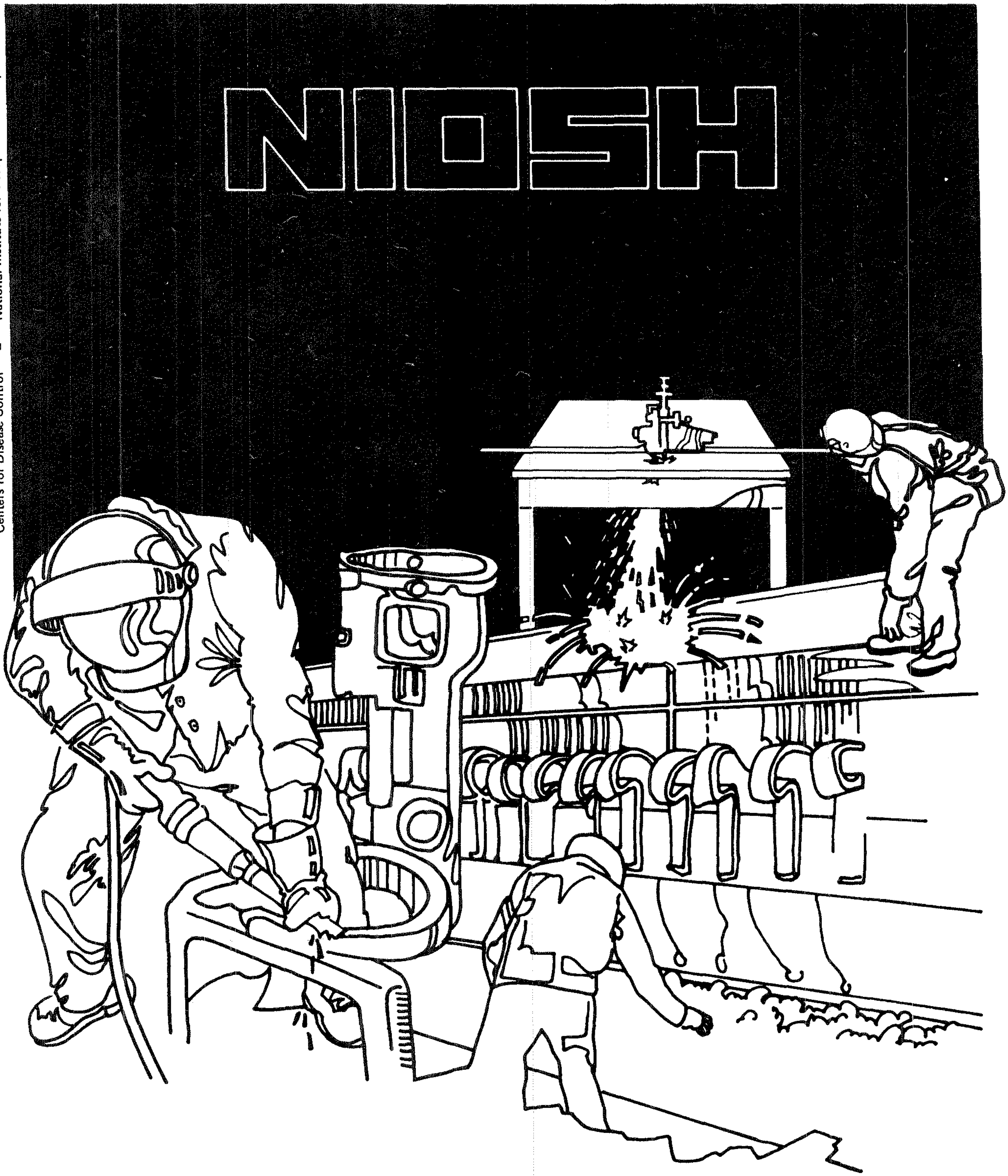
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health



Health Hazard Evaluation Report

HHE 80-040-860
ARCHER DANIELS MIDLAND
DECATUR, ILLINOIS

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

HHE 80-040-860
April 1981
Archer Daniels Midland
Decatur, Illinois

NIOSH INVESTIGATORS:
Richard W. Gorman, IH
Arthur Watanabe, Pharm.D.

I. SUMMARY

In December 1979, the National Institute for Occupational Safety and Health (NIOSH), received a request for a Health Hazard Evaluation (HHE) at Archer Daniels Midland (ADM) West Plant, Decatur, Illinois. Concern was expressed for the health effects of workers exposed to n-hexane while operating and maintaining the hexane extraction equipment.

Personal breathing zone and area air samples for hexane measurement were obtained during operation of the extraction process. The highest 8-hour, time-weighted average (TWA) hexane concentration observed was 26 parts per million (ppm). The current NIOSH recommended exposure limit is 100 ppm. The current OSHA standard is 500 ppm. Long term area samples ranged from 4 to 25 ppm. Short-term area monitoring, using a pre-calibrated, direct reading, organic vapor analyzer, documented levels as high as 1000 ppm within one inch of a leaking door seal, but, this level dropped off sharply to the same levels found in the long term samples within 3 to 4 feet of the door.

Seven hexane extraction operators and three maintenance workers were administered medical questionnaires. Two workers reported transient paresthesias following excessive, acute exposure to hexane. One worker reported a skin rash under his watchband. The predominant complaint was of temporary episodes of light-headedness and dizziness. There were no reports of symptoms suggestive of peripheral neuropathy.

The findings of another NIOSH study (1) in progress at a similar extraction facility documented similar personal exposures.

Based on the environmental and medical data obtained from this study, which is supported by a similar study in progress (1), hexane extraction operators and maintenance workers do not appear to be routinely exposed to sustained high levels of hexane vapor during normal operations and therefore, are not at high risk of developing peripheral neuropathy. However, these workers can be exposed to extremely high hexane concentrations during entry into confined spaces during equipment malfunction if the proper respiratory protection is not available or used. Reports of past practices suggest that many such potentially hazardous entries were made. Recommendations are provided to control hexane vapors and upgrade the respiratory protection and confined entry programs.

KEYWORDS: SIC 0116, 0119. Hexane, n-hexane, soybean extraction, wheat germ extraction, solvent extraction

II. INTRODUCTION

The major hazard associated with employment in grain mills is that of explosion. There have been 250 feed mill and grain elevator dust explosions reported in a 20 year period 1958 through 1978(2). The number of deaths and injuries as a result of these incidents number 164 and 605 respectively. Hexane extraction plants, the subject of this investigation, have contributed to these numbers since processing and storage of extracted materials in conveyor systems, grain elevators, storage bins and loading facilities can potentially generate explosive airborne dust concentrations. In addition to this safety aspect, hexane extraction and maintenance personnel may be subjected to potentially hazardous levels of n-hexane, especially during repair or during malfunctioning of the extraction and related equipment. Considering that n-hexane has been associated with peripheral neuropathy (3-8) and that an OSHA investigation (July 1978), cited that employees performing maintenance work on hexane extraction equipment were exposed to n-hexane levels of 500 to 6000 ppm, the International AIW requested that NIOSH, by authority of the Occupational Safety and Health Act of 1970, investigate the toxic effects of n-hexane exposure on extraction and maintenance workers at Archer Daniels Midland, West Plant.

In response to this request, field surveys were conducted on January 3-4 and October 20-22, 1980, at the ADM West plant and results of a concurrent study at a similar extraction facility (still in progress) were reviewed.

III. BACKGROUND INFORMATION

A. Site Selection

The ADM facility was chosen by the requestor because it is one of the largest hexane extraction plants and the equipment is typical of that found in other plants.

B. Interim Reports

An interim report was forwarded to management and labor in January, 1980, which presented the results of the initial survey at ADM (January 3-4, 1980), and included recommendations concerning the respirator protection program, confined space entries and control of the hexane vapors escaping from the hot well in the north end of the refinery.

C. Process Description

The ADM plant extracts oil from corn germ and soybeans using n-hexane. The extracted material is further processed and primarily sold as animal feed. The oil is separated from the hexane/oil mixture (called miscella), further refined, and sold as products such as vegetable oil.

There is one operator per shift per extractor. There are 20 maintenance personnel during the day shift and 2 on the second, third, and relief shifts. The plant operates 24 hours per day, seven days per week. The extraction operators closely monitor the performance of their extractor by making rounds at least every 2 hours reading gauges and drawing samples for quality control analysis. When they are not on rounds, they spend most of their time either in the control room or at the observation window for their extractor.

Figure 1 is a generalized flow diagram of the soybean and corn germ extraction process at ADM. Corn germ and soybeans are prepared by cracking, dehulling and flaking. The prepared material is fed to the appropriate hexane extractor where hexane is washed through the material extracting the oils. The solvent-laden product is fed to a desolventizer/toaster (DT), where the hexane is driven off by steam and recovered in distillation units. The product is further dried, cooled and conveyed to a process that grinds it for subsequent storage and sale. Hexane is also recovered from the miscella by distillation. Recovered hexane is re-used and the oil is pumped to the refinery where it is further processed into products such as vegetable oil. The extraction area was the specific area evaluated, except for the hot-well area of the refinery (a reported source of hexane vapors). The extraction process is designed to operate as a closed system and under negative pressure (minus 1-2 inches of water).

ADM was operating two rotary basket extractors until the spring of 1980 when the corn extractor was replaced with a rectangular loop extractor. The operating principles of both extractors along with descriptions of typical DT's, distillation units, and condensers are presented in Appendix A[9].

IV. STUDY DESIGN AND METHODS

A. Sequence of Events

1. HE request was received in December 1979.
2. Initial survey accomplished January 3-4, 1980.
3. Interim Report #1 forwarded to management and labor on January 27, 1980.
4. Employees went out on strike in February 1980.
5. NIOSH notified that employees were back to work on July 23, 1980.
6. Follow-up survey conducted October 20-22, 1980. (The decision was made to wait at least 3 months after notification that employees were back to work to insure that equipment was back to normal operation and to minimize the effect that the strike may have on employee responses during the medical questionnaire part of this study.

B. Environmental

Area spot sampling was accomplished on all decks in both the soybean and corn extraction areas utilizing an Organic Vapor Analyzer (OVA) meter that was pre-calibrated with n-hexane. Sampling was also performed at the "hot well" in the refinery.

Personal breathing zone and area sampling was conducted to determine 8-hour, TWA exposure values for n-hexane. The sampling device used consisted of 150mg charcoal tube connected to a battery-powered vacuum pump by a piece of flexible tubing. Air was pulled through the charcoal tube at the rate of 100 cubic centimeter per minute. Hexane was trapped on the charcoal for subseqent laboratory analysis using NIOSH Method Number P&CAM 126.

The Respiratory Protection Program and Confined Space Entry Procedures were reviewed. The initial environmental data obtained from a concurrent study at a Ralston Purina extraction plant in December 1980 were reviewed as a source of additional information of exposure in this industry.

C. Medical

Ten ADM workers were interviewed during the October 1980 survey. A brief questionnaire directed at skin and central and peripheral nervous system problems was used

Results of medical portion of the Ralston Purina study where 27 workers were interviewed were reviewed as a source of additional information on the occurrence of work-related illness in this industry.

V. TOXICOLOGY/EVALUATION CRITERIA

n-Hexane is a widely used solvent with a variety of applications. In occupational settings inhalation is the primary route of absorption, although some skin absorption can also occur. Two major types of nervous system damage can occur after exposure to n-hexane.

At even brief exposure above 500 ppm, n-hexane causes central nervous system depressant symptoms including headache, light-headedness, dizziness, nausea, and vomiting. These symptoms are usually transient, disappearing soon after the exposure is stopped or reduced.

A more serious occupational health problem occurs from the delayed peripheral neuropathy due to subchronic exposure to n-hexane. This illness has been recognized in a variety of occupational settings usually after workers have been exposed for several months or longer to concentraions of n-hexane in excess of 60-240 ppm(3,4). Early symptoms include loss of sensation (touch, vibration, temperature) in the hands and feet. In the more severely effected, these symptoms are accompanied by weakness of the hands and feet. As the neuropathy progresses muscle weakness and wasting become more severe and extends to include more proximal muscles (i.e., upper arms, thighs). Abnormal color vision has been associated with severe cases. Even after removal from exposure, symptoms may initially progress but this is usually followed with gradual but slow improvement. There is no recognized treatment for the neuropathy other than removal from exposure.

The current OSHA standard for n-hexane is 500 ppm(12). The current NIOSH recommended exposure limit is 100 ppm with a 510 ppm ceiling(13).

VI. RESULTS AND DISCUSSION

A. Environmental Sampling

Results of the area spot sampling conducted on January 4, 1980, using the OVA meter are presented in Table 1. Due to the nature of the OVA detector cell, other organic vapors may have contributed to these levels. Hexane vapor concentrations ranged from 2 to 100 ppm.

Results of the personal and area long-term sampling conducted at ADM on October 22, 1980, are presented in Table 2. The bean and corn extraction operators were exposed to 26.2 and 12.9 ppm respectively. A sampler in the bean and corn control room revealed concentrations of 24.5 and 3.6 ppm respectively. A concentration of 18.3 ppm was obtained at the observation window of the bean extractor. The NIOSH representative exposures were similar to those of the two extraction operators. The NIOSH representative monitoring the bean extraction operator was exposed to 24.5 ppm as compared to 26.2 for the operator while at the corn operation the NIOSH representative was exposed to 10.1 ppm compared to the 12.9 ppm for the operator.

The personal sampling conducted at the Ralston Purina hexane extraction plant resulted in extraction operator exposures of 12.4 and 13.0 ppm (8 hr., TWA). Area samples ranged from 13 to 26 ppm.

Production levels and equipment operation were considered to be normal on all days surveyed except for 22 Oct 80, when the bean production level was running at about 90% of the previous month. All systems were running under a slight negative pressure which would preclude significant leaks. There were no breakdowns. The exposure levels reported are representative of normal operations with no malfunctions in equipment operation. It is expected that the exposure levels would be higher if the system pressure went from negative to positive because any window seal, door seal, or any other seal that did not fit tight would allow hexane vapors to escape into the vicinity of the extractors. The condition described as causing the most frequent problem in this regard is "bad drainage" in the extractors. This overloads the distillation units and results in the system going to a positive pressure. There is no way of knowing ahead of time when this is going to happen, but, it would tend to occur more frequently when the extractors are operated beyond their designed production capacity.

B. Respirator Program

The major deficiency in the respirator program at the ADM facility on the first survey (Jan 3,4) was that there were no air-supplied, hose-line respirators available for use during operations that require entering a confined space. This system was available at the time of the Oct 20-22 visit, however, one of the units (at the corn extractor) was in unsanitary condition. The hose-line was not in the cabinet with the air tanks. It was lying on the concrete floor in a puddle of water and debris.

Although supervisors were aware of the precautions required for safe entry into confined space, there was no formal checklist that would help insure a safe entry.

The extraction equipment was purged with fresh air before entry, when possible. However, the disturbing of hexane-laden soybean flakes or corn flakes, which may be dry on the surface, may generate hazardous levels of hexane vapors. Unscheduled entries (breakdowns) would represent the greatest risk due to the fact that the hexane laden grain would still be in the baskets or on the conveyor systems.

There were reports that these extractors used to be entered without respiratory protection. An operator would enter an extractor for example, and work holding his breath. When he came out another worker would enter in the same manner.

C. Medical

There is no formal plant medical program other than a pre-employment physical, which is conducted by a number of different local physicians, and an ongoing annual hearing test for employees.

Review of the OSHA forms for 1979 revealed primarily strains and other physical injuries to the limbs, back and eyes.

Of the ten workers who were interviewed at ADM, there were 6 extraction operators, 3 maintenance workers, and one bean preparation worker (formerly an extraction operator). One retired extraction operator worker was also interviewed but not included in tabulations. All were male; age and seniority are listed in Table 3. Eight were smokers or tobacco chewers. Table 4 lists symptoms reported by the workers. The one case of skin rash occurred in a worker without known allergies. At the time of this visit, it was limited to the area under his leather watchband. This same worker reported a previous rash which occurred in the "germ" area where germ dust entered down the neck of his shirt or up his sleeves.

All workers reported experiencing CNS symptoms in the past which were most often related to performing maintenance work in poorly ventilated or enclosed spaces without respiratory protection. Symptoms reportedly resolved within 20-30 minutes after termination of exposure. No worker reported residual symptoms suggestive of peripheral neuropathy (i.e., hand/feet distribution of numbness, weakness, paresthesias, physician-diagnosed reduced reflexes in the hands or feet). Two workers did report transient paresthesias following excessive acute exposure to hexane. Information collected from the retired worker was consistent with the above.

Medical data collected during evaluation of the Ralston Purina extraction plant, where 27 employees (extraction operators and maintenance workers) were interviewed were in agreement. All workers reported acute CNS symptoms as a result of occasional short term exposure to n-hexane vapors. There were no overt symptoms of peripheral neuropathy.

VII. CONCLUSIONS

The medical questionnaire data obtained from 37 hexane workers (10 at ADM, 27 at a similar extraction operation) failed to reveal evidence of symptomatic peripheral neuropathy in this workforce.

Employees who work as extraction operators or maintenance workers are subject to exposure to high concentrations of hexane vapor if the proper respiratory protection is not utilized during repair or malfunction of extraction equipment. Each worker interviewed related episodes when they experienced dizziness and light-headedness. A recent incident involved the cleaning of a 24" horizontal section of a DT vent line. An operator had to crawl part way into the vent line to scrape out hexane-laden corn meal that had blown up from the DT due to excess pressure. The operator was not wearing a respirator and experienced light-headedness and dizziness.

Hexane exposures appear to be well below current criteria during normal, trouble-free operation. Since there were no breakdowns or equipment malfunctions during the two surveys at ADM and the one survey at a similar extraction facility, the extent of the probable increase in hexane level in such situations was not evaluated.

Respiratory protection was reportedly not routinely used in the past. The CNS symptoms experienced could have been avoided through utilization of the proper respiratory protection.

VIII. RECOMMENDATIONS

A. Environmental

Although ADM has had a written respiratory protection program since 1973, there was evidence that it was not effectively implemented. For example, there was no airline respiratory system available prior to 1980 for use during entry to clean or repair the hexane extractors. The following respirator systems are recommended to protect against overexposure to hexane vapors:

1. Half-masks with organic vapor cartridges should be used at the discretion of the operators during normal operation or when an equipment malfunction may cause a temporary increase in hexane concentrations in the immediate vicinity of the extraction equipment.

2. Full-face mask, forced-air breathing systems for entry into confined spaces where high concentrations of hexane vapor are present or potentially generated during the maintenance activity.

3. Self-contained breathing systems (SCBA) for use in emergencies or when use of the forced air system is not feasible. At least two units should be available at each plant.

Half-masks were available, but they were locked in a room remote from the extraction site. Each operator should be issued a mask and store it in a cabinet in the control rooms. The fact that the respirators were not easily available probably contributed to the apparent lack of use in the past.

The American Industrial Hygiene Association has published a Respiratory Protection Manual [14] which offers excellent guidelines to insure that the respiratory protection program at ADM meets the minimum requirements of OSHA respiratory protection standard 1910.134.

Entries into confined spaces should be accomplished in accordance with the provisions of a written program. Reference 15 offers guidelines for the establishment of such a program. A copy of this document was forwarded to management and labor on March 11, 1981.

Recommendations to control the hexane vapors escaping from the "hot well" in the refinery were included in the Interim Report (January 1980). Effective corrective action was taken by the time of the October 1980 survey.

It is strongly recommended that labor and management, through their safety and health committees, arrange to determine representative hexane exposure levels during those occasions when the extraction system goes under positive pressure. This could most easily be accomplished through the use of passive dosimetry badges. Although there appears to be some shortcomings with this sampling method under certain conditions, it could effectively be used as a screening method in this case. Should the data obtained indicate that exposure levels exceed 100 ppm (8 hour, TWA) then NIOSH should be contacted for a more detailed study. Supplemental ventilation, designed to activate when the system turns positive, may be necessary if system leakage cannot be controlled.

B. Medical

Workers should receive a pre-placement physical examination and subsequent periodic physical examination with attention to the signs and symptoms of peripheral neuropathy.

Workers should be educated about the acute and chronic effects of hexane. The union and company should develop a means of reviewing regularly the results of annual physical examinations of workers for the purposes of monitoring for any developing cases of peripheral neuropathy. Any cases of possible peripheral neuropathy should be investigated for work-relatedness and corrective actions taken if appropriate.

IX. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Technical Services, Information Resources and Dissemination Section, 4676 Columbis Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

Copies of this report have been sent to:

1. Archer Daniels, Midland Company
2. AIW Local 876
3. AIW International
4. NIOSH Region V
5. OSHA, Region V

For purposes of informing the approximately 125 affected employees, a copy of this report shall be posted in a prominent place, accessible to the employees, for a period of thirty (30) calendar days.

X. AUTHORSHIP AND ACKNOWLEDGEMENTS

Evaluation Conducted and Report Prepared By:	Richard W. Gorman, M.S., C.I.H. Industrial Hygienist Industrial Hygiene Section
	Arthur S. Watanabe, Pharm. D. Medical Officer Medical Section
Originating Office:	Hazard Evaluations and Technical Assistance Branch Division of Surveillance, Hazard Evaluations and Field Studies Cincinnati, Ohio
Report Typed By:	Odessa Brown Clerk Typist

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FIGURE 1

Generalized Flow Diagram

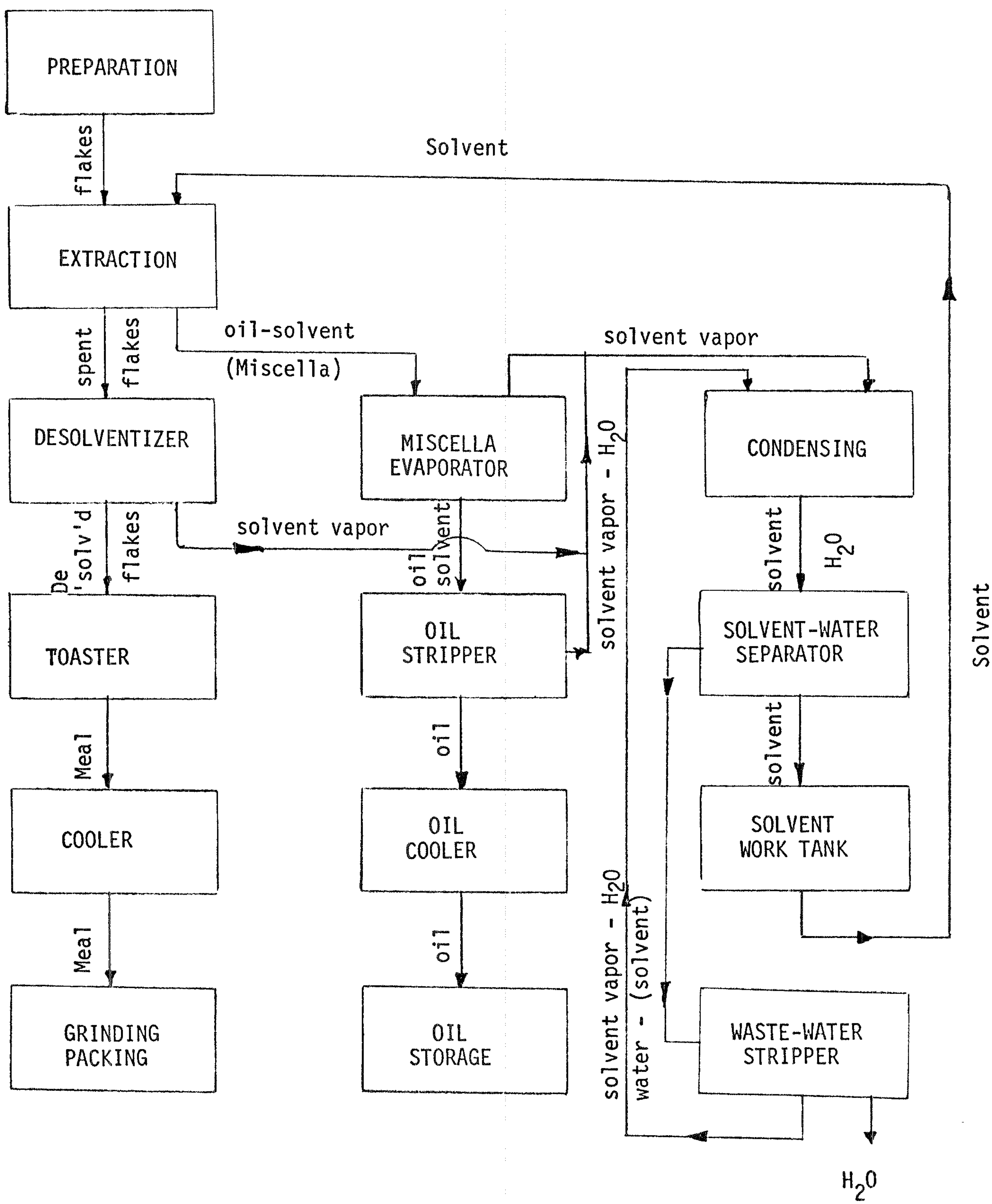

Table 1

Hexane Results (ppm)*
ADM West Plant

January 4, 1980

Corn Extraction	Concentration Range	Number of Readings
Corn Prep Area	2-3	6
Dryer Inlet	10-30	3
Control Room	25-60	4
Operation Port	30-60	6
Operation Deck, 2nd floor	20-1000**	6
Operating Deck, 3rd floor, above DT's	20-100	6
Soybean Extraction		
1st Floor, under Rotocel	10-20	6
Control Room	5-8	4
Around Catwalk (Rotocel ext.)	60-100	6
3rd Deck above distillation area	5-8	6
Refinery		
Hot Well (north side)	20-150	4

*Readings were "spot checks" using an OVA meter pre-calibrated for n-hexane. The duration of each reading was 10-65 seconds. Readings are assumed to be hexane. Any other organic vapor would have been a positive interference.

**"Hot Spot" leak in door seal of Corn DT.

Table 2

Hexane Results
ADM West Plant

October 21, 1980

Location/Job	Type Sample[1]	Sampling Time (Min)	Sample Vol. (liters)	Concentration TWA (ppm)
Extraction Operator, Corn	P	457	48.4	12.9
NIOSH Representative[2]	P	457	47.9	10.1
Control Room, Corn	A	457	46.9	3.6
Extraction Operator, Bean	P	460	47.7	26.2
NIOSH Representative[2]	P	405	40.7	24.5
Control Room, Bean	A	460	46.8	24.5
Observation Window, Bean	A	420	34.5	18.3

[1] A: area, P: personal
[2] Due to the fact that there was only one operator per shift a sampler was placed on the NIOSH representative who closely monitor the activities of the operator throughout the day.

Table 3

Worker Demographics By Work Area
Archer Daniel Midlands
Decatur, Illinois

October 1980

	Mean Age (years)	Current Job Duration* (Mean) (years)	Total ADM Employment (Mean) (years)
Extractor Operators (n = 7)	28	1.5	5.8
Maintenance (n = 3)	51.7	24.8	27
Total	35.1	8.5	12.5

* Refers to time in extractor areas

Table 4

Worker Symptoms
Archer Daniel Midlands
Decatur, Illinois

October 1980

Symptom (n = 10)	Number	Percent
Skin rash	1	10
Central nervous system light-headedness dizziness sensation of "high" or drunkedness	10	100
Paresthesia in hands or feet	2	20
Other*	2	20

*Nausea, loss of appetite after acute exposure only

Appendix A

Rotary Extractor

Rotating element consists of a series of concentrically arranged cells with a hinged perforated bottom in each cell. As each cell successively passes under the intake feeding device, a slurry of oil bearing material and half miscella fills each cell. The speed of rotation of the cell element and the continuous feed of material are so regulated that each cell is filled to the desired depth during its passage under the feeding device. While the rotating element is completing a revolution several stage pumps pick up the gradient concentrated miscella from several chambers of drain pans under the cells and spray it back onto the top of the cells. At approximately two-thirds of the distance around from the intake, raw solvent is sprayed to the top of the cells after which the cells are allowed to drain free of excess solvent. After the draining stage the cells pass over a discharge hopper and as each cell is directly over the hopper, the cell bottom is tripped mechanically and the charge of spent material drops into the hopper. Immediately after passing this position the cell bottom is raised back into closed position mechanically and is ready for another charge of material. The spent material is continuously conveyed from the discharge hopper at a rate so regulated that at the time the hopper is empty another charge of spent material drops in.

Rectangular Loop Extractor

The same basic extraction principle is used in most modern solvent extractors. The rectangular loop extractor is, however, different from the other designs in overall shape, in the use of an 'en-masse' type conveyor instead of individual baskets, in the use of a stationary linear, vee-bar screen, and in the use of a liquid cyclone full-miscella clarifier rather than a bank of filters or classifier screens.

In a typical oil seed example, flakes enter near the top of the rectangular loop extractor at the inlet hopper. A conveyor chain carries the flakes away from this hopper and down the first leg of the loop where the flakes are first washed with half-miscella. In the horizontal bottom run of the extractor loop, the flakes are washed with progressively less concentrated miscellas. As they travel up the vertical part of the loop, they are subjected to a fully counter-current wash of miscella coming down the loop. On the sloping top run of the extractor, they are washed with fresh solvent, allowed to drain, and are discharged continuously from the chain near the top of the machine. The chain proceeds to the inlet hopper where it is refilled.

The chain is open at the top, bottom, and sides and is partly open along the line of travel. This allows free loading and emptying of material, and the free passage of solvent through the material as it is turned over several times during its wash cycle. The flaked material is in sliding contact with the stationary bar screens, providing a continuous cleaning action.

The chain speed is automatically controlled by the level of flakes in the inlet hopper; this allows the machine to absorb any reasonable surges from the preparation area, to maintain a uniformly filled chain, and to maintain an effective barrier against hexane vapor escape at the inlet. The level of flakes in the hopper is measured by a nuclear sensor which controls the infinitely variable-speed drive.

The full miscella is partly clarified of fines during its last recycle through the flake-bed. The last traces of flakes or fines are removed centrifugally in the liquid cyclone; the fines are redistributed evenly on the surface of the flake bed below the cyclone, and the clarified miscella is ready for evaporation.

Distillation

The distillation system of a solvent extraction plant refers to the means of evaporating and stripping the solvent from the oil. There are numerous devices and methods for accomplishing this from the early pot type stills to the currently popular constant level re-circulation type, primary evaporation with high vacuum final stripping stage. A few of the pot and pan type evaporators are still in use but by far the bulk of the current processing is being done in the newer type installations. Some of the pan type evaporators were arranged as a series of stages, the miscella flowing by gravity from one stage to the next. Each stage accomplished a further evaporation of solvent and higher concentration of oil. From the last stage of this type system the oil with a slight amount of solvent left in was pumped or drawn to the stripping column which may have been of the bubble cap, sieve plate or packed tower type, operated with or without vacuum.

Some plants use the long tube rising film evaporator with or without re-circulation. The re-circulating type evaporator with constant level control and automatic temperature control provides some increased safety. The choice of oil stripper is determined by design balance with the other components of the distillation system, desired through-put rate, material being processed, etc. Some of the types in use are packed towers, bubble cap, sieve plate and disc and donut towers. The packed and bubble cap towers have a disadvantage in that they may foul up with certain components and contaminants in the oil due to the high temperature at this phase of the process. It is generally thought that this carbonized material which builds up on the film surfaces of the stripper is caused partially by phosphatides and a trace of meal fines in the oil. The sieve plate and disc and donot towers are the least subject to the above fouling. Any of the above types must for highest efficiency be operated under a vacuum of 22 to 28 inches of mercury.

The function of all stripping columns is contingent on spreading the oil to be stripped in a very thin film over a large surface area with a relatively high velocity of dry steam passing over the film. A counterflow relation of the above is established by introducing the oil at the top of the column and allowing it to pass downward through the tower against the flow of stripping steam which is introduced at the bottom. The mixture of steam and solvent vapor passes from the top of the tower to the stripper condenser from whence the condensate is pumped to the solvent water separator. Solvent flows from the separator to the work tank and water flows from the separator to the waste water evaporator. The finished oil is usually pumped away from the vacuum stripping column by a rotary type positive displacement pump.

Desolventizing

The desolventizing of extracted material, or spent material as it is usually referred to, is accomplished in several ways. In the batch type extractors the single vessel may serve as pre-cooking, extraction and desolventizing. After the last wash of solvent is drained from the batch extractor the jacket steam is turned on and by the action of indirect and direct steam plus the tumbling action of the material in the vessel, the solvent is driven from the material to a suitable condenser.

Where desolventizing takes place in other than the extracting vessel, the spent material may be desolventized by passing it through a series of jacketed tubes with a longitudinal rotating member inside consisting of a shaft with attached paddles or ribbon flights for both lifting and progression of the spent material. These tubes are usually stacked one above the other and the material after passing through a tube drops by gravity to the next lower tube. Vapor ducts attached to the ends of the tubes conduct the solvent vapor to a suitable vapor scrubbing and condenser system. The desolventized material is discharged from the bottom tube through a vapor seal such as a rotary or plug type seal.

Another type of desolventizer is the re-cycled vapor type which consists of a single vessel of cylindrical shape with a rotating element which tumbles and progresses the spent material from the intake end to the discharge end. The vessel is steam jacketed and part of the solvent vapor that is driven off the material is superheated and passed directly back to the vessel. Since the evaporation of solvent tends to depress the temperature of the material being desolventized, or in other words has a refrigerating effect, the super-heated vapors returned to the desolventizer aid in overcoming the above effect and allow a considerably higher desolventizing efficiency.

The advance in desolventizers, and certainly significant from a fire protection standpoint, is the use of a single vessel for desolventizing and toasting with the complete elimination of intermediate vapor seals, conveyors, etc. This desolventizer-toaster, or simply D-T as it is usually referred to, permits these two important steps in processing to be accomplished by a minimum of moving machinery and maximum safety against loss of vapors since at least half of the kettles of the D-T are loaded with desolventized material, at all times offering a very effective seal against fluctuating vapor pressures or any other sudden change in plant performance. The D-T consists of individual kettles stacked, one above the other, the intermediate joints being gasketed vapor tight. There is a series of kettles making up the combination desolventizer and toaster. Each kettle contains a layer of spent material from 1 to 2 feet in depth and the feeding of material from one kettle to the next lower is accomplished by an automatic gate mechanism or by spout. The kettles are steam jacketed and in operation steam is also sparged directly to the material. The top kettle is ducted to a suitable vapor scrubber and condenser.

Condensing Systems

The condensing of solvent vapors and steam in extraction plants is accomplished by the use of more or less standardized type condensers. These are usually of shell and tube type construction consisting of an outer shell with an internal tube bundle. The tubes are usually of brass, bronze or stainless steel and in most plants the water is passed through the tubes and the solvent vapor and steam to be condensed around the tubes and within the shell. There has been a tendency in recent years to do the condensing for the entire plant in one or two large condensers rather than placing a condenser at each stage requiring one. This is accomplished by regrouping the principal components of the plant into an arrangement that permits very short vapor ducts and a minimum of piping. The cold water for condensing may be from deep wells, cooling towers, spray ponds or any source where the water is cool enough to operate the condensers efficiently and clean enough to prevent fouling of the condenser.

DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
CENTERS FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
ROBERT A. TAFT LABORATORIES
4676 COLUMBIA PARKWAY, CINCINNATI, OHIO 45226