geneva: World Health Organization, 1983. (Environmental health criteria 28).

11. American Industrial Hygiene Association. Odor thresholds for chemicals with established occupational health standards. AIHA, Akron, Ohio. 1989.

12. E.I. DuPont de Nemours & Company. Epidemiologic study of workers exposed acrylonitrile. Preliminary results. (1977).

13. Centers for Disease Control. Morbidity and mortality weekly report: NIOSH recommendations for occupational safety and health standards. August 26, 1988. Vol 37, No. S-7.

14. Occupational Safety and Health Administration. General industry standards. 24 CFR 1910.1045 Occupational exposure to acrylonitrile. July 1, 1988.

15. Szabo S, Selye H. Adrenal apoplexy and necrosis produced by acrylonitrile. Endokroinologie 1971;57:405-08.

16. Krysiak B, Knobloch K. The effect of acrylonitrile (AN) upon the central nervous system. Medycyna Pracy 1971;22(6):601-10.

17. Knobloch K, Szendzikowski S, Czaikowska T, Krysiak B. Experimental studies upon acute and subacute toxicity of acrylonitrile. Medycyna Pracy 1971;22(3):257-69.

18. Scheufler H. The experimental testing of chemical substances for embryotoxicity, teratogenicity and mutagenicity - Ontogenic reactions of the laboratory mouse to these substances and assessment of these reactions - a critical analysis of the methods. 1976;14(4):227-29.

19. International Agency for Research on Cancer. IARC monographs on the evaluation of the carcinogenic risk of chemicals to humans. 1982;4:25-27.

20. Chen JL, Walrath J, O'Berg MT, Burke CA, Pell S. Cancer incidence and mortality among workers exposed to acrylonitrile. Am J Indus Med 1987;11:157-63.

21. Delzell E, Monson RR. Mortality among rubber workers: VI. Men with potential exposure to acrylonitrile. J Occup Med 1982;24(10):767-69.

22. O'Berg MT. Epidemiologic study of workers exposed to acrylonitrile. J Occup Med 1980;22(4):245-52.

23. O'Berg MT, Chen JL, Burke CA, Walrath J, Pell S. Epidemiologic study of workers exposed to acrylonitrile: an update. J Ocup Med 1985;27:835-40.

24. Theiss AM, Frentzel-Beyme R, Link R, Wild H. Mortalitatsstudie bei chemiefacharbeitern verschiedener produdtionsebttiebe mit exposition auch gegenuber acrylnitril. Zbl. Arbeitsmed 1980;30:259-67.

25. Werner JB, Carter JT. Mortality of United Kingdom acrylonitrile polymerisation workers. Brit J Indus Med 1981;38:247-53.

26. Kiesselbach M, Koralus U, Lange H-J, Neiss A, Zwingers T. Bayer acrylonitrile study 1977. J Med Protec Labor Indus Hug Ergon 1979;7. (as transl. by Ralph McElroy Co., Austin, Tx.

27. Collins J, Page L, Caporossi J, Utidjian H, Lucas L. Mortality patterns among employees exposed to acrylonitrile. J Occup Med 1989;31(4):368-71.

28. Ott M, Kolesar R, Scharnwever H, et al. A mortality survey of employees engaged in the development or manufacture of styrene-based products. J Occup Med 1980;33:445-60.

29. American Conference of Governmental Industrial Hygienists. Threshold limit values and biological exposure indices for 1989-90. Cincinnati, Ohio. 1989.

Appendix I

AN Personal Air Samples Collected By An NCI Contractor
Monsanto Chemical Company
Decatur, Alabama
August 25-28, 1986

Location & Job title	Date	Conc.	Comments
Nitriles/Cell House Operator	8/26	0.06	
" /Cell House Operator	8/27	1.99	Wore 1/2 face resp.
" /Distillation Operator	8/26	0.13	
" /Distillation Operator	8/27	0.82	Worked on AN line.
" /Field Operator	8/25	1.10	
" /Field Operator	8/26	0.13	
ADN/Distillation	8/25	0.42	Collect samples, check pumps.
" /Distillation Operator	8/25	0.11	
Acrylic North/Solvent Operator	8/25	5.67	C line down, wore FFR.
" /Solvent Operator	8/27	0.07	
" /Solvent Operator	8/26	0.03	
" /Field Operator	8/26	0.14	
" /Field Operator	8/27	0.43	Collected QC samples.
" /Field Operator	8/28	0.03	
" /Control Room Operator	8/25	0.07	
" /Control Room Operator	8/26	0.03	
" /Control Room Operator	8/27	0.03	
Acrylic/Foreman	8/28	0.10	C line down.
Dope Prep North/Operator	8/28	0.06	
Dope Prep/Operator	8/25	0.06	
" /Operator	8/27	0.03	
" /Spinning Operator	8/27	0.03	
Spinning North/Spinning Operator	8/26	ND	
" /Spinning Operator	8/25	0.06	Pulling tow, patrolling lines, etc.
Laboratory/Technician	8/25	0.07	Analyzed Nylon, AN, ADN.
" /Technician	8/27	0.03	
" /Technician	8/28	0.03	
Tank Farm/Operator	8/25	0.09	
" /Operator	8/27	0.12	No AN unloading.
" /Operator	8/28	0.06	No direct AN contact.

(continued)

AN Personal Air Samples Collected By AN NCI Contractor
Monsanto Chemical Company
Decatur, Alabama
August 25-28, 1986

Location & Job title	Date	Conc.	Comments
Utility/Waste Treatment Operator	8/28	0.06	Routine day.
" /Mechanic-Elec.	8/28	0.03	
Maintenance/Mechanic	8/25	0.18	
" /Mechanic	8/26	0.04	
" /Mechanic	8/28	0.07	
" /Mechanic-Elec.	8/25	0.02	
" /Mechanic-Elec.	8/26	1.31	
Administration/Secretary	8/26	ND	In office area except for lunch and breaks.
" /Safety Superint.	8/27	0.03	Office work, meetings.
" /Personnel Sup.	8/28	ND	Out of office 15 minutes.

All samples are time weighted averages unless otherwise noted.

Appendix II

Chronological Summary of Significant Events
Which May Have Affected Employee AN Exposure

Year(s)	Month	Description of Event
1950	10	Site purchased.
1952	04	Acrylic fiber start-up (south).
1954	?	Pilot Plant started operation.
1954-67	?	Pilot Plant Polymer area operated 50% of the time.
1956	?	Maintenance workers were assigned to specific plant departments instead of all being in a central pool.
1956	?	Pilot Plant changed from batch to a continuous process.
1957	07	50% expansion of Acrylic Fibers unit, continuous process started and ran adjacent to the batch process.
1958	?	Control room for Acrylic Fiber area built.
1959	?	Began using jet cleaners for reactor cleaning.
1960	?	Pilot Plant polymer reactor moved to a new location and improvements were made in the process including exhaust hoods over the polymer filters and better filtering of the polymer
1964	?	New Chem Lab opened.
1965	03	Nylon Intermediates began production.
1965	04	Acrylics North (continuous process) started production.
1965	?	Open air incinerator began operation.
1965	?	Scrubbers installed on filters, hold tanks, and mixer vents in the CP process.
1965	?	EHD process started in ADN Synthesis.
1967		402 process was down for about one year.
1967	entire yr	EHD process down for one year.
1968	10	North Acrylic Fiber unit expanded.
1968	12	Nylon Intermediates doubled in size and production capacity.
1968-76	?	Pilot Plant Polymer area operated 10% of the time.
1971	?	Marine boiler installed.
1971	?	Open air incinerator decommissioned.
1972	12	Liquid waste treatment plant start-up.
1972	late part of year	EHD process shut down permanently and was replaced with the "Unicell" process.
1974	06	Polystyrene facility started operation.
1974-75	?	Curtains were added to the Pilot Plant pelletizer.
1975	?	Water flow was introduced on the overflow of the reactor.
1975	?	Changed to a closed system for unloading AN barges, tank cars, rail cars.
1976	?	Slurry stripping installed on line 3 in South CP 12.

(continued)

Chronological Summary of Significant Events
Which May Have Affected Employee AN Exposure

Year(s)	Month	Description of Event
1976	?	Industrial hygiene activities separated from safety program at plant.
1976	?	Pilot Plant Polymer operation increased to 50%.
1977	01	Switched from a rotating 8-hour work schedule to 12-hour shifts.
1977	01	Acrylic Polymer (Modacrylic) began production.
1977	?	Recyclable filters installed in the 403 area so that filters did not have to be changed as often.
1977	?	Pilot Plant centrifuge decommissioned.
1978	?	VCF centrifuge decommissioned.
1978	?	Batch process ceased operation.
1977-78	?	Seals on agitators and reactors were improved.
1977-78	?	Curtains installed on the pelletizer.
1977-78	?	Strahman valves with good o-rings installed in CP area.
1977-82	?	Modacrylic fiber project resulted in pilot plant operating at 50%.
1978-80	?	QC sample points were enclosed in ventilated sample boxes.
1978	?	Earliest available monitoring records for AN.
1970s - Late		Loading vents and overflow lines closed and scrubbed or sent to hazardous waste reservoir.
1980	?	Began using passive dosimeters for AN air samples.
1980	06-11	Acrylic slurry stripping implemented.
1980-81	?	An onstream monitoring system installed on mix tanks in CP.
1981	?	Dual vent scrubbers installed on all AN tanks.
1982	?	Pilot Plant Polymer production cut back to less than 10%.
1984	?	South unit spinning operation ceased production.
1985	?	Major plant lay-off, reduced employees total from 1800 to 1300.

? = Indicates the month event occurred is uncertain.

Appendix III

Summary of Personal AN Air Samples
Collected by Monsanto Chemical Company (1979-1985)
Decatur, Alabama

Department/Job or Job Code	Arithmetic Mean (ppm)	Number of Samples	Highest Result (ppm)	Sample Type
CP Modacrylic Polymer/SR CP Oper	2.94	2	5.70	T
" /CP Area Oper	0.70	62	5.22	T
" /Polymer Oper	0.75	56	9.51	T
" /Polymer Oper	4.2	1	4.2	C
" /Maint Spec A	0.46	3	0.58	T
" /Mechanic 3-C	0.11	2	0.14	T
" /000195	2.92	2	5.62	T
SO CP Polymer/SR CP Oper	0.62	10	1.70	T
" /CP Area Oper	1.35	130	11.79	T
" /CP Area Oper	9.70	2	13.00	C
" /MA* Polymer Oper	1.23	58	10.65	T
" /SR MA Poly Oper	3.39	3	4.50	T
" /Maint Spec A	0.43	9	2.06	T
" /000195	1.45	1	1.45	T
NO Solvent/Inter NO FLD Oper	1.4	2	2.64	T
NO CP Polymer/SR Inter N Fl Op	1.44	9	7.77	T
" /Inter No Fld Op	1.42	301	44.2	T
" /Spinning Oper	1.47	3	3.4	T
" /Modacrylic Poly Oper	0.74	3	1.53	T
" /Laborer	0.19	1	0.19	T
" /Maint Spec A	0.34	11	0.75	T
" /Mechanic 2-C	0.2	1	0.2	T
" /Mechanic 3-C	0.4	3	0.8	T
NO Dope Prep/Dope Prep Oper	0.25	2	0.25	T
Nitriles Mfg/Nylon Int Fld Op	0.32	16	1.70	T
" /Nylon Int Fld Op	0.40	38	2.60	T
" /Nylon Int Fld Op	1.01	65	6.05	T
" /Nylon Int Fld Op	0.48	2	0.54	T
" /Nylon Int Fld Op	0.27	68	1.03	T
" /SR Nylon Int Op	0.11	4	0.15	T
" /SR Nylon Int Op	0.23	2	0.36	T
" /SR Nylon Int Op	0.82	9	2.27	T
" /SR Nylon Int Op	0.50	8	1.33	T
" /Package Hand Op	0.60	7	1.3	T
" /Maint Spec A	0.44	6	0.76	T
" /Maint Spec A	8.2	1	8.2	T
" /Mechanic 2-C	0.16	1	0.16	T
" /Mechanic 3-C	0.1	1	0.1	T
" /Mechanic Learner	0.1	1	0.1	T
" /Staple C&B Oper	0.25	2	0.25	T
" /000248	2.1	1	2.1	T
" /000326	0.12	1	0.12	T

* MA = Modacrylic

Summary of Personal AN Air Samples
Collected by Monsanto Chemical Company (1979-1985)
Decatur, Alabama

Department/Job or Job Code	Arithmetic Mean (ppm)	Number of Samples	Highest Result (ppm)	Sample Type
Diam & Hyd Mfg/SR Nyl Int OP	0.35	36	2.00	T
" /Nyl Int Fld Op	0.25	24	1.52	T
Marine Boiler/SR Stm & Coke Op	0.21	2	0.21	T
Steam Gen/Sr Steam & Coke Op	0.1	3	0.1	T
" /Steam & Coke Op	0.26	1	0.26	T
Utilities Sup/Foremen	0.2	1	0.2	T
Chem-Coke/Sr Steam & Coke Op	0.22	2	0.25	T
" /Steam & Coke Op	0.20	2	0.21	T
Package Assembly/Pack Hand Op	0.49	57	3.00	T
" /Services Equip Op	0.61	1	0.61	T
" /CP Area Oper	0.57	3	0.82	T
Tank Farm Acryic/Modacrylic Poly Op	1.31	23	5.70	T
" /SR Modacrylic Poly Op	1.72	16	9.5	T
" /Solvent Fld Op	0.16	1	0.16	T
Chemical Lab/Lab Technician	0.22	11	0.54	T
Mechanic Shops/Maint Spec A	0.39	102	6.20	T
" /Maint Spec B	0.65	5	2.63	T
" /Mechanic 1-C	1.01	10	4.02	T
" /Mechanic 2-C	0.91	8	2.77	T
" /Mechanic 3-C	2.09	20	21.1	T
" /Learner Mech	0.29	6	0.63	T
? /SR CP Oper	1.02	2	1.09	T
? /Nylon Int Fld Op	0.21	3	0.21	T
Pilot Plant/Technician	1.00	230	8.60	T
" /Lab Technician	0.52	11	0.74	T
" /Foreman	0.63	2	0.77	T
South Solvent/Solvent Fld Op	0.22	2	0.22	T

Sr = Senior, Op & Oper = Operator, Maint = Maintenance, Diam & Hyd = Diamine & Hydrogen, T = Time weighted average, C = Ceiling Value
? - Department uncertain

Appendix IV
Brief Description of Most Significant Job Titles
by Department

Job Title	Description
	Acrylic Intermediates - North Plant
Intermediate Tank Farm Op	Operates the equipment needed to receive and distribute diamine, AN, ADN, ammonia, and other chemicals. Checks the waste pond routinely and takes action as directed by Foreman. Takes samples as prescribed for laboratory tests.
Process Engineer	Assigned to the unit. Only worked the day shift.
Control Room Oper	Responsible for the Control Room functions of CP polymer and solvent recovery. Continuously observes all control instruments and relays information to the Field Operators as needed, prepares monomer mixes as necessary. Assists in training Field Operators to perform Control Room functions. Shuts down equipment for maintenance when necessary.
Relief Control Rm Oper	Duties include the CP Polymer and Solvent Recovery areas as needed. Provides shift relief for Control Room Operator and Shift Field Operator as needed, responsible for PPE equipment in the area, checks safety shower and eye bath operation weekly, and unloads and stores dry chemicals.
CP Polymer Field Oper	Relieves Control Room Operator, performs periodic duties in solvent recovery. Normal duties in CP polymer include collecting all routine and special samples, checking reactor overflows and cleaning overflow strainers, obtaining catalyst and SO_2 readings, and preparing premixes.
Relief Field Oper	Duties include the Solvent Recovery and CP Polymer areas. Provides relief for Field Operators in both areas, provides relief for Control Room Operator when needed, unloads and stores dry chemicals, collects special samples, and assists with cleaning process vessels.
Solvent Rec Field Oper	Required to perform duties in both Solvent Recovery and CP Polymer. Solvent Recovery duties were to collect all samples, check area for leaks and equipment malfunction, perform necessary housekeeping duties. Duties for CP Polymer were to collect samples and check area for leaks and equipment malfunction, and perform housekeeping duties.

Appendix IV (Continued)
Brief Description of Most Significant Job Titles
by Department

Job Title	Description
	Acrylic Intermediates - South Plant
South CP Cont Room Oper	Monitors and controls the CP Polymer process through utilization of instrumentation and direction of Field Operators. Prepares monomer mixes as necessary, performs shutdowns and start-ups as operations dictate.
South CP Field Oper	Patrols the CP area monitoring equipment operation, preparing premix solutions, performing housekeeping duties as needed, and collecting QC samples. Some samples are analyzed (pH), carries others to the labs.
So Solvent Field Oper	Collects readings of thermometers, gauges, tank levels, etc., patrols equipment to detect problems and takes corrective action. Takes samples and delivers them to the lab. Checks pH of neutralized column overhead and runs the pan dryer. Makes bicarb and sodium hydroxide mixes. Periodic assignments include unloading raw materials and assisting in cleaning process vessels.
Tank Car Loading Oper	Operates the equipment required for bulk storage, loading, and transfer of blended HMD and refined ADN into tank cars as shipments to and from other company locations. Also operates the equipment required to supply a continuous flow of RADN as feed to Diamine Synthesis area. Takes samples of the various products as directed by Foreman.
Tank Farm Operator	Receives, stores, and transfers raw materials, maintains inventory and adequate levels at all feed tanks. Collects QC samples and delivers them to the laboratory.

Appendix IV (Continued)
Brief Description of Most Significant Job Titles
by Department

Job Title	Description
	Nylon Intermediates
Control Room Oper	Monitors the corresponding activity from the control room. Keeps field operator informed of status and directs him to make necessary changes.
Field Operator	(Also called operator A or B) Monitored the equipment, collected QC samples, decontaminated and cleaned the equipment.
Absence & Vac Relief Op	Assumes the duties of the various operators in all areas of Nylon Intermediates whenever the operators are absent. When not needed to provide relief he is assigned duties by the ADN or HMD operator pertaining to training, safety, housekeeping, etc.
Nitrile Dist Field Op	Operates the continuous distillation and extraction columns, filters, pumps, tanks, and related equipment for the purpose of producing refined adiponitrile.
Catalyst Prep Oper	Operates Catalyst preparation equipment to produce the catalysts used in EHD process. Disassembles and reassembles membranes in frames as necessary to prepare membranes for installation in the electrolytic cell.
Nitrile Cell House Control Room Oper.	Monitors the adiponitrile synthesis instruments to insure they are working properly. Directs the Field Operator informed of process status and necessary changes. Relieves and assists other operators as required. Periodically works the jobs of other operators in the area.
Nitrile Cell House Field Oper.	Starts up, shuts down, and patrols nitrile electrolytic cell units to produce adiponitrile from acrylontirile and operates the 401 Tank Farm including unloading raw material tank cars, cleans cathodes & anodes, assembles membranes of cells in frames and cleans up spills.

Job Title	Description
	Nylon Intermediates (continued)
Nitrile Dist Cont Rm Op	Runs the distillation operation by constantly monitoring the instrumentation and making adjustments as needed. Keeps Field Operator informed of status and directs him to make needed changes. Spends most all of his time in the Control Room. Periodically will work the jobs of the other Nitrile Area Operators (i.e., Catalyst Mfg Operator).
Diamine Distil Cont Rm Op	Constantly patrols the instruments of the diamine distillation and ammonia recovery systems. Keeps Field Operator informed and directs him to make necessary changes. Periodically will work other jobs in the area. Performs housekeeping and other jobs as directed by Supervisor.
Diamine Distil Fld Op	Operates the diamine distillation train, diamine batch distillation system, and ammonia recovery equipment. Makes transfers and receives materials to and from other buildings and units in cooperation with the Control Room Operator. Patrols equipment looking for problems. Takes samples for laboratory tests.
Diamine Synthesis C R Op	Monitors the instruments of the Diamine Conversion Units and Catalyst Reduction Units to insure they are performing properly. Directs the Field Operators of corrective measures. Periodically works the jobs of other area operators.
Diamine Synthesis Fld Op	In conjunction with the Control Room Operator runs the operation to produce crude diamine, patrols the area to determine the status of equipment, makes transfers and receives materials from the other buildings. Takes samples for the laboratory and performs necessary chemical tests to operate the unit.
Diamine Utility Oper	Provides relief for Field and Control Room Operators and completes special assignments for the Foreman. Carries special samples to the Laboratory, picks up supplies from Plant Stores, at intervals will work the jobs of other Nylon Intermediates Operators.

Job Title	Description
	Nylon Intermediates (continued)
Hydrogen Plt Cont Rm Oper	Coordinates the operation of the Hydrogen Manufacturing and Compression Area with Diamine Synthesis. Constantly monitors the operation by observing instruments in the Control Room. Directs the activities of the Field Operator in making needed adjustments. Relieves the Hydrogen Field Operator and the Diamine Synthesis Control Room Operator. Periodically works the jobs of other personnel and rotates through all HMD area Control Room positions.
Hydrogen Field Oper	Coordinates the operation of start-up and shutdown of equipment in the Hydrogen Area. Makes adjustments and takes hourly readings of various equipment. Checks automatic drainers, and makes additions to the monoethanolamine system as needed. Relieves and assists other Operators as required. Maintains PPE in the Hydrogen Area.
Hyper Oper	Operates the hydrogen compressors, patrols the hydrogen hyper area equipment making necessary adjustments. Performs housekeeping duties as required.
ADN Utility Oper	Provides relief for various Operators and Control Room Operators in the ADN area to insure complete coverage of the operating equipment. Performs other jobs to assist area operations as directed by Foreman. Routinely checks the plant incinerator. Checks PPE, eye washes, showers in the ADN area. Periodically works the jobs of the other Operators.
Incinerator Oper	Operates the incinerator to burn nitrile and diamine tars and low boilers and waste lubrication oil from areas 404 and 406. Patrols the equipment looking for leaks, breaks, and malfunctions, and takes samples as required.
Helper	Historically this was a job title for new employees, no longer used. Their exposures were believed to be similar to the Operators.

Appendix IV (Continued)
Brief Description of Most Significant Job Titles
by Department

Job Title	Description
	Maintenance
Custodian	Performs janitorial work and maintains sanitary conditions in Office Areas, Locker Rooms, Break Areas, Control Rooms, and Laboratories.
Mechanic 1-C	Top grade for Mechanics expected to work with minimal suspervision. This job title includes Brick Layers, Carpenters, Electrical, Instrumentation, Machinery Maintenance, Machine Work, Painters, Pipe Fitters, Welders, and Sheet Metal Workers.
Mechanic 2-C	Second highest grade for Mechanics, expected to work with average supervision. Includes same categories as Mechanic 1-C.
Mechanic 3-C	Third highest grade for Mechanics, expected to have more supervision than higher grades. Includes same categories as Mechanic 2-C.
Mechanic Apprentice	Fourth highest grade for Mechanics, this job title also called Learner Mechanic.
Mechanic Helper A/B	Entry level positions for Mechanics. Mechanic B was the bottom level. This job title was also called Mechanic Trainee.
	Utilities
Boiler House Cont Rm Op	Controls the operation of both conventional steam and steam-coke generating units, observes controls in the Central Control Room, directs other boiler house personnel as needed.
Boiler Operator	Starts and stops various steam and motor driven equipment as needed. Operates coal stoking and ash removal equipment in the steaming and steam - coke areas, relieves the Control Room Operator for short periods.

Job Title	Description
	Utilities (continued)
Utilities Field Oper	Patrols all areas checking temperature, humidity, compressed air, inert gas, and other equipment and systems. Relieves Control Room Operator when necessary, performs housekeeping and other duties when required.
Utilities Cont Rm Oper	Controls the operation of the refrigeration system, compressed air production, inert gas production, etc. Observes and adjusts control instruments in the Central Control area.
	Fiber Manufacturing Department
Dope Prep Cont Room Oper	Controls the dope preparation operation from a Central Control Room and coordinates the activities of operators in the field. Assists with training Dope Prep personnel. Periodically patrols the Dope Prep area to survey operations, housekeeping, etc.
Sr Dope Prep Oper	Operates and coordinates the operational duties in the Control Room. Ensures that all equipment in shutdown and locked out before maintenance activities. Assists Foreman in special assignments when requested.
Dope Prep Oper	Operates all equipment necessary to produce a spin dope from raw material, polymer and CR (solvent), and pigment masterbatch. Monitors filter presses, cleans and changes filter presses. Collects dope samples.
Sample Operator (N Spin)	Collects all routine samples and delivers them to lab, resample if necessary. Helps out in trouble spots when possible.
Dope Prep Trainee	Job title for new employee in the Dope Prep area.
Jet Inspector	Maintains adequate supply of inspected jets for normal operation, inspects with microscope all jets at least once per month. Responsible for housekeeping in Jet Rooms, Candle Rooms, and Finish Make-up Room.

Appendix IV (Continued)
Brief Description of Most Significant Job Titles
by Department

Job Title	Description
	Fiber Manufacturing
Sr Spinning Oper	Primary duties include direct assistance to the Foreman, can perform any job in the department. Directs the work of Operators and Helpers assigned to machines. Provides relief for other personnel.
Spinning Operator	Operates, maintains, controls, and services spinning machines which extrude spin dope into filament form. Collects and segregates waste produced from machines. Prepares batches of finish used in the process. Installs candles and jets on machines, cleans jet, jet assembles, and candles filters.
Spin Machine Relief Oper	Relieves Spinning Machine Operators for breaks and lunch.
Day Relief Oper	Relieves all Spinning Operators and jobs for a day of rest while shift people are working day shift.
Candle & Jet Operator	Maintains adequate operating supply of clean jets, filter cores, rounder arms, rupture disc assemblies, and makes finish batches as needed. Responsible for housekeeping in Candle Room, Jet Room, and Finish Room.
Utility Operator	Redresses filter pots and makes jet changes on spinning machines. Helps bag wet tow, relieves drum Hauler and Machine Operators when needed, cleans Basement and Finish Room.
Sr Cutting & Baling Oper	Directs the operation of all equipment in the Cutting and Baling department. Trains and directs new employees. Assists and directs Operators and Helpers in the performance of their duties. Relieves Operators and Helpers as needed.

Appendix IV (Continued)
Brief Description of Most Significant Job Titles
by Department

Job Title	Description
	Fiber Manufacturing
Cutting & Baling Oper	Performs all work necessary to cut fiber to the selected lengths. Performs clean out of cutting and baling equipment. Relieves other Operators for breaks, etc.
Day Senior Oper	Relieves the Senior Operators and Field Operators for lunch, also relieves the Senior Operators on their day off. Operates the strap cutter as required.
Sample Man (No C&B)	Obtains, prepares, and delivers all area samples to their designations. Relieves other Operators as needed. Cleans the Break Area.
Cut & Baling Area Helper	Helped out in the Cutting and Baling Area.
Baler (No C&B)	Run bale presses, keeps work area clean, removes all fiber from ducts during clean out.
Sr Operator Checker	Checks bales and cartons with shipping lists for correct loading of shipments, also checks weights, merges, and other pertinent data for shipment.
Shipping Operator	Operates a fork truck in moving finished materials, and loads trailer or cars. Performs housekeeping and other duties.
Shipping Stacker	Checks the condition of bales or cartons placed in the transfer area. Moves finished goods to Aclag system. Assists with housekeeping and other duties.

Appendix IV (Continued)
Brief Description of Most Significant Job Titles
by Department

Job Title	Description
	Technical Center/Pilot Plant
	People rotated through the various job titles during the initial production period and duties performed were interchangeable. Job titles included Technician, Operator, Laborer, Engineer, and Chemist.
	R & D Analytical Lab (Pilot Plant Lab)
Group Leader	Supervised the activities of the Lab.
Shift Leader	Supervised all workers in the Lab on a specific shift.
General Tech	Main job title for the Lab. Performed miscellaneous duties including analyzing QC samples.
Specialist, Research Chemist & Senior Research Chem	(Historical job titles, no longer used.)
	Quality Control - Chem Lab
Foreman	Supervised the operation of the Chem Lab.
Chemist	Senior job title for the Chem Lab.
Technicians	Included the following job titles: Bottle Washer, Selectivity Technician, NSP Technician, Nylon Instrument Technician, Salt Split Technician, Tech Lab Technicians, Day Crew Technician.
	Engineering (by group)
Process Engineering	Supported manufacturing. Engineers worked with ongoing processes. Spent some time in the plant observing ongoing operations.
Project Engineering (Plant Engineering)	Involved with implementation of new processes and modification of existing operations. Very little time spent in production areas.
Engineering Development	Associated with the Technical center, specifically the PP. Had exposure to AN.
Industrial Engineering	Developed written job descriptions with corresponding job duties, for the plant.

Appendix V

Exposure Measurement Before and After Engineering Changes,
Nylon Intermediates
Monsanto Chemical Company
Decatur, Alabama
August 25-28, 1986

Engineer Changes	Date of Change	Exposure Prior, 1978 ppm (n)*	Exposure After, 1981 ppm (n)*
Install sampling stations (13)	Late 1979-1980	8.3 (5)	0.44 (12)
402 Bldg ventilation	"	2.4 (7)	0.3 (7)
Azr Bldg ventilation	"	19 (3)	0.5 (1)
051 Sump ventilation	"	0.8 (3)	-
Funda filters added	Late '80-Early '81	0.8	0.9
Dual conservation vents on tanks	"	121 (9)	-
Reactor flush	1981	10.7 (3)	3.3 (4)
OVERALL:	1979-81		
402	"	3.52 (17)	0.4 (12)
403	"	0.9 (17)	0.4
Package Handling	"	2.8 (13)	0.3 (7)
Instr NI	"	5.4 (6)	-

*n denotes number of samples, samples are long-term time-weighted averages.

Appendix VI

Summary of Persons Interviewed by Department

Department	Number of people Interviewed	Time Period * Interviewees Had Worked at Plant
Acrylic Intermediates	5	1956 - 1983
Nylon Intermediates	9	1958 - 1983
Utilities/Marine Boiler	2	1956 - 1983
Laboratories (Chem, R & D, Pilot Plant)	6	1954 - 1983
Research & Development/ Pilot Plant	4	1959 - 1983
Maintenance	7	1955 - 1983
Engineering	2	1964 -1983
Miscellaneous (Personnel, Ind Hyg, Med)	4	?

* 1983 is the end date of the AN Mortality Study, most of the interviewees worked beyond this date. The years presented represent the time period covered by the interviewees. Typically for a group of interviewees one or two began working at the plant in the early years and the others started in the mid-1960s.

Figure 1
Plant Layout

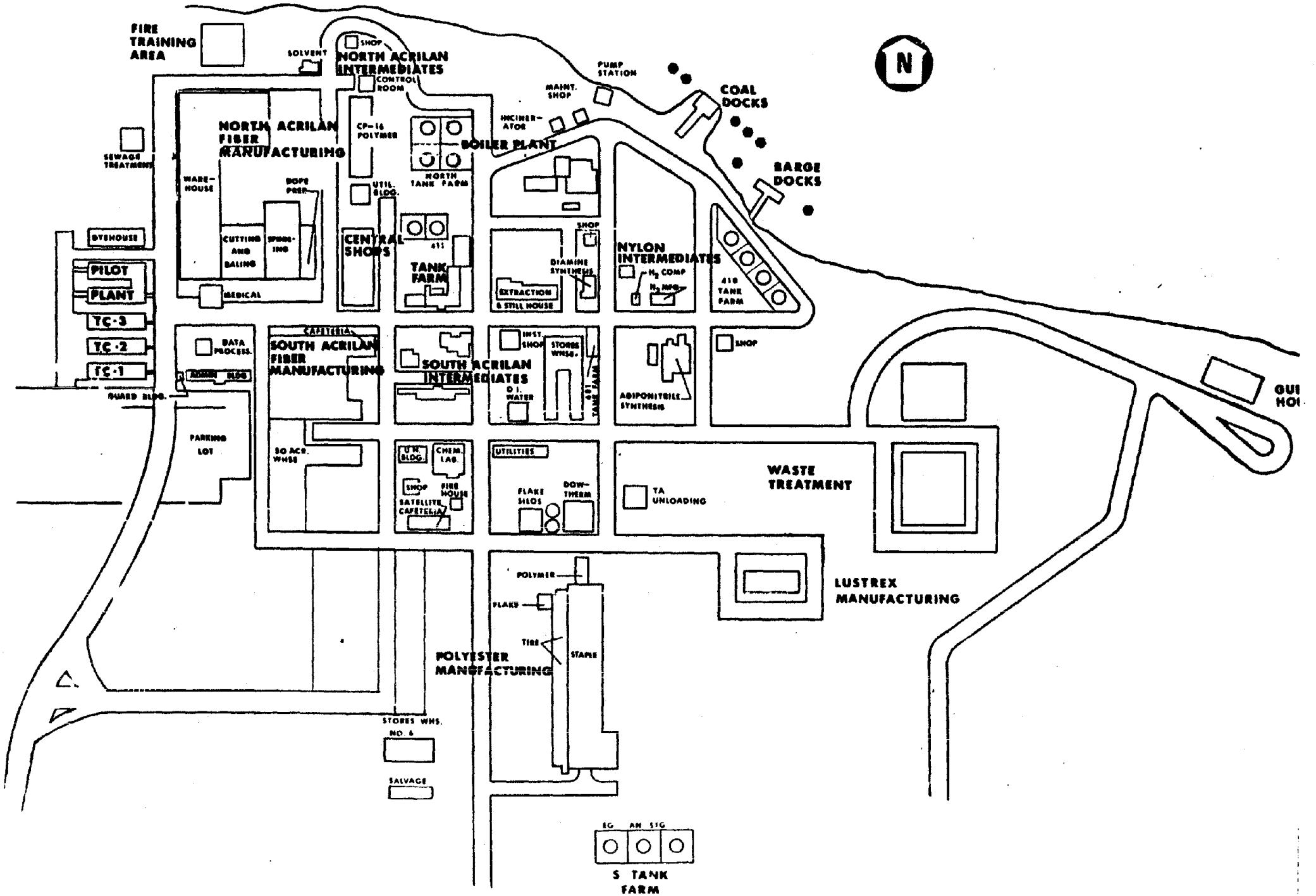

Figure 2
Acrylic Manufacturing

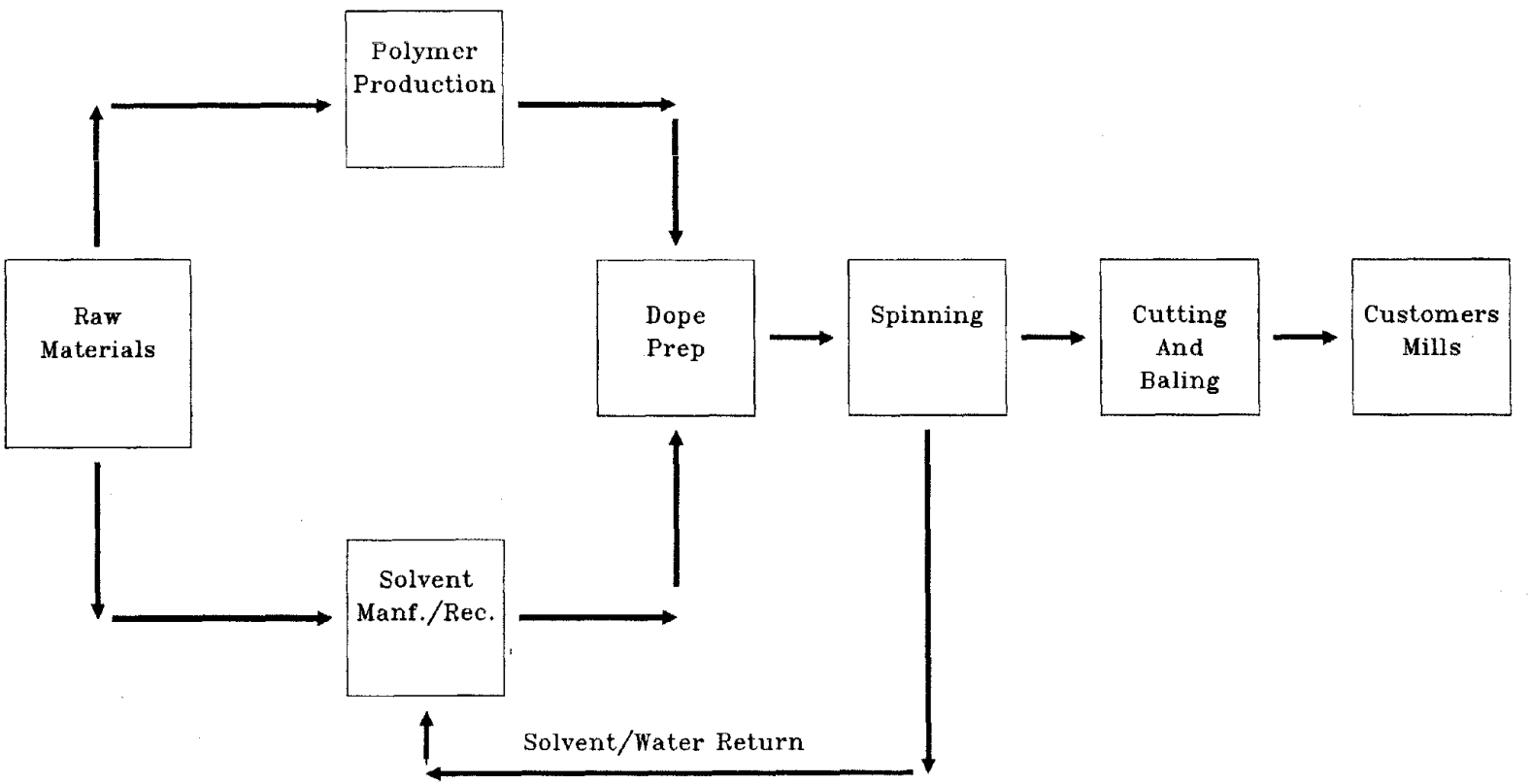

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Figure 4
North Dope Prep

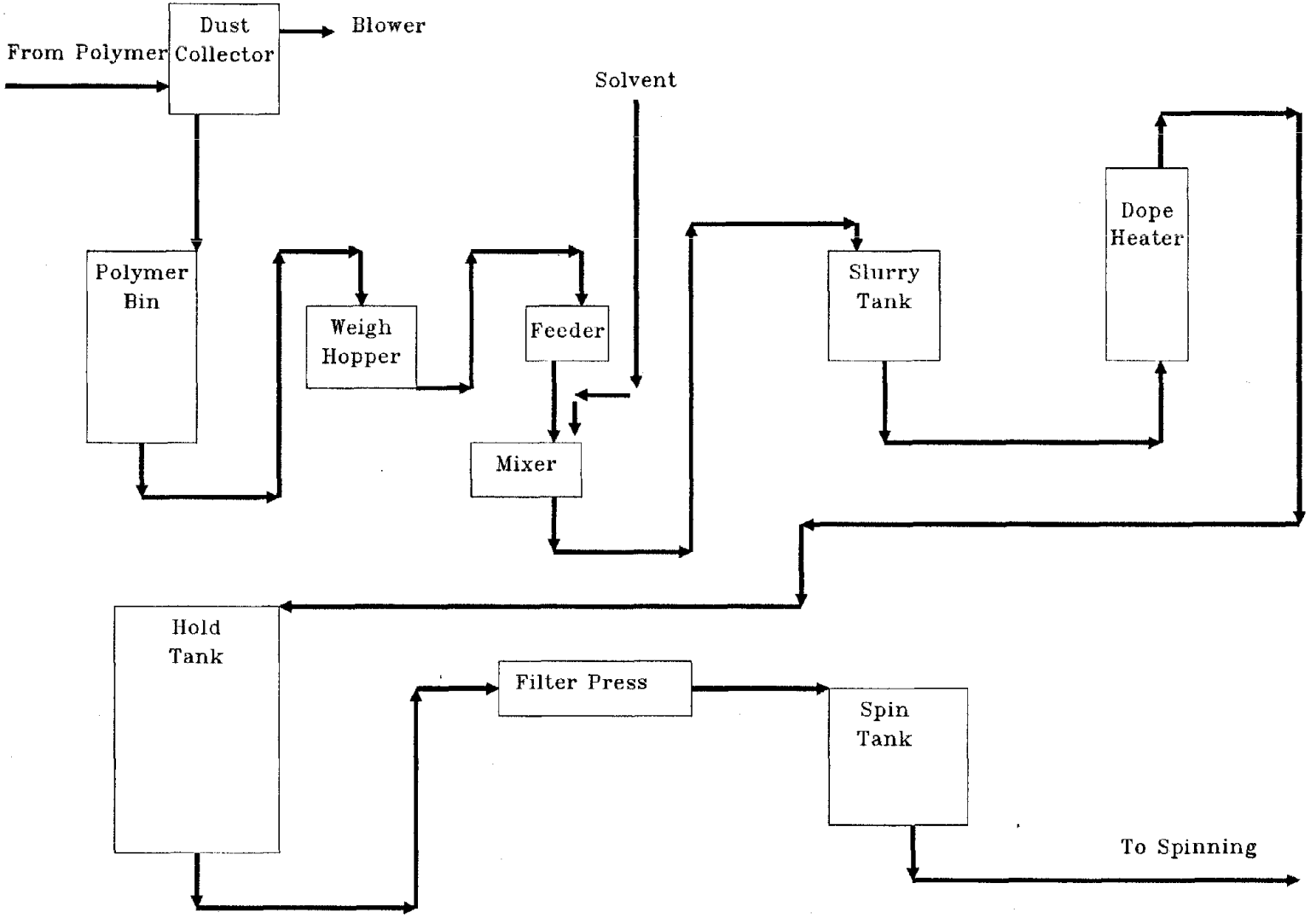

Figure 5
North Spinning

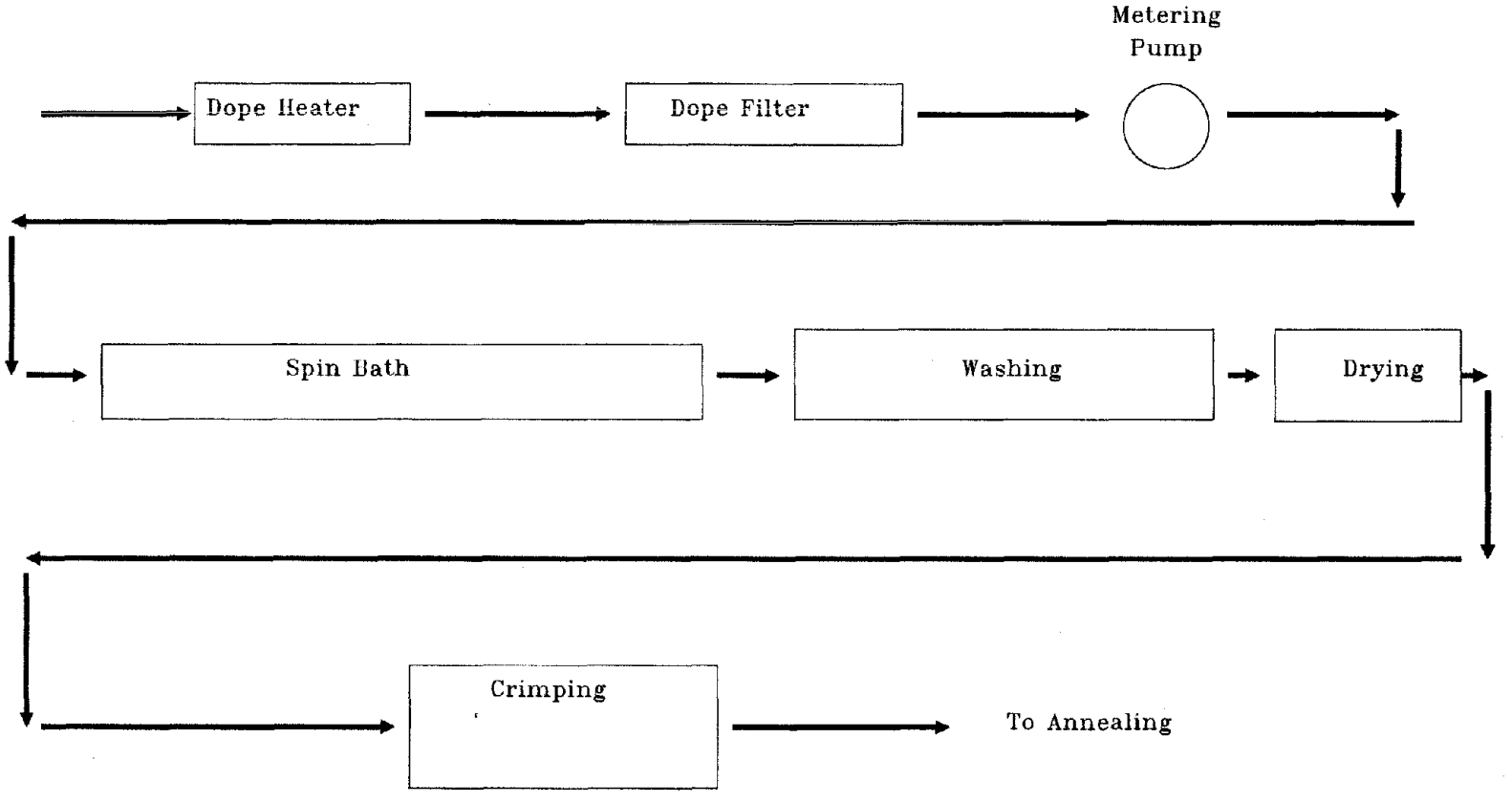

Figure 6
Cutting & Baling

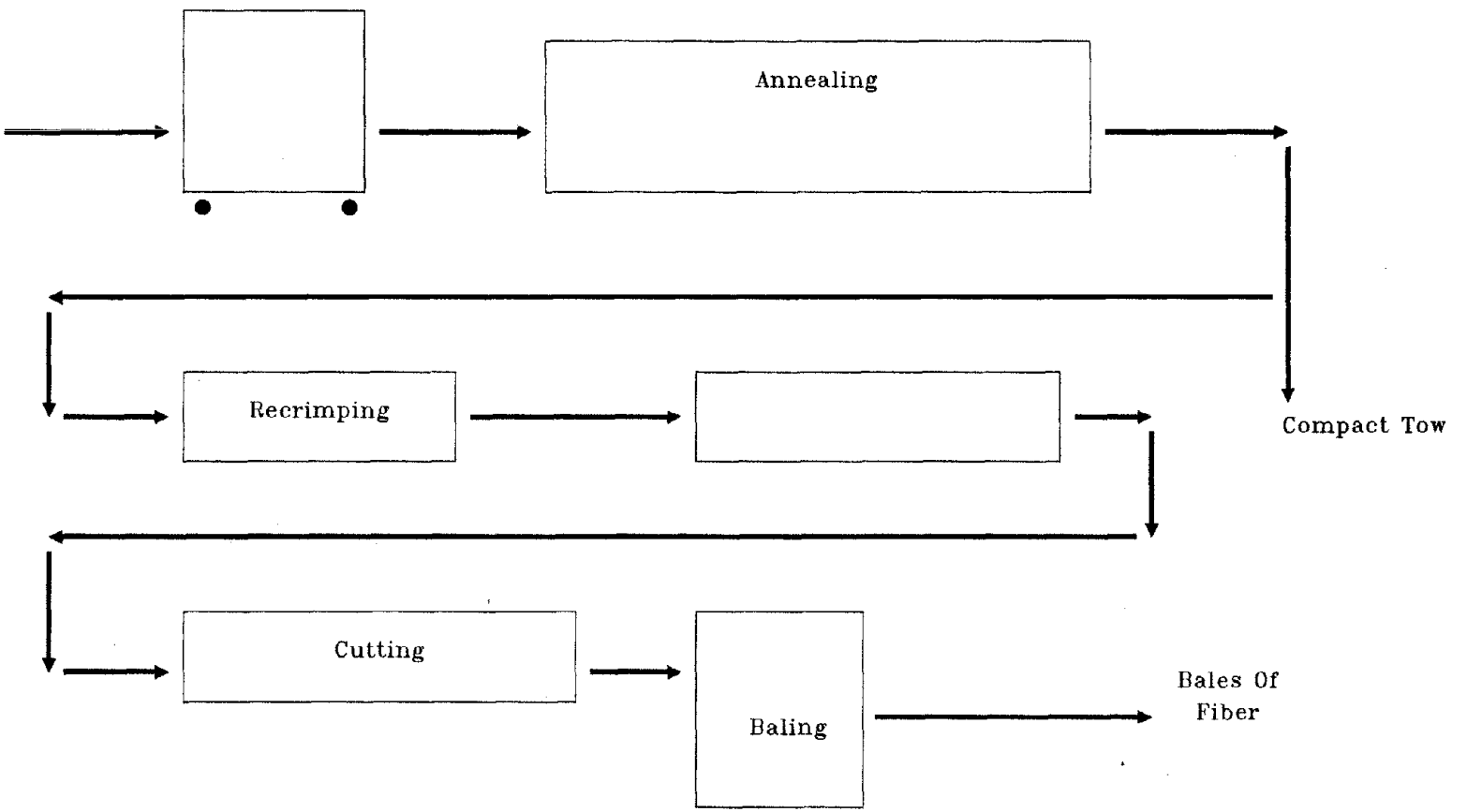

Figure 7
Simplified Diagram of HMD & ADN Manfacturing Process
Nylon Intermediates