Dioxin Registry Report
of
Monsanto Company
Sauget, Illinois

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Abstract

The National Institute for Occupational Safety and Health (NIOSH) Dioxin Registry is a compilation of demographic and work history information for all U.S. production workers who have synthesized products known to be contaminated with 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) and/or hexachlorodibenzo-p-dioxins (HxCDD). There are fourteen production facilities and approximately 7000 workers included in the Registry.

Included in the Registry is the Monsanto Company facility in Sauget, Illinois which produced esters of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), tetrachlorophenol (TetCP) and pentachlorophenol (PCP). 2,4,5-T esters were produced at the Sauget facility from 1960 to 1970, while TetCP and PCP were produced from 1938 to 1978. Presented in this report is a historical compilation of information and data on the operations and the personnel involved in these production processes. This information was obtained from documents received from Monsanto, plus interviews with Monsanto employees or former employees. Included in this report are descriptions of the facility, workforce, processes, past exposure, and personnel record systems.

Introduction

The National Institute for Occupational Safety and Health (NIOSH), Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS), Industrywide Studies Branch (IWSB), is conducting an investigation of health effects resulting from occupational exposure to polychlorinated dibenzo-p-dioxins (PCDD) and in particular 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) and hexachlorodibenzo-p-dioxin (HxCDD). This study, referred to as the Dioxin Registry, is a compilation of demographic and work history information for all U.S. production workers who have synthesized products known to be contaminated with 2,3,7,8-TCDD and/or HxCDD. The Registry, initiated in 1979, was prompted by animal studies showing 2,3,7,8-TCDD to be acutely toxic and a chloracnegen, as well as a carcinogen and a teratogen.[1-7] 2,3,7,8-TCDD is a contaminant found in 2,4,5-trichlorophenol (2,4,5-TCP) and/or its sodium salt, which are raw materials used to produce 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). HxCDD is a contaminant found in tetrachlorophenol (TetCP) and pentachlorophenol (PCP). There are fourteen production facilities and approximately 7000 workers included in the Registry.

This report is a compilation of information and data collected from the Monsanto Company and other sources regarding the W.G. Krummrich plant in Sauget, Illinois. This facility produced 2,4,5-T esters, tetrachlorophenol (TetCP), pentachlorophenol (PCP), and sodium pentachlorophenate (NaPCP). Because of the dioxin contamination the workers involved in these processes are included in the Dioxin Registry.

Much of the history and descriptions for the processes and personnel in this report were obtained from Standard Manufacturing Process (SMP) descriptions for PCP, TetCP, NaPCP, and 2,4,5-T ester processes which were provided to NIOSH by the Monsanto Company. Ten SMPs were provided for the PCP and TetCP processes for the years 1943, 1953, 1954, 1955, 1956, 1958, 1961, 1965, 1968, and 1972. Seven SMPs were provided for NaPCP for the years 1949, 1954, 1956, 1959, 1961, 1965, and 1972. Three SMPs were provided for the 2,4,5-T ester processes for the years 1962, 1966, and 1969.

Description and History of the Facility

The W.G. Krummrich plant is located in Sauget, Illinois, an industrialized area five miles southeast of St. Louis, Missouri. The plant was established in 1907 as the Commercial Acid company and occupied 30 acres and employed 70-100 people. Monsanto purchased the plant in 1917 and called it Plant B. In 1951, the plant was renamed the W.G. Krummrich plant in honor of a former plant manager. As of 1985, the plant occupied 329 acres of land.

A 1977 report by Jones[8] indicated that the W.G. Krummrich plant employed 1300 workers, of whom 835 were hourly workers. In a 1985 study protocol,[9] Hryhorczuk et al. reported 1100 workers were employed at the plant. The plant is administered by one of Monsanto's operating companies (Monsanto Chemical Company), and is organized by the International Chemical Workers Union, Local 12.

In 1974, Jones [8] reported that the facility produced approximately 47 different chemical compounds. The highest percentage of the compounds produced were chlorinated. In the 1985 Hryhorczuk [9] protocol, the W. G. Krummrich plant was said to have produced one billion tons of material a year and approximately 20 different intermediate chemical products. The major raw materials used included chlorine, phosphorus, benzene, sulfur and sodium chloride to produce such products as chlorinated benzenes, chlorophenols, orthonitrophenol, nitroaniline, phosphorus trichloride, phosphorus oxychloride, phosphorus pentasulfide, sulfuric acid, chlorosulfonic acid, muriatic acid, chlorine bleaches, and stabilizers, detergent materials, feed grade antioxidants and elastomers. Tables 1 through 4 list chemical products produced at the Sauget plant for the years 1971, 1975, 1977, and 1978. Table 5 provides a list of notable chemical products, the departments where they were manufactured, and the years they were manufactured.

A plant layout, circa 1980, is shown in Figure 1. The departments of interest to the Dioxin Registry are departments 236 (TetCP & PCP), A-236 (NaPCP), and 268 (2,4,5-T ester). Departments 236 and A-236 were housed in Building BO and Building BD, which were centrally located in the plant, in the block surrounded by Second Street, Third Street, E Street, and Falling Spring Road. Building BO was demolished in 1958, however the area where it was located as well as the location of Building BD and Department 268 are noted on Figure 1. Department 268 was located in the northern section of the plant, north of Monsanto Avenue and west of Falling Spring Road. This section of the plant (the shaded area) was sold to Edwin Cooper, Inc. in November 1969.

Monsanto first began producing PCP and NaPCP at another site, the John F. Queeny plant, in East St. Louis, Missouri in 1938 in the W Building. The W Building was a process research building. On October 11, 1938, full scale production of PCP, TetCP, and NaPCP was started at Plant B (currently referred to as the W.C. Krummrich plant) in Building BO. The building was a large one-room wooden structure which housed not only Depts. 236 (PCP and TetCP) and A-236 (NaPCP) but also Depts. 226 and 237. Dept. 226 manufactured Monsanto salt (ortho-chloro-para-toluene sulfonate). Monsanto salt was sold as a red dye to manufacturers who produce paints, inks, etc.. Dept. 226 operated in Building BO during the entire time that Depts. 236 and A-236 were located in Building BO. Dept. 237, which began operation in 1935 in Building BO, produced chlorophenols, such as para- and orthochloro-phenol and 2,4-dichlorophenol (2,4-DCP). 2,4-DCP was used to produce 2,4-dichloro-phenoxyacetic acid (2,4-D Acid) in Dept. 262. In 1940, Dept. 237 was moved from Building BO to an adjacent open air facility.

In 1946, construction of Building BD was started. Building BD was constructed specifically for the production of PCP, TetCP, and NaPCP. In 1947 the PCP, TetCP, and NaPCP processes were gradually moved to Building BD. Building BO was used for supplemental briquetting of NaPCP until 1958 when Building BO was demolished. PCP and NaPCP were produced in Building BD from 1947 to April 1978 and December 1975 respectively, when each process ceased production.

Initially Monsanto referred to its PCP as Santophen 20®. In 1954, Santophen 20® was renamed Monsanto Penta or just Penta. NaPCP, produced using PCP and caustic, was initially referred to as Santophen 20S®. Shortly after the process was moved to Building BD in 1947, Santophen 20S® was renamed Santobrite®.

As with PCP, Monsanto initially began producing 2,4,5-T esters at their Queeny plant in East St. Louis, Missouri. The dates and types of 2,4,5-T esters produced at Queeny are as follows:

Product	Production Period
Isopropyl 2,4,5-T ester	03/13/50 - 11/01/56
Butyl 2,4,5-T ester	08/18/52 - 07/31/60
Isooctyl 2,4,5-T ester	02/25/60 - 07/31/60
Butoxy etoxy propyl 2,4,5-T ester	12/15/54 - 11/01/56
60:40 Butyl:isobutyl 2,4,5-T ester	12/61 - date unknown

In addition, 2,4,5-T acid was manufactured at Queeny from late 1952 to early 1953, however most of the 2,4,5-T acid used to produce 2,4,5-T esters was produced at Monsanto's Nitro, West Virginia plant.

In August 1960, 2,4,5-T and 2,4-D esterification operations were started at the W.G. Krummrich plant in the northern section of the plant in Dept. 268, which was an open air structure with an air conditioned control room located in the north end of the process. Dept. 268 produced butyl, isobutyl and isooctyl ester of 2,4,5-T and 2,4-D. The esterification process was shared equally between 2,4-D and 2,4,5-T ester production. All 2,4,5-T acid used to produce 2,4,5-T esters was produced by Monsanto at their Nitro, West Virginia plant, while all 2,4-D acid used to produce 2,4-D esters was produced at the W.G. Krummrich plant in Dept. 262 which was located just north of Dept. 268. The land where Dept. 268 was located was sold to Edwin Cooper, Inc. in November, 1969 and 2,4,5-T and 2,4,-D ester operations ceased by January, 1970.

Production capacities for PCP varied depending on demand and whether 2 or 3 chlorinators were used. PCP production for the time period between 1938 and 1947 ranged between 230,000 to 260,000 lbs. per month; for the time period between 1948 and 1954, 440,000 to 1,125,000 lbs. per month; for the time period between 1955 and 1958, 1,150,000 to 1,800,000 lbs. per month; for the time period between 1959 and 1969, 1,800,000 to 2,400,000 lbs. per month; and for the time period between 1970 and 1978, 2,700 to 3,400 lbs. per month. The Chemical Marketing Reporter[10] reported in 1977 that the W.G. Krummrich plant had a production capacity of 26 million lbs. annually for PCP. Production capacities for NaPCP ranged from 200 lbs. per month to 800 lbs. per month for the years 1949 to 1975. 2,4,5-T ester production capacities (isobutyl + butyl) were 900,000 lbs. per month for the years 1960 to 1964, 1,000,000 lbs. per month for 1965, 1,150,000 lbs. per month for 1966 and 1967, and 1,250,000 lbs. per month for 1968 through 1970.

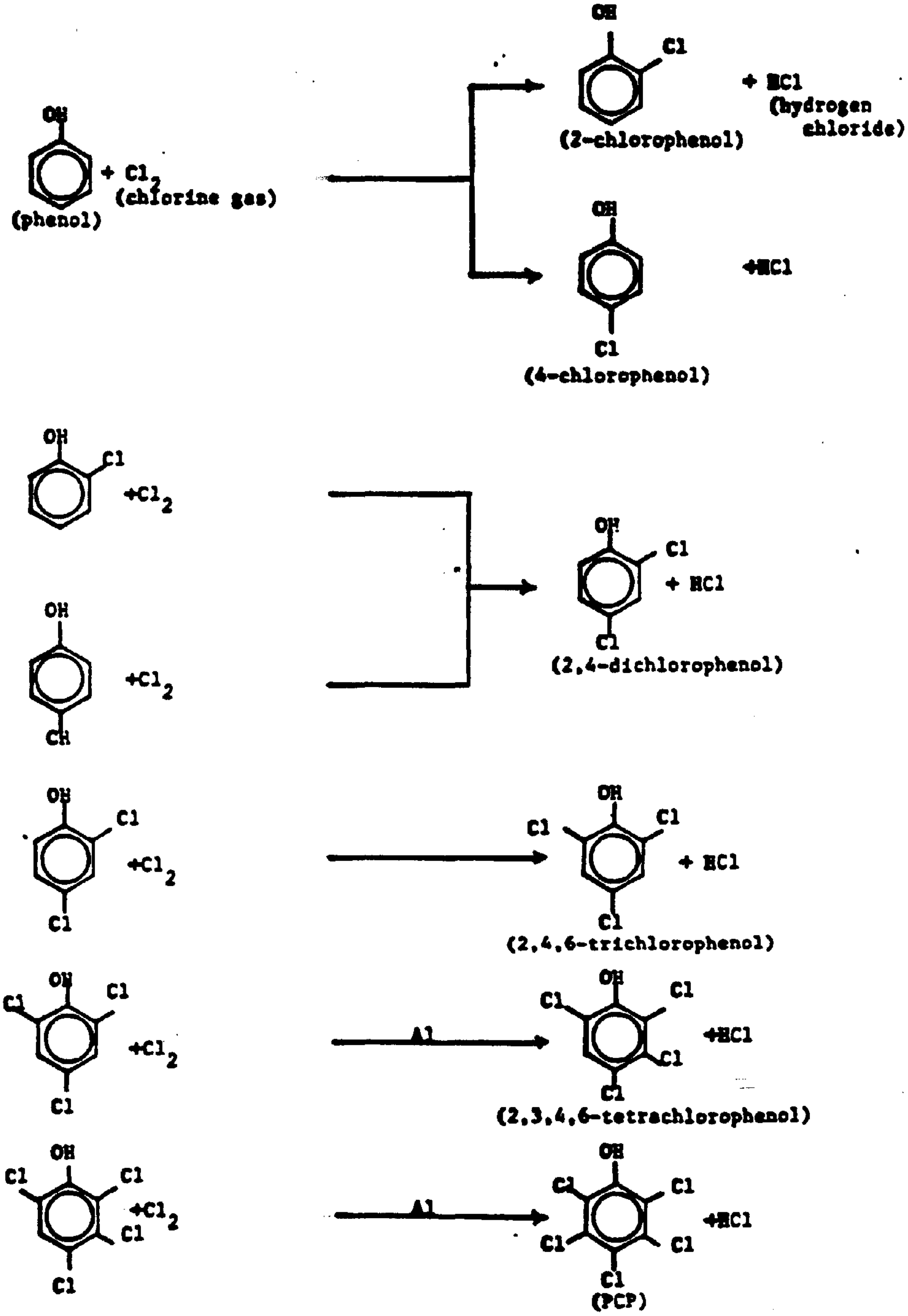
Descriptions of the Processes

This portion of the report provides historical descriptions for the PCP, NaPCP, and 2,4,5-T esters processes. The NaPCP production process is being treated as a separate production because it had a distinctive department number and workforce. In reality, the NaPCP process was a continuation of the PCP process where PCP was used as a raw material to produce NaPCP. Process equipment used to produce PCP and NaPCP were housed in the same buildings (Building BO from 1938 to 1947 and Building BD from 1948 to 1978). TetCP was produced using the same equipment and raw materials used to produce PCP, although chlorination of PCP was continued for a longer period. The process equipment used to produce 2,4,5-T esters was also used to produce 2,4-dichlorophenoxyacetic acid (2,4-D) esters.

A. PCP Process Description

1. Chlorination

PCP was produced by Monsanto using the same chemistry for the entire production period (1938 - 1978). The raw materials used in the production of PCP were phenol, chlorophenol fractions (mono, di, and trichlorophenols), chlorine gas, a catalyst, and sulfuric acid for scrubbing purposes. The production of PCP involved chlorinating phenol and/or chlorophenols with chlorine gas in the presence of a catalyst at elevated temperatures. The following chemical mechanism shows the sequence of reactions which produce PCP:


OH
+ Cl2
(chlorine gas)
(phenol)
OH
Cl
(2-chlorophenol)
+ HCl
(hydrogen chloride)
OH
+HCl
Cl
(4-chlorophenol)
OH
Cl
+Cl2
OH
+Cl2
Cl
OH
Cl
+ HCl
Cl
(2,4-dichlorophenol)
OH
Cl
+Cl2
Cl
OH
Cl
Cl
+ HCl
Cl
(2,4,6-trichlorophenol)
OH
Cl
Cl
+Cl2
Cl
Al
OH
Cl
Cl
+HCl
Cl
Cl
(2,3,4,6-tetrachlorophenol)
OH
Cl
Cl
+Cl2
Cl
Cl
Al
OH
Cl
Cl
+HCl
Cl
Cl
Cl
(PCP)

The block flow diagram in Figure 2 illustrates the steps used to produce PCP. Figures 3 through 10 are photocopies that depict the flow diagrams as they were found in the SMPs for the years, 1943, 1953, 1954, 1956, 1957, 1961, 1965, and 1972. These figures provide a chronological overview of how the PCP process evolved and changed during the time it operated.

Pentachlorophenol production began October 11, 1938 in Building BO. The first step in the process was the chlorination of phenol and chlorophenol fractions in a chlorinator. Initially, Monsanto used two 600 gallon Monel® chlorinators with agitators in series to produce PCP. Two thousand four hundred pounds of phenol or the phenol equivalent of mono-, di-, or trichlorophenol were charged into the first or primary chlorinator. The phenol and/or chlorophenols were chlorinated with vaporized liquid chlorine at 60-65°C until the batch reached the trichlorophenol stage, which was determined from hourly chlorinator sample measurements of specific gravity. The trichlorophenol stage was reached when the specific gravity was between 1.490 and 1.500 at 70°C. Once this was reached, the reaction mass in the preliminary chlorinator was transferred to the second or final chlorinator. Three pounds and three ounces of ground aluminum catalyst (0.1% of phenol) was added and chlorination was then carried to the PCP stage with vaporized liquid chlorine at an initial temperature of 70-75°C. The temperature was maintained at 70-75°C until the batch specific gravity of 1.670 at 70°C was reached. At this point the batch temperature was gradually increased and crystallizing points were taken instead of specific gravities. The batch temperature was maintained 10°C to 12°C above the crystallizing point. Chlorination was stopped when a crystallizing point of 174.5 to 175.5°C was reached. The PCP from the final chlorinator was either delivered to a flaker, flaked and packaged into fibre packs or dropped into a dissolver tank containing caustic and water and made into NaPCP. Chlorination remained essentially the same throughout the time PCP was produced in Building BO (1938-1947).

In 1946, Building BD was built specifically for PCP and NaPCP production. The production process in BD was to take place in 2 chlorinators in series, as in Building BO, using two 1300 gallon Monel® chlorinators containing 2" Monel® cooling coils, a Monel® 24" Nettcostirrer and chlorine gas sparging. During the preliminary start-up, failure of the preliminary chlorinator's stirrer necessitated that the complete chlorination process be conducted in the final chlorinator. The same results were achieved using the single chlorinator as when two chlorinators were used in series. From this point on, chlorination of a batch of PCP was carried out in one chlorinator instead of two in a series. In 1953, a third chlorinator was installed in Building BD. Two chlorinators were normally used to produce PCP and one to produce crude 2,4-DCP for Department 237. In 1959, a fourth chlorinator was added and normal operations were to use three chlorinators for PCP production and one for crude 2,4-DCP production. In 1970, one of the chlorinators was removed and replaced with a jumbo Monel® chlorinator which had a 3800 gallon capacity with multiple level Monel® sparge pipes.

Phenol and chlorophenol fractions from Department 237 and the phenol scrubbers were used as the starting raw materials in the PCP process. Starting in 1960, recovered redistilled 2,4-DCP from Department 262 was also used as a raw material. Vaporized liquid chlorine was used initially to chlorinate phenols and chlorophenols. In 1949, snift-cell gas chlorine (86% $C1_2$) replaced vaporized liquid chlorine up to the point when aluminum catalyst was added to the chlorinator (trichlorophenol stage) and in 1955 chlorine cell gas was used throughout the entire chlorination process. In 1969, cumene phenol (phenol produced from cumene) began to be used. Prior to this date only United States Pharmacopeia (USP) phenol was used.

As stated previously, the final crystallizing point of PCP was initially between 174.5 and 175.5°C. During the years between 1938 and 1950, Monsanto was one of only a few major PCP producers. Due to steadily increased competition in the 1950's, the quality of Monsanto's PCP was improved in order to remain competitive. The first quality improvement consisted of increasing the crystallizing point. In 1955, the average final crystallizing point was increased from 175°C to 176°C; then, in 1958, from 176°C to 178°C and finally, in 1963, from 178°C to 180°C. By 1965, final crystallizing points were set for various types of PCP: Penta L 175°C; Regular Penta 180°C; Santobrite® Penta 178.5°C, and Penta 60 145°C. From 1938 to 1958, TetCP, which was also produced in the PCP process on an "as demand" basis, had a final crystallizing point between 60°C and 63°C.

A catalyst was used to insure that the chlorination reaction continued to completion to form PCP. Without a catalyst, the reaction would have stalled between the TetCP and PCP stages at a specific gravity of approximately 1.750. Initially in 1938, iron oxide was used as the catalyst, but after approximately five batches, in which poor color quality resulted, a switch to aluminum was made. Aluminum grained ingot was used for all years PCP was produced. From 1938 to 1947, 3 lbs., 3 ozs. of aluminum (0.0013 lb. Al/lb. phenol) were added to the chlorinator when the reaction mass specific gravity was between 1.490 and 1.510. Between 1947 and 1955, 7-1/4 lbs. of aluminum (0.0013 lb. Al/lb. phenol) was added to the chlorinator reaction mass when the reaction mass specific gravity was between 1.400 and 1.450. From 1956 until 1965, the amount of aluminum catalyst used was doubled to 14-1/2 lb (0.0026 lb. Al/lb. phenol) and was added to the chlorinator reaction mass when the specific gravity was between 1.475 and 1.510. In 1965 in an effort to eliminate clogging at the prilling plate, the amount of aluminum catalyst was reduced to 4 lbs. (0.0007 lb. Al/lb. phenol) and was added early in the process when the specific gravity was between 1.400 and 1.425. By 1968, the amount of catalyst had been lowered to 3 lbs. of aluminum added at a specific gravity between 1.400 and 1.425 with the option of adding an additional 2 lbs of aluminum when the specific mass gravity was between 1.625 and 1.675. In the jumbo chlorinator (installed in 1970), 7 to 16 lbs. of aluminum (0.0005 to 0.0010 lb. Al/lb. phenol) were added to the reaction mass when the specific gravity was between 1.400 and 1.415.

Once a specific crystallizing point was reached chlorination was stopped and the molten PCP was either finished or dissolved to produce NaPCP.

2. PCP Flaking

PCP was finished in several ways depending on the time period. From 1938 to 1963, PCP was finished into flakes. In Building B0 (1938-1947) flaking was accomplished using a J.P. Devine 48 inch diameter by 30 inch long enclosed flaker with a vapor condenser. Molten PCP from the chlorinator was drained to a flaker pan. The PCP in the flaker pan was removed from the pan by a revolving roll and was cut from the roll by a doctor blade, from which the flaked PCP was discharged into fibrepaks. Each fibrepak was filled with 100 pounds of PCP, and a small grab sample was collected. The complete flaking cycle required approximately 3-1/2 hours to complete. Once a batch was flaked the grab samples were combined to make 2- 16 oz. composite samples.

After the PCP was flaked it was allowed to cool for at least 48 hours. In order to ship a free-flowing product, the fibrepaks of PCP flakes were emptied into the hopper of a Robinson Crusher with ½ inch openings, were crushed and then discharged back into the fibrepaks.

With the increase in chlorinator capacity as a result of using the 2 chlorinators for parallel batch chlorination rather than in a series for a two-step chlorination, larger flakers were needed. Two 60-inch in diameter by 72-inch long J.P. Devine enclosed flakers were used in Building BD. These flakers were operated in the same manner previously described. Three fibrepaks were filled at one time. The fumes generated during flaking were removed through a vent to a Schutte - Kjorting obnoxious vapor condenser. Four and one-half hours were required to flake a 14,700 pound batch of PCP.

No crushing of the PCP flakes was done in Building BD. By 1955 the flaked material was conveyed to an automatic scale for packaging in 50-pound bags or 100-pound Leverpaks instead of directly into fibrepaks as was previously done. In 1956, in an effort to reduce sublimation and caking of the PCP flakes, oil (3% by weight) was added to some of the flaked PCP. This was accomplished by the addition of oil through spray heads mounted in the automatic scale hopper. The oil used was a 5% solution of turpentine in #5 C.S. oil. The turpentine functioned as a scavenger to remove residual HCl from the PCP flakes.

3. PCP Prilling

In order to keep up with competitors, experiments were conducted starting in February 1963 to produce prilled PCP. A new prill system was started up on October 20, 1963 and replaced the flaking operations. The prilling system consisted of a hold tank, prill tower, bucket elevator, product hopper, packer, scrubber tank and fume scrubber. The hold tank was a 6-foot diameter by 10-foot high vertical Monel® tank with external plate-heating coils with a capacity of 33,000 pounds of PCP or 2500 gallons. The introduction of the hold tank freed the chlorinator from being used as a hold tank, as was the case when flaking was done. With the introduction of the hold tank, it became apparent that PCP held in the hold tank longer than two hours would increase alkali insolubles and decrease the gas liquid chromotography (GLC) PCP assay in the finished batch, both undesirable changes. Therefore, molten PCP, chlorinated beyond the 1.650 specific gravity stage, could be held in the holding tank no longer than two hours. The temperature of the molten PCP held in the holding tank was maintained at 188-193°C.

The prill tower was an eight foot in diameter by 51.5-foot high vertical uninsulated 316SS tower. Molten PCP was pumped from the hold tank through 200 pounds per square inch gauge steam-jacketed Monel® piping to the prill tower head tank. A constant head pressure was maintained on the prill plate by overflowing excess liquid back to the hold tank. The head pressure maintained in the head tank forced molten PCP through the holes in the prill plate. The PCP was discharged into the prill tower, and droplets of PCP were formed. As the droplets fell in the tower, they were drawn into a spherical shape due to surface tension. The PCP entered the tower at 185-195°C. As the PCP droplets fell, they were cooled by a counter-current flow of ambient air and crystallized. The prilled PCP, at a temperature of 60 to 70°C, flowed by gravity from the bottom of the prill into the Roto-Louvre cooler.

In the cooler, the prills were cooled by a counter-current flow of ambient air to a temperature of 30-45°C. A protective coating, Armoflo-67, was sprayed on the prills at a rate of 0.4-0.5 pounds Armoflo-67 per hour in the prill cooler. The coating was used to prevent sublimation and caking. The coated prills discharged from the cooler were transferred into the prill hopper by a continuous belt-type conveyor. The prills then flowed by gravity into a St. Regis fluidizing bag packer. The finished prills were packaged into 50-pound bags, 100-pound fibrepacks or 475-pound steel drums. The only change in the prilling system occurred in August 1965 when a larger capacity prill blower was installed. This enabled a prill system rate increase from 2700 pounds of prilled PCP per hour to 5000 pounds of prilled PCP per hour.

Exhaust from the prilling operation was cleaned with a Venturi Scrubber and a cyclonic separator. Cooling air for the prilling operations entered through openings in the bottom of the prill tower and was circulated with an induced draft blower (4000 CFM: 1963-1966; 12,000 CFM: 1966-1978). The cooling air for the cooler was circulated with a forced draft blower. The exhausts from the tower and cooler connected together and the combined gases were cleaned in a Venturi Scrubber using a 4-6% NaOH solution wash. This removed PCP, TetCP, and HCl that had evolved in the off-gas. To prevent foaming in the NaOH solution NOPCO JMY antifoam solution was added. Any remaining non-gaseous impurities in the off-gas from the Venturi Scrubber were removed as the gas passed through a cyclonic separator on its way to the blower and atmosphere. The spent NaOH from the Venturi was returned to a storage tank and recirculated. After every other batch, the spent NaOH was pumped to the NaPCP recovery tank where it was used to prepare NaPCP. If the NaPCP process was idle, the spent caustic was discharged to the sewer.

4. PCP Block Molding

Starting in 1970, Monsanto began producing blocks of PCP. Molten PCP was pumped from the hold tank through 200 pounds per square inch pressure steam-jacketed Monel® piping to a header where it was manually charged to the block molds. The molds were filled volumetrically to provide a block of 2000 pounds. There were six pour spots and 14 truncated molds. The molds were carbon steel truncated cones which stood 40 inches high, with a top diameter of 36 inches and a bottom diameter of 30 inches and rapping rings which held the molds shut. A mold was positioned under a spout and gravimetrically filled. After filling, the mold was left in position for two to three hours to allow a crust to form on top. Removing the block from the mold required heating the mold. Because of the high melting point of PCP it was necessary to use a welding torch to heat the mold. The blocks were then removed from the molds and packed in containers for shipment.

5. HCl By-Product

Throughout the chlorination process, the by-product HCl was scrubbed with phenol in a Monel®-jacketed reaction vessel by means of a draft tube and agitator. Unreacted chlorine from the chlorinator, was removed from the HCl by reaction with the phenol. Temperature was maintained between 35-45°C during this exothermic reaction by controlling cold water flow to the external jacket. The chlorinated phenols resulting from this reaction were then used as a starting material in the subsequent batches. Entrained chlorophenols in the cooled off-gas leaving the scrubber were recovered. Initially the entrained chlorophenols were recovered in a Monel® catch pot and Vogt cooler. From the coolers the HCl gas entered the bottom of a packed sulfuric acid scrubbing tower and was forced out the top. Flowing counter-current to the HCl gas, 98% sulfuric acid entered the top of the tower and flowed by gravity to the bottom. Any remaining chlorophenols would have been removed. The circulating sulfuric acid temperature was maintained between 20 and 25°C. When the strength of the sulfuric acid fell below 80%, the acid was discharged to the sewer and replenished with fresh 98% sulfuric acid. In 1955 the packed sulfuric acid scrubbing towers were replaced by a sulfuric acid jet scrubber which consisted of a 12 inch Schutte - Kjorting jet on a 13,000 gallon tank. The scrubbed HCl gas contained approximately 0.015% phenols. The HCl gas was pumped to three locations: Dept. 233 where it was absorbed in water to form muriatic acid; Dept. 217 where it was used to make chlorosulfonic acid; or to a Haveg water jet and discharged. By 1958 the HCl gas was sent either to Dept. 217 or to the water jet. By 1961 the cooler had been replaced with a Brink Mist Eliminator. In 1965 the minimal strength of the sulfuric acid was raised to 85% and the spent sulfuric acid was sent to a toxic dump.

6. PCP Process Ventilation Controls

Ventilation was used to control dust and fume levels in the PCP product process area. A Schutte - Kjorting vapor condenser was connected to the flakers (1938 through 1953). A Dracco dust collecting system served to collect dry material throughout the entire process and return the collectable dust to the hopper. There was also a powerful vacuum cleaning unit to assist in keeping the bagging and tableting areas clean.

In 1954, two fume control systems were placed in operation for the PCP process. One was a section blower with ducts leading to the packing glands and vessel closures on the phenol scrubbers and the chlorinators. The second system used a Haveg Waterjet to remove sublimation fumes from the flaker. In 1961, NaOH solution replaced the water in the Haveg jet and the NaPCP solution formed was used in the NaPCP process. In 1963, as previously described, a Venturi NaOH scrubber was used to scrub the exhaust air from the prill tower.

In 1968, a chlorophenol air scrubbing system was installed in an attempt to reduce the level of chlorophenols in exhaust air to below the chlorophenol odor threshold of 30 parts chlorophenol per billion parts air. Chlorophenol vapors, small quantities of HCl gas, and chlorine gas were drawn into the system from 34 vents in Depts. 236 and 237. The vents were located on storage tanks, chlorinators, sampling stations, and loading spots in the two departments. The gas mixture was continuously drawn through a network of furan-lined glass fiber reinforced (GFR) polyester duct, by a furan-lined GFR polyester blower (16,000 cubic feet of gases per minute capacity). The gases were discharged from the blower in the base of an eight feet in diameter by 34 feet, GFR polyester scrubbing tower. The tower was packed with 10 feet of 2 inch polypropylene Pall rings. The gas stream was continuously scrubbed with a counter-current flow of 500 to 600 gallons per minute of 5 to 12% caustic solution. The CO_2, HCl, and chlorophenols reacted with the caustic, forming their respective sodium salts. When the percent caustic fell below 5% free NaOH, 2500 gallons of a total volume of 3700 gallons was pumped out of the system and transported by tank truck to the toxic dump. The system was then recharged with 2500 gallons of 10 to 12% caustic solution.

B. NaPCP Process Description

NaPCP was produced by Monsanto using the same chemistry for the entire production time (1938-1975). The raw materials used to produce NaPCP were PCP, and a caustic solution. Although the NaPCP process is being described separately from the PCP process, it was in effect a continuation of the PCP process, even though Monsanto used two department numbers (Dept 236 for PCP and Dept A-236 for NaPCP). Figure 11 depicts the block flow diagram for the NaPCP process. Figures 12 through 19B are photocopies of flow diagrams of the NaPCP found in SMPs for the years 1949, 1954, 1956, 1959, 1961, 1965, 1968, and 1972. These flow diagrams show how the NaPCP process evolved during the time it operated.

1. PCP Neutralization

PCP was charged into a dissolver containing 7% aqueous caustic soda solution. The PCP reacted with caustic soda to form NaPCP as shown:

(NaPCP)

Initially in Building BO, there was one dissolver. This remained the case when the process was moved from Building BO to Building BD in 1947. A second dissolver was added by 1961. The 8000 gallon capacity dissolvers were 14-feet in diameter by 7-feet deep steel tanks with heating coils, agitators, and submerged pumps. By 1972 the demand for NaPCP had decreased such that only one dissolver was being used.

A dissolver was charged with 4200 gallons of 7% caustic solution prepared by adding water and 50% caustic solution. Starting in November 1962, when the Santobrite® process was modernized, weak NaPCP solution was used instead of water to make up the dissolver's caustic solution. The caustic solution was heated to 50°C, and for approximately an hour, molten PCP from a chlorinator was charged to the caustic solution in the dissolver. The dissolver liquor was stirred vigorously throughout the PCP addition in order to prevent large lumps of PCP from forming.

Once the PCP was added, the batch in the dissolver was heated to 80-90°C and agitated for 1-2 hours while maintaining this temperature range. Through the years there were minor differences in product specifications. By 1972 the specific gravity was adjusted to 1.185-1.190 at 60°C/15.5°C by the addition of water or PCP and the pH was adjusted to 9-11 by the addition of caustic or PCP as required. The resulting solution contained 29.5-30.5% NaPCP with an insoluble content of 0.3-0.8% based on the NaPCP present.

The next step in the process was the filtration of the resulting NaPCP solution. From 1938 to November 1962 filtration was accomplished using a precoat, Oliver rotary, continuous vacuum filter. The filter was precoated with Hyflo-Supercel #524-B. One hundred pounds of Hyflo were mixed with about 350 gallons of water. This suspension was fed into the filter pan and a 2 inch coat was filtered onto the filter roll. The roll was 3 feet in diameter and 4 feet long giving approximately 36 square feet of filtering surface. When an even precoat was on the filter roll the dissolver liquor was fed into the filter pan. The NaPCP solution was pulled through the precoat by vacuum to the dryer feed tank. The alkali insoluble material was deposited on the surface of the filter coat and was removed each revolution of the drum by a doctor blade. This material was thrown away. One precoat would filter a full dissolver batch. The filter had a capacity of 400 gallons per hour. About 8 to 16 hours were needed to filter a dissolver batch, and about 1-1/2 to 4 hours to clean and precoat the filter. The resulting solution from the filter was pumped to the dryer feed tank.

Starting in November 1962 through February 1963, modifications were made to the NaPCP production process. One change was the replacement of the oliver filter with a cone settling tank. The cone settler was a 12 feet diameter by 13-1/2 feet high, conical bottom, settling tank with a 1000 gallon capacity. The dissolver batch was transferred to the cone settler and held for 12 hours at 70-80°C. The insolubles were allowed to settle, and after 8 hours of settling, samples were collected from the draw-off point and water insoluble analyses were conducted. Once the water insoluble content was less than 0.2%, the NaPCP solution was drawn off and pumped to a Santobrite® storage tank where it was held for the finishing steps. After transferring the batch from the cone settling tank to the Santobrite® storage tank, a 500 gallon heel of solution was left behind. The heel contained solids composed of insolubles, precipitated NaPCP and NaPCP solution. When the insolubles in the cone settling tank reached 0.2% (usually 4-5 batches) the cone heel solution was washed with 5500-6000 gallons of water or weak NaPCP solution from the Schneible system (described later). The mixture was agitated with heat and steam sparged for two hours at a temperature of 70-80°C. The wash was settled and part was returned to the dissolver as part of the water feed for the next batch and part was drained to the sewer.

2. NaPCP Finishing

NaPCP was finished in several ways and forms through the time it was produced. NaPCP in the dryer feed tank was finished on Buflovak atmospheric, twin drum dryers. The dryer drums measured 32-inches in diameter and 52-inches long and had a bottom splash feed. Steam was applied to the drums and the NaPCP solution in the dryer feed tank was pumped to the dryer pan.

The NaPCP solution dried on the surface of the drum and was scraped off by knife blades. The dried NaPCP powder, containing less than 8% water, fell to an elevator discharge conveyor which fed the powder to a unique horizontal mixer which blended the powder. Initially, there was one J.P. Devine drum dryer in Building BO. When the process was moved to Building BD there were two Buflovak drum dryers and by 1954 there were three. Each dryer dried 114 gallons of 30% NaPCP solution or 345 pounds of NaPCP powder per hour.

The NaPCP powder was blended to increase its density, which permitted the use of smaller containers. Additionally, the increased density allowed briquettes to be made from a single compression. Two unique horizontal ribbon blenders increased NaPCP density from about 0.4 grams per cubic centimeter to 0.9 grams per cubic centimeter. Each blender held 2500 pounds of powder. Approximately two hours were required for this operation. One of the two blenders was provided with an overflow outlet on the side so that it could be operated continuously. The other blender was used only in emergencies. The blended powder was packaged in a Carter vacuum packer. This machine served to compact the powder during container filling and also confine the dust. Fiberpaks of 50, 100, and 200 pounds were filled with this packer.

Starting in 1954, Monsanto began to produce pellets of NaPCP. The pellets were formed by spraying water into NaPCP powder in a cylindrical rotary pelletizer. The damp pellets were conveyed to a Roto-Louvre dryer and dried at 150°C. The dried pellets were classified on U.S.S. No. 3 and No. 20 screens. The oversize, +3 mesh, were redissolved and recycled. The 3 to 20 mesh fraction was packaged as Regular Pellets and the minus 20 mesh fraction as Pellet Fines, or the fines were returned to the pelletizer feed by a Hapman tube conveyor.

NaPCP was also finished in briquette form. A briquette was a tablet 1-5/8 inches in diameter by 1/2 inch thick. Briquetting was done in Building BO from 1938 to 1958 and in Building BD from 1956 to 1975. After the NaPCP process was moved to Building BD in 1948, briquetting operations continued in Building BO with filtered NaPCP solution from Building BD. The solution was dried on a drum dryer. The low density powder was slugged in a preliminary Stokes briquetting machine for densification. These slugs were then granulated to 1/4 inch size and the coarse powder was fed to a second Stokes briquetting machine where it was compressed into the desired tablet form. In 1956, a Colton briquette machine was installed in Building BD. This briquette machine was fed NaPCP powder from the continuous blender which produced the desired tablet form which were packaged in 100 pound drums by means of a Thayer automatic scale.

3. NaPCP Process Changes

Beginning in November 1962 and completed in February 1963 the NaPCP production process was modernized. As stated previously, one change was the replacement of the Oliver filter by the cone bottom settler. In addition, finishing procedures were significantly changed. The Buflovak double drum dryers were replaced by a system which mixed NaPCP solution with recycled NaPCP powder to form NaPCP pellets. NaPCP solution (30-35% wt.) coming from the cone settler was pumped to a feed liquor storage tank from which it was fed into a paddle mixer (24 inch diameter twin paddle 12 inches in diameter by 8 feet long). In the paddle mixer the feed liquor was mixed with recycled NaPCP powder from the recycle bin to form wet pellets of various sizes. The wet pellets were dropped from the paddle mixer through a chute into a direct fire Roto-Lourve dryer and dried to a moisture level of 6.0-7.0% (wt.). The dry pellets were conveyed through the dryer by a Redler conveyor either to the recycle bin or to a rotex screen. Three mesh sizes (-10 + 20 pellets), (-16 + 40 #1 fines), and (-30 #2 fines) were separated and dropped into finished product hoppers. The product was then packaged in either fibrepaks or bags using a St. Regis pneumatic packer. In order to reduce dust, the #1 fines were coated with monacetin as they passed through the blender to the product hopper. In 1969 the Rotex screener was replaced with a Tyler-Hummer screener. The system was otherwise unchanged until it was shut down in December 1971, ending the production and packaging of sized pellets. In 1972, with the discontinuation of selling the sized fines, #2 fines were used in addition to the #1 fines to produce briquettes in the Colton briquette machine. In addition, the #2 fines were used for Dowicide G® Beads or Dowicide® G Beads ST.

4. NaPCP Process Ventilation Controls

The dust and vapors of NaPCP were irritating to the workers in the NaPCP process and therefore ventilation was used throughout the process. Fumes evolving from the dissolver were absorbed with a Haveg water jet and discharged to the sewer. Schutte - KJorting scrubbers were used to collect dust and vapors evolving from the drum dryers. In 1954, the scrubbers were replaced by a Schneible tower. The Schneible tower was a 6 feet in diameter by 11 feet high multiwash dust collector rated at 10,000 to 12,000 cubic feet of air per minute. A Dracco dust collector was used to maintain a slight suction on the various conveyors, blenders, NaPCP bagging room ducts and the dry end of the NaPCP pelleting equipment. Dust collected in the Dracco was recycled back to the powder blenders. In 1959 the Dracco dust collector was replaced with a Schneible tower. A multiclone tangential separator removed dry powder from the pelletizer dryer and recycled it to the powder blender. Periodically the Schneible scrubbing water became laden with NaPCP and would be recycled back to the dissolver. Starting in 1961, Dow-Corning anti-foam B was added to reduce foaming in the Schneible tower. Later in 1965, a switch was made and Delfoam replaced the Dow-Corning anti-foam B.

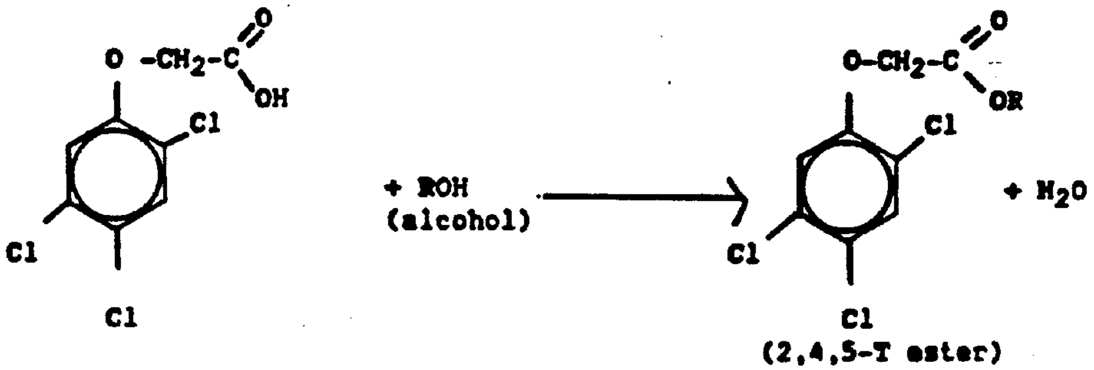
C. 2,4,5-T Ester Process Description

Monsanto began 2,4,5-T ester production at the W.G Krummrich plant in an open air process area with an enclosed control room in September 1960 and continued production until January 1970. 2,4,5-T ester production, as well as 2,4-D ester production took place in Dept. 268. During these years of production, the process to produce 2,4,5-T esters remained essentially the same. The only significant change made during this time was the addition in 1964 of toluene as an azeotropic agent for more efficient water removal. Figure 20 shows the block flow diagram for the 2,4,5-T ester process. Figures 21 through 23C are photocopies of flow diagrams found in SMPs for the years 1962, 1965, and 1969. These figures provide chronological evolution of the 2,4,5-T ester process for the years it was operated.

The raw materials used to produce 2,4,5-T esters were 2,4,5-T acid received from Monsanto's Nitro, West Virginia plant, isobutyl, butyl or iso-octyl alcohol, toluene, sulfuric acid as a catalyst, and cyclohexylamine as a neutralizing agent. The mole ratio for acid to alcohol was one to one. Prior to the addition of toluene in 1964, a batch charge was made up of 10,700 pounds of recovered and virgin alcohol and 28,000 pounds of 2,4,5-T acid. After the addition of toluene, a batch charge was made up of 8,050 pounds of recovered and virgin alcohol, 3,200 pounds of recovered and virgin toluene and 25,600 pounds of 2,4,5-T acid.

The initial step in the process took place in the pre-mix slurry tank. Recovered toluene and alcohol were pumped to the slurry tank and supplemented with virgin toluene and alcohol. 2,4,5-T acid was dumped from fiber drums into a feed hopper conveying system. The feed hopper was in actuality a tote bin (used for bulk shipment of solids). Beginning in 1968, 2,4,5-T acid was shipped from Nitro to Krummrich in tote bins rather than drums. The tote bins were mechanically tilted to feed the 2,4,5-T acid to a bucket conveyor system. The pre-mix slurry tank was a 316 S.C. 4000 gallon tank with heating coils and an agitator. Once all raw materials were added to the slurry tank the contents were heated to 70°C. The total cycle time for this pre-mix stop was 12 hours; the addition of alcohol-toluene took one hour while the 2,4,5-T acid was added over a 12-hour period. Typically this operation had a 10% down time.

The contents in the slurry tank were charged to the glass-lined 4000-gallon ester reactor by both gravity and a vacuum. After the slurry tank contents were added, 20 pounds of sulfuric acid were added and a vacuum of 580 mm Hg. abs. pressure was applied to the reactor. The reactor was then steam heated through the reactor's jacket to 130°-140°C. The following reaction took place;



ROH represents either butyl, isobutyl or isooctyl alcohol. Vapors of alcohol, toluene, and water evolving from the reactor were condensed in a 500 foot square Karbate condenser, and separated in a 400 gallon stainless steel tank. The top layer of alcohol and toluene was refluxed back to the reactor. The water layer (bottom layer), containing the water by-product of the reaction and some alcohol and toluene, was periodically drained to a 1000 gallon glass-lined, dilute alcohol tank to prevent water from accumulating in the separator and being refluxed back to the reactor.

Six to eight hours after the batch was in the reactor and every hour thereafter, the amount of unreacted 2,4,5-T acid in the batch was checked. A 10 ml. sample was collected from the reactor and titrated to measure the amount of free 2,4,5-T acid. Sampling was continued until two consecutive titrations showed 0.51% or less free 2,4,5-T acid. When the rate of ester formation slowed, virgin alcohol was dribbled in to help remove water formed during the reaction and to drive the reaction to completion.

Following the reaction, excess alcohol and toluene were stripped from the batch, condensed and collected in a 1000 gallon steel alcohol tank. This was accomplished by lowering the temperature to 145°C and the pressure to 50 millimeters of mercury absolute. During the two hour stripping period, total reflux was stopped and both the separator and weak alcohol tank were by-passed. At the end of the stripping period, the vacuum was released by the addition of carbon dioxide to the reactor.

Once the excess alcohol and toluene had been stripped from the crude 2,4,5-T ester, the ester was transferred to the neutralizer tank, a 4000 gallon steel tank. Excess catalyst and other acidic compounds were neutralized by the addition of 25 pounds of cyclohexylamine. The cyclohexylamine reacted with the sulfuric acid catalyst to form cyclohexylamine sulfate. The temperature of the neutralization was 90-100°C and at atmospheric pressure. The batch was agitated for 30 minutes and samples were collected and then analyzed in the laboratory. If excess cyclohexylamine was less than 0.01% (specifications called for 0.01-0.03% of excess cyclohexylamine), an additional 10 pounds of cyclohexylamine were added. The batch was again agitated for 30 minutes and resampled. This continued until excess cyclohexylamine was between 0.01 and 0.03%.

The batch was also sampled for acid equivalents. If the acid equivalence was low, the batch was pumped back to the reactor to strip off excess alcohol. If the free acid was high the batch was pumped back to the reactor, heated, and alcohol, toluene and sulfuric acid were added to complete the reaction.

When the batch was within specifications for excess cyclohexylamine, free acid and acid equivalents, it was circulated through the filter until the forward flow stream from the filter was clear. This filter was a Shriver horizontal tank, vertical leaf pressure filter. The screens were 24 x 100 mesh and the filter removed sulfates, 2,4,5-T tars and precipitated cyclohexylamine sulfate. It needed cleaning every 4-5 batches. Complete analysis of the finished, filtered 2,4,5-T ester was determined by the laboratory.

Following the filtration step, the batch was then pumped to a 4000 gallon, steel, product hold tank. The 2,4,5-T ester was then either drummed, pumped to tank trucks, tank cars or to 127,000 gallon or 88,000 gallon steel storage tanks. The ester was passed through a 25 micron cartridge polishing filter before being shipped by drum, tank car, or tank truck, or stored in storage tanks.

Description of the Workforce

The Monsanto workforce at the W.G. Krummrich plant is organized into departments. Workers from four departments are included in the Dioxin Registry study. These departments are 236 (Penta), A-236 (Santobrite®), 268 (2,4,5-T ester), and 821 (Experimental Prilled Penta). Job titles and descriptions for these departments were obtained from several sources, such as Monsanto personnel records, the International Chemical Workers, Local 12 Working Agreements and SMPS.

A. PCP and NaPCP Job Titles

Departments 236 and A-236 job titles are listed in Table 6. This table was constructed by the International Chemical Workers, Local 12 Working Agreement and shows how the job titles evolved as the PCP and NaPCP processes evolved through the years of their operations. The workforce size in Departments. 236 and A-236 was estimated, from Production Cost Standards in the SMP's to be 12-15 workers for the years 1938 through 1947. For the years 1948 through 1978 the workforce size of Departments. 236 and A-236 ranged between 10 and 25 workers with an average of 17 workers.

For the years between 1938 and 1947, there were the job titles of relief foreman, chief operator, operator, and helper. When Departments. 236 and A-236 moved from Building BO to Building BD in 1947, more job titles were created and as time went on the job titles became more specific as to what duties were performed. Table 7 was constructed from SMPs for the years 1965, 1968, and 1972 and information obtained from the Hryhorczuk[9] study, it provides a list of all the job titles used in Departments. 236 and A-236 along with job descriptions and the years the job titles were in effect. Job titles and descriptions for Dept. B-821, Experimental Prilled Penta, are shown in Table 8. Dept. B-821 was a PCP department that was in operation in 1963, during which time the flaking of PCP was replaced by prilling.

Initially, the PCP and NaPCP processes were operated by operators and helpers. The operators were responsible for the chlorinators, flaker, dissolver, filter dryer, and briquette machine, while the helpers assisted the operator, primarily with the flaking, packaging, dissolving, drying, and briquetting. In 1947, the job title of "B" operator was introduced with the responsibilities essentially the same as the helpers. In 1948 operators from Buildings BO and BD were distinguished from each other with most of the work occurring in Building BD. In 1953, the job titles of intermediate operator, pelletizers, and porter were added to the list of job titles used in Departments. 236 and A-236. An intermediate operator was responsible for drying NaPCP and assisted in dissolving and pelletizing operations. The pelletizers or pellet operators were responsible for pelletizing and screening NaPCP and packaging pellets and NaPCP powder. The porters were junior helpers primarily responsible for general housekeeping and cleanup. They also took care of the respirators and gave out work clothes. By 1956, the job title of premium operator had replaced the job title of operator (Bldg. BO) with more specific job duties of operating chlorinators, phenol scrubbers, and procurement of process samples and data. Job duties such as dissolving, flaking, or prilling and operating the central fume scrubber, which were once operators' responsibilities, were now defined to "A" operator duties. In addition, by 1956, briquetting of NaPCP was performed by briquette operators, previously performed by the helper. In 1963, with the completion of the improvements to the NaPCP process, the job title of Santobrite® operator was introduced. The Santobrite® operator was in complete charge of the NaPCP process except for the dissolver, overseeing the pellet and briquette operators and packer-helpers. In 1971, Dept. 237 operations (chlorophenol production) were consolidated into Dept. 236 and as a result of this, the job title of 237 operator began to be used to distinguish workers involved in chlorophenol production to those in PCP and NaPCP production.

Time cycles for the PCP production process for the years 1943, 1953, 1954, 1955, 1956, 1958, 1961, 1965, 1968, and 1972 are shown in Tables 9, 10, 11, and 12. These tables provide a breakdown of the time required to produce a batch of PCP and indicate the time required to perform the various tasks for the various job titles in Table 7.

B. 2,4,5-T Ester Job Titles

Job titles, duties, and the workforce size remained essentially the same in Dept. 268, for all the years 2,4,5-T and 2,4-D esters were produced (1960-1970). The work force size was six to seven workers. Four of these workers were premium operators, one or two were intermediate operators and/or helpers, and one or two were clean-up helpers and/or utility helpers.

Table 13 lists the job titles and descriptions used in Dept. 268. This table was constructed from SMPs and the Hryhorczuk[9] study. The premium operators operated all Dept 268 equipment, collected process samples and data, directed the activities of the intermediate operator, and charged 2,4,5-T and 2,4-D acids to the esterification reactor in relief of the intermediate operator. The intermediate operator unloaded and inventoried all raw materials, charged 2,4,5-T and 2,4-D acids to the esterification reactor, loaded finished 2,4,5-T and 2,4-D esters to tank cars and trucks, and drummed some of the finished esters. He also assisted the premium operator in the daily operations of the manufacturing unit. During large drum orders, up to twelve utility shift helpers were used. This classification was organized on a bid job basis, and was used to help charge 2,4,5-T and 2,4-D acids to the esterification reactor and do all drumming.

Description of Medical, Industrial Hygiene, and Safety Programs

Medical, industrial hygiene, and safety programs at the W.G. Krummrich facility have existed for some time, although the exact startup dates of these programs is not known. The earliest available information was found in the Pentachlor Phenol and Derivatives Report by E. Mather[13], June 16, 1946. In this report there were several pages dated April 10, 1945 which listed protective clothing and equipment for workers in Depts. 263 and A-236. The operators and helpers from these departments received the following items of protective clothing and equipment, which they were responsible for and expected to use at appropriate times:

"1. A complete change of company clothing each day.
2. A pair of rubber shoes or rubbers.
3. A pair of safety glasses and case.
4. A pair of rubber framed goggles.
5. A dust-proof respirator.
6. A pair of rubber-covered gloves with either long or short cuffs."

In addition the following items were made available for use in the departments at all times:

"1. Cloth respirator.
2. Rain clothes.
3. Emergency clothes.
4. Emergency gas mask (located outside the building).
5. Alcohol and acetic acid for burns.
6. Face cream as an added protection against Santobrite® dust.
7. Stretcher and blankets."

In reference to the face cream, a March, 1946, note said that "Lanam protective ointment gave several hours protection. In hot weather beads of perspiration which well up through the ointment, pick up Santobrite® and become very irritant. Briquettes may be handled with bare hands in winter. Alcohol wash is used for burns by phenol, pentachlorophenol or Santobrite®." Special safety procedures for handling Santobrite® were also included as part of the 1945 protective clothing and equipment listing in the report. These procedures for handling Santobrite® were:

"1. Do not inhale the dust - Wear a respirator.
2. Do not expose the eyes - Wear goggles.
3. Do not expose any part of the body to the briquettes, or the powder, or the solutions of Santobrite® - Wear protective garments.
4. Do not employ individuals, who have skin eruptions such as acne or pimples, in the handling of Santobrite® or its water solutions.
5. Do not permit employees, who through accidents, have abrasions of the skin or burns, or who have chopped skin to handle Santobrite® or its water solutions until after such injuries have thoroughly healed."

Similar safety information was found in the Safety and Fire Protection sections of the ten SMPs for Penta. Through the years, some of the SMP's noted changes and improvements that were made. In the 1953 SMP for Penta, a statement was made that "some solvents such as Pine Oil, and Stoddard's Solvent Naptha which may be irritating in themselves, tend to enhance the absorption of pentachlorophenol through the skin" and that safety showers were available on all operating levels for use if any of the men are sprayed with acid. In the 1965 Penta SMP, safety procedures at this time indicated that even small amounts of Penta spilled on the skin should be washed off immediately with the alcohol located in the First Aid Station. The alcohol was then to be followed by a thorough washing with soap and water. If large amounts were spilled on the skin, the contaminated area was flushed with a large volume of water (i.e., safety showers) and then treated at the dispensary.

From the NIOSH report of a study at the W.G. Krummrich facility by Jones[8] and Cohen[11] general remarks about the medical, industrial hygiene, and safety programs were obtained. These reports written in the mid-1970's indicate that the W.G. Krummrich facility had a formalized safety program, which included an environmental health group, composed of health and safety professionals. A dispensary at the facility was staffed by nurses 24 hours a day and a physician was present two hours per day each weekday. All employees were required to take pre-employment physical examinations and annual physical examinations. Certain employees were required to take additional examinations and/or special tests (e.g. skin examinations for workers in Depts. 236 and A-236). Biological monitoring was also performed for phenols in urine.

Industrial hygiene at the facility was handled by the Environmental Control Group. The six people assigned to this group conducted environmental monitoring at the facility and worked in conjunction with the safety department. Safety meetings were held monthly and safety information was provided to the different departments through the safety committees. A corporate industrial hygienist also provided support to the facility's industrial hygiene and safety program.

Similar to the safety information reported in 1945, the reports from the mid 1970s indicated that the company required each employee involved in manufacturing to wear coveralls, safety shoes, hard hats, and safety glasses at all times. All employees also had at their disposal additional safety equipment, which included respirators (fitted with chemical cartridge canisters suitable for organic vapors and acid gases), Scott Air-Paks®, gloves, boots, rubber aprons, face shields, and other safety equipment. Written procedures had been established for proper protection of employees executing potentially high exposure tasks, such as opening process lines/equipment.

Description of Past Exposures

The earliest documented evidence of exposures to PCP and NaPCP came from the Pentachlor Phenol and Derivative Report [13] by E. Mather of Monsanto. The report is a compilation of information collected from June 1946 through April 1955. In a section titled Safety Considerations are the following statements:

"The dust of the sodium salt (NaPCP) is very irritating to the mucous membranes, and to the skin, especially if the operator is perspiring. Work in the old unit (Building BO) at Plant "B" (Krummrich) is sometimes very disagreeable, and great attention was given to this point in designing the new unit (Building BD). Conditions are considerably better in the new unit, but it is hardly possible to go too far in this manner. There does not appear to be any serious health hazard, but the irritation to the operating force can be very troublesome."

These statements from 1946 indicate that exposure to NaPCP occurred in Building BO and was unpleasant and troublesome. Later in the Mather report a statement made March 9, 1948 indicated that "a great deal of attention has been given to the search for ways of preventing the dustiness of Santobrite®." This indicated that there was some dustiness and therefore exposure to NaPCP was occurring in Building BD. Also in the Mather report, a May 26, 1948, entry (Item 34 Bagging room) described the bagging rooms in both Building BO and Building BD. "The room in the old unit is a small glass and steel erection in the middle of the ground floor. It is, however, small and inconvenient and working conditions in it are very unpleasant. In the new unit, the room is at one end of the building, under the blenders. Tiled walls. Every care has been taken with dust prevention and dust removal, but the packers still wear dust pads. Conditions are however, tolerable and it is believed that with practice the operators will be able to diminish the amount of material escaping and left lying about." This citation indicates that in 1948, in Building BD, exposures to NaPCP still occurred but may not have been as intense as those which occurred in Building BO. Also, it appears that the packaging room for NaPCP was centrally located in Building BO making it likely that workers in Depts. 236, 237, and 226 were also exposed to NaPCP dust.

By 1945, dusts from Depts. 236 and A-236 were recognized as being injurious to the health of human beings and causing skin irritation, redness, and pimples. A policy was made that individuals with skin eruptions such as acne or pimples were not permitted to work in these departments. Also workers who through accidents had abrasions of the skin or burns were not permitted to work in these departments until the injuries were healed.

An inspection of the new facilities for the production of PCP (Building BD) was conducted in 1947 by the State Department of Labor's Factory Inspection. This inspection identified several sources of PCP and/or NaPCP emissions and exposures: 1) the flakers on the 1st floor emitted considerable fumes and dust under ordinary operating conditions; 2) maintenance workers involved in the Dracco dust collector maintenance were exposed to the product when the Dracco bags occasionally broke; 3) workers involved in the drumming and bagging operations bagged much of the product by hand; 4) the hopper which fed the NaPCP pelletizing system was frequently clogged and was unclogged by hand; and 5) the ventilation system in the NaPCP briquette operation in Building BO was poor.

A. Medical Studies

Three studies have been conducted involving the workers from Departments 236 and A-236. In 1977, Dr. Ernest Tillman[14] reviewed the plant medical records of 60 workers in the PCP and NaPCP processes. The study group included all persons who had worked in Departments 236 and A-236 at the time of the study and those who had been assigned to these departments in the past for one year or more since 1951. Twenty-nine out of 60 (48%) workers developed chloracne at some time while working in Departments 236 and A-236. The duration of assignment ranged from three months to 13 years. In the majority of the cases of active employees chloracne appeared within one year of being assigned in Dept. 236. The age at which chloracne was first noted ranged from 20 years to 61 years. Chloracne was reported in the medical records between l959 and 1977 with no peak at any particular time. However, the number of persons with observed chloracne on routine examination during the winter months was higher in 1977, than in the preceding two years.

Dr. Tillman concluded that a health hazard was present in Dept. 236 and made the following recommendations:

"1. More frequent examinations of workers in Dept. 236 for presence of chloracne.
2. Workers who show lesions should be removed from all exposure until the conditions has cleared.
3. If chloracne returns when the worker is returned to Dept. 236, he should be permanently removed from further exposure.

4. A complete study of the workplace (including engineering and industrial hygiene studies) should be made to determine the sources of exposure.
5. Facilities and equipment should be upgraded to minimize exposure.
6. Work practices should be reviewed and upgraded in order to reduce exposure.
7. If facilities, equipment, and work practices cannot be upgraded to a degree sufficient to provide workers with maximum protection, the manufacture of pentachlorophenol should be discontinued."

On October 1-5, 1979, a medical survey of 115 workers was conducted by the Department of Environmental Health, University of Cincinnati headed by Dr. Raymond Suskind[15]. The objective was to determine the health status of employees of the W.G. Krummrich plant who had been exposed to chlorinated phenols and to identify those conditions which might be related to the work environment. The medical survey included administration of questionnaires to employee-participants, a medical history, and a thorough dermatologic examination, as well as the examination of other organ systems, if indicated by the clinical history. Clinical laboratory tests included: blood calcium, phosphorous, blood urea nitrogen (BUN), creatinine, BUN creatinine ratio, uric acid, glucose (fasting blood sugar), total protein, albumin, globulin, total bilirubin, direct bilirubin, glutamic-oxaloacetic transaminase (SGOT) and glutamic-pyruvic transaminase (SGPT), alkaline phosphatase, lactate dehydrogenase, cholesterol, iron, magnesium, sodium, potassium, chloride, G-glutamyl-transpeptidase, triglycerides, and lipoprotein profiles; complete blood count and differential, urinalysis, and urinary coproporphyrin, uroporphyrins, and creatinine.

One significant finding from this survey was that 66 of 115 (57%) workers examined had a history of chloracne. Residual chloracne was found in 43 of 66 (65%) chloracne cases. Of the 43 cases, 68% were diagnosed as mild and 32% as moderate. All of the residual cases were comedonal in type and a third of those cases had cystic lesions as well. No significant differences were found when comparing the various clinical test results from workers with chloracne histories to those without chloracne histories.

B. Industrial Hygiene Sampling

Limited industrial hygiene data was available for the W.C. Krummrich plant. The only recorded industrial hygiene sampling data were collected in March, April, and August, 1977 in Dept. 236 while the PCP process was in operation. Monsanto's industrial hygienist collected six personal air samples , two area air samples, and eighteen surface wipe samples during these surveys. The results of the samples are shown in Table 14.

The personal and area air samples were collected in midget impingers containing 0.1 N aqueous solution of NaOH attached by tubing to air sampling pumps calibrated for an air flow rate of one liter per minute. The NaOH solutions were analyzed for PCP concentrations using an electron capture gas chromatograph, interfaced with a data processor. The minimum detectable amount of PCP was 10 nanograms per sample. One sample was below the minimum detectable amount, for calculation of the arithmetic mean for the air samples, this sample was assigned half the detection limit. The mean for the personal air samples analyzed in the job classifications of A Operator, B Operator, and Premium operator was 0.048 milligrams of PCP per cubic meter of air (mg/m^3). The results of the area air samples, which were collected just outside the control room, were 0.026 mg/m^3 and nondetectable at a detection limit of 0.001 mg/m^3 PCP

The surface wipe samples were collected by wiping 100 square centimeters of work area surface using a template and wetted Whatman No. 41 filter papers. The filter papers were extracted with 0.1 N aqueous NaOH solution and analyzed for PCP using electron capture gas chromatography interfaced with a data processor. The limit of detection was 10 nanograms per sample. Surface wipe samples were collected from office and control room surfaces. The results ranged from 15 to 216 micrograms of PCP per 100 square centimeters of work surface (mg/100 cm^2) for wipes collected in April 1977. After the institution of more stringent industrial hygiene practices, sample results ranged from 1.4 to 15.1 mg/100 cm^2 for wipes collected in August 1977.

About a year and a half after the PCP process in Building BD shutdown, surface wipe samples were collected and analyzed for mono-, tri-, tetra-, penta-, hexa-, hepta-, and octachlorodibenzo-p-dioxins. Surface samples of the blower housing of a wall fan, the office wall, a handrail, a horizontal beam, and the building wall were collected with dry Whatman No. 4. filter papers and wiped over 100 square centimeter of surface area. The samples were prepared by shaking the wipes with 40 milliliters of petroleum ether for 15 minutes. These samples were cleaned by extraction with 1 N NaOH followed by a water wash, concentrated to 1 milliliter and applied to a Woolson basic alumina column. The elutriates coming from the column were analyzed for PCDDs using gas chromatography and mass spectrometry. The lower limit of detection for these PCDDs was 5 micrograms per sample. The results of the samples are shown in Table 15. For all samples collected the results for mono-, di-, tri-, and pentachlorodibenzo-p-dioxins were less than 5.0 micrograms per 100 square centimeters. All five samples collected and analyzed for tetrachlorodibenzo-p-dioxins (TCDD) indicated a contamination level of less than 5.0 micrograms per 100 square centimeters except one collected on the blower housing which was 87.2 micrograms of TCDD per 100 square centimeters. Two of five samples analyzed for hexachlorodibenzo-p-dioxins (HxCDD) had detectable quantities. These results, collected from the blower housing and horizontal beam, were 370 and 57.7 micrograms of HxCDD per 100 square centimeters. Three of the five samples analyzed for heptachlorodibenzo-p-dioxins (HpCDD) had detectable quantities. For two samples, it was reported that a trace may be present but it was less than the reliable limit of detection. For calculation of the arithmetic mean the two trace samples were assigned half the limit of detection. The mean for the HpCDD sample results was 230 micrograms of HpCDD per 100 square centimeters. Analyses of the samples for octachlorodibenzo-p-dioxin (OCDD) were all detectable with a mean value of 23,272 micrograms of OCDD per 100 square centimeters.

C. PCDD Analyses of Process Stream Samples

Monsanto PCP, NaPCP, and 2,4,5-T acid and esters have been analyzed for PCDDs by Monsanto and others. Table 16 lists prilled PCP analyzed by the Dow Chemical Company[16] in April, 1972. Dow analyzed Monsanto Penta as part of an arrangement they had with Monsanto, where Monsanto supplied prilled Penta to Dow and Dow supplied NaPCP pellets to Monsanto. Dow analyzed the prilled Penta for 2,3,7,8-TCDD, HxCDD, HpCDD, OCDD, hexachlorodibenzofurans (HxCDF), heptachlorodibenzofurans (HpCDF), and octachlorodibenzofuran (OCDF). Eight prilled Penta samples were analyzed with the following mean results: 2,3,7,8-TCDD: <0.1 micrograms of analyte per gram of sample (µg/g); HxCDD = 18 µg/g; HpCDD = 244 µg/g; OCDD = 984 µg/g; HxCDF = 339 µg/g; HpCDF = 244 µg/g; and OCDF = 268 µg/g. Gas chromatography and mass spectrometry (GC/MS) analytical instrumentation and techniques were used to obtain these sample results.

Table 17 lists other analytical PCDD data obtained from the sources of Dow[16], Firestone[17], Monsanto[18], and Woolson[19]. All these sources used GC/MS analytical instrumentation and techniques to obtain their sample results. The Dow Chemical Company analyzed a sample of Santobrite® pellets in 1971 and found it contained 150 µg/g of HxCDD and 520 µg/g of OCDD. In 1973 a sample of Monsanto Penta analyzed by Dow contained 18 µg/g of HxCDD and 1550 µg/g of OCDD. Six Monsanto Penta samples from 1976 and 1977 were analyzed by Dow and the mean of the sample results for HxCDD, and OCDD were 12.2 µg/g, and 283 µg/g, respectively. Five of the samples were analyzed for HpCDD and had a mean of 100 µg/g. One sample from 1977 contained 4.2 µg/g HxCDD and 584 µg/g of OCDD.

In 1970, Firestone et al[17], in a study for the Food and Drug Administration, analyzed a variety of commercial chlorophenols for PCDDs. Among these commercial chlorophenols analyzed were three Monsanto Penta samples. Means of the sample results of these analyses showed the Monsanto Penta contained 24.6 µg/g of HxCDD and 24 µg/g of HpCDD. One Monsanto Penta sample was analyzed for OCDD and was shown to contain 15 µg/g.

In 1975, Monsanto[18] analyzed their Penta and found it to contain a mean of 14.5 µg/g HxCDD in two samples, a mean of 306 µg/g HpCDD in eight samples, and a mean of 465 µg/g of OCDD in two samples.

Woolson et al[19] collected samples of commercial pesticides which contained chlorophenol or used chlorophenol in their manufacturing process from the U.S.

Department of Agriculture's former Pesticide Regulation Division laboratories and analyzed them for PCDD content. Among these samples collected and analyzed were five Monsanto Penta samples. One sample was from 1965 and the others were from 1969. They found that the 1965 Monsanto Penta sample contained 110 µg/g of HpCDD and 140 µg/g OCDD. Three Penta samples from 1969 were analyzed for HpCDD and OCDD content. The means for HpCDD and OCDD in these samples was 104 µg/g and 115 µg/g, respectively. A summary of these analysis results are listed in Table 17.

All the 2,4,5-T esters produced at the W.G. Krummrich plant were manufactured using 2,4,5-T acid produced at Monsanto's Nitro, West Virginia plant. Table 18 summarizes analysis results of 2,3,7,8-TCDD concentrations in 2,4,5-T acid produced at the Nitro plant. These data were obtained from Monsanto[20] and to a lesser extent from three other sources.[16,19,21]

Samples of 2,4,5-T produced from 1958 through 1964 were saved and analyzed for TCDD in 1965. Monsanto developed the capability to analyze 2,4,5-T for TCDD in 1965 and began to routinely analyze their 2,4,5-T from 1965 until production ceased in 1969. The saved samples for the years 1960 to 1964 had a mean value of 8.5 micrograms per gram TCDD. Monsanto analyses of their 2,4,5-T acid for the years 1965, 1966, 1967, 1968, and 1969 showed mean values to be 23-, 10.5-, 8.8-, 3.4-, and 2-micrograms of 2,3,7,8-TCDD per gram of 2,4,5-T acid. Woolson et al.[19] in 1970 analyzed a sample of 2,4,5-T acid produced at Nitro and reported 2.3 micrograms of 2,3,7,8-TCDD. Dow[16] measured 2,3,7,8 TCDD in 2,4,5-T acid from Nitro and found a range of 6.5-11 µg/g of 2,3,7,8 TCDD in 13 samples of 2,4,5-T acid from 1965 and 1.4 µg/g of 2,3,7,8-TCDD in a 2,4,5-T acid sample from 1970.

The U.S. Air Force had stock piles of Agent Orange, a 50% 2,4,5-T n-butyl ester and 50% 2,4-D n-butyl ester mixture, analyzed for 2,3,7,8 TCDD concentrations in 1972.[21] Monsanto provided 3,561,040 gallons of Agent Orange to the U.S. Air Force between 1964 and 1970.[22] Six samples of Monsanto Agent Orange from these stockpiles contained 2,3,7,8-TCDD concentrations ranging between 6.9- and 9.3-micrograms of 2,3,7,8-TCDD per gram of 2,4,5-T acid with a mean value of 7.6 micrograms of 2,3,7,8-TCDD per gram of 2,4,5-T acid.[22] An additional 30 samples of Agent Orange analyzed at Wright State University, were found to contain a mean of 12.3 µg/g, with a range between 9 and 17 µg/g TCDD.[23]

Description of the Record Systems

A. Personnel Records

At the W.G. Krummrich plant, personnel files are maintained for all individuals. Service cards listing job titles in chronological order for each worker are kept separately from the personnel files. Job descriptions of various job titles were found in an incomplete set of bid sheets dating back to 1957, which also contained the names of successful bidders by date and department.

B. Medical Records

The first medical office opened in the 1940's and was staffed by the same nurse (and subsequently additional nurses) until her retirement in 1973. The facility continued to be staffed by full and part-time nurses on a 24 hour basis; part-time contract physicians were on-site a designated number of hours per week and were available for consultation and emergencies. The medical files include preplacement and interval questionnaires and medical examinations, doctor and nurses notes, laboratory test results, and data from surveillance programs. In some instances, non-work related health complaints and records such as copies of hospitalization records are also present in the files. There were few worker's compensation records because workers reportedly utilized the insurance company, and only filed with Worker's Compensation when they were unhappy with the insurance settlement. Medical records are maintained in the dispensary on microfiche, in alphabetical order.

Monsanto provided NIOSH with microfilmed medical records for 881 workers employed in PCP and 2,4,5-T. The records were found to be incomplete for some workers. The company indicated that all medical records for workers employed before 1950 had been destroyed or lost.[24]

C. Medical and Environmental Health Information System

In 1980, Monsanto initiated an ongoing Medical and Environmental Health Information (MEHI) computerized data base. Since initiation of the data base, medical, industrial hygiene, and work history data on current workers has been entered into the MEHI system.

Monsanto has entered into the MEHI system all workers ever employed in the production of pentachlorophenol or 2,4,5-T esters and has audited the data for errors. Northwestern University also audited the data prior to conducting a medical study of workers employed in the production of PCP, chlorophenols and 2,4,5-T. Demographic and work history information from the MEHI system was sent to NIOSH on computer tape. The computerized work histories for all hourly workers and for the hourly portion (where applicable) of salaried workers include the employee's name, social security number, race, sex, date of birth, date of hire, employment status (active, terminated), vital status, department code, job code, and date first assigned to each job. Jobs held for less than two days are not included in the MEHI System.

From February 22-25, 1988, NIOSH staff conducted an audit of Monsanto's personnel and medical records. Records were sampled to compare the accuracy of coding from hard copy record systems onto the computerized system and to search for any additional exposed workers. Audited records were chosen according to a random sampling strategy that provided 95% confidence that errors in coding exposed departments was less than 10%. The NIOSH audit found no errors. The two prior audits conducted by Monsanto and Northwestern University found error rates under 5%

Monsanto also sent to NIOSH a notebook containing a listing of names and notes made by the W.G. Krummrich medical staff since 1970 about examinations for chloracne of employees potentially exposed to chloracnegens.[23] The registry notes contain examination dates (or scheduled examination dates), and brief descriptive clinical notes.[24]

Conclusions

This report describes production processes, personnel work history and medical information, analytical dioxin data, and the history of Monsanto's W.G. Krummrich plant in Sauget, Illinois relevant to the production of PCP, NaPCP, and 2,4,5-T esters. Except where noted, information used to write this report was obtained from Monsanto. Detailed work histories are available for most workers involved in these processes. The operations and changes in these operations for the processes of interest are well documented and comprehensive.

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Table 1
Monsanto Chemical Products 1971
Monsanto Company
Sauget, Illinois

Chemical Compounds
1,2-Dichloro-4-nitrobenzene
1,3,5-Trichloro-s-trianzine-2,4,6 (1H,3H,5H) trione
1-Chloro-4-nitrobenzene
1-Phenol-4-suphonic acid
2,2'-Thiobis (4,6-di-sec-amyphenol)
2,4-Dichlorophenol
2-Chloro-N-isopropyl acetanilide
4,4'-Sulfonyldiphenol
4-Nitrodiphenylamine
Alkylate, linear
Alkylbenzenesulfonic Acid and Salts
Aromatic naphtha, heavy
Butyl chloroacetate
Capacitor fluid
Chlorine
Chloroacetic acid, mono-
Chlorobenzene, mono-
Chlorosulfonic acid
Coumarone-idene and Petroleum polymer resins
Cyanuric acid
Cyclohexylamine and derivatives
Dichloro-s-triazine-2,4,6 (1H,3H,5H) trione, potassium salt
Dichloro-s-triazine-2,4,6 (1H,3H,5H) trione, soduim salt
Dicyclohexylamine
Dodecylaniline
Ethyl chloroacetate
Hydrochloric acid
Hydrochloric acid
Lubricating oil and grease additives (unspecified)
N,N'Bis-(1,4-dimethylpentyl)p-phenylenediamine
N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine
N-isopropyl-N'-phenyl-p-phenylenediamine
Nitrobenzene
Pentachloronitrobenzene
Pentachlorophenol
Pentachlorophenol, sodium salt

Table 1 Continued
Monsanto Chemical Products 1971
Monsanto Company
Sauget, Illinois

Chemical Compounds
Phenol
Phosphoric acids,ortho-
Phosphorus oxychloride
Phosphorus pentasulfide
Phosphorus trichloride
Polychlorinated biphenyl
Polychlorinated biphenyls, unspecified
Potassium hydroxide
Sodium hydroxide
Sodium m-nitrobenzesulfonate
Sodium p-nitrophenate
Sodium sulfate
Sodium sulfite
Sulfur dioxide
Sulfuric acid
Transformer fluids
Tri-p-cresyl phosphate
Trichlorobenzyl chloride
Triphenyl phosphate
Triphenyl phosphite
[(Monotrichloro) tetra-(monopotassium dichloro)] pentaisocyanurate
a-Chlorotoluene
m-Nitrobenzene sulfonic acid, sodium salt
o-Benzyl-p-chlorophenol
o-Chlorophenol
o-Dichlorobenzene
o-Nitroaniline
o-Nitrophenol
p-Chlorophenol
p-Cresyl diphenyl phosphate
p-Dichlorobenzene
p-Nitroaniline
p-Nitrophenol
p-Phenetidine
p-Terphenyl

Reference: SRI International 1971 Directory of Chemical Producers, USA

Table 2
Monsanto Chemical Products 1975
Monsanto Company
Sauget, Illinois

Chemical Compounds
1,3,5-Trichloro-s-trianzine-2,4,6 (1H,3H,5H) trione
1-Chloro-4-nitrobenzene
1-Chloro-2-nitrobenzene
111-V Intermetalics compounds
2,4-Dichlorophenol
4,4'-Sulfonyldiphenol
4-Nitrodiphenylamine
Capacitor fluid(pyranol series)
Chlorine
Chlorobenzene, mono-
Chlorosulfonic acid
Cyclohexylamine and derivatives
Dodecylaniline
Hydrochloric acid
N,N'Bis-(1,4-dimethylpentyl)p-phenylenediamine
N-(1,3-dimethylamyl)-N'-phenyl-p-phenylenediamine
N-(1,4-dimethylamyl)-N'-phenyl-p-phenylenediamine
N-isopropyl-N-phenyl-p-phenylenediamine
Nitro-dodecylbenzene
Nitrobenzene
Pentachlorophenol
Pentachlorophenol, sodium salt
Phosphorus oxychloride
Phosphorus pentasulfide
Phosphorus trichloride
Polychlorobiphenyl
Potassium hydroxide
Santophen
Sodium hydroxide
Sodium sulfite
Sulfuric acid
Transformer fluid(pyranol)
Tri-p-cresyl phosphate
Triphenyl phosphate
Ultra pure silicon
[(Monotrichloro) tetra-(monopotassiumdichloro)] pentaisocyanurate

Table 2 continued
Monsanto Chemical Products 1975
Monsanto Company

Chemical Compounds
o-Benzyl-p-chlorophenol
o-Chlorophenol
o-Nitroaniline
o-Nitrophenol
o-Nitrophenol
o-Dichlorobenzene
p-Chlorophenol
p-Cresyl diphenyl phosphorus
p-Dichlorobenzene
p-Nitroaniline
p-Nitrophenol
p-Phenetidine

Reference: SRI International 1975 Directory of Chemical Producers, USA

Table 3
Monsanto Chemical Products 1977
Monsanto Company
Sauget, Illinois

Chemical Compounds
1,3,5-Trichloro-s-trianzine-2,4,6 (1H,3H,5H) trione
1-Chloro-4-nitrobenzene
1-Chloro-2-nitrobenzene
2,4-Dichlorophenol
4,4'-Sulfonyldiphenol
4-Nitrodiphenylamine
Capacitor fluid(pyranol series)
Chlorine
Chlorobenzene, mono-
Chlorosulfonic acid
Cresyl diphenyl phosphate
Cyclohexylamine and derivatives
Dodecylaniline
Hydrochloric acid
N,N'Bis-(1,4-dimethylpentyl)p-phenylenediamine
N-(1,3-dimethylamyl)-N'-phenyl-p-phenylenediamine
N-(1,4-dimethylamyl)-N'-phenyl-p-phenylenediamine
N-isopropyl-N'-phenyl-p-phenylenediamine
Nitro-dodecylbenzene
Nitrobenzene
Pentachlorophenol
Pentachlorophenol, sodium salt
Phosphorus oxychloride
Phosphorus pentasulfide
Phosphorus trichloride
Polyclorinated biphenyls
Potassium hydroxide
Santophen
Sodium hydroxide
Sodium sulfite
Sulfuric acid
Transformer fluid(pyranol)
Triphenyl phosphate
[(Monotrichloro) tetra-(monopotassiumdichloro)] pentaisocyanurate

Table 3 continued
Monsanto Chemical Products 1977
Monsanto Company

Chemical Compounds
o-Benzyl-p-chlorophenol
o-Chlorophenol
o-Dichlorobenzene
o-Nitroaniline
o-Nitrophenol
p-Chlorophenol
p-Dichlorobenzene
p-Nitroaniline
p-Phenetidine

Reference: SRI International 1977 Directory of Chemical Producers,

Table 4
Monsanto Chemical Products 1978
Monsanto Company
Sauget, Illinois

Chemical Compounds
1,3,5-Trichloro-s-trianzine-2,4,6 (1H,3H,5H) trione
1-Chloro-2-nitrobenzene
2,4-Dichlorophenol
4,4'-Sulfonyldiphenol
4-Nitrodiphenylamine
Chlorine
Chlorobenzene, mono-
Chlorosulfonic acid
Cyclohexylamine and derivatives
Dodecylaniline
Hydrochloric acid
N,N'Bis-(1,4-dimethylpentyl)p-phenylenediamine
N-(1,3-dimethylamyl)-N'-phenyl-p-phenylenediamine
N-(1,4-dimethylamyl)-N'-phenyl-p-phenylenediamine
N-isopropyl-N'-phenyl-p-phenylenediamine
Nitro-dodecylbenzene
Nitrobenzene
Pentachlorophenol
Phosphoric acids, ortho
Phosphorus oxychloride
Phosphorus pentasulfide
Phosphorus trichloride
Potassium hydroxide
Santophen
Sodium hydroxide
Sodium sulfide
Sulfuric acid
Triphenyl phosphate
[(Monotrichloro) tetra-(monopotassiumdichloro)] pentaisocyanurate
a-Chlorotoluene
n-Butyl benzyl phthalate
o-Benzyl-p-chlorophenol
o-Chlorophenol, p-Chlorophenol
o-Dichlorobenzene, p-Dichlorobenzene
o-Nitroaniline, p-Nitroaniline
o-Nitrophenol,
p-Phenetidine

Reference: SRI International 1978 Directory of Chemical Producers,

Table 5
Monsanto Departments, Chemical Products and Production Years
Monsanto Company
Sauget, Illinois

Department Number	Products	Production Years	
218	Muriatic acid		
224	Chlorinated benzenes		
226	Monsanto salt (Orthochloroparatoluene sodium sulfonate)	1923-1953	
233	Chlorinated benzenes		
237	Ortho-, para-and dichlorophenols	1935 - 1983	
239	Santophen 1 (o-benzyt p -chlorophenol)		
246	Alachlors (polychlorinated biphenyls)	1936 - 1977	
262	2,4-Dichlorophenoxyacetic acid (2,4,-D acid)	1947 - 1970	
268	2,4,5-Trichlorophenoxyacetic acid and 2,4,-D esters	1960 -1970	
		Building BO	Building BD
236	Molten pentachlorophenol	1938 -1947	1948 -1978
236	Flaked PCP	1938 - 1947	1948 - 1963
236	Prilled PCP		1963 - 1978
236	Block PCP (1000 lb.)		1972 - 1978
236	Block PCP (2000 lb.)		1970 - 1978
A-236	Santobrite (NaPCP) powder	1938 - 1947	1948 - 1975
A-236	NaPCP pellets		1949 -1975
A-236	NaPCP 30% solution		1972 - 1975
A-236	NaPCP briquettes	1938 - 1956	1948 - 1975
821	Experimental PCP Prilling		1963

Table 6
International Chemical Workers, Local 12 Job Titles
Monsanto Company
Sauget, Illinois

YEAR	DEPT.	JOB TITLE
1940	236	Relief Foreman
1940	236	Operator
1940	236	Helper - Shift
1940	236	Helper - Day
1943	236	Relief Foreman
1943	236	Chief Operator
1943	236	Operator
1943	236	Helper - Shift
1943	236	Helper - Day
1944	236	Relief Foreman
1944	236	Chief Operator
1944	236	Operator
1944	236	Helper - Shift
1944	236	Helper - Day
1946	236	Relief Foreman
1946	236	Chief Operator
1946	236	Operator
1946	236	Helper - Shift
1946	236	Helper - Day
1946	236	Repairman
1947	236	Relief Foreman
1947	236	Chief Operator
1947	236	Operator
1947	236	Helper - Shift
1947	236	Helper - Day
1947	236	Repairman
1947	236"	B' Operator (Bldg.. BD)

Table 6 continued
International Chemical Workers, Local 12 Job Titles
Monsanto Company
Sauget, Illinois

YEAR	DEPT.	JOB TITLE
1948	236	Relief Foreman
1948	236	Chief Operator
1948	236	Operator
1948	236	Helper - Shift
1948	236	Helper - Day
1948	236	Repairman
1948	236	"B' Operator (Bldg.. BD)
1948	236	Operator (Bldg.. BD)
1949	236	Relief Foreman
1949	236	Chief Operator
1949	236	Operator (Bldg.. BD)
1949	236	Helper - Shift
1949	236	Helper - Day
1949	236	Repairman
1949	236	"B' Operator (Bldg.. BD)
1949	236	Operator (Bldg.. BD)
1953	236	Relief Foreman
1953	236	Chief Operator
1953	236	Operator (Bldg.. BD)
1953	236	Repairman
1953	236	"B" Operator - Oiler
1953	236	Operator Bldg.. BD
1953	236	Intermediate Operator (Bldg.. BD)
1953	236	Pelletizer Operator
1953	236	Helper
1953	236	Porter
1956	236	Relief Foreman
1956	236	Chief Operator
1956	236	Operator (Bldg.. BD)
1956	236	Repairman
1956	236	Premium Operator (Bldg.. BD)
1956	236	"A" Operator Bldg.. BD
1956	236	"B" Operator Bldg.. BD

Table 6 continued
International Chemical Workers, Local 12 Job Titles
Monsanto Company
Sauget, Illinois

YEAR	DEPT	JOB TITLE
1956	236	Intermediate Operator (Bldg.. BD)
1956	236	Pelletizer Operator
1956	236	Briquette Operator (Bldg.. BD)
1956	236	Helper
1956	236	Porter
1958	236	Relief Foreman
1958	236	Chief Operator
1958	236	Operator (Bldg.. BD)
1958	236	Repairman
1958	236	Premium Operator (Bldg.. BD)
1958	236	"A" Operator Bldg.. BD
1958	236	"B" Operator Bldg.. BD
1958	236	Pelletizer Operator
1958	236	Briquette Operator (Bldg.. BD)
1958	236	Helper
1958	236	Porter
1959	236	Relief Foreman
1959	236	Chief Operator
1959	236	Repairman
1959	236	Premium Operator
1959	236	Operator
1959	236	"A" Operator
1959	236	"B" Operator
1959	236	Pelletizer Operator
1959	236	Briquette Operator
1959	236	Helper
1959	236	Porter
1961	236	Relief Foreman
1961	236	Chief Operator
1961	236	Repairman
1961	236	Premium Operator
1961	236	Operator
1961	236	"B" Operator

Table 6 continued
International Chemical Workers, Local 12 Job Titles
Monsanto Company
Sauget, Illinois

YEAR	DEPT	JOB TITLE
1961	236	Pelletizer Operator
1961	236	Briquette Operator
1961	236	Helper - Porter
1963	236	Relief Foreman
1963	236	Chief Operator
1963	236	Repairman
1963	236	Premium Operator
1963	236	"A" Operator
1963	236	"B" Operator
1963	236	Santobrite Operator
1963	236	Briquette Operator
1963	236	Helper - Porter
1963	236	Packer - Helper
1965	236	Relief Foreman
1965	236	Chief Operator
1965	236	Repairman
1965	236	Premium Operator
1965	236	"A" Operator
1965	236	"B" Operator
1965	236	Santobrite Operator
1965	236	Briquette Operator
1965	236	Helper - Porter
1971	236	Relief Foreman
1971	236	Chief Operator
1971	236	Repairman
1971	236	"A" Operator
1971	236	"B" Operator.
1971	236	Briquette Operator
1971	236	237 Operator
1971	236	Helper - Porter

Table 6 continued
International Chemical Workers, Local 12 Job Titles
Monsanto Company
Sauget, Illinois

YEAR	DEPT	JOB TITLE
1977	236	Relief Foreman
1977	236	Chief Operator
1977	236	Repairman
1977	236	"A" Operator
1977	236	237 Operator.
1977	236	Premium Operator
1977	236	"B" Operator
1977	236	Helper - Porter

Table 7
Monsanto Penta and Santobrite ® Production
Job Titles and Descriptions
Departments 236 and 236 A
Monsanto Company
Sauget, Illinois

Job Title	Job Description	Effective Years
A Operator (A Oper., Bldg. BD) (Std Operator) (Oper., Bldg.. BD)	Transferred molten Penta from the chlorinators to the hold tank and/or dissolver and/or flaker. Received chlorophenol fractions from Dept. 237. Flaked Penta (47-63). Complete operation of Prilling system to include the prill tower, prill tower clean-out, changing the prill scrubber solution, washing and clean out of pluggage in equipment, obtain all data and samples needed for operations (63-78). Complete operation of block facilities (71-78). Added additives to molten Penta in the hold tank (71-78). Complete operation of Central Fume Scrubber system including change out and recharging, washing equipment and taking sample data as needed (63-78). Complete operation of dissolver and cone tank, including transfers from the dissolver to the cone tank (63-75). Complete operation of the prill coating facilities (63-78).	47 - 78
B Operator (B Oper., Bldg.. BD)	A shift helper who was assigned to Penta, Santobrite® or chlorophenols, as needed(47-60). Packaged the finished product (flakes 47-63 and prills 63-78). Assisted in prill tower clean out (63-78). Assumed responsibility for preparing molds and pulling and packaging Penta blocks (72-78). Pelletized Santobrite® (63-75). Assisted with additives charged to the feed tanks (71-78) Transferred Penta into dissolvers and operate filters (60-62). Assisted in charging briquette hopper (60-75). Packaged 10# bags of Santobrite® (60-62). Operated caustic scrubbing system (60-62)	47 - 78

Table 7 continued
Monsanto Penta and Santobrite ® Production
Job Titles and Descriptions
Departments 236 and 236 A
Monsanto Company
Sauget, Illinois

Job Title	Job Description	Effective Years
Briquette Operator	Prepared Santobrite® powder for briquetting. Operated briquette machine. Cleaned machine and accessories. Packages briquettes	47 - 75
Chief Operator	Kept records, prepared daily inventory sheets, adjusted dissolver batches, prepared night sheets, prepared clothing reports (38-62). Prepared repair orders, checked maintenance work (38-62). Was responsible for material entering and leaving department. Pumped out and recharged sulfuric acid scrubber, received phenol from Dept. 233, unloaded and loaded chlorophenol fraction car, relieved Premium Operator and collected daily sewer samples (63-78).	38 - 78
Clean-up Clean-up Helper)	A day helper who assisted in clean-up as needed.	47 - 78
Foreman	Salaried supervisor for Depts. 236 and 236A	47 - 78
Helper (BO Helper (Helper, Bldg.. BD) (Packer) (Laborer) (Packer Helper)	Assisted the Dept. 236 Operator in the production of Penta including flaking and packaging of finished product (between 47 & 49 called BO Helper). A day helper primarily involved in packaging of finished product and loading and unloading raw materials (47-78). Assisted 236 Operator in production of Santobrite® including dissolving, filtering, drying and briquetting (38-47).	38 - 78

Table 7 continued
Monsanto Penta and Santobrite ® Production
Job Titles and Descriptions
Departments 236 and 236 A
Monsanto Company
Sauget, Illinois

Job Title	Job Description	Effective Years
Intermediate Operator (Intermediate BD)	Operated drum dryers. Relieved operators of their duties connected with the dissolve and Santobrite® filtration. Responsible for pelletizer equipment when the pelletizer operator was absent.	47 - 62
Operator (BO Operator)	Operated all Dept. 236 equipment including chlorinators, flaker, dissolver, filter dryer, and briquette machine. Between 1947 and 1952 called BO Operator	38 - 72
Pellet Operator	Operated rotary pelletizer. Packaged Santobrite® powder. Operated Sueco screener for pellet separation (60-75)	47 - 75
Porter	Performed general housekeeping including sweeping and cleaning. Took care of respirators. Gave out work clothes.	53 - 78
Porter - Helper	50% of time as Porter and 50% of time as helper	61 - 78
Premium Operator (Premium Operator BD) (Operator, Bldg.. BD) (Operator)	Complete charge of chlorinations, to include recharging chlorinators and phenol scrubbers, procurement of all process data and samples required to maintain operations.	47 - 78
Repairman	Maintained and repaired equipment in Depts. 236 and 236A.	38 - 78

Table 7 continued
Monsanto Penta and Santobrite ® Production
Job Titles and Descriptions
Departments 236 and 236 A
Monsanto Company
Sauget, Illinois

Job Title	Job Description	Effective Years
Santobrite® Operator	Complete charge of Santobrite® process operation except for dissolver operations. Collected samples and measure % moisture in Santobrite® powder. Cleaned out system pluggages. Operated Santobrite® coating facilities. Assumed the duties of dissolver make-up correction and operation of the central fume scrubber.	62 - 75
Swingman	Rotated between the jobs of operator, helper and repairman (38-47). Rotated between the jobs of chief operator, premium operator and repairman (47 - 78)	38 - 78
Utility	An hourly worker from the utility pool assigned to various jobs in Depts. 236 and 236A by supervision.	38 - 78

Table 8
Monsanto Experimental Prilled Penta
Job Titles and Descriptions
Department 821
Monsanto Company
Sauget, Illinois

Job Title	Job Description	Effective Years
Experimental Prill Operator (A Operator)	Operated experimental prill tower and associated equipment	63
Operator-Packer (Intermediate Operator)	Assisted the experimental prill operator to perform general relief assignments. Packed prilled Penta	63
Packer-Helper (B Operator)	Packed prilled Penta Performed other miscellaneous department duties.	63
Swingman	Per week: 1 day as experimental prill operator, 1 day as operator-packer and 3 days as packer-helper.	63

Table 9
PCP Time Cycles
from PCP Production Process SMP's for
1943, 1953, 1954, 1955, 1956, 1958, and 1961
Monsanto Company
Sauget, Illinois

YEAR	TIME CYCLES
1943	Average chlorination time cycle was 20 hours
	1 hour to charge chlorinator and scrubbers
	16 hours for chlorinating
	2-3 hours discharging
	Complete flaking cycle required approximately 3 ½ hours
1953	Average chlorination time cycle was 24 hours
1954	1 hour to charge chlorinator and scrubber
	18 ½ hours for chlorinating
	4 ½ hours discharging
	Complete flaking cycle required about 4 ½ hours
1955	Average chlorination time cycle was 16 hours
1956	1 hour to charge chlorinator and scrubber
1958	10 ½ hours for chlorinating
1961	4 ½ hours discharging
	Complete flaking cycle required about 4 ½ hours with one flaker or 2 ½ hours with two flakers

Table 10
PCP Time Cycles
from PCP Production Process SMP for 1965
Monsanto Company
Sauget, Illinois

Chlorination		**Time (Hours)**
Charge chlorinator		0.50
Charge scrubber		0.50
Chlorination		11.00
Pump to hold tank		1.00
Cool chlorinator before dropping scrubber		1.00
	Total	14.00
Prilling		**Time (Hours)**
Pump to headtank		0.25
Prill		4.25
Clean blower and change prill scrubber solution		0.30
	Total	4.80
Packaging - Bag	Total	3.00

Table 11
PCP Time Cycles
from PCP Production Process SMP for 1968
Monsanto Company
Sauget, Illinois

Chlorination		**Time (Hours)**
Charge chlorinator		0.50
Charge scrubber		0.50
Chlorination		11.85
Pump to hold tank		1.00
CO_2 purge chlorinator scrubber		0.25
	Total	14.70

Prilling		**Time (Hours)**
Pump from headtank to headtank		0.25
Prill one chlorinator batch		3.00
Clean blower and change prill scrubber solution		0.30
	Total	3.55

Table 12
PCP Time Cycles
from PCP Production Process SMP for 1972
Monsanto Company
Sauget, Illinois

Chlorination		**Time (Hours)**
Charge chlorinator		0.33
Charge scrubber		0.33
Chlorination		10.00
Vent, add parachlorophenol, mix add additive, mix		0.45
Pump to hold tank		0.25
CO_2 purge chlorinator		0.16
	Total	11.07

Prilling		**Time (Hours)**
Line up prilling		0.16
Prill one batch		8.00
Clean blower and change prill scrubber solution		0.50
	Total	8.76

Table 13
Monsanto 2,4,5-T Esters Production Department 268
Job Titles and Descriptions
Monsanto Company
Sauget, Illinois

JOB TITLE	JOB DESCRIPTION	EFFECTIVE YEARS
Clean-up (Clean-up Helper)	Sporadic clean-up operations.	60 - 71
Foreman	Responsible for Dept. 268	60 - 71
Helper (Pack-up Helper)	Transferred drums to be filled and labeled and moved them out for shipping. Charge 2,4,5-T acid to esterification (69-71, when tote bins were used to transport 2,4,5-T acid to the plant).	60 - 71
Intermediate Operator (Intermediate Helper)	Unloaded and inventoried all raw materials including connecting and disconnecting tank cars and tank trailers, made minor adjustments to operating equipment and pumps. Charge 2,4,5-T acid to esterification operations. Loaded finished 2,4,5-T esters in tank cars and trucks and maintained finished product inventory and some drumming of finished esters. Maintained housekeeping in the loading and unloading areas and tank farm. Assisted in the daily operation of manufacturing unit as directed by the premium operator.	60 - 71

Table 13 Continued
Monsanto 2,4,5-T Esters Production Department 268
Job Titles and Descriptions
Monsanto Company
Sauget, Illinois

JOB TITLE	JOB DESCRIPTION	EFFECTIVE YEARS
Premium Operator (Operator)	Operated all Dept. 268 equipment including the esterification reactor, filter, neutralization tank and finished product hold tank. Conducted quality control measurements of finished product which included simple filtration of intermediate steps, sampling for laboratory analyses and maintenance of control charts of the operating variables. Pumped raw materials and finished products, as necessary, between storage and production equipment. Maintained housekeeping of the esterification area. Directed the activities of the intermediate operator. Charged 2,4,5-T acid to the esterification reactor to relieve intermediate operator (60-69).	60 -71
Supervisor	Responsible for Depts. 262 and 268	60 - 71
Utility	Performed various duties as directed by supervision.	60 - 71

Table 14
Monsanto Industrial Hygiene Samples Analyzed for PCP
Monsanto Company
Sauget, Illinois

Date	Sample description	Sample Type	Sample Result	Units	Sample Method
3-31-77	Outside control room	A	0.026	mg/m^3	1
3-31-77	Outside control room	A	<0.001	mg/m^3	1
3-15-77	B Operator	P	0.034	mg/m^3	1
3-15-77	B Operator	P	0.025	mg/m^3	1
3-15-77	A Operator	P	0.026	mg/m^3	1
3-15-77	B Operator	P	0.066	mg/m^3	1
4-26-77	Premium Operator	P	0.14	mg/m^3	1
4-26-77	A Operator	P	<0.001	mg/m^3	1
4-26-77	Cabinet, control room	W	23.7	μg/wipe	2
4-26-77	Refrigerator, control room	W	24.0	μg/wipe	2
4-26-77	Central table, control room	W	30.2	μg/wipe	2
4-26-77	Book shelf, office	W	38.5	μg/wipe	2
4-26-77	Table, office	W	216	μg/wipe	2
4-26-77	Desk, control room	W	12.5	μg/wipe	2
4-26-77	Sink top, control room	W	15.0	μg/wipe	2
8-29-77	Central table, control rm,	W	11.1	μg/wipe	2
8-29-77	Book shelf, Office	W	4.6	μg/wipe	2
8-29-77	Refrigerator in lunch & control rm,	W	1.4	μg/wipe	2
8-29-77	Cabinet, control rm,	W	15.1	μg/wipe	2
8-29-77	Sink top, control rm,	W	6.1	μg/wipe	2
8-29-77	Table, office	W	1.9	μg/wipe	2
4-29-77	Desk, control room	W	8.9	μg/wipe	2

PCP = pentachlorophenol
A = area air sample
P = personal air sample
W - surface wipe sample
mg/m^3 = milligrams of PCP per cubic meter of air
μg/wipe = micrograms of PCP per 100 square centimeters
1 = 0.1 N aqueous NAOH solution in an impinger at a flow rate of 1 liter of air per minute
2 = wetted Whatman No. 41 filter paper wiping 100 square centimeters of surface using a template

Table 15
Monsanto Industrial Hygiene PCDD Surface Wipe Sample Results Building BD
Monsanto Company
Sauget, Illinois
June 6, 1979

Sample Location	PCDD Analytes					
	MCDD-TriCDD (μg/wipe)	TCDD (μg/wipe)	PeCDD (μg/wipe)	HxCDD (μg/wipe)	HpCDD (μg/wipe)	OCDD (μg/wipe)
Blower housing	<5.0	87.2	<5.0	370	960	57800
Office wall	<5.0	<5.0	<5.0	<5.0	37.5	8900
Handrail	<5.0	<5.0	<5.0	<5.0	<5.0	1760
Horizontal beam	<5.0	<5.0	<5.0	57.7	148	47200
Wall	<5.0	<5.0	<5.0	<5.0	<5.0	700

PCDD = polychlorinated dibenzo-p-dioxins
MCDD-TriCDD = mono-, di- and trichlorodibenzo-p-dioxins
TCDD = tetrachlorodibenzo-p-dioxins
HxCDD = hexachlorodibenzo-p-dioxins
HpCDD = heptachlorodibenzo-p-dioxins
OCDD = octachlorodibenzo-p-dioxin
μg/wipe = micrograms of analytes/square meter of surface

Table 16
Analyses of Monsanto Prilled Penta
by The Dow Chemical Company
Monsanto Company
Sauget, Illinois
April 28, 1972

Sample Description	Analyte Concentrations‡						
	2,3,7,8-TCDD (μg/g)	HxCDF (μg/g)	HxCDD (μg/g)	HpCDF (μg/g)	HpCDD (μg/g)	OCDF (μg/g)	OCDD (μg/g)
Brown Prilled Penta	<0.1	390	10	280	220	110	770
Green Prilled Penta	<0.1	200	7	80	130	70	310
Green Prilled Penta	<0.1	190	6	260	150	140	660
Black Prilled Penta	<0.1	350	10	370	180	240	760
Black Prilled Penta	<0.1	410	45	590	390	460	1760
Black Prilled Penta	<0.1	470	35	670	430	510	1880
Tan Prilled Penta	<0.1	330	15	400	230	270	860
Black Prilled Penta	<0.1	370	15	480	220	220	870
n = 8 GM	<0.1	324	14	336	225	209	859
GSD	—	1.4	2.0	1.9	1.5	1.9	1.7
Mean	<0.1	339	18	244	244	268	984
SD	—	98	14	109	109	161	546

Penta = technical grade pentachlorophenol
2,3,7,8-TCDD = tetrachlorodibenzo-p-dioxin
HxCDF = hexachlorodibenzofurans
HxCDD = hexachlorodibenzo-p-dioxins
HpCDF = heptachlorodibenzofurans
HpCDD = heptachlorodibenzo-p-dioxins
OCDF = octachlorodibenzofuran
OCDD = octachlorodibenzo-p-dioxin
GM = geometric mean
GSD = geometric standard deviation
SD = standard deviation

μg/g = micrograms of analyte per gram of sample
‡ = all analyses were conducted using gas chromatography/mass spectrometry

Table 17
Summary of Monsanto PCP
Dioxin Analyses
Monsanto Company
Sauget, Illinois

YEAR	SAMPLE TYPE	ANALYTE	NUMBER OF SAMPLES	NUMBER OF NON DETECTS	ARITHMETIC MEAN (μg/g)	STD‡	REFERENCE †
1976	PCP	2,3,7,8-TCDD	2	2 (<.01 μg/g)		—	MONSANTO #18
1970	PCP	HxCDD	3	0	24.6	20.5	FIRESTONE #17
1972	PCP	HxCDD	8	0	17.8	14.2	DOW #16
1973	PCP	HxCDD	1	0	18	—	DOW #16
1976	PCP	HxCDD	2	0	14.5	4.9	MONSANTO #18
1976	PCP	HxCDD	6	1	12.2		DOW #16
1977	PCP	HxCDD	1	0	4.2	—	DOW #16
1971	NaPCP	HxCDD	1	0	150	—	DOW #16
1965	PCP	HpCDD	1	0	110	—	WOOLSON #19
1969	PCP	HpCDD	3	0	104	32.1	WOOLSON #19
1970	PCP	HpCDD	3	0	24	14.5	FIRESTONE #17
1972	PCP	HpCDD	8	0	243	109	DOW #16
1976	PCP	HpCDD	8	0	306	101	MONSANTO #18
1976	PCP	HpCDD	5	0	100	25.5	DOW #16

Table 17 Continued
Summary of Monsanto PCP
Dioxin Analyses
Monsanto Company
Sauget, Illinois

YEAR	SAMPLE TYPE	ANALYTE	NUMBER OF SAMPLES	NUMBER OF NDS	ARITHMETIC MEAN (μg/g)	STD	REFERENCE†
1965	PCP	OCDD	1	0	140	—	WOOLSON #19
1969	PCP	OCDD	3	0	115	22.9	WOOLSON #19
1970	PCP	OCDD	1	0	15	—	FIRESTONE #17
1972	PCP	OCDD	8	0	984	546	DOW #16
1973	PCP	OCDD	1	0	1550	—	DOW #16
1976	PCP	OCDD	2	0	465	254	MONSANTO #18
1976	PCP	OCDD	6	0	283	430	DOW #16
1977	PCP	OCDD	1	0	584	—	DOW #16
1971	NaPCP	OCDD	1	0	520	—	DOW #16

μg/g = micrograms of analyte per gram of sample
‡ STD = standard deviation
† See References
PCP = pentachlorophenol
NaPCP = sodium pentachlorophenate
HxCDD = hexachlorodibenzo-p-dioxins
HpCDD = heptachlorodibenzo-p-dioxins
OCDD = octachlorodibenzo-p-dioxins

Table 18
Summary of 2,7,8-TCDD Analyses of 2,4,5-T Acid
Monsanto, Company
Sauget, Illinois

Year	Sample	Reference	Number Of Samples	Number of Non-Detectable*	Mean+	Range	
1960	2,4,5-T	Monsanto #24	1	0	8		
1961	2,4,5-T	Monsanto #24	1	0	5		
1962	2,4,5-T	Monsanto #24	1	0	10		
1963	2,4,5-T	Monsanto #24	1	0	11		
1964	2,4,5-T	Monsanto #24	1	0	12		
1965	2,4,5-T	Monsanto #24	17	0	23	5	55
1965	2,4,5-T	Dow #16	13	0	8.7‡	6.5	11
1966	2,4,5-T	Monsanto #24	27	0	10.5	3	28
1967	2,4,5-T	Monsanto #24	116	8	8.8	<3	25
1968	2,4,5-T	Monsanto #24	29	12	3.4	<3	12
1969	2,4,5-T	Monsanto #24	83	0	2.0	0.3	22
1970	2,4,5-T	Dow #16	1	0	1.4		
**	Agent Orange	Dow #21	6	0	7.6	6.9	9.3
**	Agent Orange	Wright State University #23	30	0	12.3	9	17

+ Mean TCDD concentration in micrograms per gram, non-detectable samples set to the limit of detection divided by 2.

‡ Midpoint of range, individual results were not provided.

** Actual Date of Production not available

Figure 1
W.G. Krummich Plant Layout
The Monsanto Company
Sauget, Illinois
Circa 1980

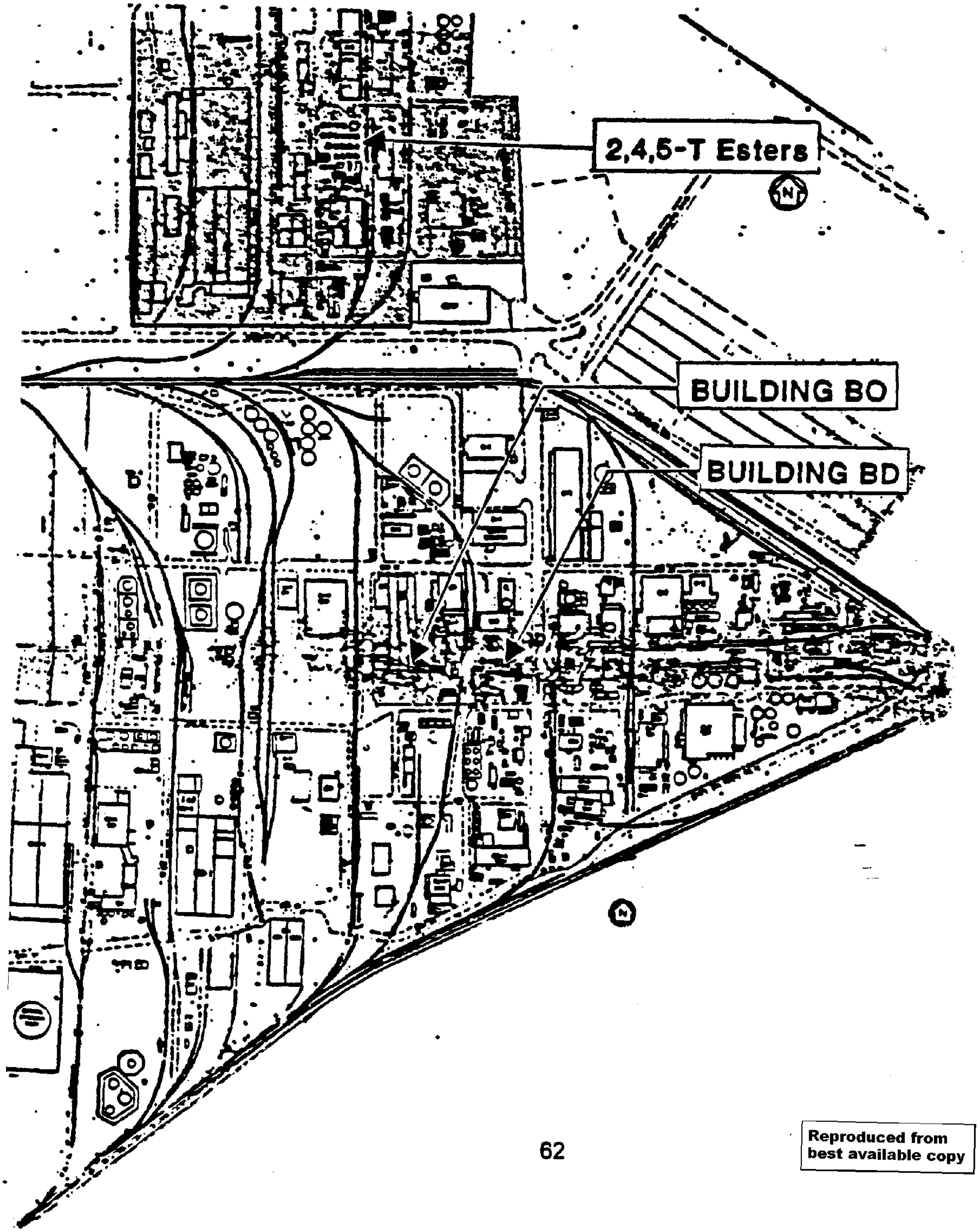


Figure 2
PCP Block Flow Diagram
Compiled from Monsanto PCP Process SMP's 1938-1978
Monsanto Company
Sauget, Illinois

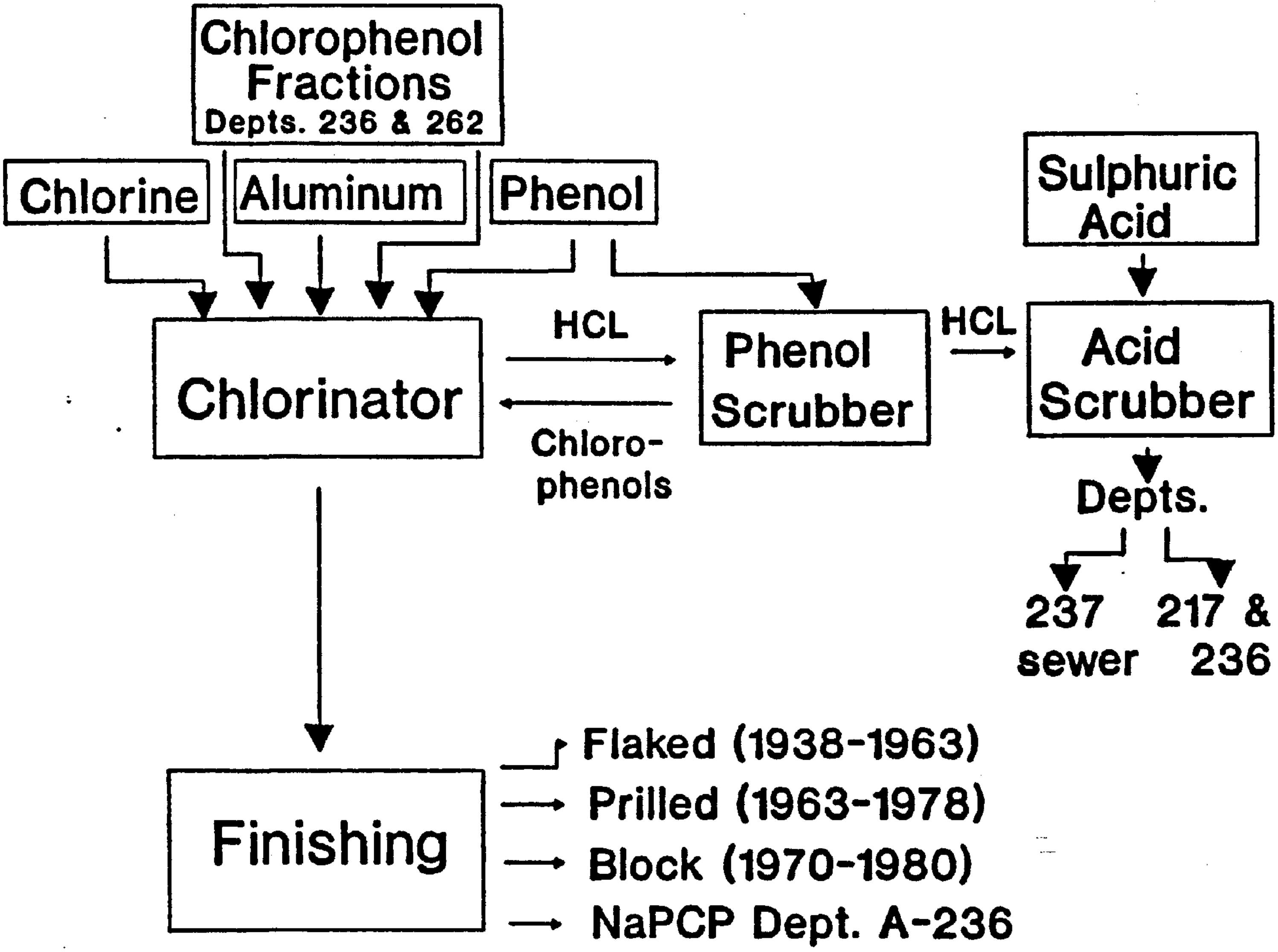


Figure 3
PCP Flow Diagram
Monsanto PCP Process SMP 1943
Monsanto Company
Sauget, Illinois

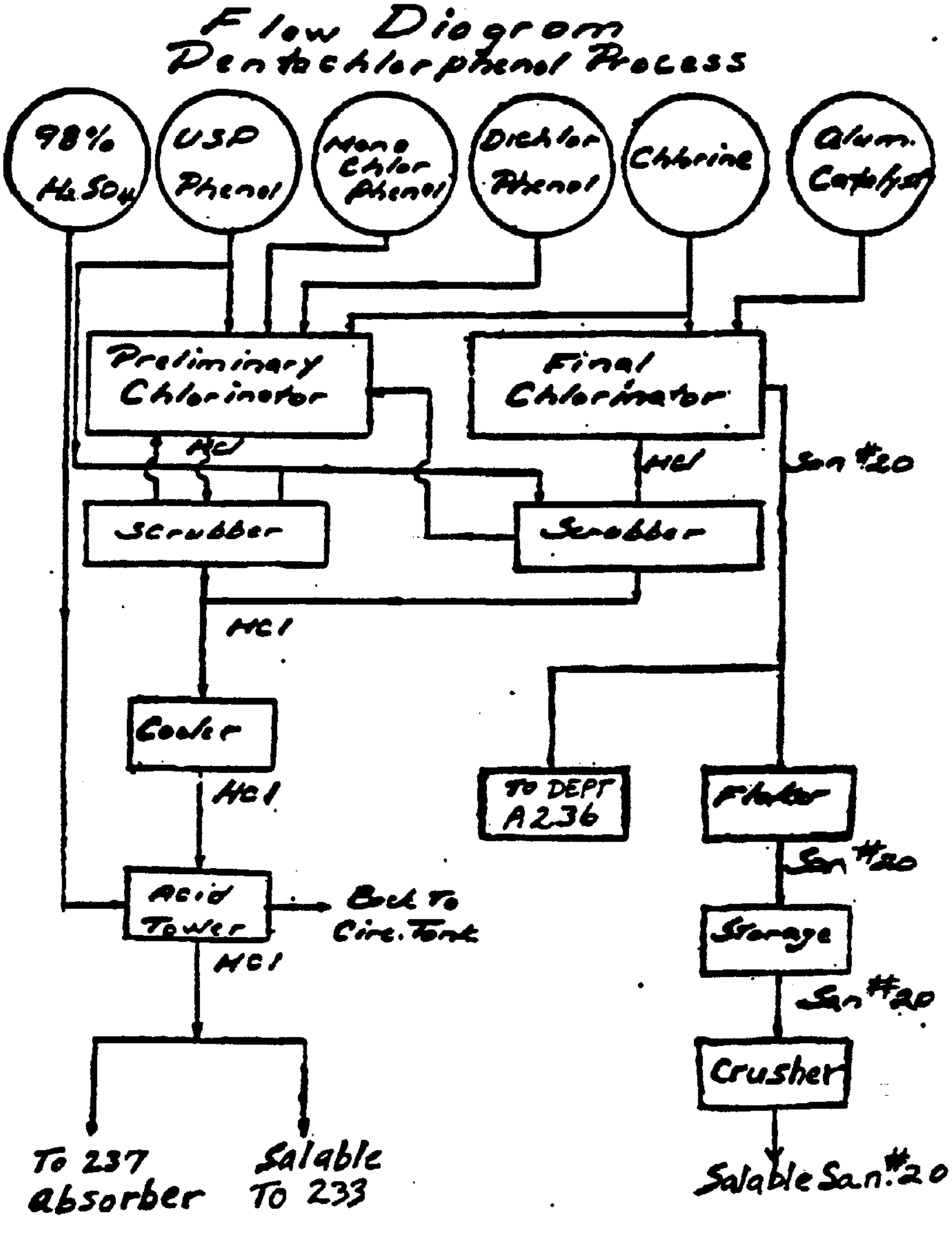


Figure 4
PCP Flow Diagram
Monsanto PCP Process SMP 1953
Monsanto Company
Sauget, Illinois

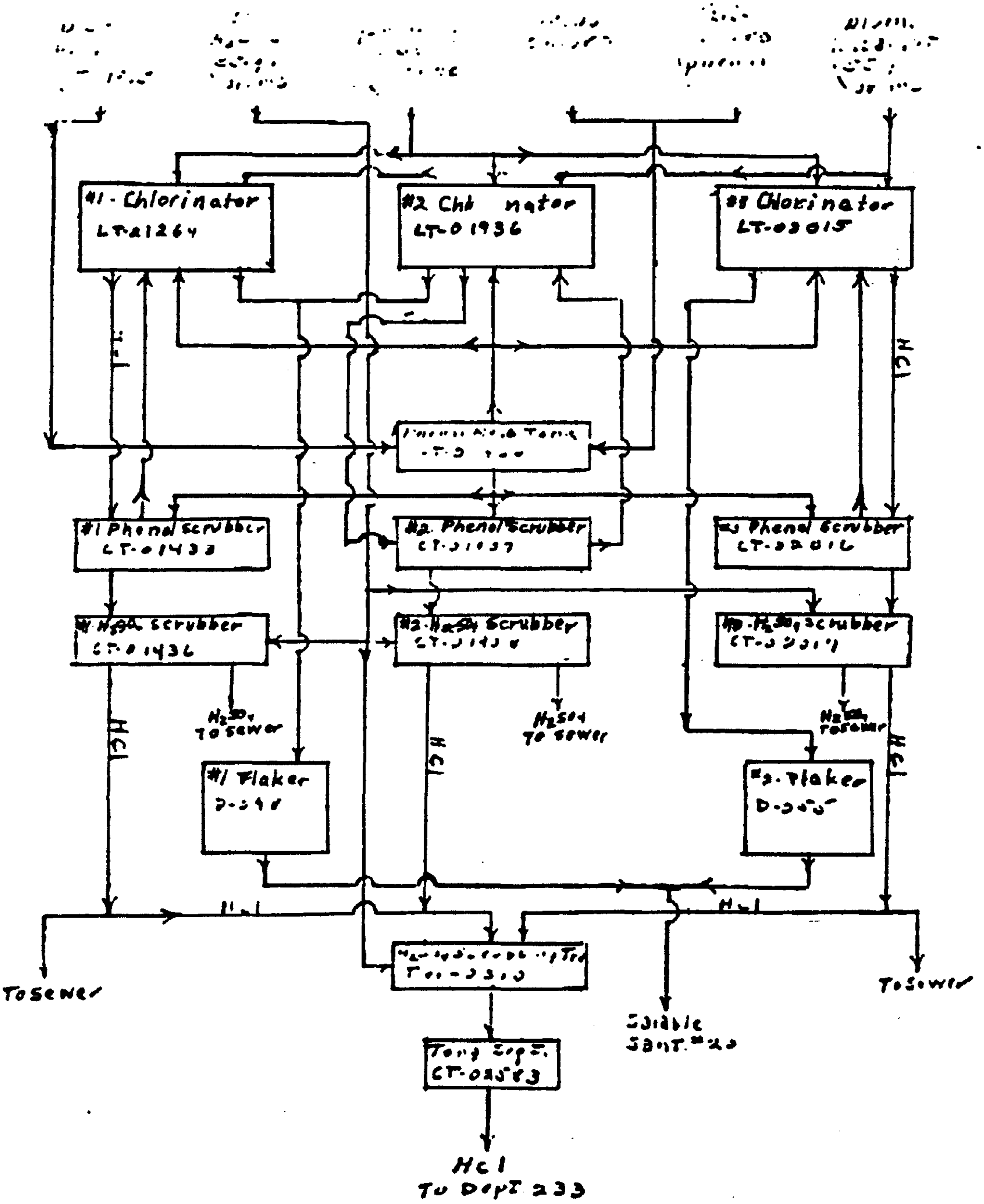


Figure 5
PCP Flow Diagram
Monsanto PCP Process SMP 1954
Monsanto Company
Sauget, Illinois

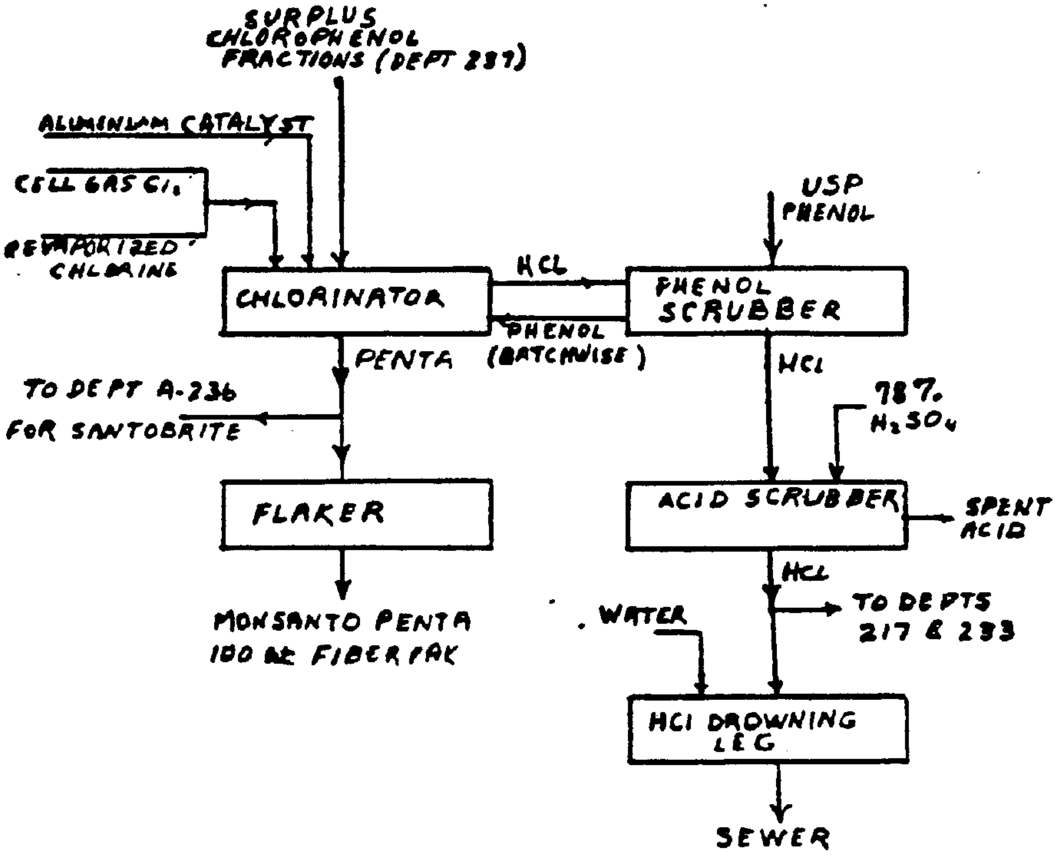


Figure 6
PCP Flow Diagram
Monsanto PCP Process SMP 1956
Monsanto Company
Sauget, Illinois

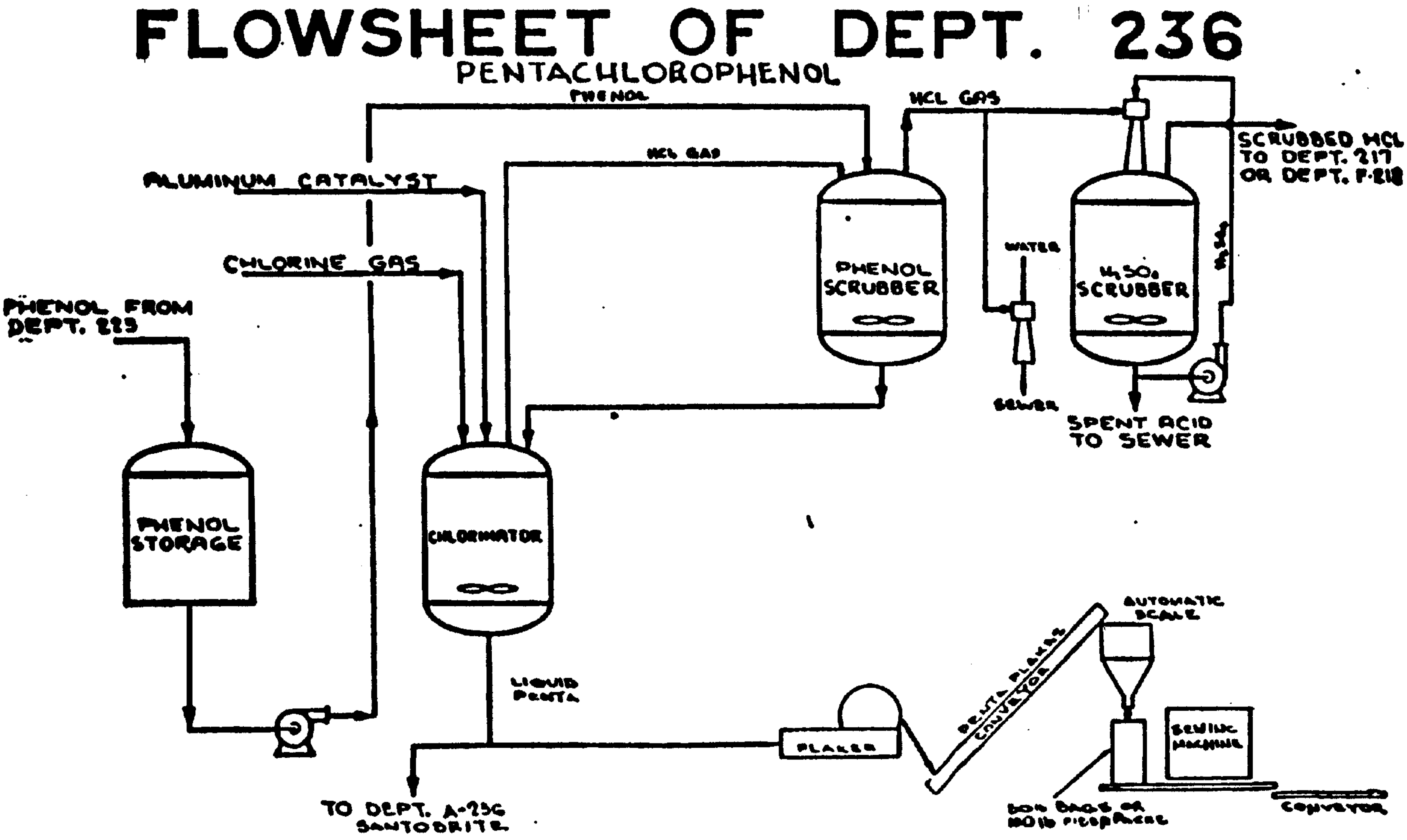


Figure 7
PCP Flow Diagram
Monsanto PCP Process SMP 1957
Monsanto Company
Sauget, Illinois

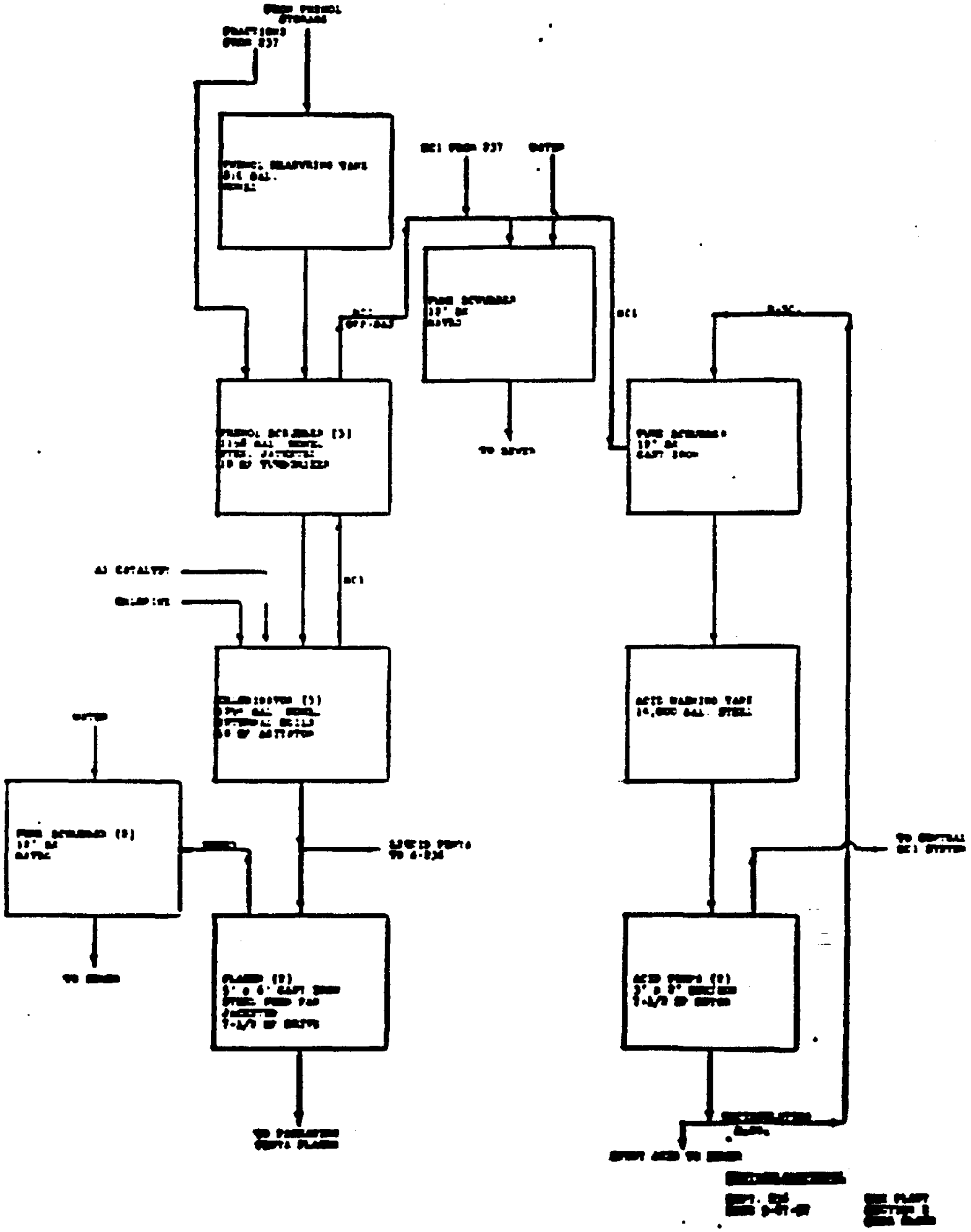


Figure 8
PCP Flow Diagram
Monsanto PCP Process SMP 1961
Monsanto Company
Sauget, Illinois

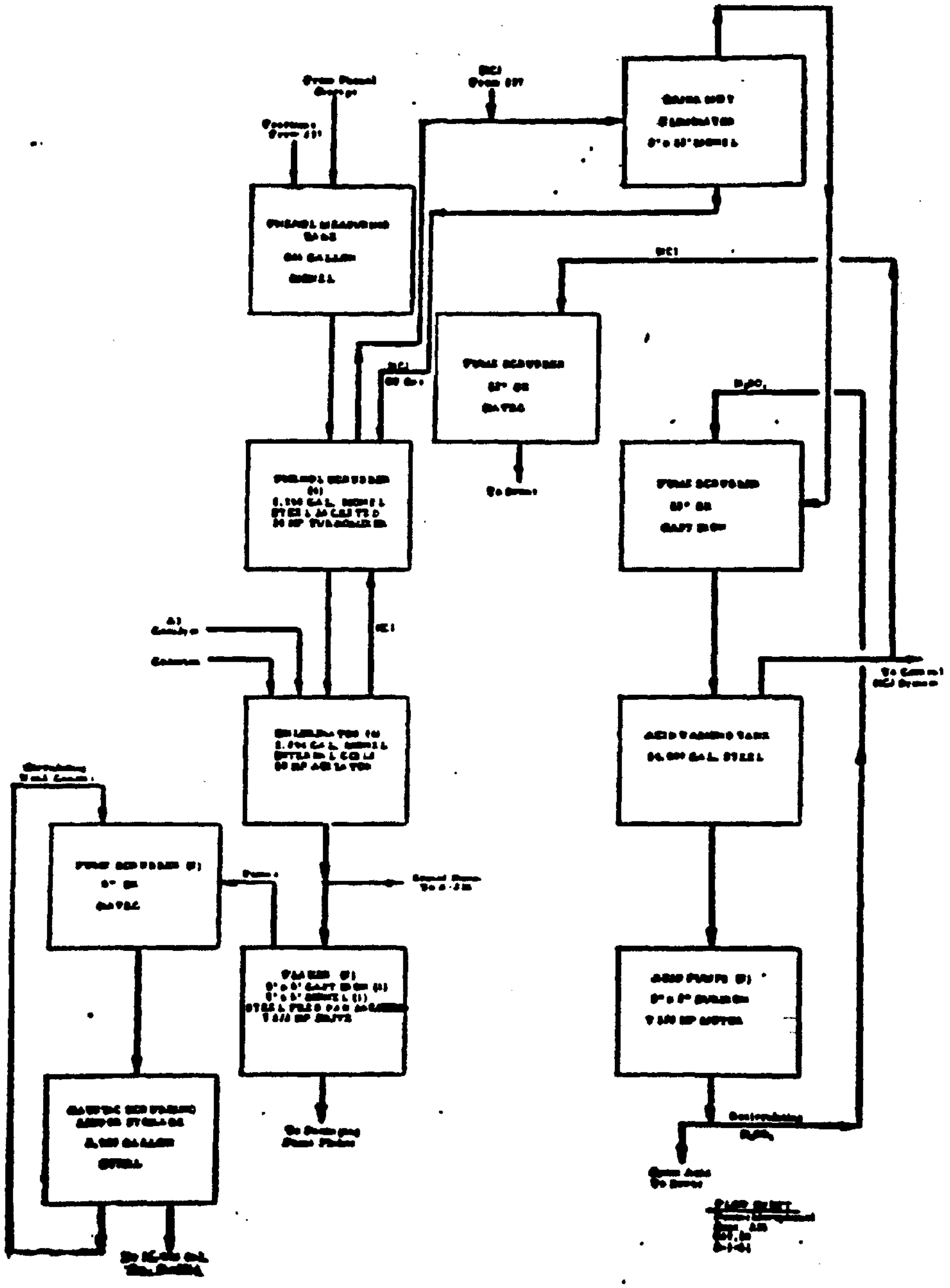


Figure 9A
PCP Flow Diagram
Monsanto PCP Process SMP 1965
Monsanto Company
Sauget, Illinois

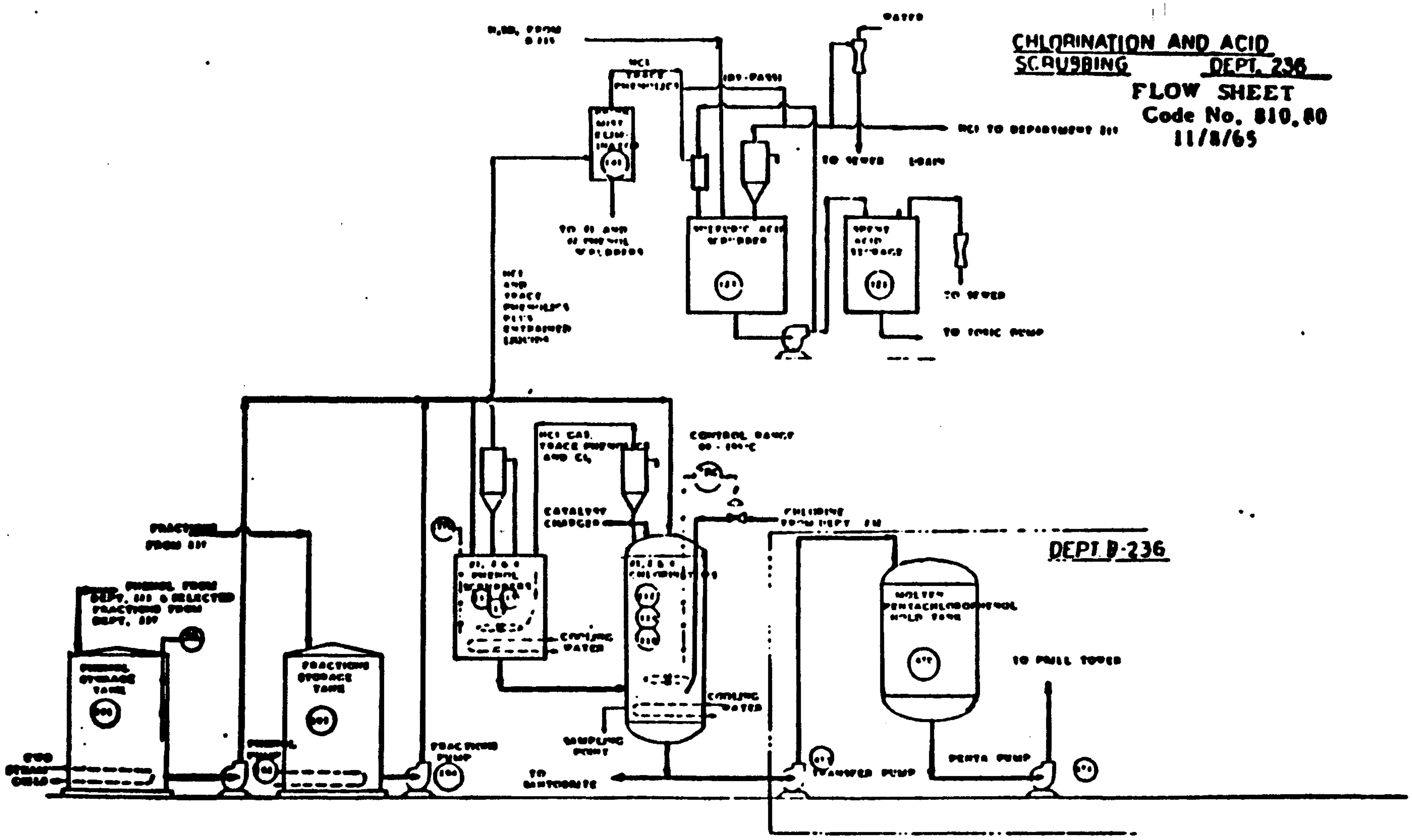


Figure 9B
PCP Flow Diagram
Monsanto PCP Process SMP 1965
Monsanto Company
Sauget, Illinois

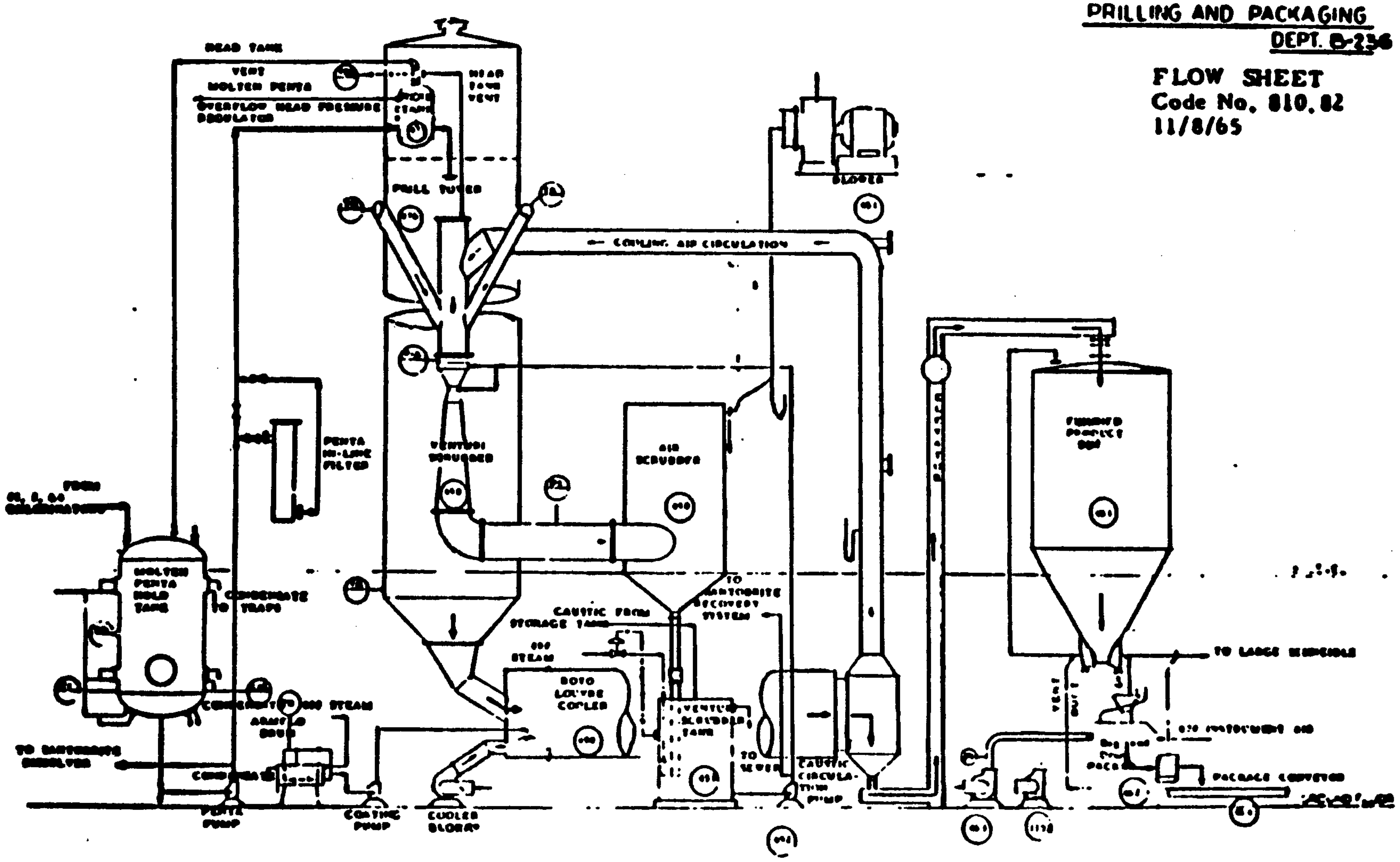


Figure 10A
PCP Flow Diagram
Monsanto PCP Process SMP 1972
Monsanto Company
Sauget, Illinois

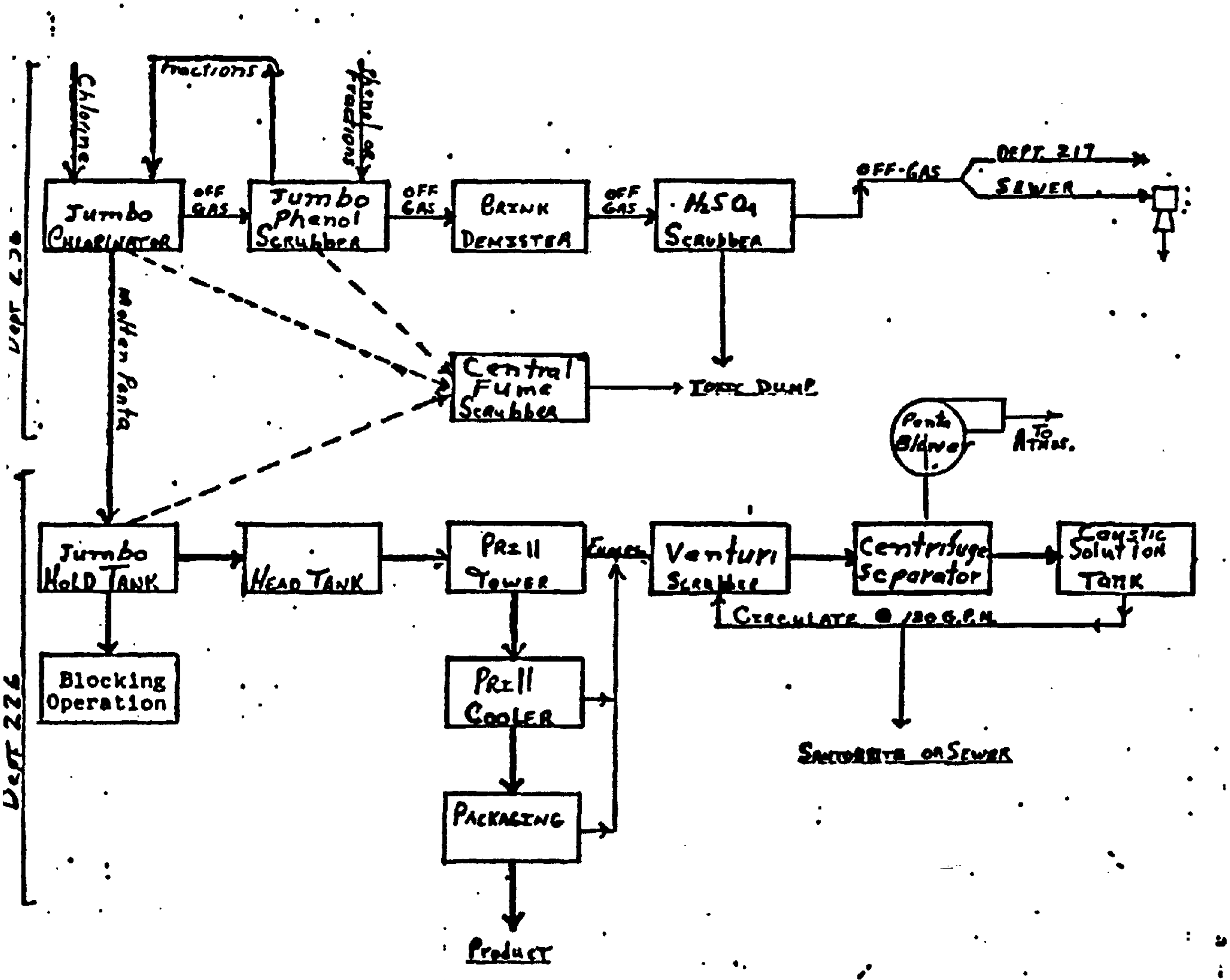


Figure 10B
PCP Flow Diagram
Monsanto PCP Process SMP 1972
Monsanto Company
Sauget, Illinois

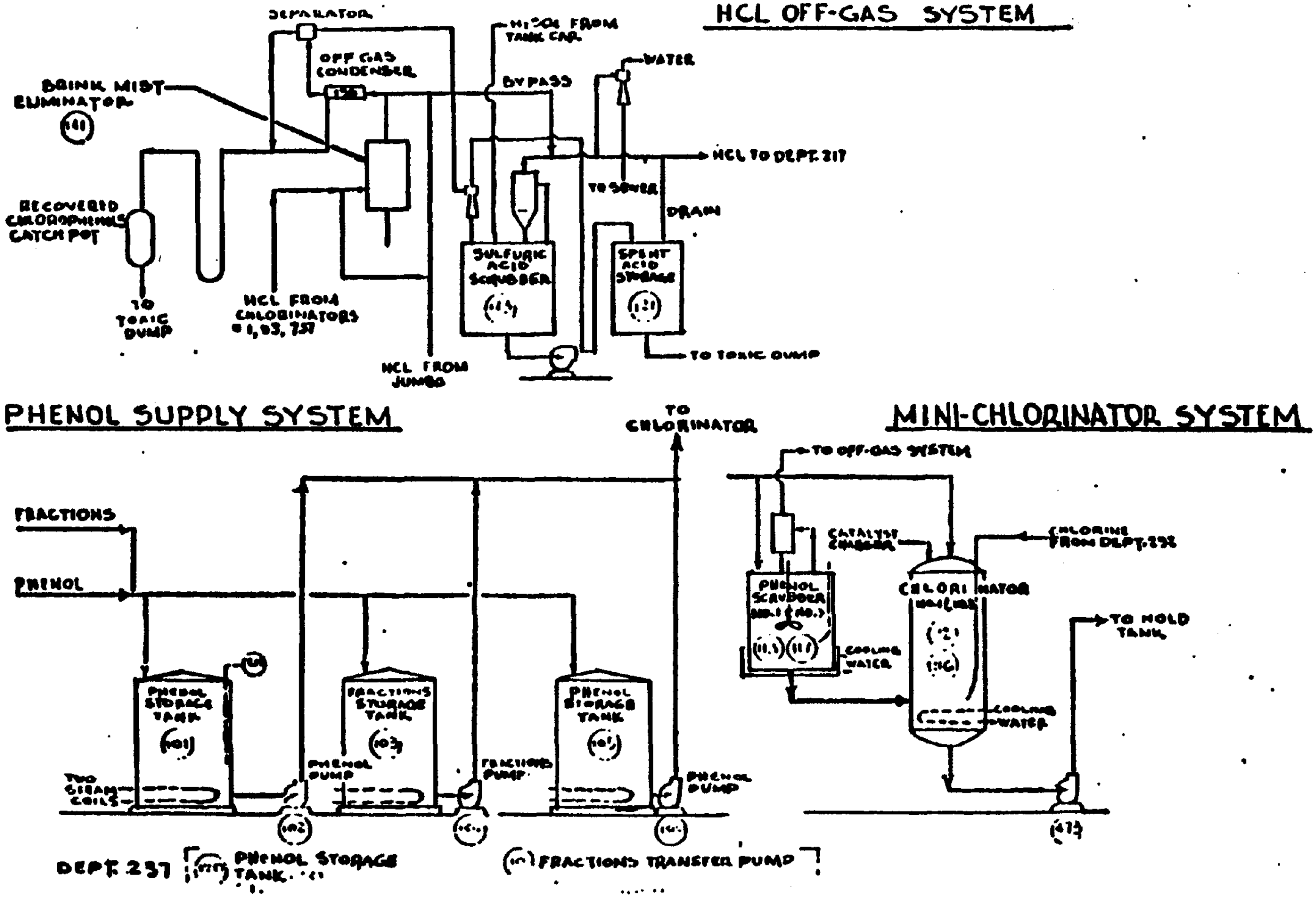


Figure 10C
PCP Flow Diagram
Monsanto PCP Process SMP 1972
Monsanto Company
Sauget, Illinois

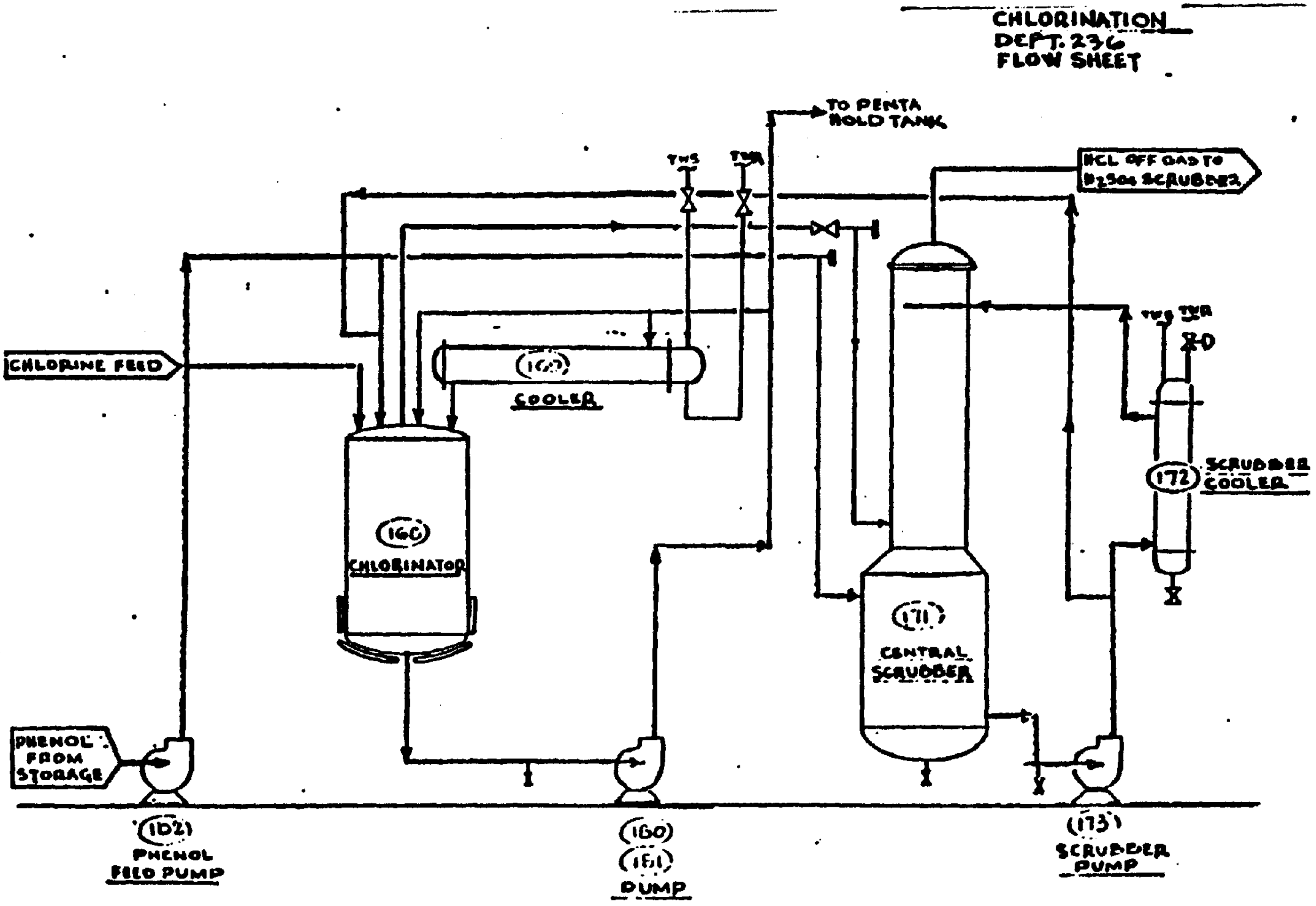


Figure 10D
PCP Flow Diagram
Monsanto PCP Process SMP 1972
Monsanto Company
Sauget, Illinois

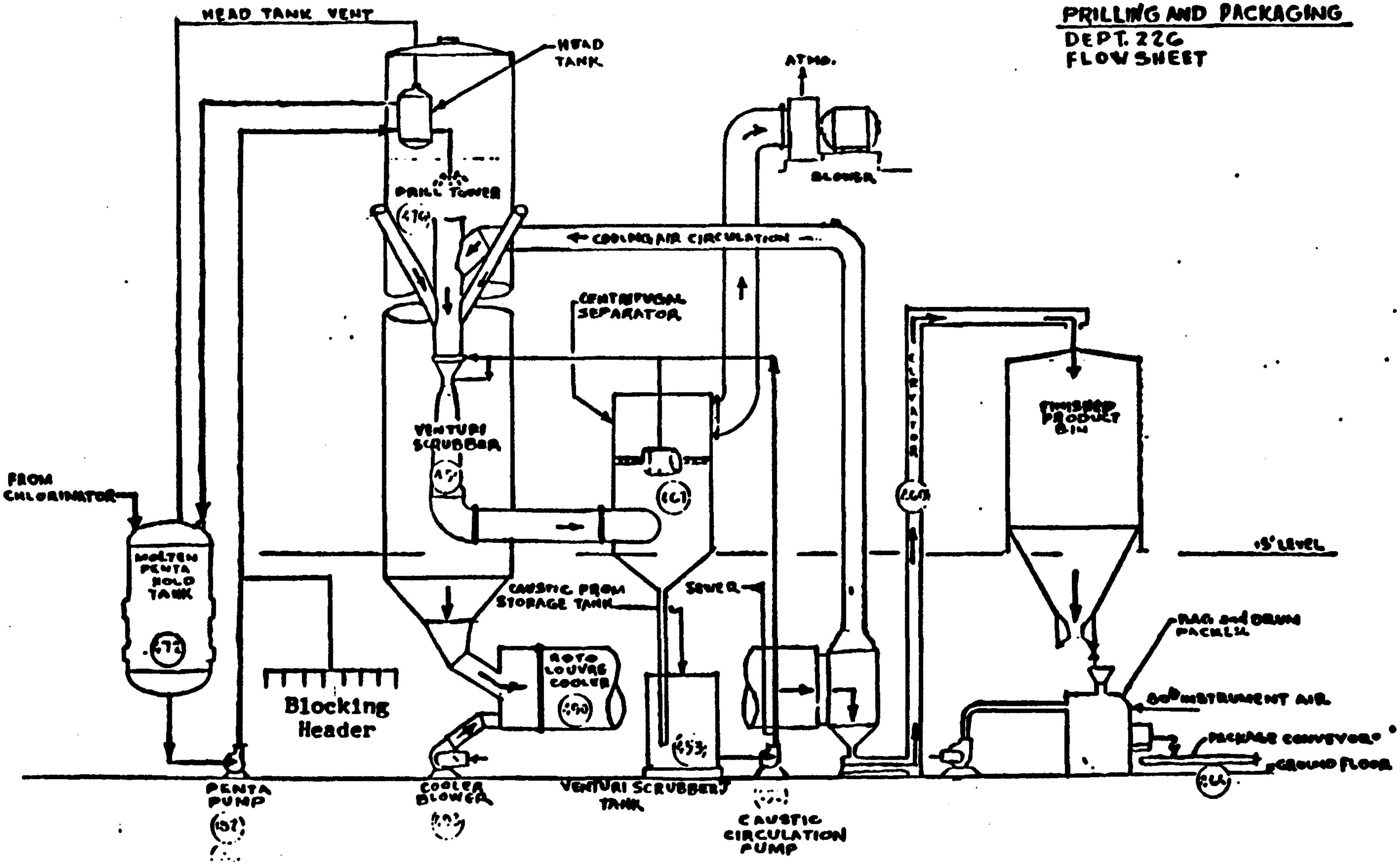


Figure 10E
PCP Flow Diagram
Monsanto PCP Process SMP 1972
Monsanto Company
Sauget, Illinois

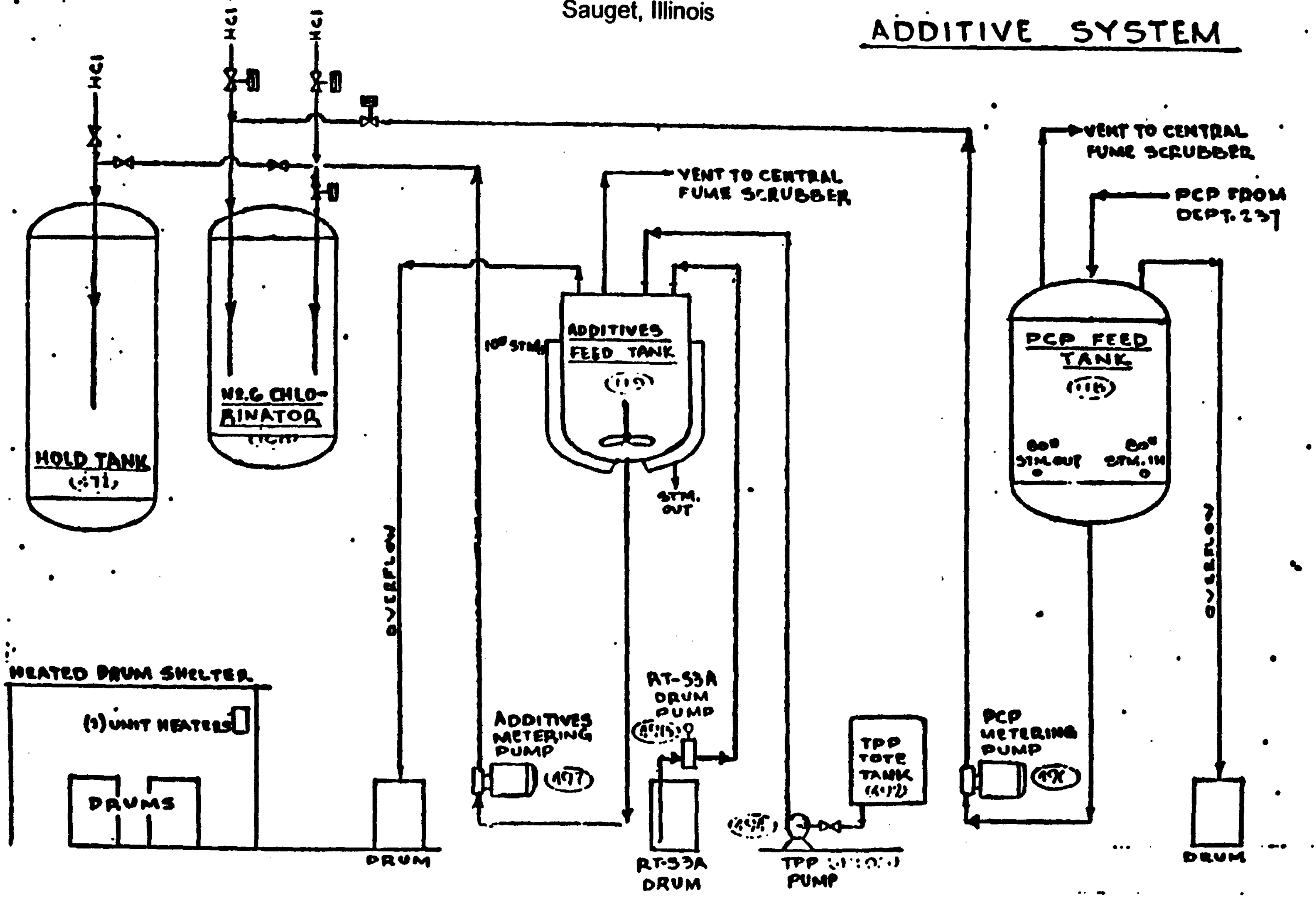


Figure 11
NaPCP Flow Diagram
Compiled from Monsanto NaPCP Process SMPs 1938-1975
Monsanto Company
Sauget, Illinois

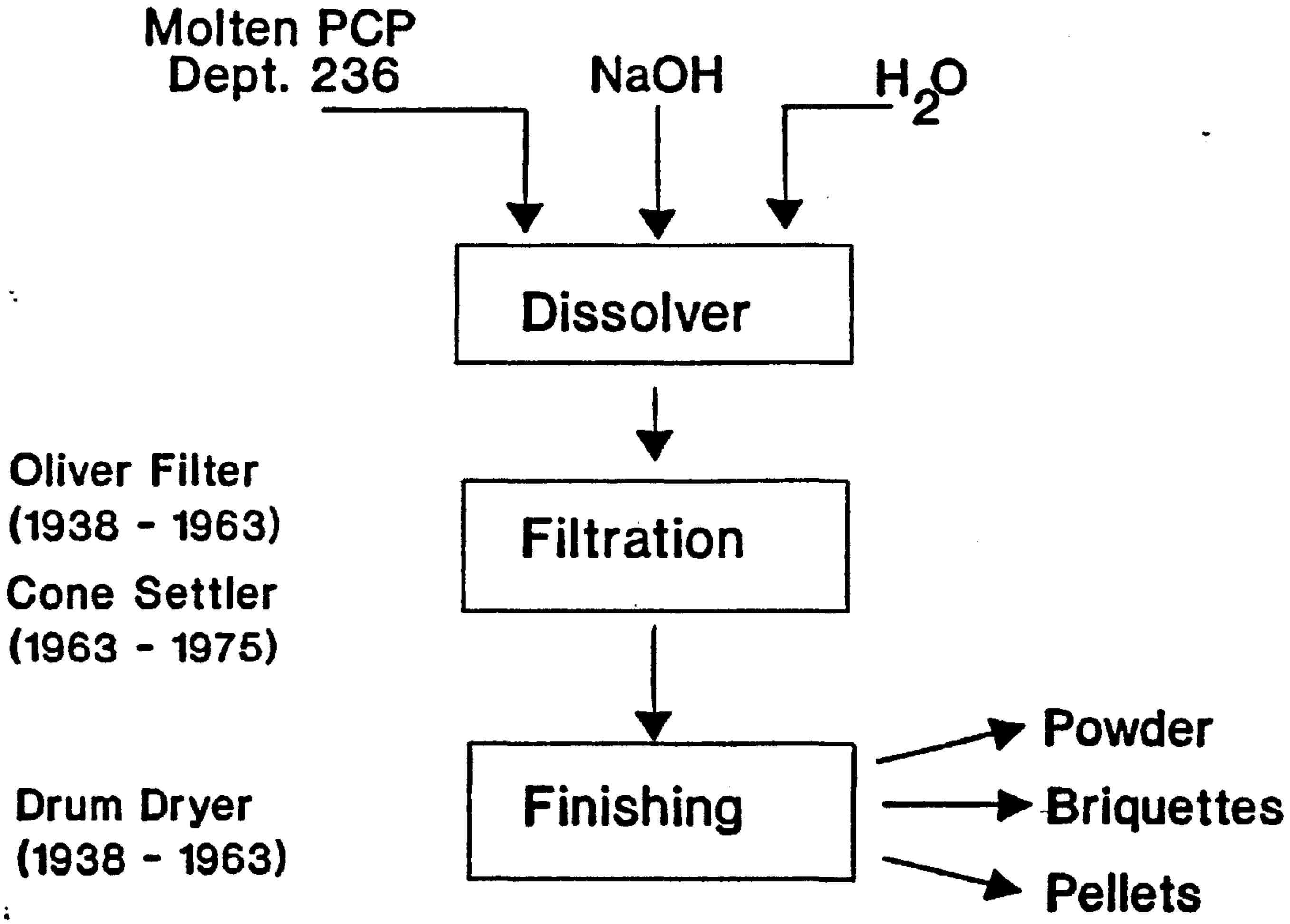


Figure 12
NaPCP Flow Diagram 1949
Monsanto Company
Sauget, Illinois

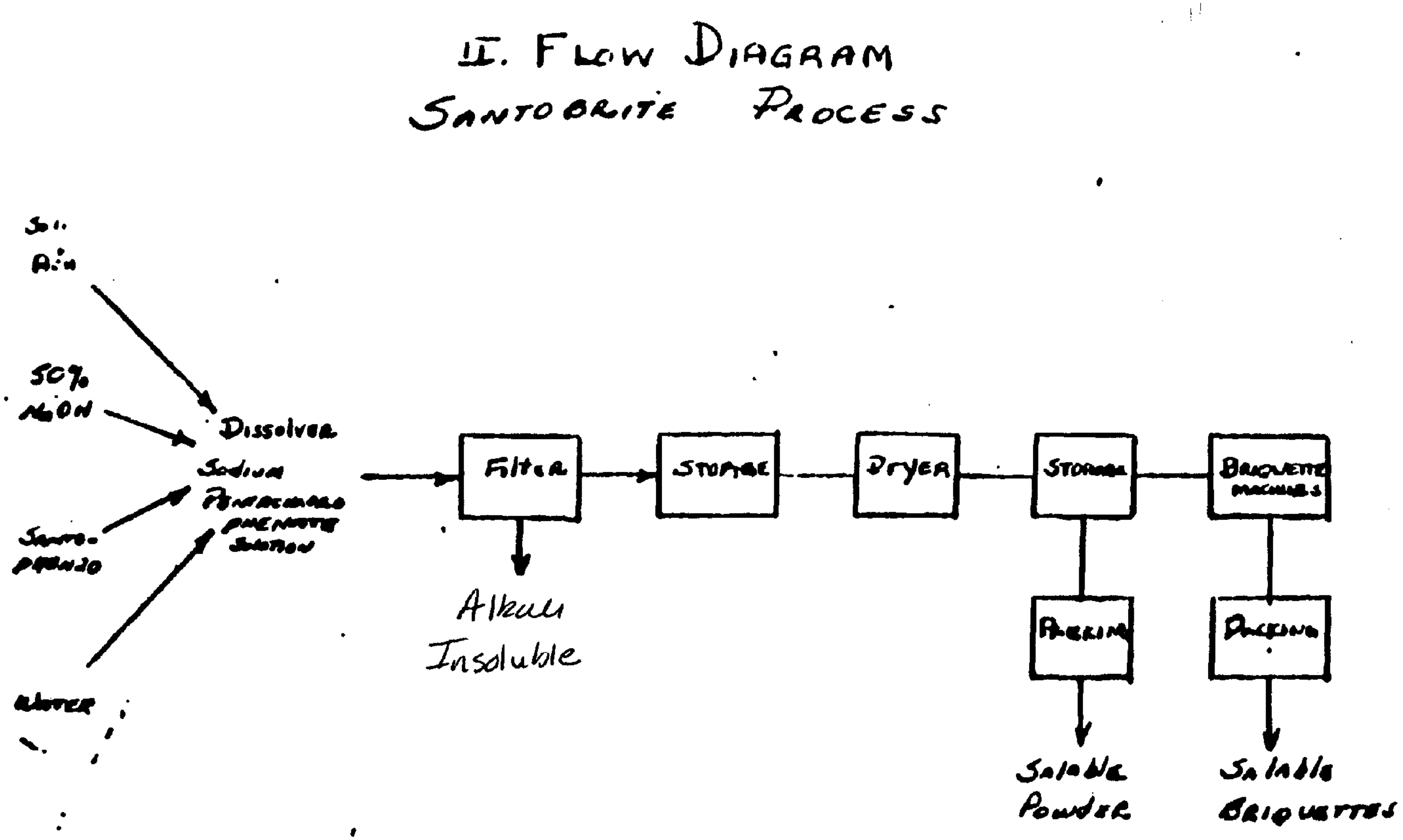


Figure 13
NaPCP Flow Diagram 1954
Monsanto Company
Sauget, Illinois

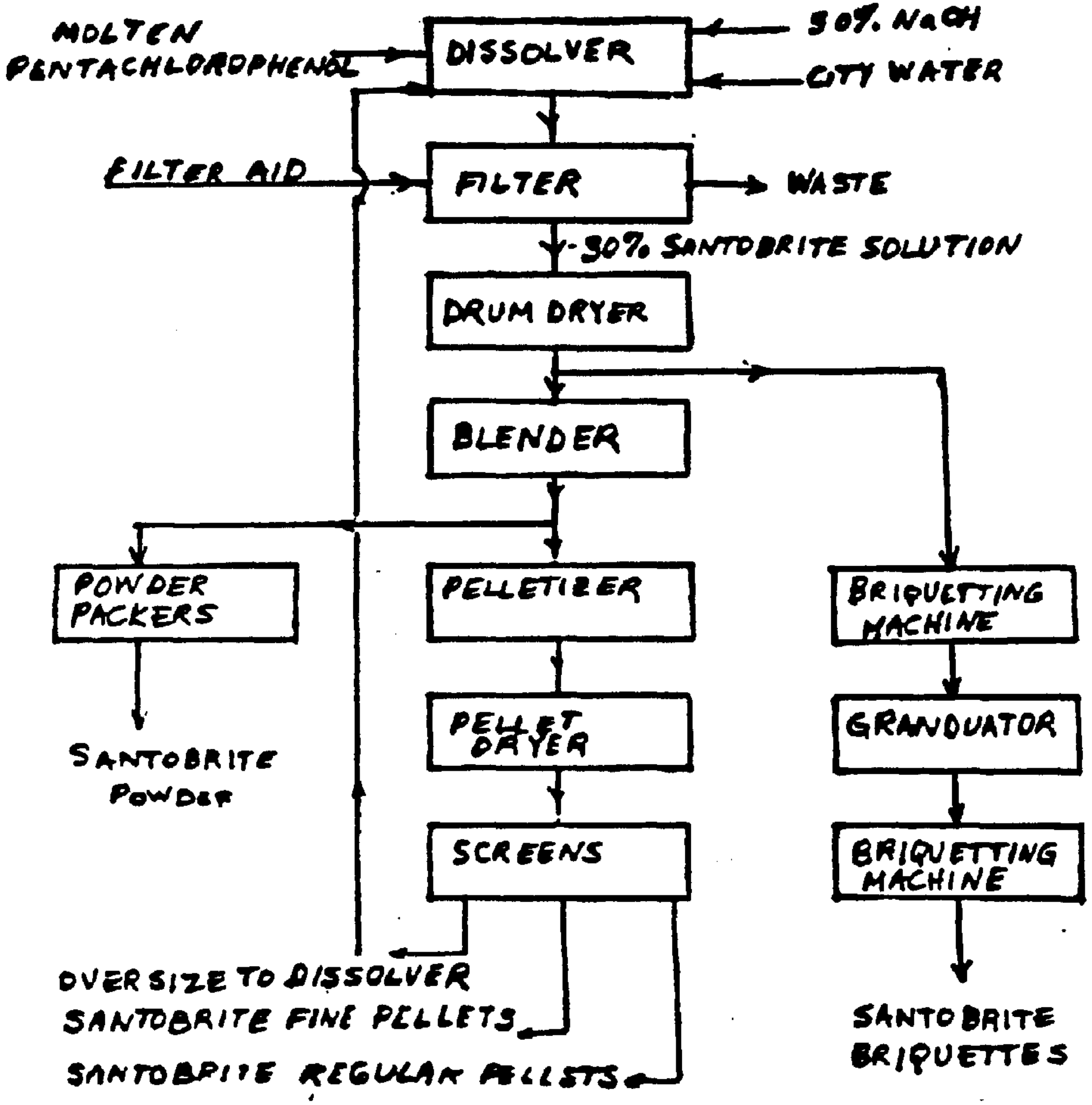


Figure 14
NaPCP Flow Diagram 1956
Monsanto Company
Sauget, Illinois

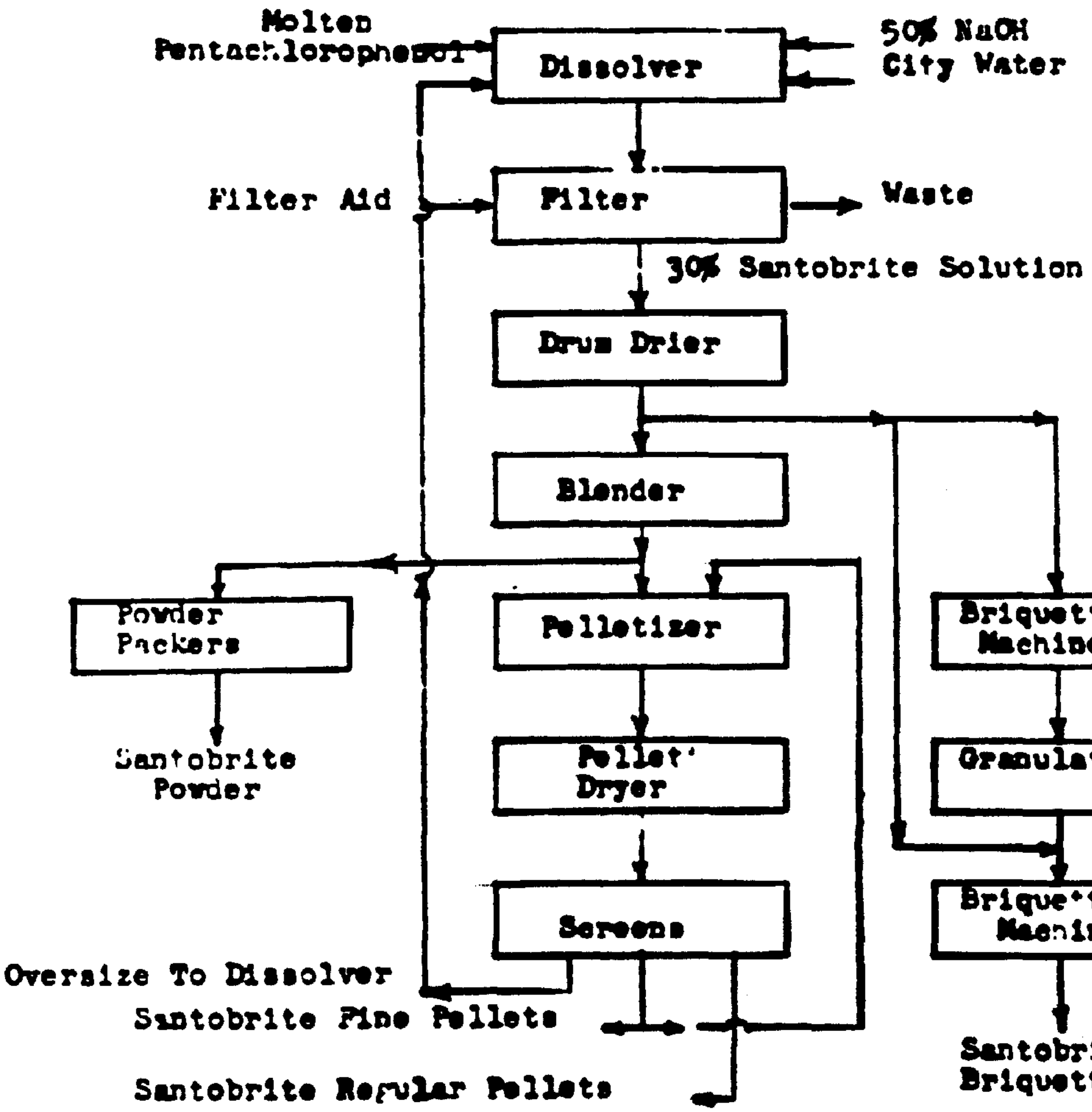


Figure 15
NaPCP Flow Diagram 1959
Monsanto Company
Sauget, Illinois

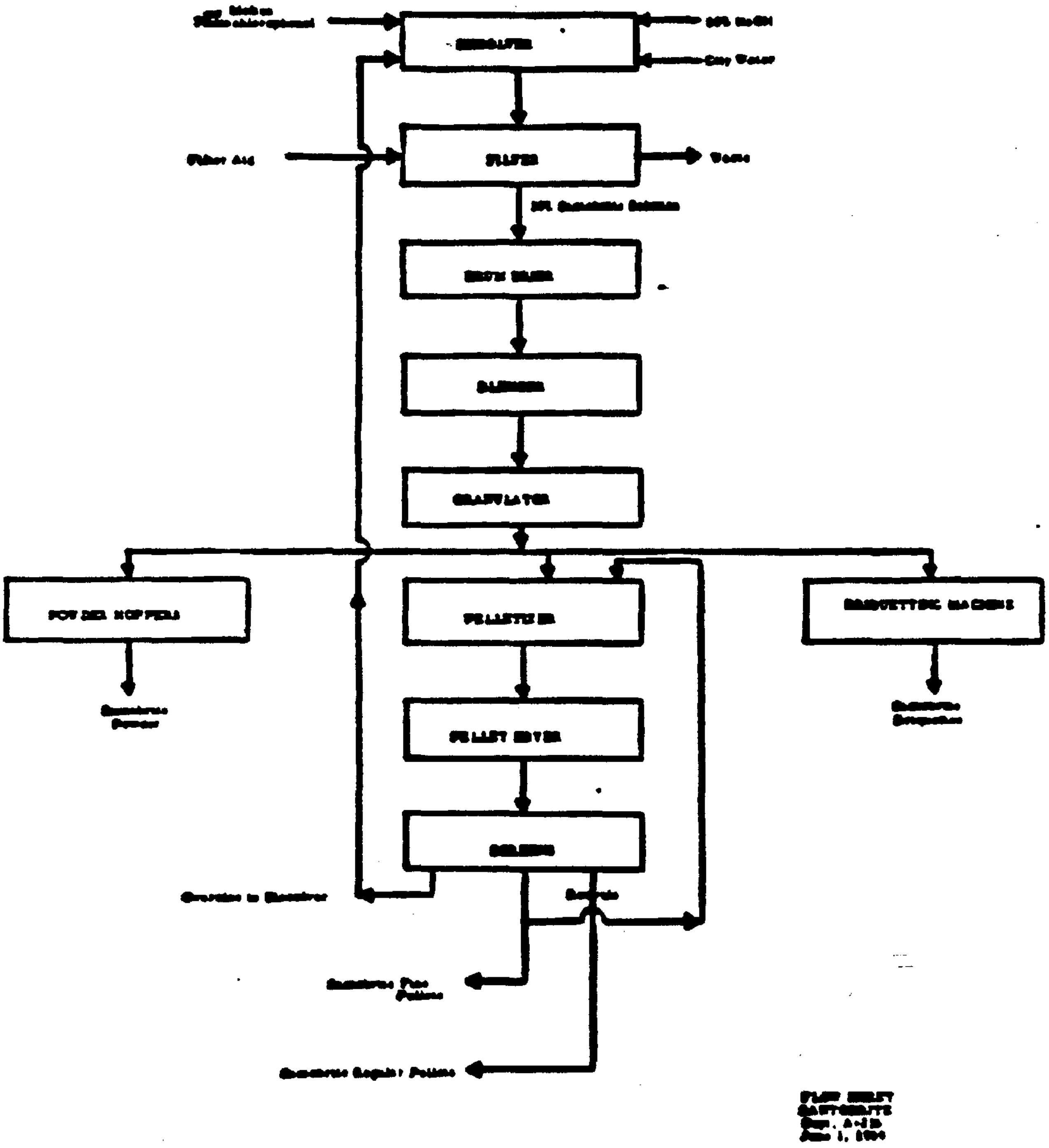


Figure 16
NaPCP Flow Diagram 1961

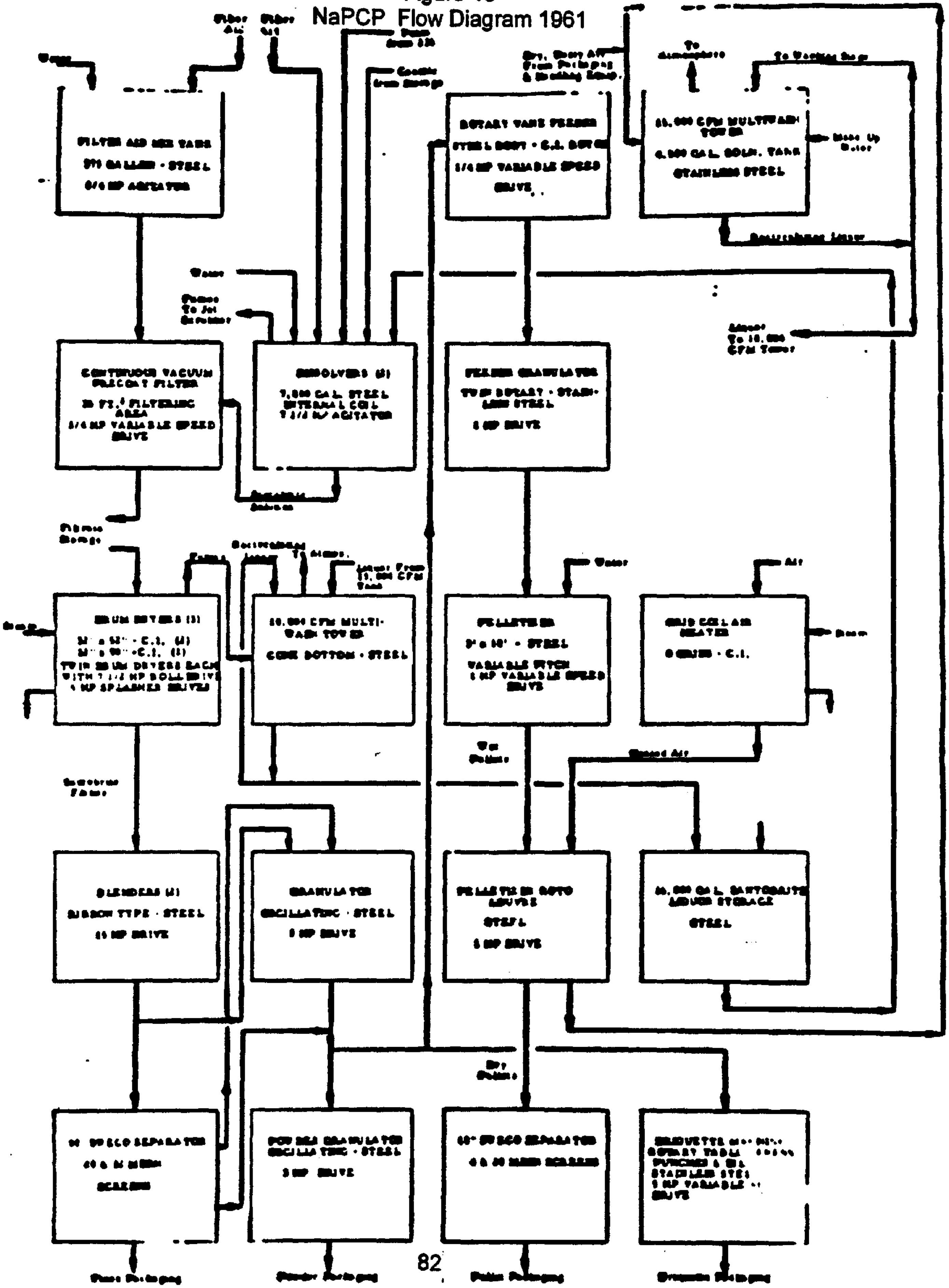


Figure 17A
NaPCP Flow Diagram 1965
Monsanto Company
Sauget, Illinois

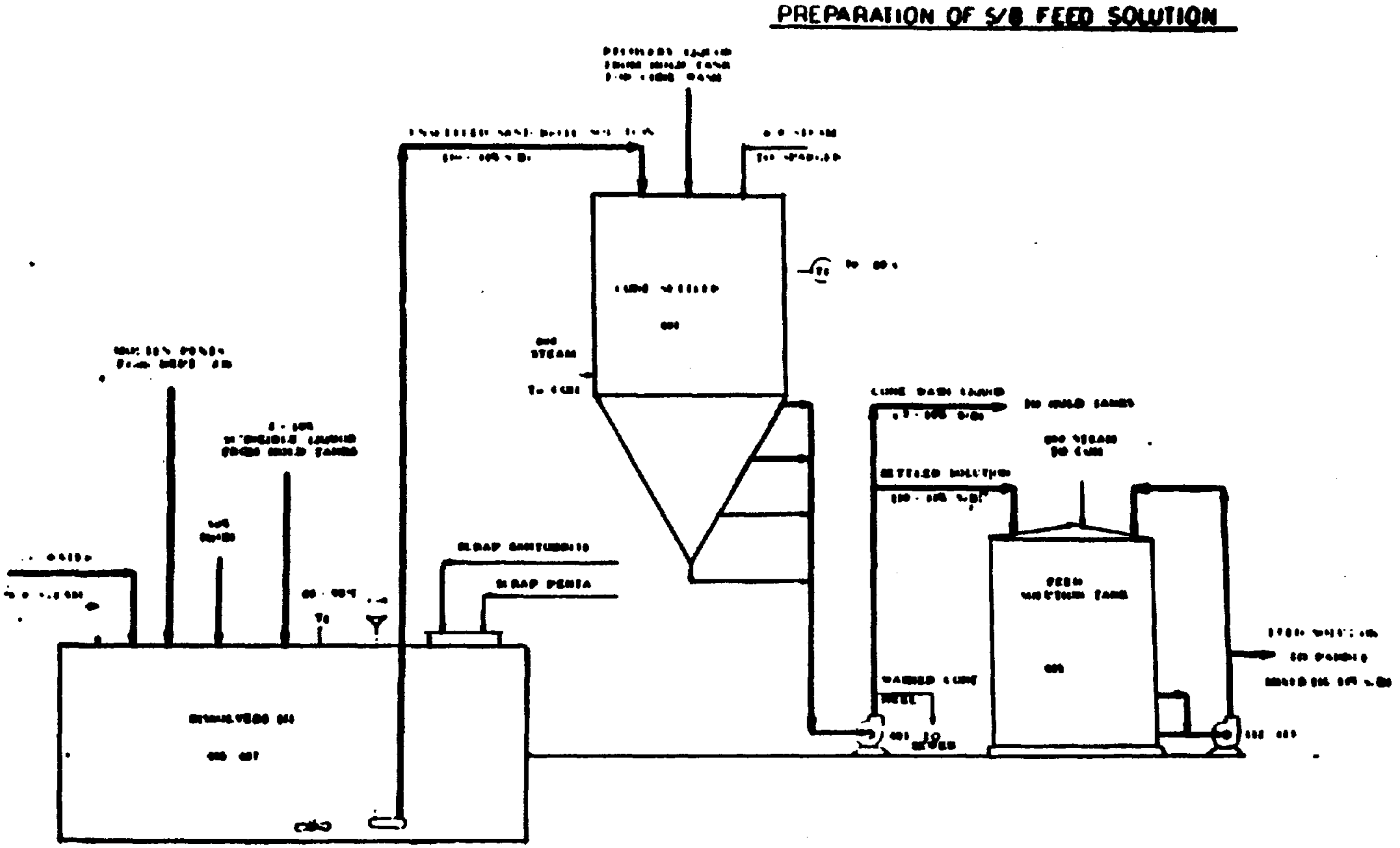


Figure 17B
NaPCP Flow Diagram 1965
Monsanto Company
Sauget, Illinois

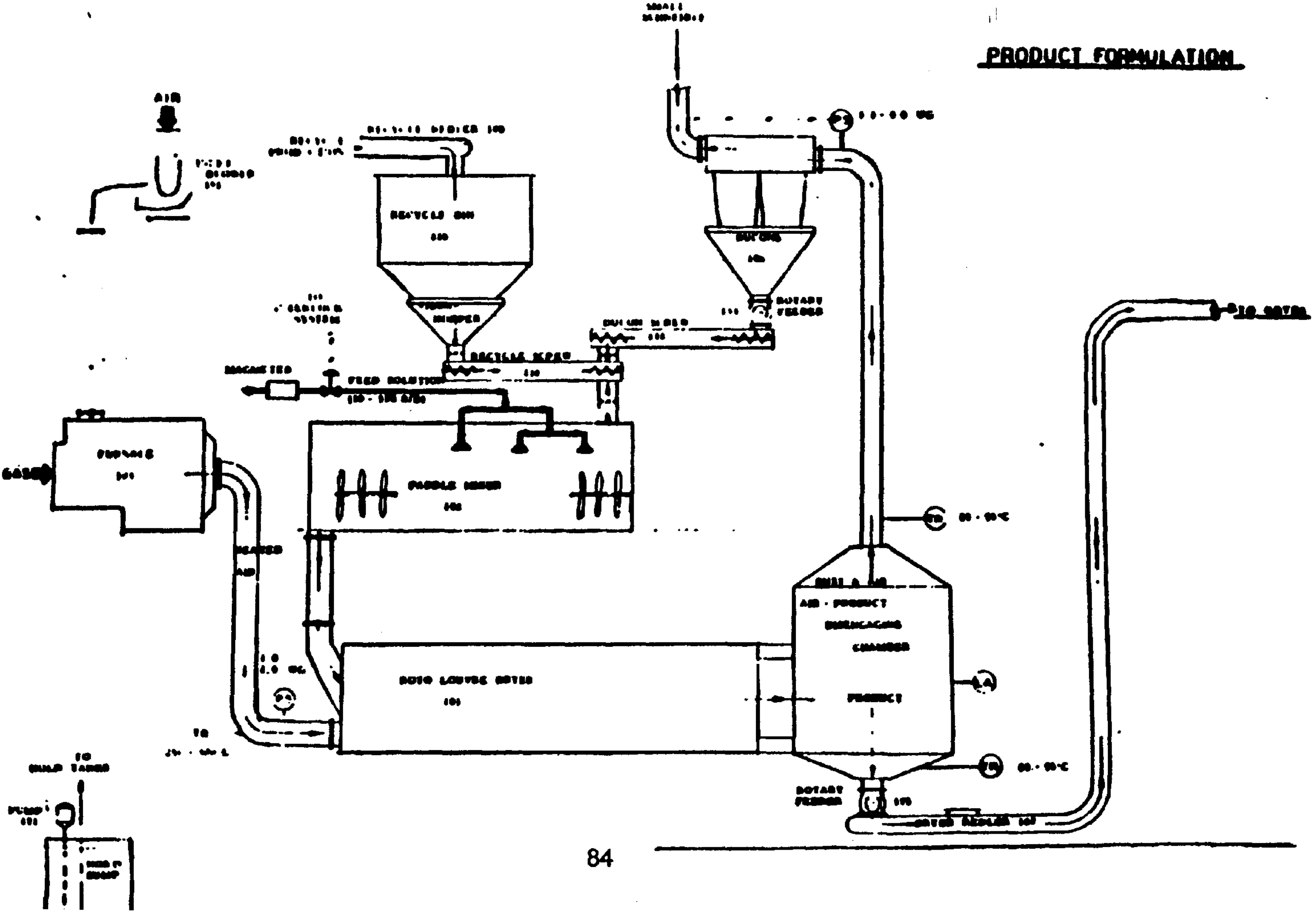


Figure 17C
NaPCP Flow Diagram 1965
Monsanto Company
Sauget, Illinois

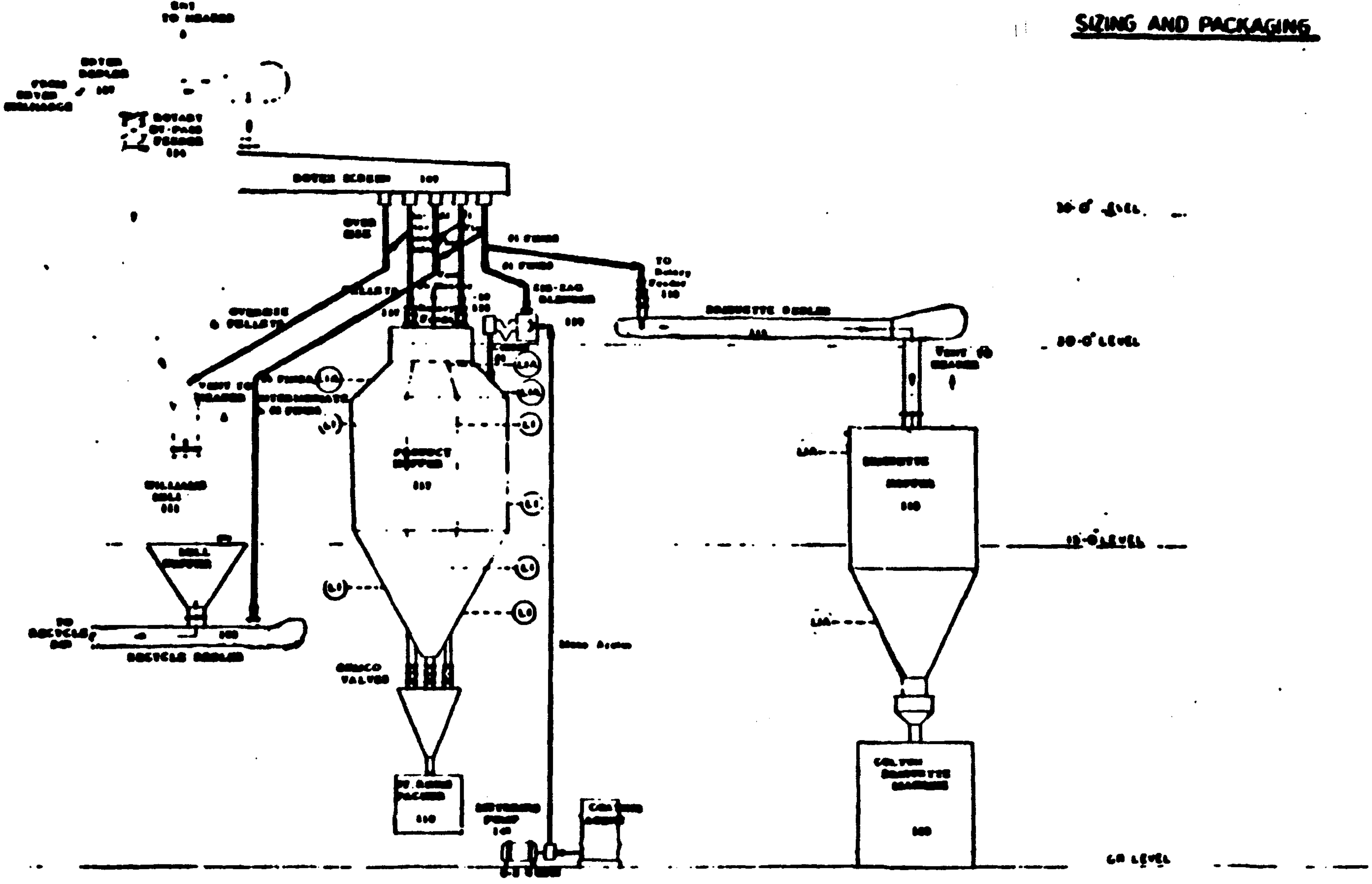


Figure 17D
NaPCP Flow Diagram 1965
Monsanto Company
Sauget, Illinois

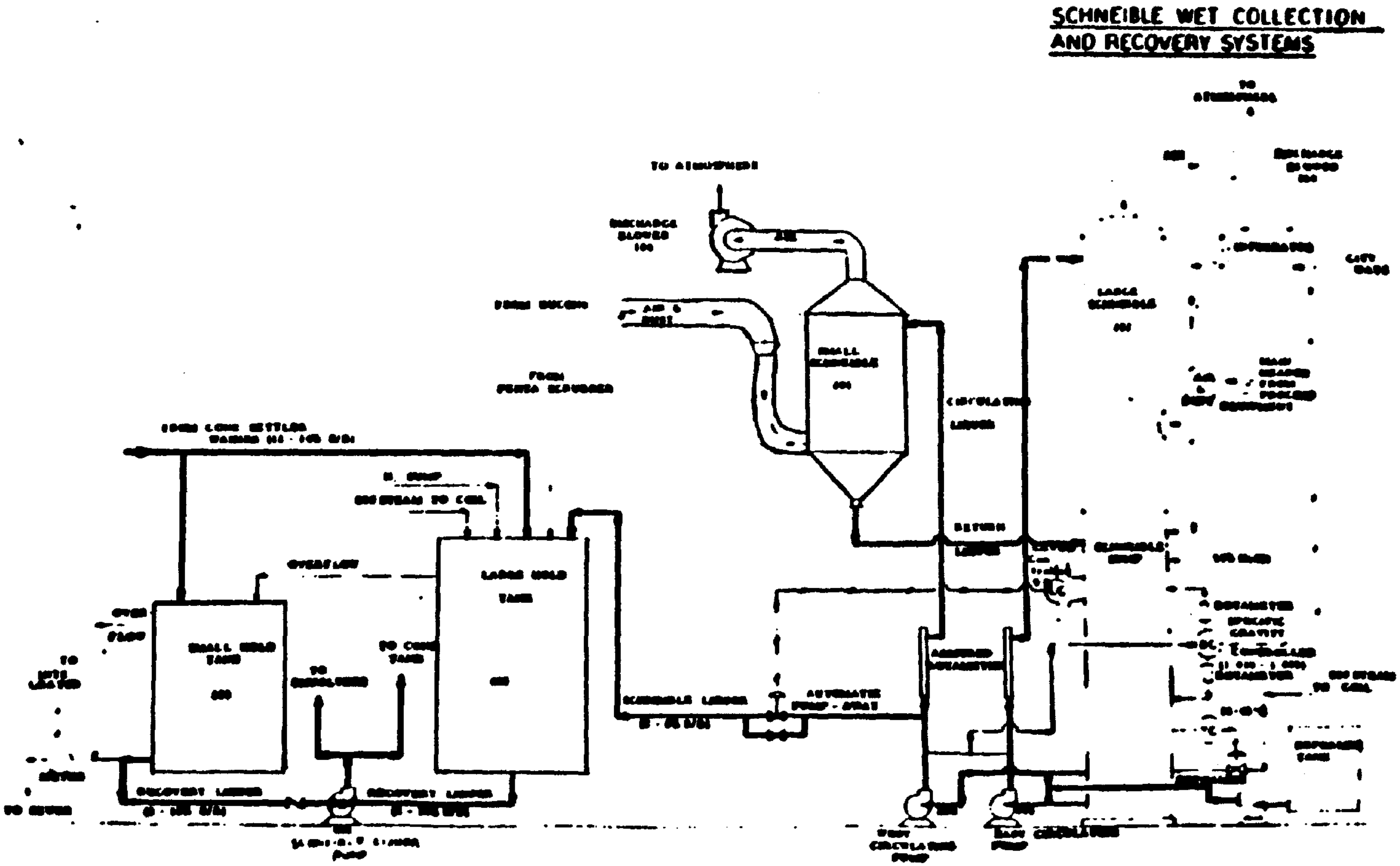


Figure 18A
NaPCP Flow Diagram 1968
Monsanto Company
Sauget, Illinois

PREPARATION OF S/B FEED SOLUTION

810.76

7/19/68

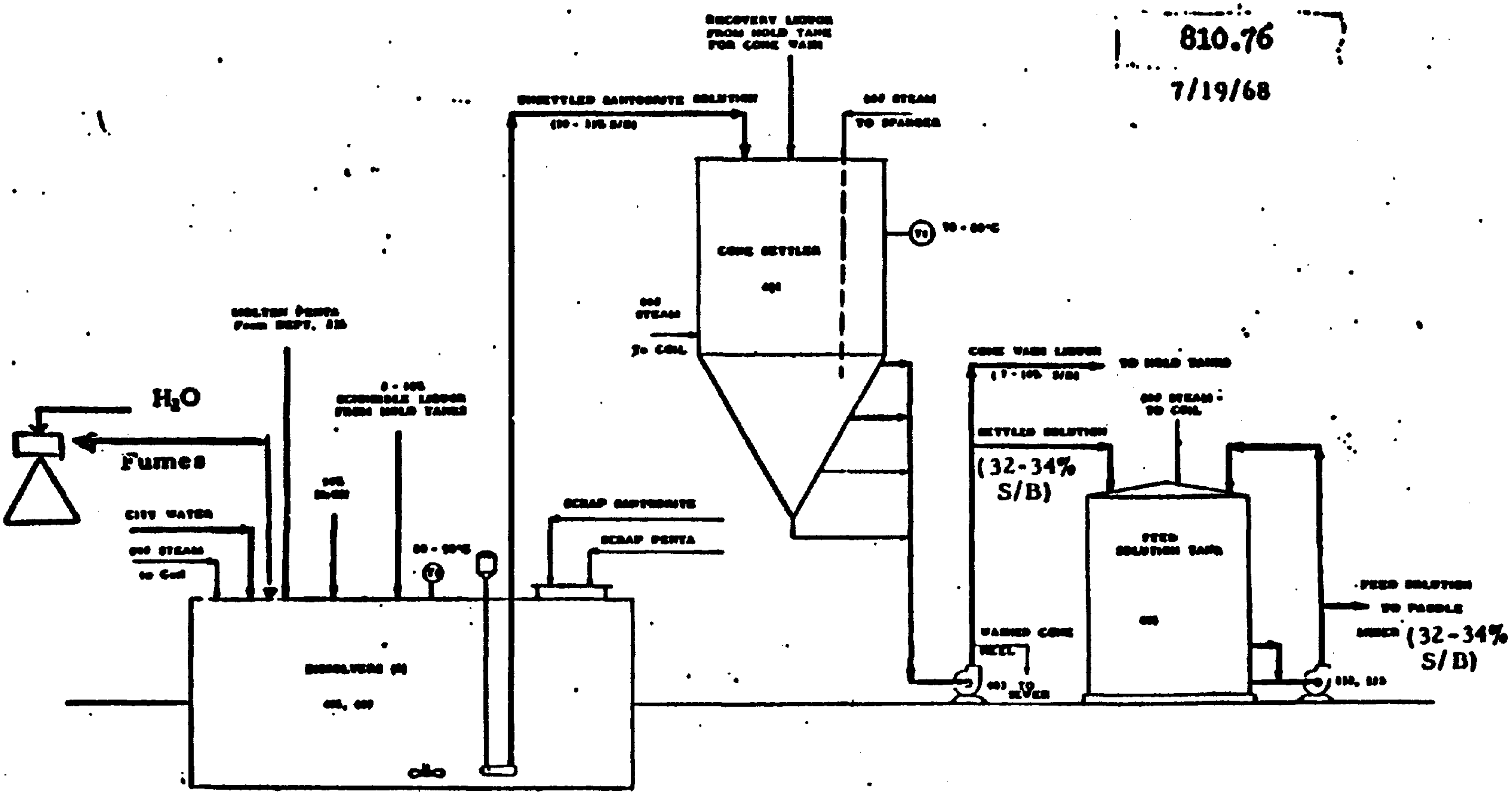


Figure 18B
NaPCP Flow Diagram 1968
Monsanto Company
Sauget, Illinois

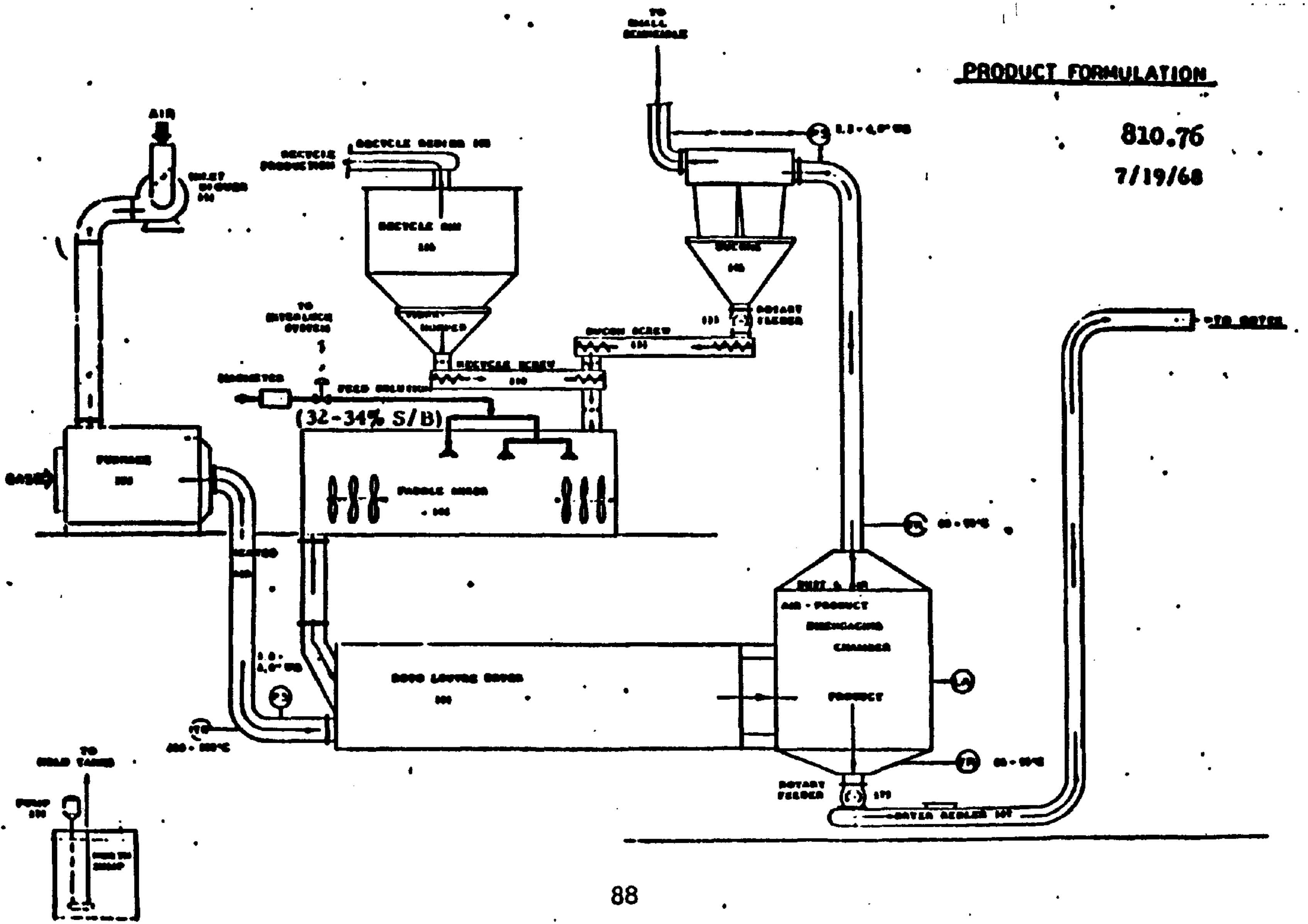


Figure 18C
NaPCP Flow Diagram 1968
Monsanto Company
Sauget, Illinois

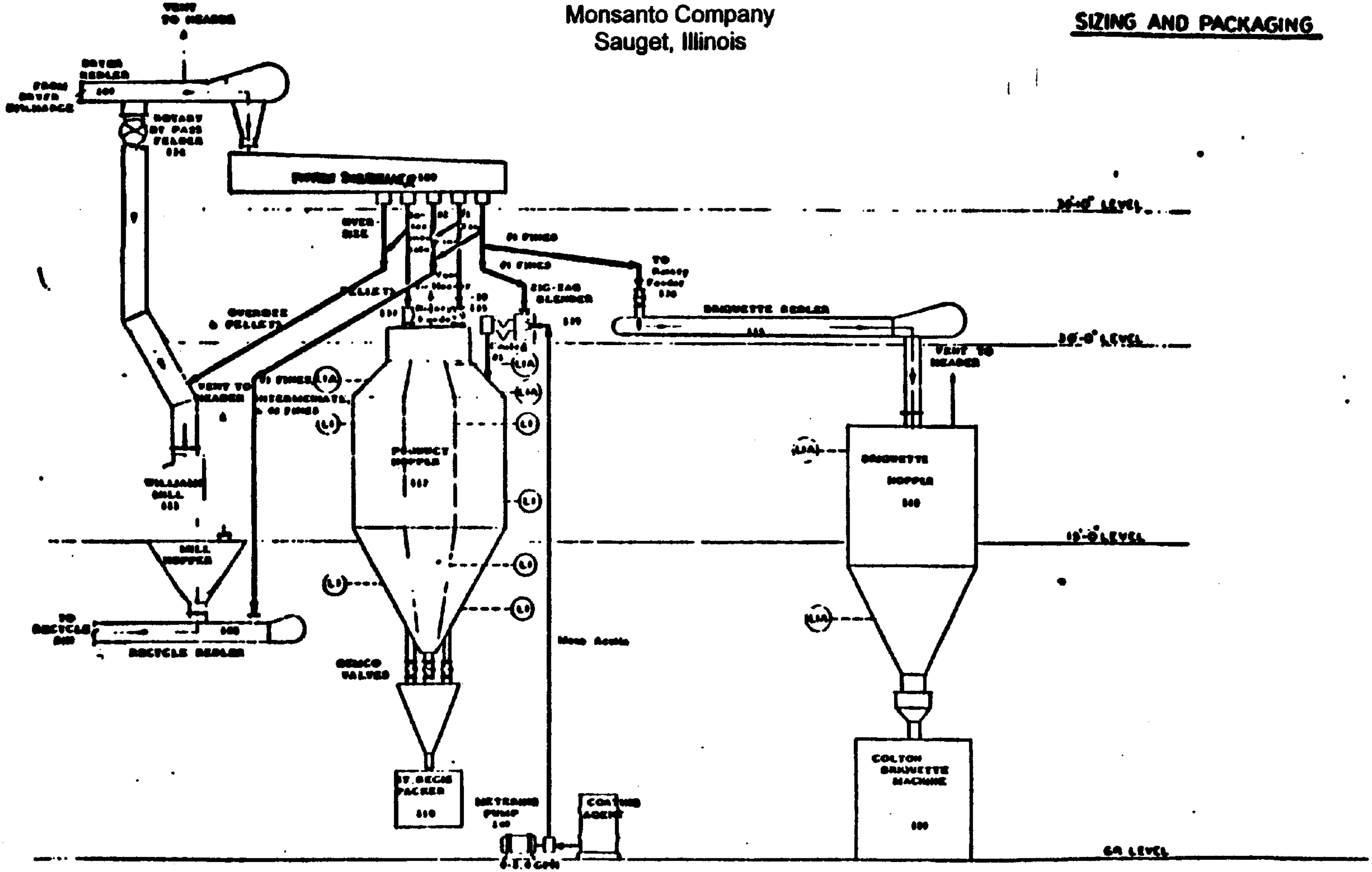


Figure 18D
NaPCP Flow Diagram 1968
Monsanto Company
Sauget, Illinois

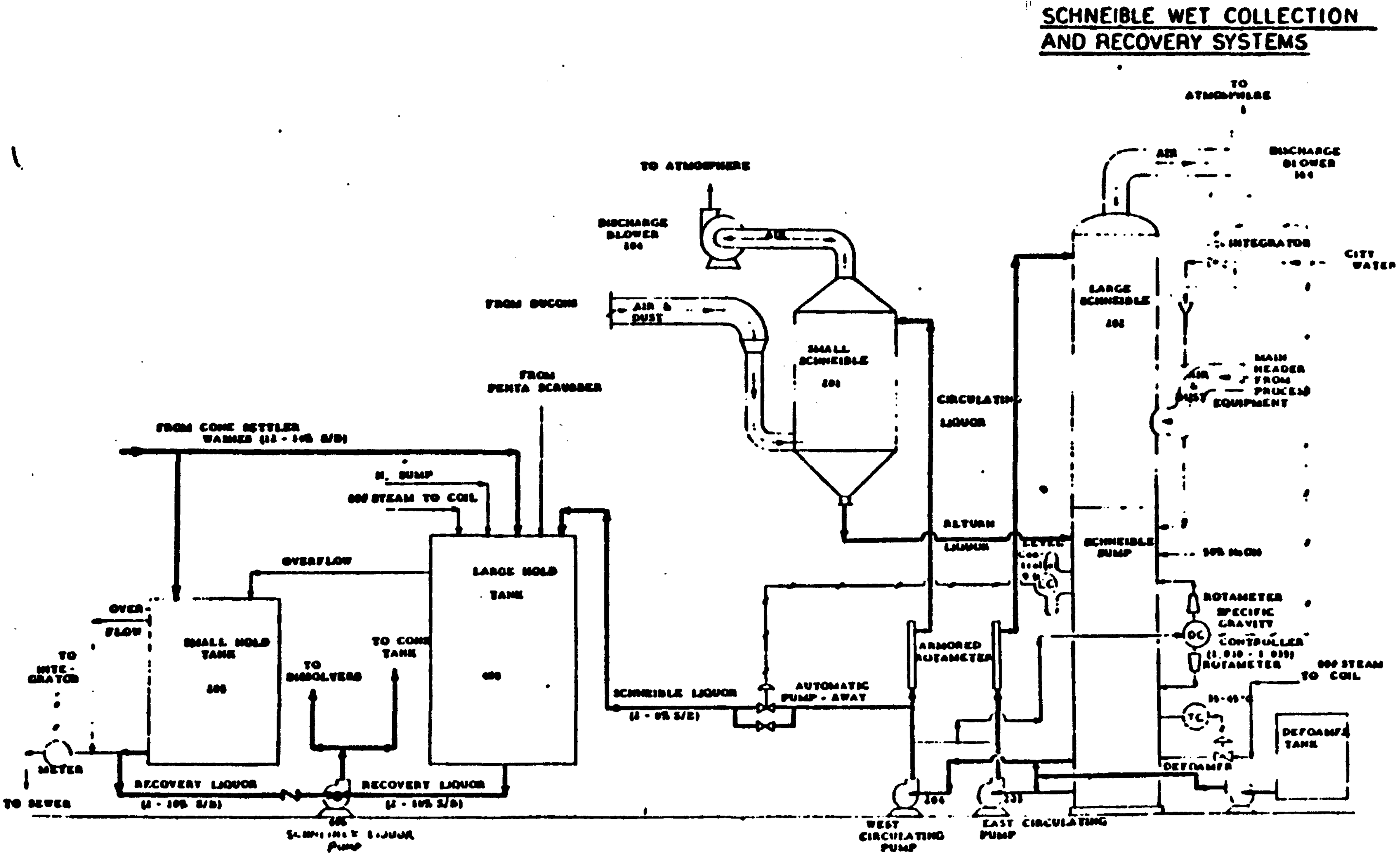


Figure 19A
NaPCP Flow Diagram 1972
Monsanto Company
Sauget, Illinois

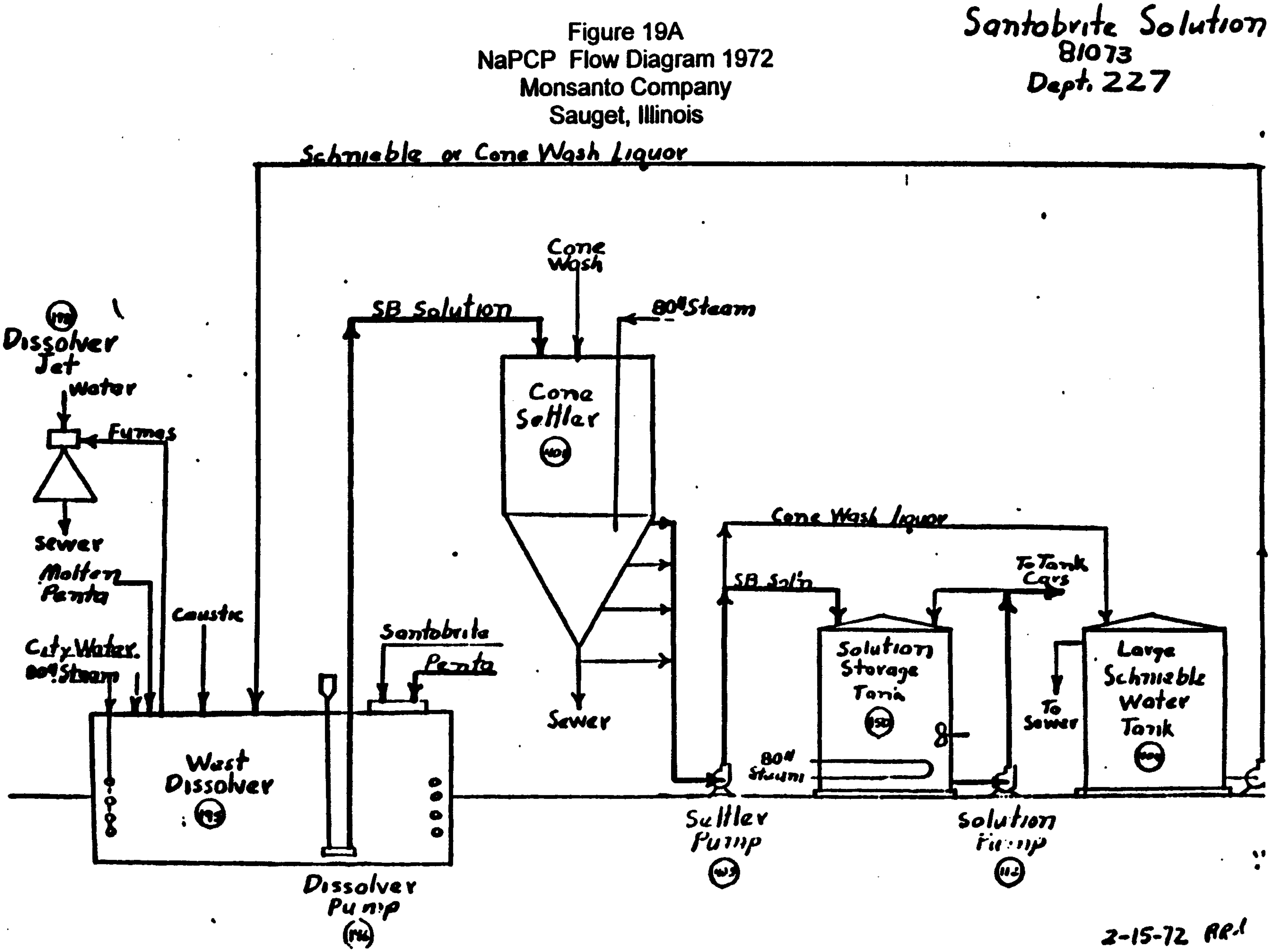


Figure 19B
NaPCP Flow Diagram 1972
Monsanto Company
Sauget, Illinois

Santobrite Briquettes
810.76
Dept. 225

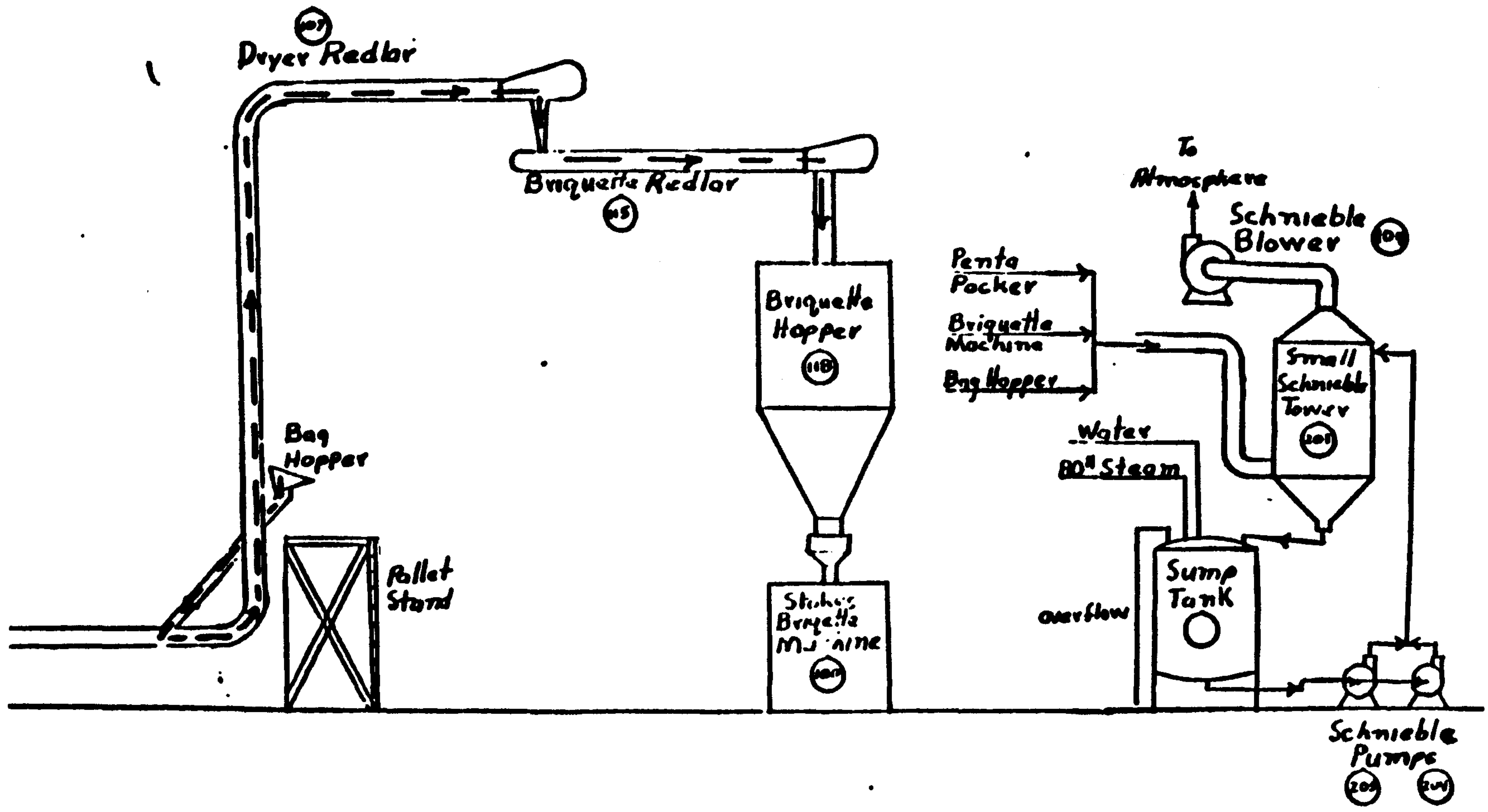


Figure 20
2,4,5-T Ester Block Flow Diagram
Compiled from 2,4,5-T Ester Process SMP's
Monsanto Company
Sauget, Illinois

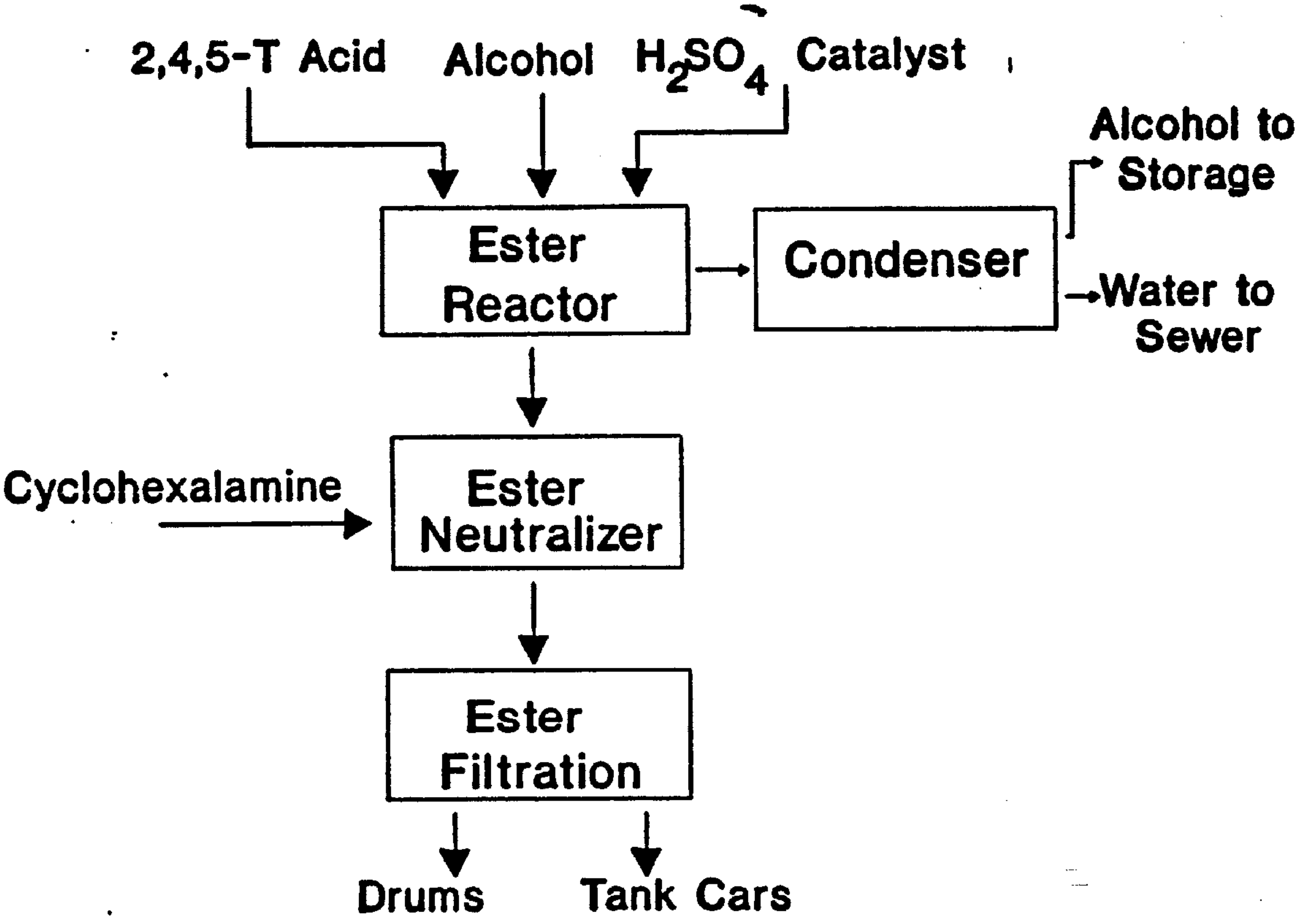


Figure 21
2,4,5-T Ester Block Flow Diagram 1962
Monsanto Company
Sauget, Illinois

FLOW SHEET
Iso Octyl 2,4,5-T
Dept. 268
3-1-62
894.13

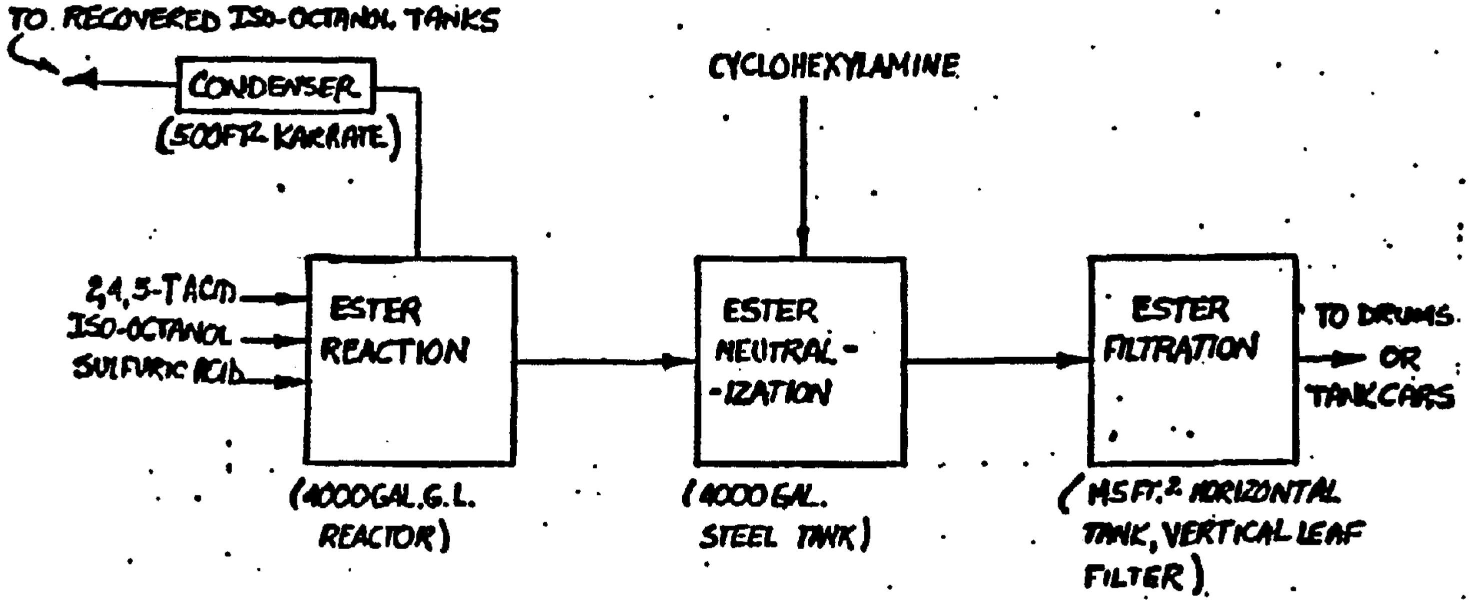


Figure 22A
2,4,5-T Ester Flow Diagram 1965
Monsanto Company
Sauget, Illinois

A. PRE-REACTION

	DEPT. 268 AG ESTERS
BUTYL 2, 4-D	894.08
BUTYL 2, 4, 5-T	894.12
ISO BUTYL 2, 4-D	894.10
ISO BUTYL 2, 4, 5-T	894.28

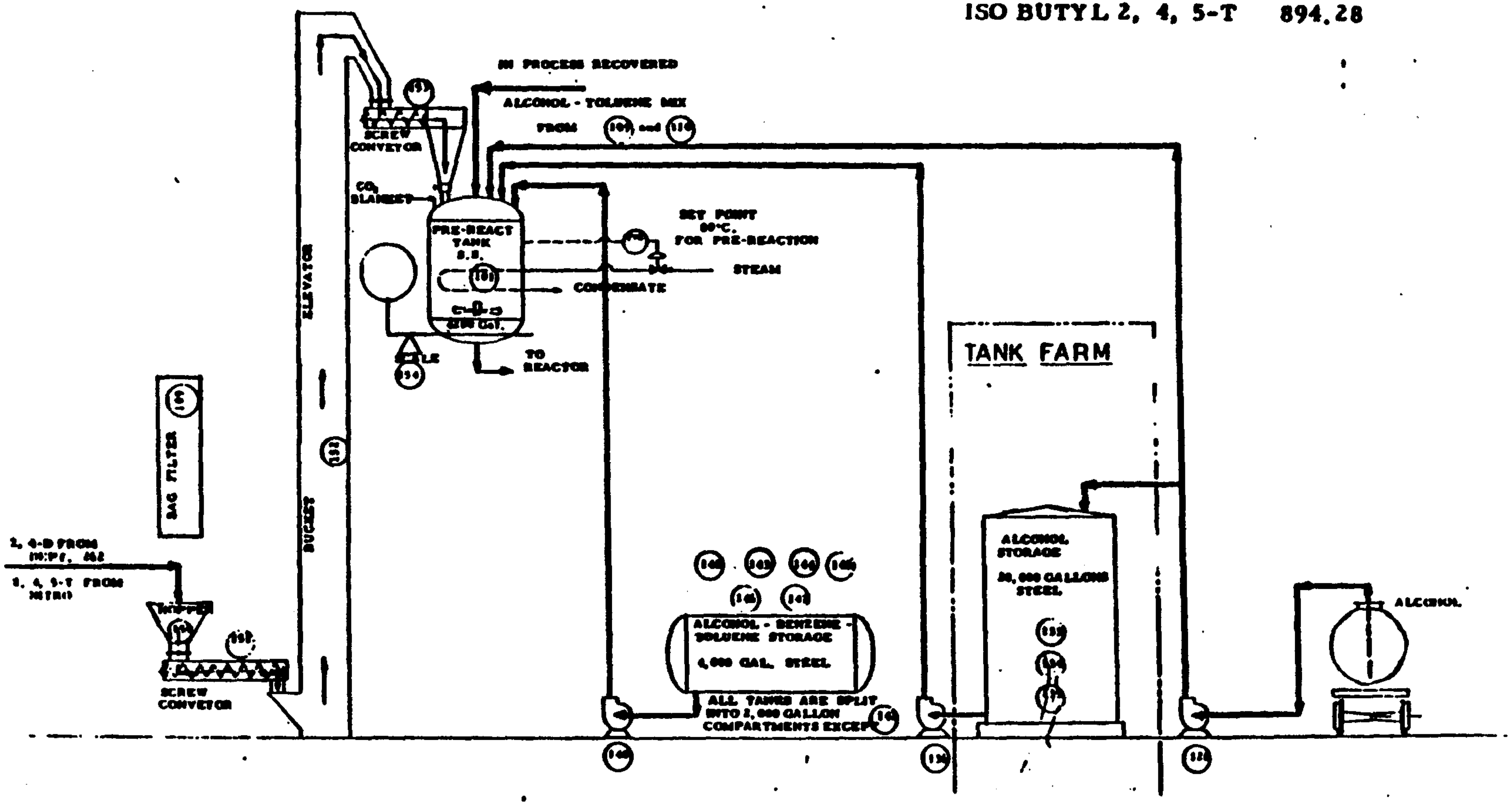


Figure 22B
2,4,5-T Ester Flow Diagram 1965
Monsanto Company
Sauget, Illinois

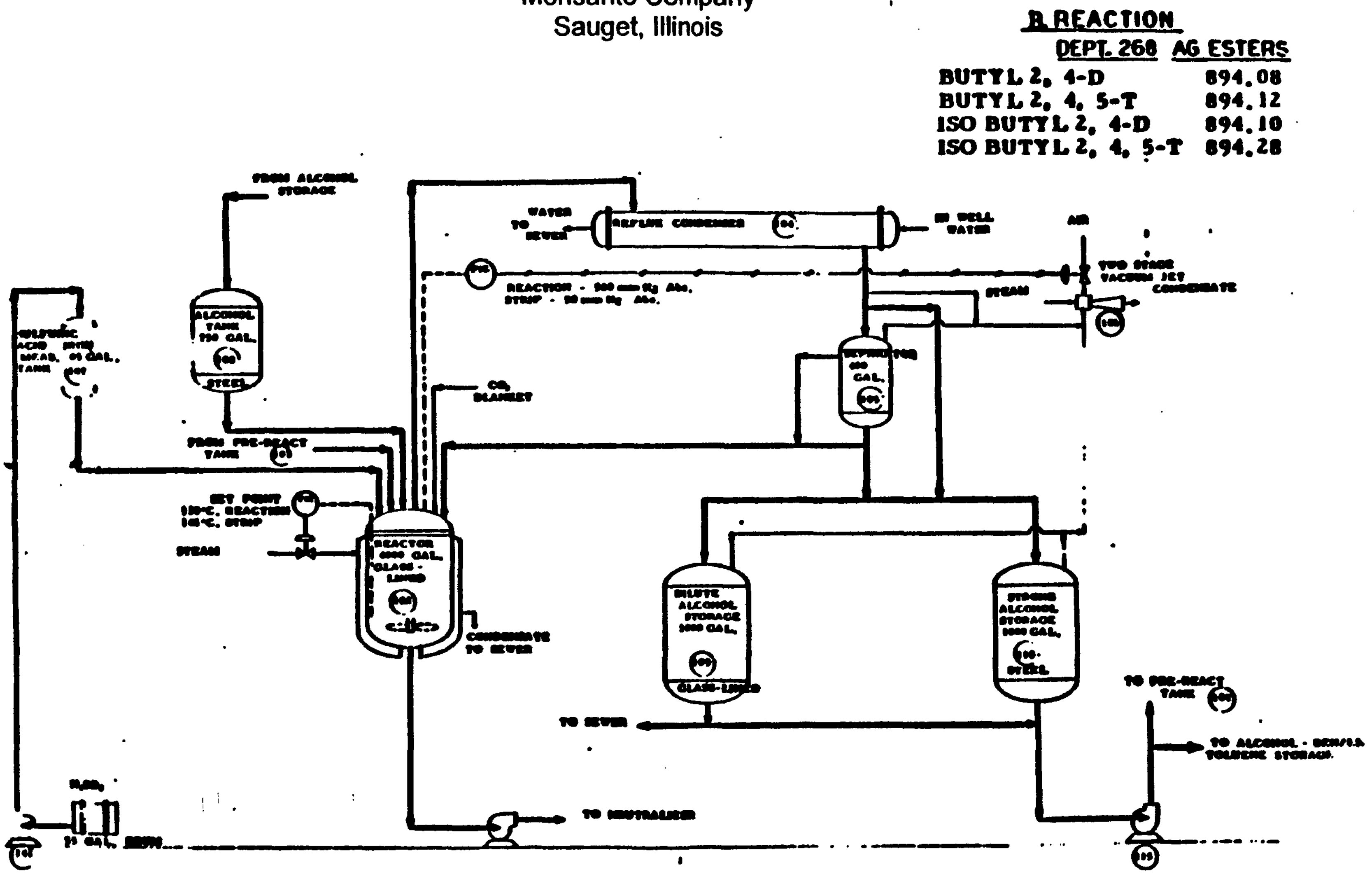


Figure 22C
2,4,5-T Ester Flow Diagram 1965
Monsanto Company
Sauget, Illinois

C. NEUTRALIZATION & FILTRATION

DEPT. 268 AG ESTERS

BUTYL 2, 4-D	894.08
BUTYL 2, 4, 5-T	894.12
ISO BUTYL 2, 4-D	894.10
ISO BUTYL 2, 4, 5-T	894.28

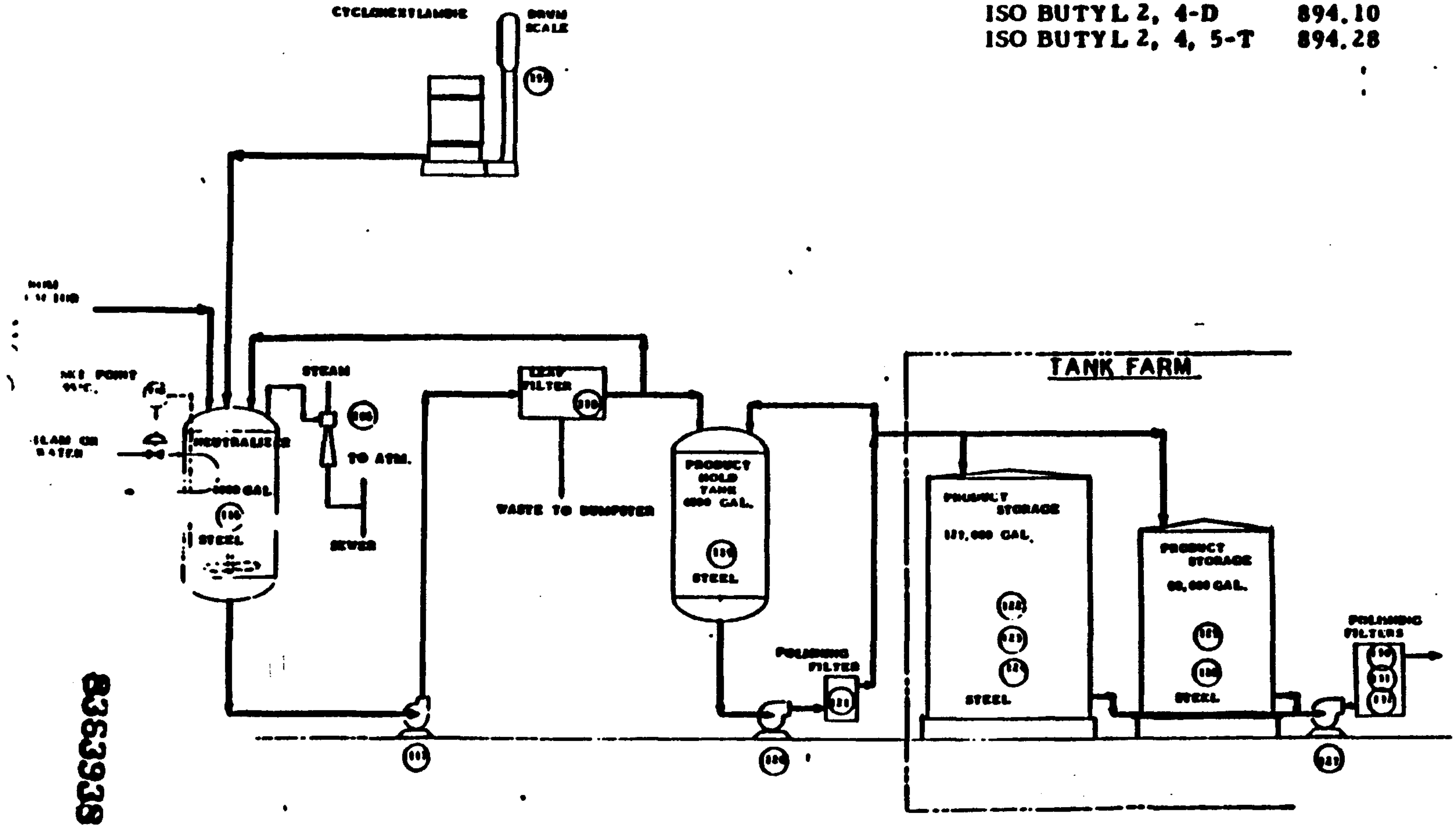


Figure 23A
2,4,5-T Ester Flow Diagram 1969
Monsanto Company
Sauget, Illinois

Mix (Slurry)

A. ~~PRE-REACTION~~;

	DEPT. 268 AG ESTERS
BUTYL 2, 4-D	894.08
BUTYL 2, 4, 5-T	894.12
ISO BUTYL 2, 4-D	894.10
ISO BUTYL 2, 4, 5-T	894.28

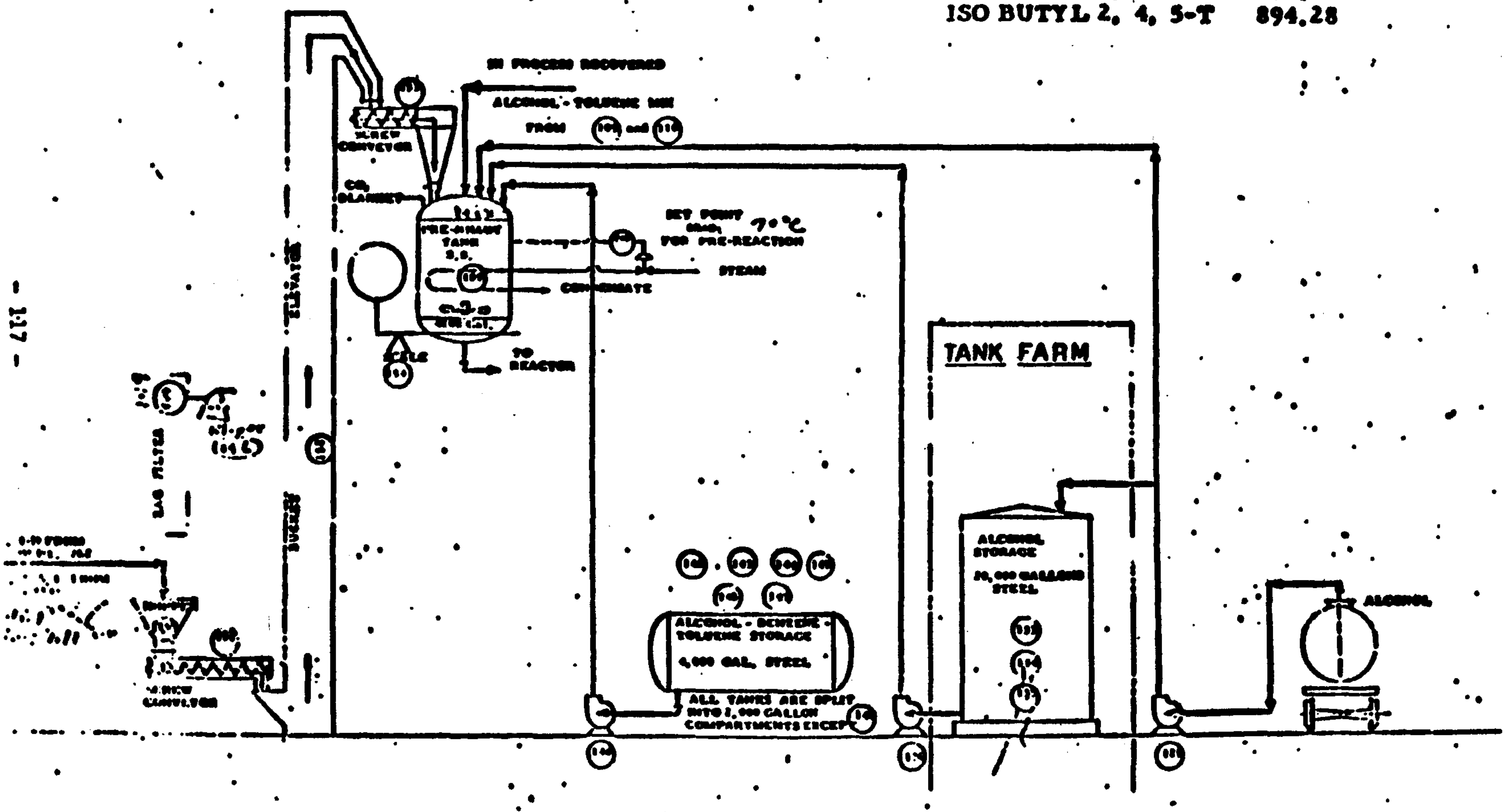
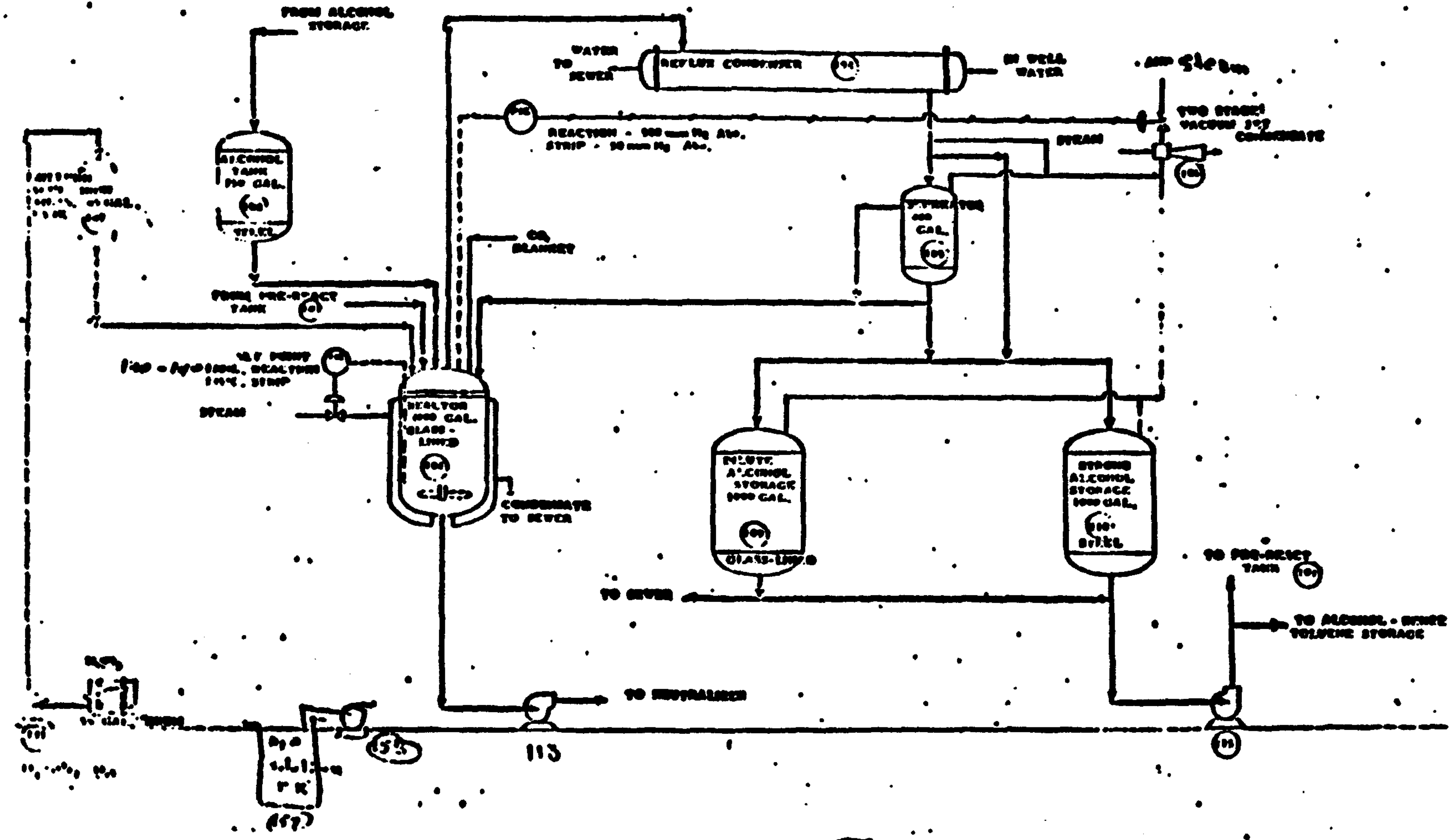


Figure 23B
2,4,5-T Ester Flow Diagram 1969
Monsanto Company
Sauget, Illinois

B REACTION

	DEPT. 268 AG ESTERS
BUTYL 2, 4-D	894.03
BUTYL 2, 4, 5-T	894.12
ISO BUTYL 2, 4-D	894.10
ISO BUTYL 2, 4, 5-T	894.28



Portable Steam Cleaner 168

163
well H2O P

154

Figure 23C
2,4,5-T Ester Flow Diagram 1969
Monsanto Company
Sauget, Illinois

C. NEUTRALIZATION & FILTRATION

DEPT. 268	AG ESTERS
BUTYL 2, 4-D	894.08
BUTYL 2, 4, 5-T	894.12
ISO BUTYL 2, 4-D	894.10
ISO BUTYL 2, 4, 5-T	894.28