IN-DEPTH SURVEY REPORT

CONTROL TECHNOLOGY ASSESSMENT OF HAZARDOUS WASTE DISPOSAL OPERATIONS IN CHEMICALS MANUFACTURING

AT

3M COMPANY CHEMOLITE INCINERATOR
COTTAGE GROVE, MINNESOTA

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National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
Engineering Control Technology Branch
Chemical Industry Section
Cincinnati, Ohio 45226

PLANT SURVEYED:	3M Company Chemolite Incinerator Cottage Grove, Minnesota
STANDARD INDUSTRIAL CLASSIFICATION OF PLANT	Chemical and Allied Products Sector (SIC 28)
SURVEY DATE:	September 13-16, 1982
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INTRODUCTION

The Resource Conservation and Recovery Act (RCRA) (PL-94-580) of 1976 was enacted to provide technical and financial assistance for the development of management plans and facilities for the recovery of energy and other resources from discarded materials, for the safe disposal of discarded materials, and for the regulation of hazardous wastes management. Under Subtitle C of RCRA, the Environmental Protection Agency (EPA) was required to promulgate regulations on identification and listing of hazardous wastes and regulations affecting the generators, transporters, and owners/operators of facilities for the treatment, storage, and disposal of hazardous wastes. These regulations appeared in the Federal Register on May 8, 1980. Amendments affecting the listing of hazardous wastes appeared in the Federal Register November 12, 1980.

There are between 35 and 60 million tons of hazardous wastes generated annually, of which, about 15 million are generated by industries in the Chemical and Allied Products Sector (SIC 28). These wastes contain toxic substances which may also be carcinogenic, mutagenic, and teratogenic. Some of the companies in SIC 28 treat, store, and dispose of the wastes that they generate. Wastes may also be transported to companies who specialize in the treatment, storage, and disposal of these wastes. This group of companies is classified as "Refuse Systems" (SIC 4953). It is estimated that about 6,200 workers are directly involved in the transportation, treatment, storage, and disposal of hazardous wastes from SIC 28.

There are many companies in both SIC 28 and SIC 4953 which are currently treating and disposing of hazardous wastes from chemicals manufacturing. Many of these companies also have hazard controls in place that are designed to protect the workers from known hazards, both during normal operations and during upsets or emergencies. The objective of this control technology study is to document and disseminate information on effective engineering controls, work practices, monitoring programs, and personal protective equipment. The NIOSH study will result in a technical report which will be designed to assist hazardous waste operators in their efforts to prevent worker exposures to occupational health hazards. Furthermore, an attempt will be made to present a spectrum of available alternatives for hazard control in various treatment and disposal operations.

The implementation of RCRA regulations has created business opportunities in the area of hazardous waste treatment and disposal. This has also created employment opportunities reflected in a steady rise in the number of workers who are involved in the treatment and disposal of hazardous wastes.

The Occupational Safety and Health Act of 1970 (PL-91-596) was enacted to "assure safe and healthful working conditions for men and women." The Act established the National Institute for Occupational Safety and Health (NIOSH) in the Department of Health and Human Services. NIOSH was charged by this Act with the duty and responsibility to conduct research and develop guidance for preventing or reducing exposure of workers to harmful chemical and physical agents. In response to this legislative mandate, NIOSH has conducted major programs to document, develop, and disseminate information regarding the health effects of such agents. To complement these ongoing programs, NIOSH has instituted a major effort to prevent occupational health and safety problems through the assessment and application of hazard control technology in the workplace.

This survey was conducted as part of a NIOSH project to assess and document effective controls in the routine disposal of hazardous wastes from chemicals manufacturing.

AUTHORITY

Two of the main policy objectives of the 1970 Occupational Safety and Health Act (PL-91-596) are to:

- o Encourage employers and employees in their efforts to reduce the number of occupational safety and health hazards at their places of employment, and to stimulate employers and employees to institute new and to perfect existing programs for providing safe and healthful working conditions.
- o Provide for research in the field of occupational safety and health with a view to developing innovative methods, techniques, and approaches for dealing with occupational safety and health.

Under Section 20 of the Act, the Secretary of Health and Human Services is authorized to conduct special research, experiments, and demonstrations relating to occupational safety and health as are necessary to explore new problems including those created by new technology.

Paragraph (d) requires the dissemination of the information obtained to employers and employees.

The National Institute for Occupational Safety and Health was established to perform the functions of the Secretary of Health and Human Services described in Sections 2 and 20 of the Act. The manner in which investigations of places of employment are conducted by NIOSH and its representatives is outline in the Code of Federal Regulations (Title 42, part 85a).

HAZARDOUS WASTES

The 3M Chemolite incinerator facility was constructed in 1970-1971 to dispose of a variety of hazardous wastes from 3M Divisions with manufacturing operations. 3M Company products are diverse and include minerals (roofing granules), coated and uncoated plastic films, specialty chemicals, graphic arts materials, health care products, and voice, video, and data communication products. Hazardous wastes originating from 3M operations include spent solvents from coating processes, mother liquors from chemical reactions, spent cleaning solutions, off-specification products, and nonmarketable experimental items.

Prior to the advent of RCRA, 3M had, in-place, a company-wide program for the determination of hazard, subsequent identification, and labelling of wastes.[1] A waste was considered hazardous by 3M if "there are potential negative effects of the waste on the environment and public safety if the waste is improperly disposed." If it was determined to be hazardous it usually fell into two categories - wet scrap or "special" scrap. Wet scrap may be pumpable or nonpumpable, and may be handled by personnel who do not handle special materials. Figure 1 shows a typical wet scrap label for pumpable chlorinated (halogenated) waste. The label has appropriate spaces for information on the health, fire, and instability hazards (blue, red, and yellow squares), major constituents, and origin. The white square is reserved for reporting on special characteristics such as water reactivity and polymerizability. Each of the three hazards mentioned above may carry severity ratings between 0 and 4, the latter being the most severe. Special scrap, in addition to being appropriately packaged and labelled, is always under the control and/or supervision of someone who is knowledgeable of the hazards that the special scrap presents. These include materials that are extremely flammable, explosive, or have potentially severe health hazards.

Recently, the labelling requirements within 3M have changed in order to accommodate EPA and DOT regulations. A specimen of the new labels is shown in Figure 2. Essential details of the label have not materially changed. It contains information on whether it is pumpable or nonpumpable, chlorinated or

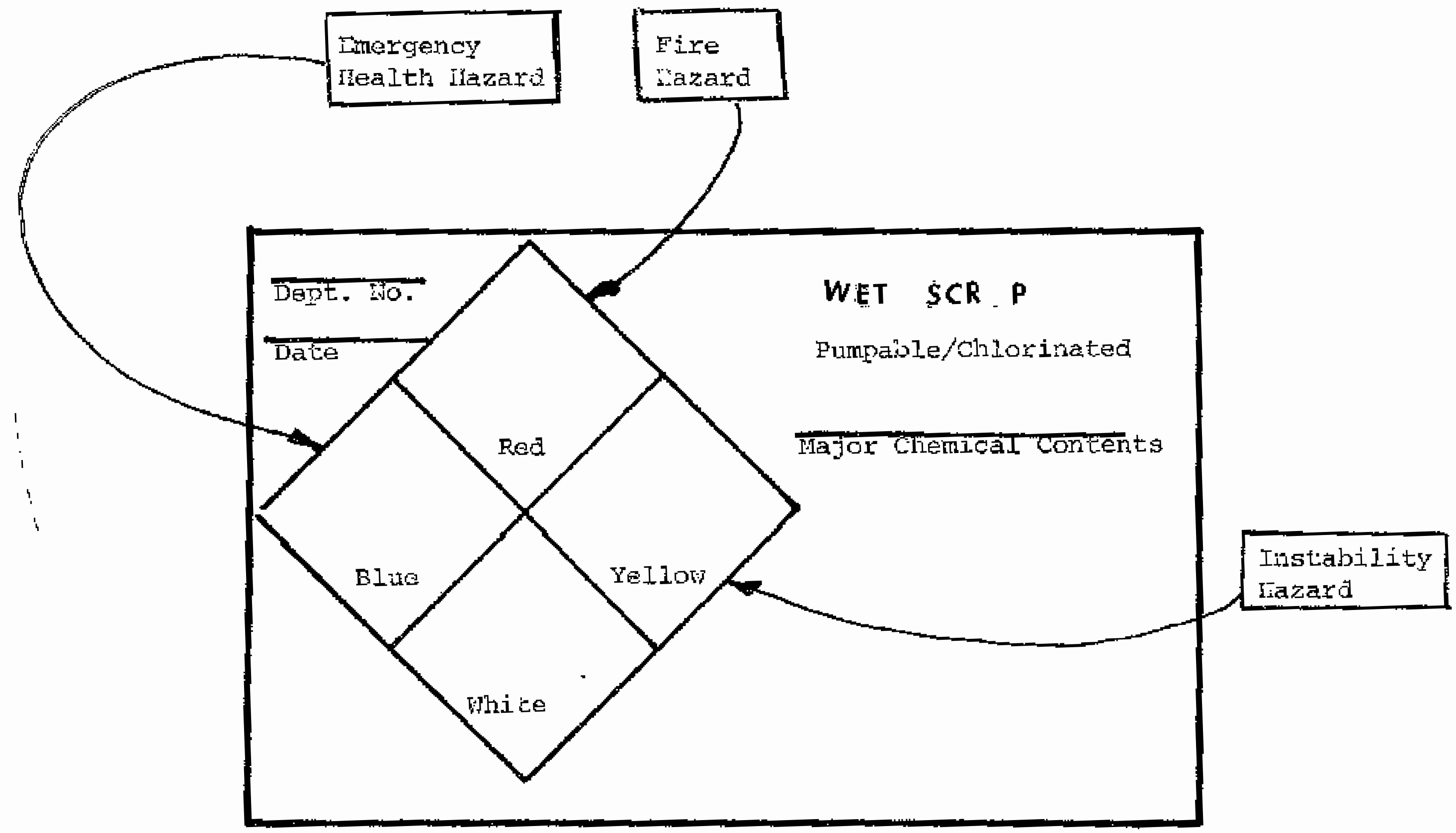

Figure 1. Wet Scrap Label.

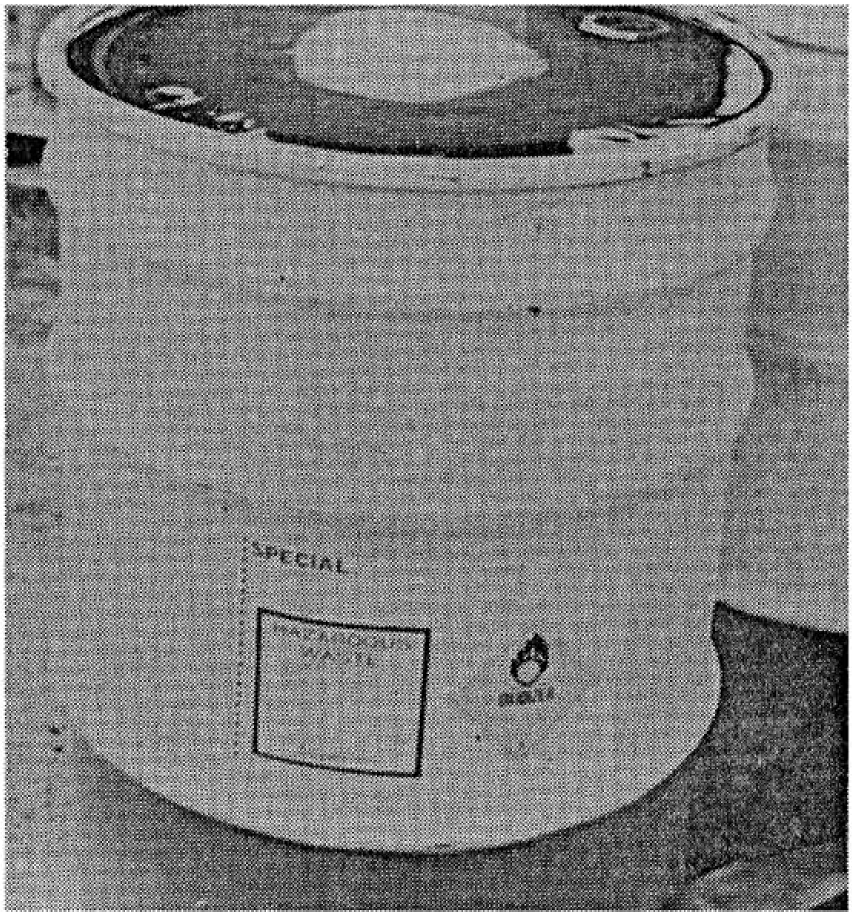

Figure 2. Sample of Currently Used Labels.

nonchlorinated, etc. The yellow square with a heavy black border contains information on origin of the waste, its RCRA code, and date. The diamond to the right shows the DOT representation for an oxidizer.

In November, 1980, 3M submitted a "Part A" application to U. S. EPA for the Chemolite Incinerator as part of the RCRA permitting requirements. A list of hazardous wastes to be disposed of by rotary kiln incineration and their quantities was provided in the application. These are reproduced in Table 1. The highest volume of wastes are those that are ignitable. These are exemplified by such organic liquids such as toluene, xylene, methyl ethyl ketone, and methanol. During the NIOSH survey, 3M officials provided a list of organic materials (Table 2) that were likely to be constituents of the wastes handled at the incinerator site during the period from September 14-16, 1982. The list was developed retrospectively from daily logs maintained by incinerator operators. Efficient incinerator operation requires flexibility in the sequence by which wastes are incinerated.

Usually it is not possible to predict the exact nature of the wastes incinerated on any given day. Typically, the wastes that are incinerated on a given day originate from more than one department. Also, some of the nonpumpable wet scrap may consist of drums containing many jars and small bottles. As a result it becomes impractical in these situations to determine chemical species. On some days, however, waste composition is fairly well known.

Table 1. Hazardous wastes disposed of at the 3M chemolite incinerator.

Hazardous Waste RCRA Designation	Major Constituents	Quantity
D001	Ignitable	20,000 tons/year
D003	Reactive	10 tons/year
P002	1-acetyl thiourea	1,000 pounds/year
P003	Acrolein	1,000 pounds/year
P005	Allyl alcohol	1,000 pounds/year
P022	Carbon disulfide	1,000 pounds/year
P028	alpha-chloro toluene	1,000 pounds/year
P053	Ethylene diamine	1,000 pounds/year
P067	2-Methyl aziridine	500 pounds/year
P100	1,2-propanediol	500 pounds/year
K086	Lead, hexavalent chromium	50 tons/year
F001	Spent halogenated solvents	100 tons/year
F002	Spent halogenated solvents	100 tons/year

Table 2. List of hazardous components in wastes handled during NIOSH survey, 9/82.

9/14/82	9/15/82	9/16/82
Xylene	Xylene	Xylene
Toluene	Toluene	Toluene
Methyl Ethyl Ketone	Methyl Ethyl Ketone	Methyl Ethyl Ketone
Heptane	Acetone	Heptane
Isopropyl Alcohol	Ethyl Acetate	Tetrahydrofuran
	Isopropyl Alcohol	2-Ethoxyethanol
	2-Ethoxyethanol	Cyclohexanone
	1,1,2-Trichloroethane	Isopropyl alcohol
	Ethylene Dichloride	

ROTARY KILN INCINERATION OPERATIONS

PROCESS DESCRIPTION

The 3M Chemolite incinerator is part of a large chemical complex located in Cottage Grove, Minnesota between Highway 61 and the Mississippi River. The incinerator was designed to dispose of 600 gal/hr pumpable wastes and 4,000 lb/hr of nonpumpable solid and semisolid wastes (wet scrap). The facility includes: (1) A material handling building; (2) two blend tanks, a decant tank, and five storage tanks for liquid wastes; (3) a semi-automatic feed system for 55 gallon drums; and (4) a rotary kiln with associated air pollution control and ash handling equipment. A schematic plan view of the facility appears in Figure 3. A process schematic is given in Figure 4.

A burner in the kiln burns liquid pumpable wastes pumped from the tank farm. Drums containing nonpumpable wastes are fed directly to the incinerator using the especially designed pak and drum feed system. The temperature in the kiln is maintained between 2,000^{o}F and 2,500^{o}F by combustion of waste and/or fuel oil. It may reach 3,000^{o}F when removal of slag is required.

The kiln rotates at a rate of approximately 0.5 rpm resulting in a residence time of approximately 2 hours for solids and several seconds for gases. A few drums "spiral" out before complete incineration is achieved. These are brought back and fed a second time.

The gas exiting the secondary chamber, at a temperature of approximately 1,100^{o}F, is then saturated in a water quench chamber. Particulates and mist are removed in a wet electrostatic precipitator, a venturi scrubber, and a packed tower. The gas is discharged to the atmosphere through a 200 foot stack. The wastewater generated by the air pollution control system is neutralized with lime and pumped to the nearby Chemolite wastewater treatment plant.

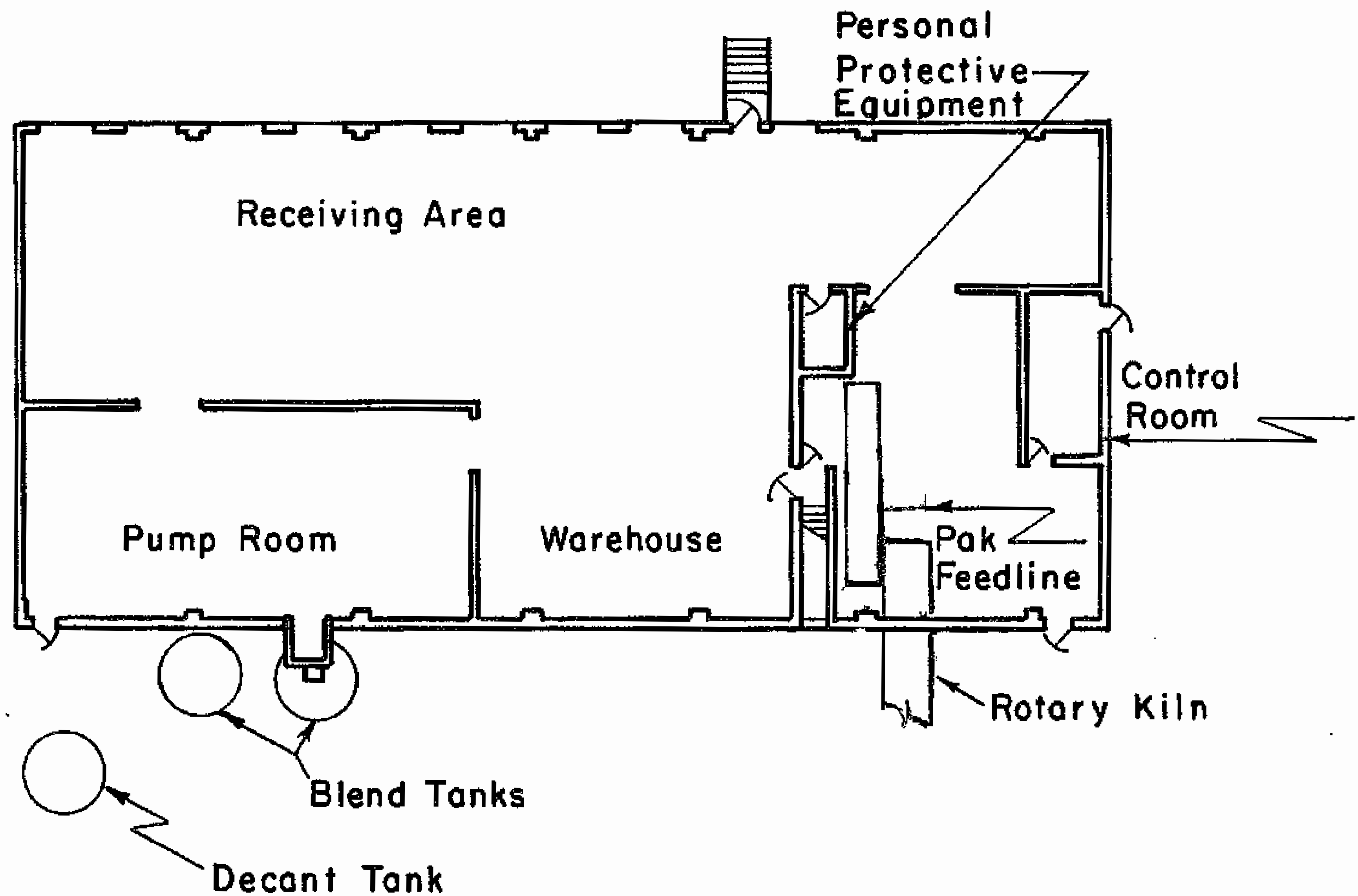

Figure 3. Schematic Plan View of Chemolite Incinerator Facility.

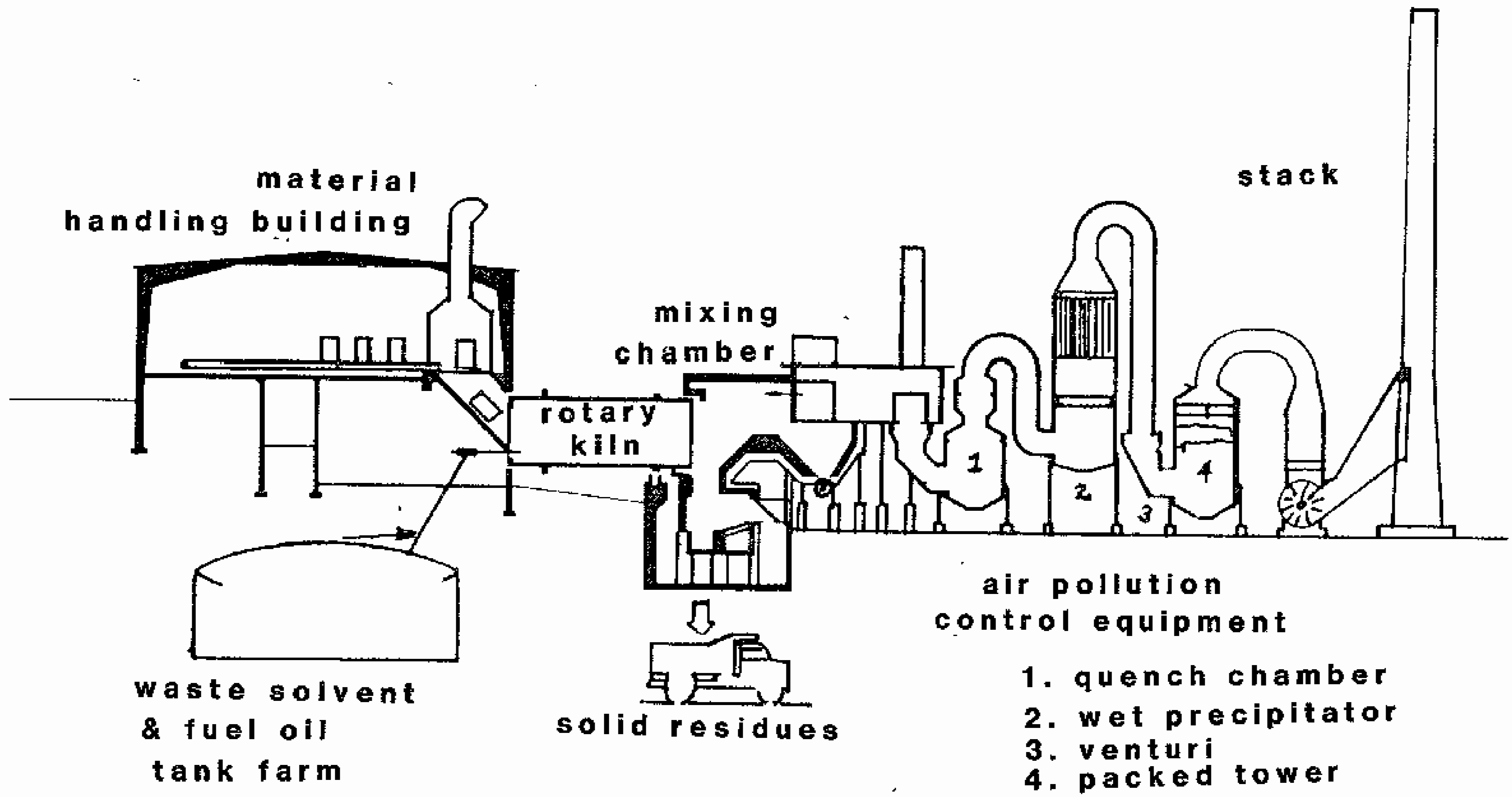

Figure 4. Schematic of Incineration System.

Burned out drums and ash drop from the kiln into a water quench chamber and then are carried by a conveyor to dump trucks for temporary storage nearby. Most of the ferrous scrap is magnetically separated for recycle.

MATERIAL HANDLING SYSTEMS

Pumpable and nonpumpable wet scrap arrive at the incinerator site mostly packaged in 55-gallon steel drums. The drums are shipped in covered trailers which dock at one of eight receiving pads. Fork lift trucks are used to transport pallets of drums (four to each pallet) or individual drums from the trailer to processing areas. Most trailers are emptied directly to the warehouse floor or to the pak and drum feeding conveyor, although some are reloaded on other trailers that serve as portable warehouse space.

PUMPABLE WASTES

Pumpable wastes are removed from their containers in the pump room. A schematic of the pump room is shown in Figure 5. A batch of about 24 drums (6 pallets) can be emptied, two at a time, in the pump room. Two types of 55-gallon drums are used. Some have closed heads with bungs and others have open heads with the lids secured by suitable clamps and gaskets. In either case, the bungs or lids are removed from all drums prior to pumping out the batch. In case of thin (low viscosity) liquids, a 4-foot aluminum suction probe attached to a flexible rubber hose is inserted into the drum. A ground wire on a retractable coil that is attached to an overhead pipe is clamped to the rim of the drum. The air-operated diaphram pump is started and liquid is pumped to one of the two blend tanks. The latter are fitted with agitators and recirculation pumps. The pump room operator knows that a drum has been pumped out when the pump strokes quicken. He then removes the probe from the empty drum and inserts it into an adjacent drum. Simultaneously, the ground wire is taken from the empty drum and clamped onto the full drum. Two pumps and two probes may be active at any given time. When all the drums have been pumped out, residues are dumped out using the drum residue dumping mechanism shown in Figure 6. The near-empty drum is manually moved (although a fork lift truck could be used) to the rotating platform of the device. An overhead

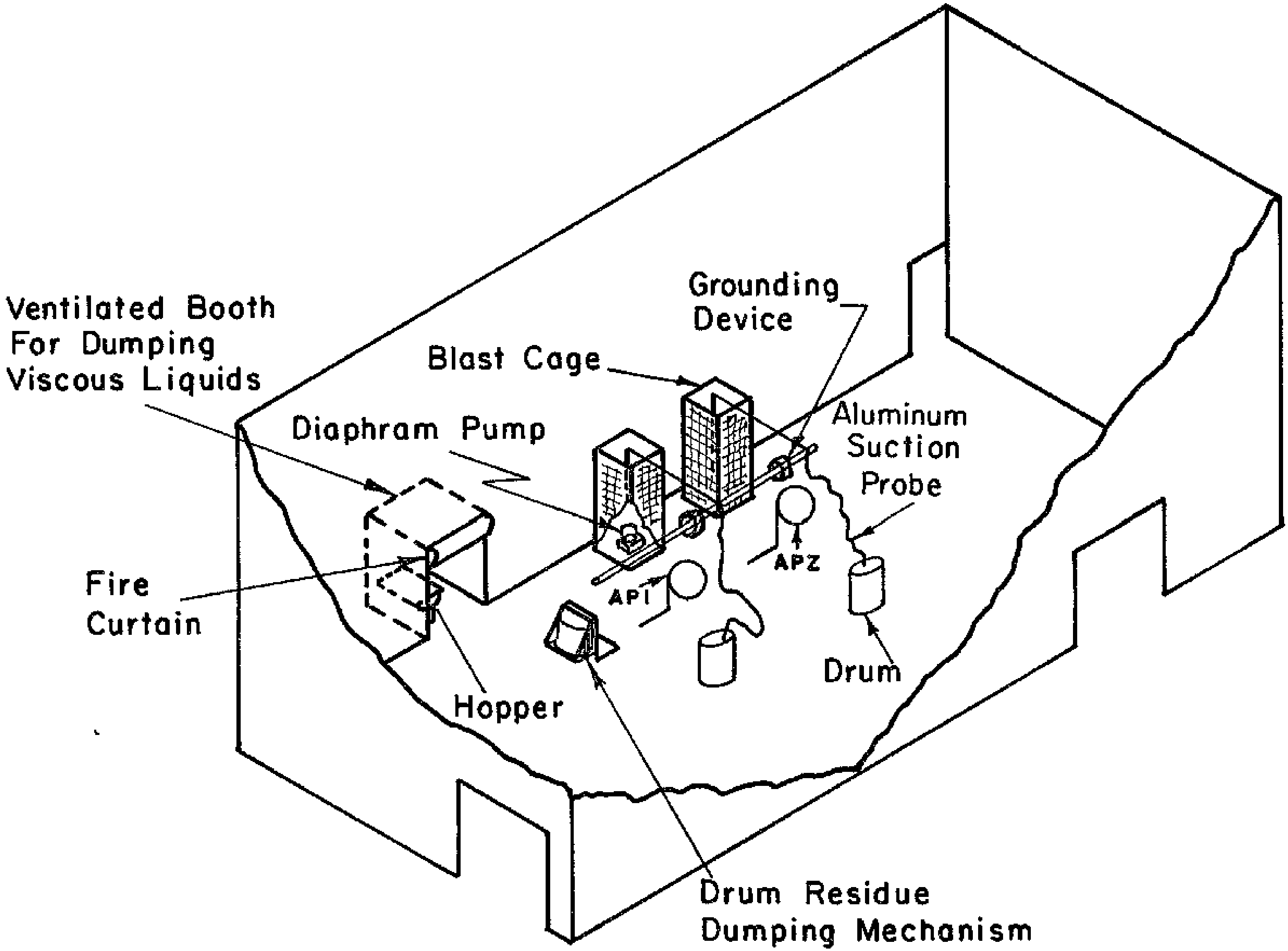

Figure 5. Schematic Representation of the Pump Room.

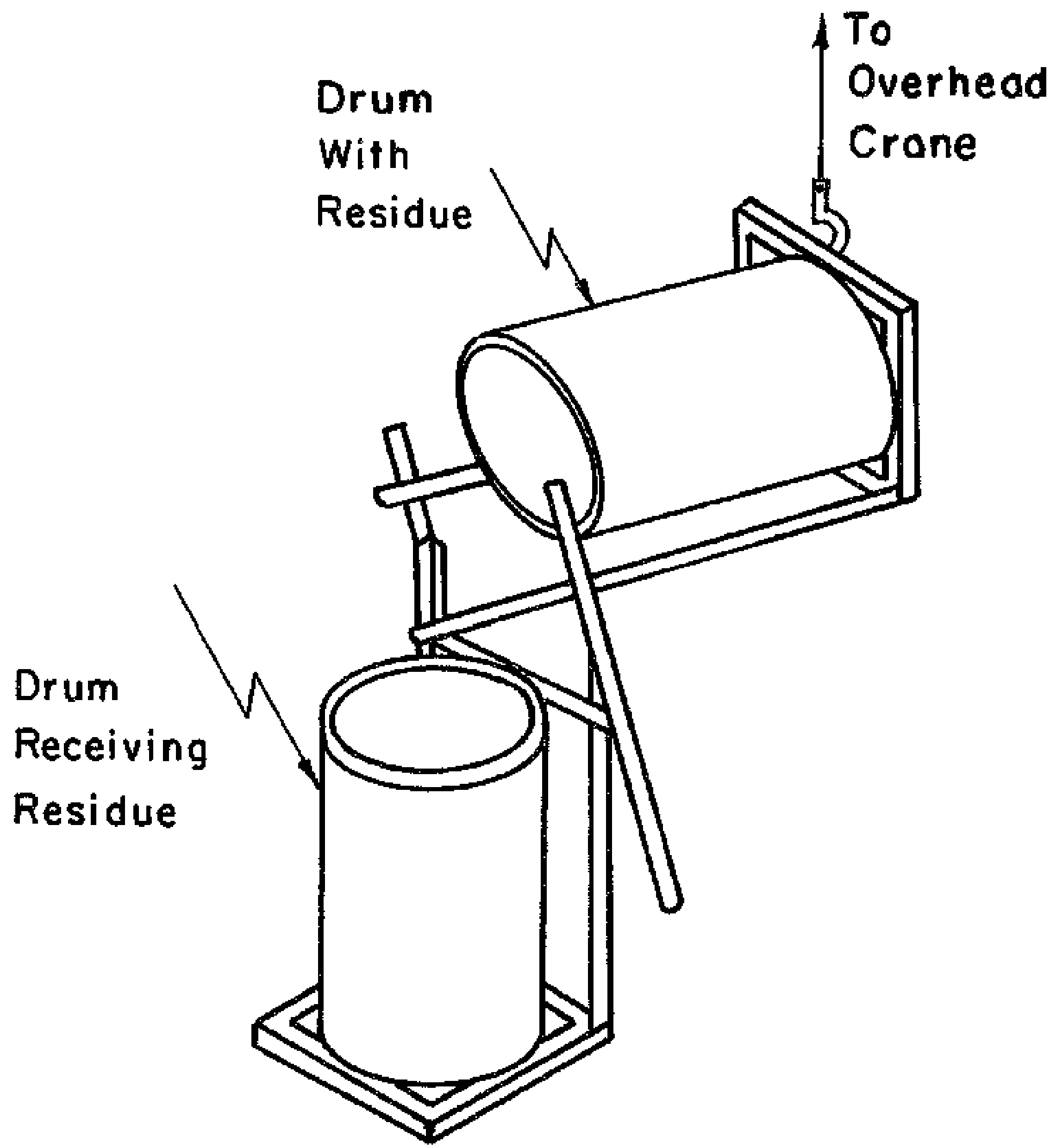

Figure 6. Drum Residue Dumping Mechanism.

crane is used to lift the platform and drum, in an arc, over the drum which receives the residue. These drums, containing residues, are disposed of in the kiln using the pak feeding system. Most drums containing pumpable wastes are reclaimed. The reclaiming process includes cleaning, sandblasting, and repainting the used drums. Drums containing viscous liquids are dumped into a hopper which feeds one of the blend tanks. The hopper is contained in a ventilated booth shown in Figure 5.

NONPUMPABLE WASTES

55-gallon steel drums containing nonpumpable (nonfluid or semifluid) wastes are transported, one at a time, from the receiving or storage area to the pak and drum feed system using a fork lift truck fitted with a "drum grab." The grab is attached to the truck with sleeves that fit both forks (Figure 7). Undersized drums are also transported to the pak feed system using a drum grab called a "beak" shown in Figure 8. It has a sleeve which fits only one fork.

The pak and drum feed system typically handles about 2,500 drums or drum equivalents per week. It was designed to feed 55-gallon steel drums automatically and continuously, one at a time, to the rotary kiln. This technically advanced feed system has the capability of reclaiming drums for reuse. About 40 percent of all drums handled by the feed system are dumped and reclaimed. The other 60 percent are dropped, drum and contents, into the kiln. The pak and drum feed system is schematically shown in Figure 9.

The pak and drum feed system consists of: (1) Four roller conveyors; (2) the dumping grid; (3) the clamping assembly; (4) the ram cylinder; (5) the feeding grid; (6) the air lock housing; and (7) electrical and hydraulic control devices. The location of the system is shown in the facility layout (Figure 3).

Conveyor No. 1 consists of one 8-foot-long section of free rollers where drum lids are removed by the assistant operator, one 8-foot-long section of inclined free rollers, a 17-foot-long section of cam clutched rollers, and a 3-foot-long section of powered rollers. After the lids are removed, the drums

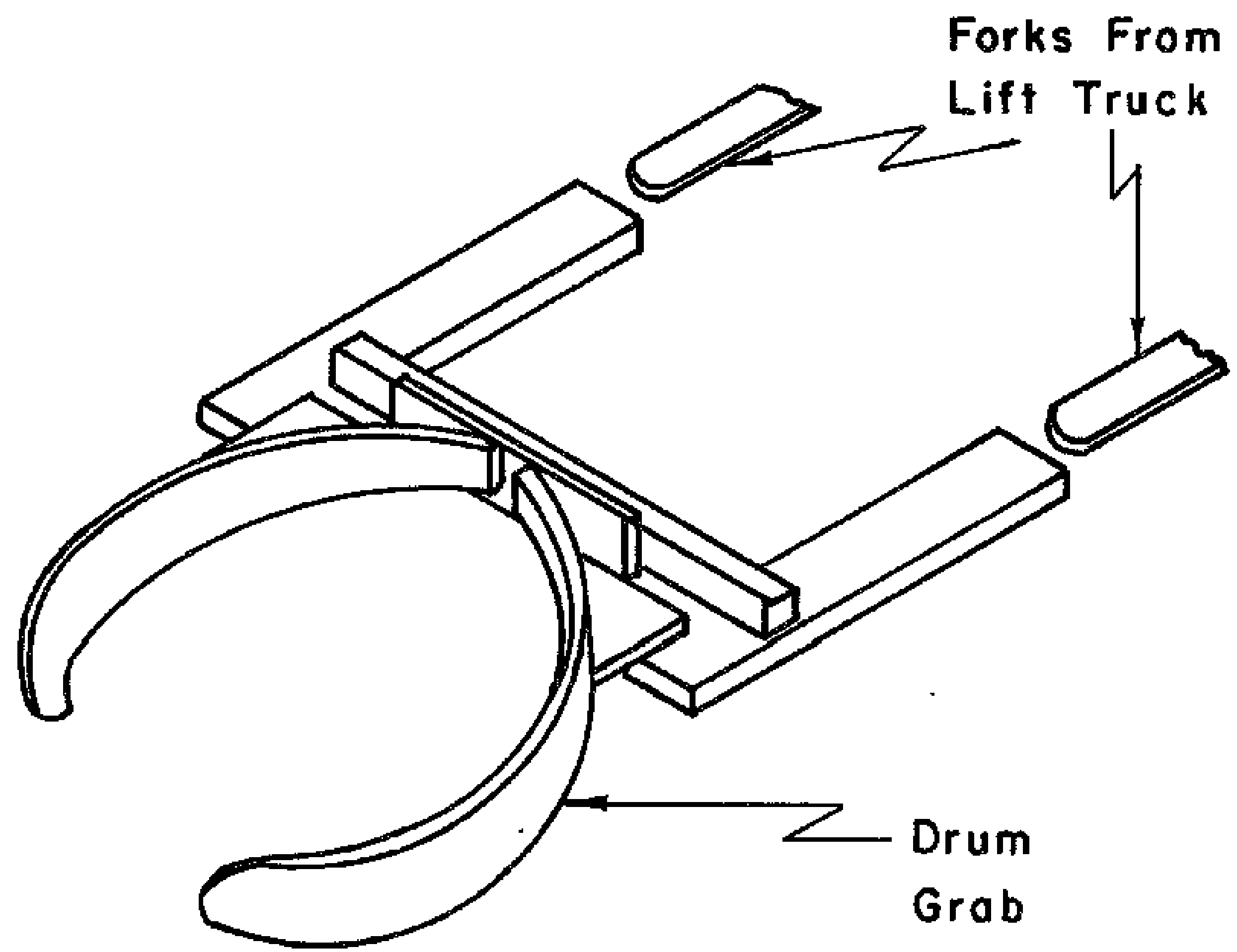

Figure 7. Drum Grab for Full-Sized Drums.

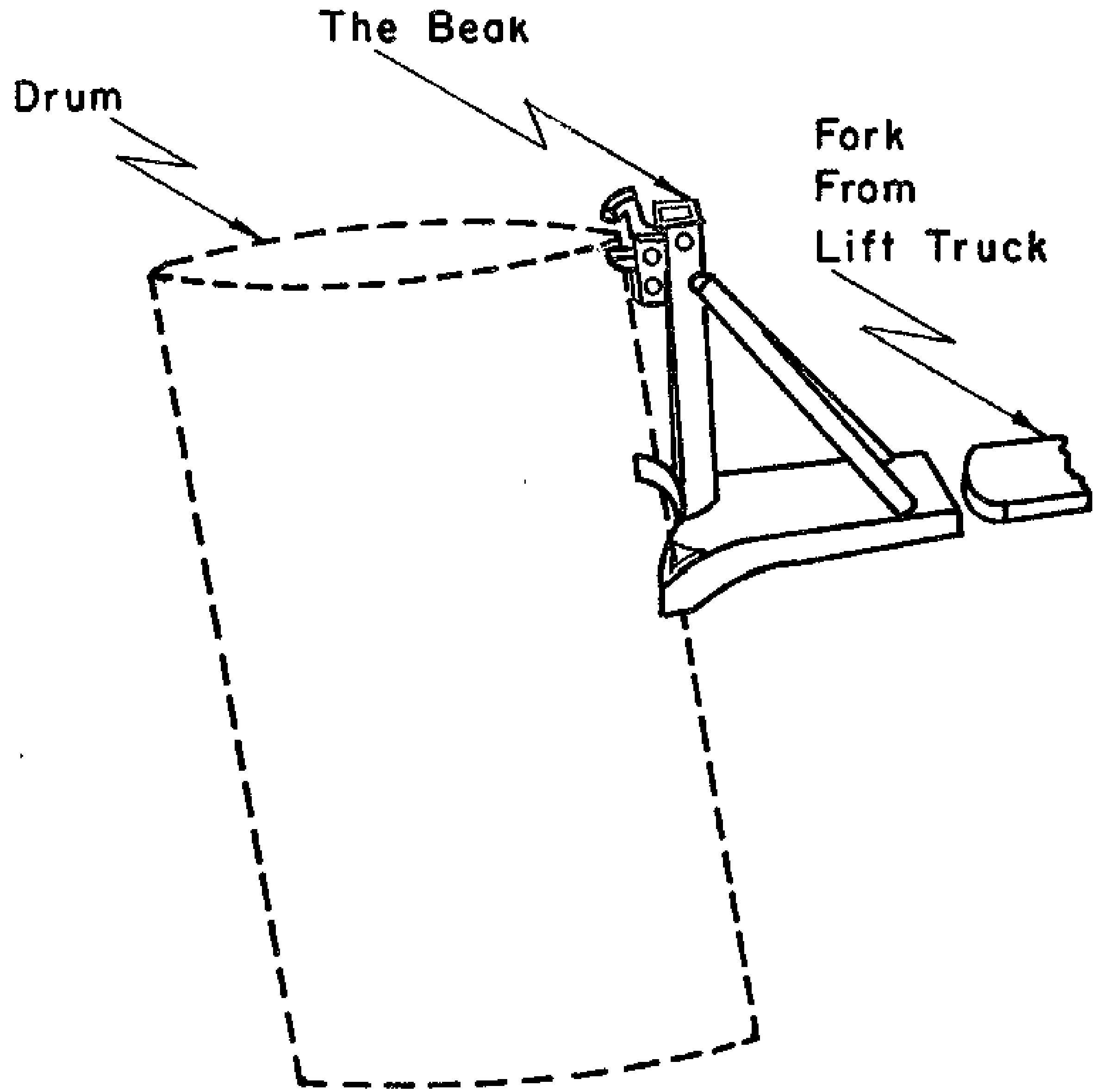

Figure 8. The "Beak" Used for Transporting "Undersized" Drums.

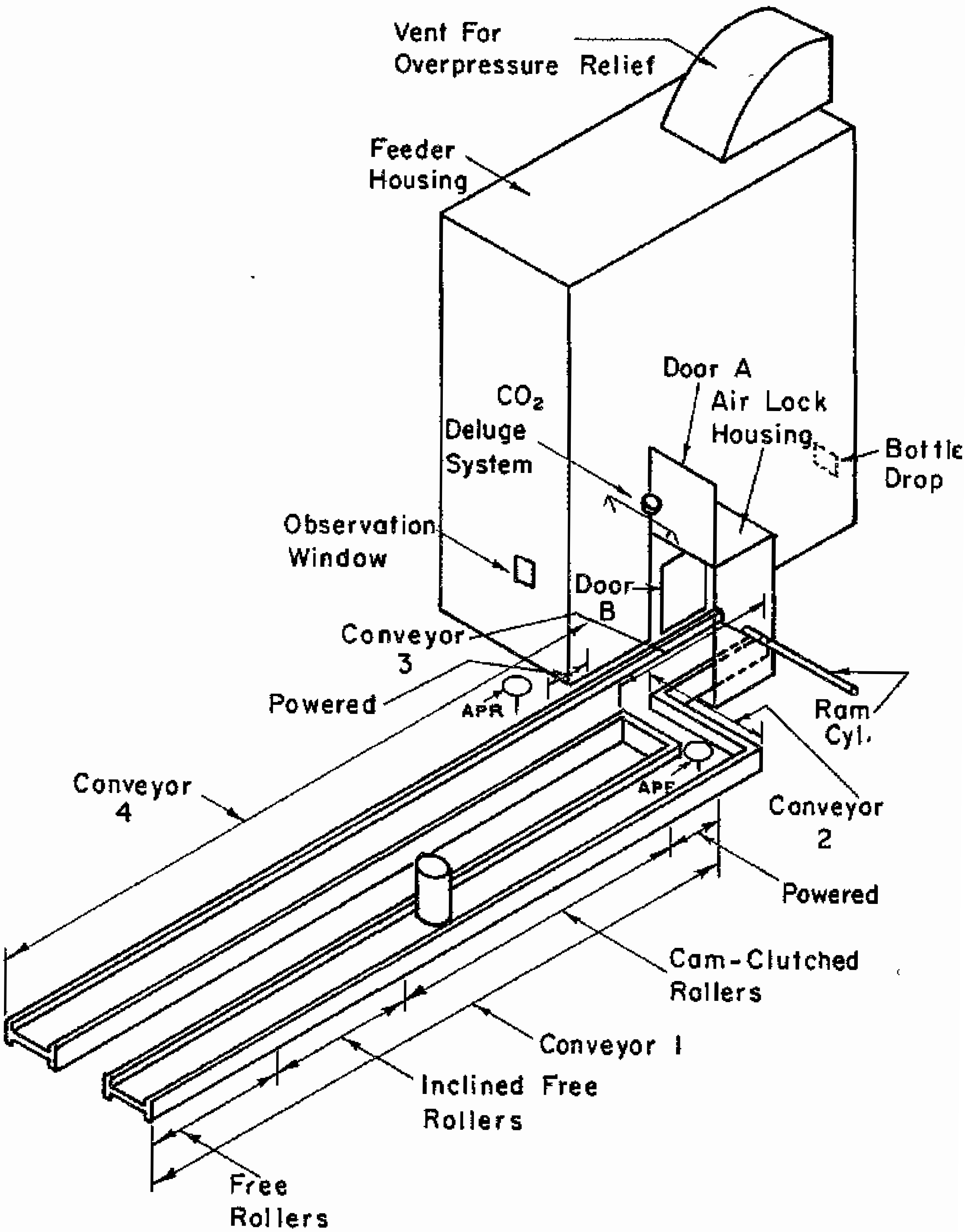

Figure 9. Schematic of Drum and Pak Feed System.

are pushed onto the cam clutched roller area. When activated, the powered section of conveyor No. 1 moves a drum onto conveyor No. 2.

Conveyor No. 2 is a short conveyor that transfers drums, one at a time, from conveyor No. 1 to conveyor No. 3 as the feeding sequence calls for a new drum. All rollers on conveyor No. 2 are powered.

Conveyor No. 3 is an all-powered roller conveyor that receives a drum from conveyor No. 2, conveys it to the proper stopping point for the dumping operation. If an empty drum is to be returned, conveyor No. 3 reverses and carries the empty drum to conveyor No. 4.

Conveyor No. 4 receives the empty drums from conveyor No. 3, and intermittently moves each one down approximately 3 feet, then stops. Conveyor No. 4 has all powered rollers except for an 8-foot section of free rollers at the end. Here the assistant operator replaces the lids and manually removes and palletizes the drums.

The dumping grid is a hydraulically actuated pivoting device consisting of six bar "fingers" that mesh between the last rollers on conveyor No. 3. Its purposes are:

1. To lift a pak or drum off the rollers for either the dumpable cycle or the reclaimable cycle.

2. To provide a level surface over which the paks or drums are pushed with the ram cylinder on the dumpable cycle.

3. To lift and rotate the drum and clamping assembly during the reclaimable cycle.

After each cycle, it disappears beneath the rollers until a pak or drum is again over it, ready for dumping.

The clamping assembly is a housing with two hydraulic cylinders and two clamp arms that hold the drum on the dumping grid during the reclaimable cycle.

The ram cylinder is a hydraulic cylinder specially designed so as not to allow twisting of the shaft. A curved plate, rolled to fit the contour of the paks and drums, has been adapted to fit the rod on this cylinder to push the paks and drums across the dumping grid onto the feeding grid during the dumpable cycle.

The feeding grid is another finger type grid, pivoted on a horizontal shaft, perpendicular to the dumping grid shaft. It works only during the dumpable cycles. This grid accepts a pak or drum in the upright position and slowly lowers it to a 45^{o} angle from vertical thus causing the pak or drum to enter the kiln bottom first and at a controlled rate of speed. This grid also incorporates a trailing link arm that prevents the load from tipping sideways while lowering.

The air lock housing is a reinforced 1/4" plate housing that attaches to the feeder housing and has a hydraulically operated guillotine type door (Door A). When closed, it forms an air seal around the pak or drum, in feeding position on conveyor No. 3, provided that the door to the feeder housing (Door B) is opened for entry. An access door has been provided in one end of this housing.

The feeder housing contains the feeding grid and has an opening through the roof to allow venting to the outside of the building. This vent also serves as an air inlet through a damper and an air inlet duct. Door B, through which the paks or drums are fed, is located in the side of this housing and opens only when Door A of the air lock housing is closed.

In order to achieve better temperature control in the kiln and in order to enhance the safety of the drum and pak feeding operation, the assistant operator uses different procedures to prepare the drums depending on BTU content. Drums containing very high BTU material are not totally uncovered. The assistant operator makes holes in the lids with a brass pick axe. If flammable liquid in the drum could splash out during the drop into the kiln, the drum top is covered with a plastic sheet secured with adhesive tape. This also prevents drum contents from igniting prematurely. For drums to be reclaimed, the assistant operator leaves the lid ring clamp on the drum. This signals the operator to initiate the system control sequence which effects the recovery of a drum.

HAZARD ANALYSIS

There are a number of areas at the Chemolite incinerator where engineering and other types of hazard controls have been implemented. The areas are the pump room, the pak and drum feed system area, and the control room.

PUMP ROOM

Hazard controls in this area have been implemented in order to eliminate or minimize the potential for: (1) Inhalation and skin exposure to a variety of solvents and organic materials; (2) fire and explosion caused by flame sources including static electricity generated by flowing fluids or sparks generated by metal-to-metal contact; (3) injuries to the back and skeletal muscles because of manual moving and lifting of heavy 55-gallon steel drums.

The health effects of overexposure to solvents contained in wet scrap handled in the pump room cover a wide spectrum. A number of these solvents are irritants to the eyes, nose, throat, and upper respiratory tract. Others cause gastrointestinal and neurological disturbances. Overexposure may also cause injury to the heart, liver, kidneys, and bone marrow. The OSHA standards for the materials handled range between 25 ppm and 1,000 ppm.[2]

Many of the solvents handled also form explosive mixtures with air with lower explosive limits of the order of 10,000 ppm. In the absence of proper controls, these mixtures could be ignited by sparks that are potentially generated by the pumping operation (static electricity),[3] metal-to-metal contact, or from electrical equipment such as motors and switches. Static electricity, in the form of high voltage differences at the open ends of a pipe which contains a flowing fluid, can cause sparking when electrical discharge occurs. A fluid velocity of 3.3 feet per second may generate a voltage difference of 1,000 volts between a point of free discharge and surrounding surfaces.

PAK AND DRUM FEEDING

The potential health hazards of solvents that may be found with the nonpumpable wet scrap are similar to those described for pumpable wastes. Also, in the absence of controls, fire and explosion hazards are amplified because of the relative proximity of the combustible material to the fire in the kiln.

Small quantities of "special" materials that may be carcinogenic, mutagenic, or teratogenic are disposed of using the "bottle drop" at the back of the feeder mechanism housing (Figure 9). The drop is also used for materials that are extremely flammable or explosive.

HAZARD CONTROLS

GENERAL CONSIDERATIONS

Important hazard controls in effect at the Chemolite incinerator fall into four categories:

1. Engineering Controls - These include ventilation, automation, and other system design features that directly or indirectly contribute to lowering occupational exposures to chemical and physical agents or enhance worker safety (fire and explosion hazards).

2. Training and Education Programs - Effective programs result in work practices which significantly minimize the potential hazards associated with the worker's performance of his/her job. These programs may include on-the-job training, formal and specialized training inside or outside the company, and presentation of educational audio visual materials to employees.

3. Monitoring - Includes environmental and medical monitoring of and observation of employees in the workplace to assure management that job duties are performed in a safe manner.

4. Personal Protective Equipment - Equipment is provided to the employees to either further reduce or completely eliminate exposure to hazards.

ENGINEERING CONTROLS

Pumpable Wastes

Exposure to solvents in the pump room are reduced by the means of general (dilution) ventilation for thin liquids and local exhaust ventilation for viscous liquids. The use of the drum residue dumping mechanism also reduces exposure since it allows the workers to empty the drums without being close to them. Protection against fire and explosion is provided by the employment of special pumps, grounding devices, and protective barriers. Additionally, all electrical equipment in the facility must comply with provisions of the National Electrical Code for Hazardous Locations, Class I, Divisions 1 and 2 for atmospheres containing materials specified in Group C and D. Division 1 locations include "those where accidents might release concentrations of flammable gases or vapors which could, at the same time, cause electrical equipment to fail." Division 2 locations include those "where flammable liquids are enclosed in containers susceptible to breakdown or rupture or those wherein the failure of ventilation systems could result in hazardous concentrations of gases and vapors." These provisions of the electrical code were adopted by OSHA in Section 1910.309 in March 15, 1972.

The dilution ventilation system in the pump room is shown schematically in Figure 10. It provides 13 air changes per hour. The booth where viscous liquids are dumped is provided with local exhaust ventilation. All supply air is tempered and none is recirculated.

Drums to be pumped out are brought to the pump room on pallets (four to each pallet) using a fork lift truck. The lids (or bungs) are removed with a pneumatically driven spark-proof tool, and a 4-foot all-aluminum suction probe, attached to a flexible hose, is inserted in the drum. The flexible hose has an electrical ground wire which runs throughout its length. One end is bonded to the aluminum probe while the other is bonded to the overhead rigid steel pipe which runs to the suction side of the pump. The pump is a diaphram type driven by compressed air. The two pumps in the pump room are shielded by 6-foot-high blast curtains constructed from woven one-half inch steel cable. These protect the pump room worker from injury in the event of a pump explosion. A ground wire, from an overhead retractable spool, is clamped to the drum being pumped to provide grounding of the drum.

When all the drums have been pumped out, residual materials (such as rags, plastic film, etc.) are dumped out using the mechanism shown in Figure 6. Even though the fork lift truck could be used to transport the drum from the pallet to the mechanism (using the drum grab shown in Figure 7), these drums were actually moved to the mechanism manually. This dumping mechanism plays a

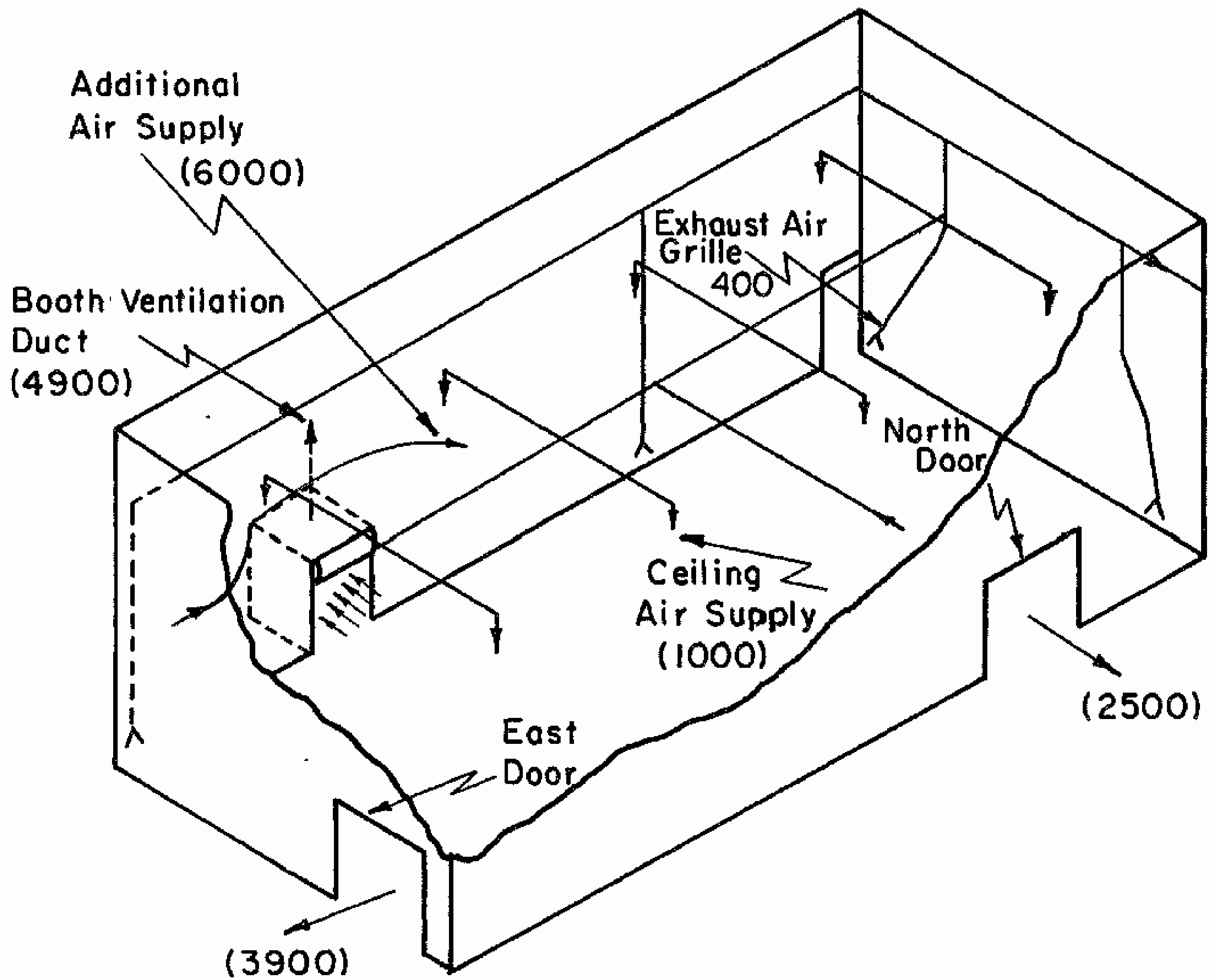

Figure 10. Ventilation System Schematic in Pump Room.
NOTE: Figures in cfm. ( ) Denote NIOSH Measurement.

significant part in reducing exposure since the worker is displaced in space from the source of exposure. Additionally, manual lifting is completely avoided thus minimizing injuries to the back and musculature.

Nonpumpable Wastes

Even though the potential for exposure to flammable solvents is less than that in the pump room, at least some of the drums that are directly fed to the kiln, contain free-standing liquid. Solids, film, and rags may also be thoroughly wetted with solvent. The primary vapor control is dilution ventilation. The scheme used and the supply and exhaust air rates are shown in Figure 11. The design features of the drum and pak feeding facility are good examples of automation which, from an occupational point of view, greatly minimizes the potential for injury to the worker from fires and explosions that may occur accidentally, and minimizes the potential for injuries resulting from excessive manual lifting. Even though a great deal of care is taken to avoid feeding highly explosive, flammable, or incompatible materials to the kiln, the possibility, however remote, always exists. Furthermore, where the pak line is operated in such a manner whereby drums are to be reclaimed, there is a potential that flammable residuals may catch on fire.

Some of the more important design features of the system are as follows:

- Interlocks are provided such that only one drum at a time is delivered to conveyor No. 3.

- The time of each cycle (dumping or reclaiming of a drum), and thus the feed rate, is controlled by the operator.

- A new cycle is initiated only when Door A is fully open, the ram is fully retracted, the grid jack is down, the kiln is not on emergency bypass, and the kiln temperature is not excessive.

- In the reclaim cycle a drum may be dumped by the operator if in his judgement the drum is not salvageable.

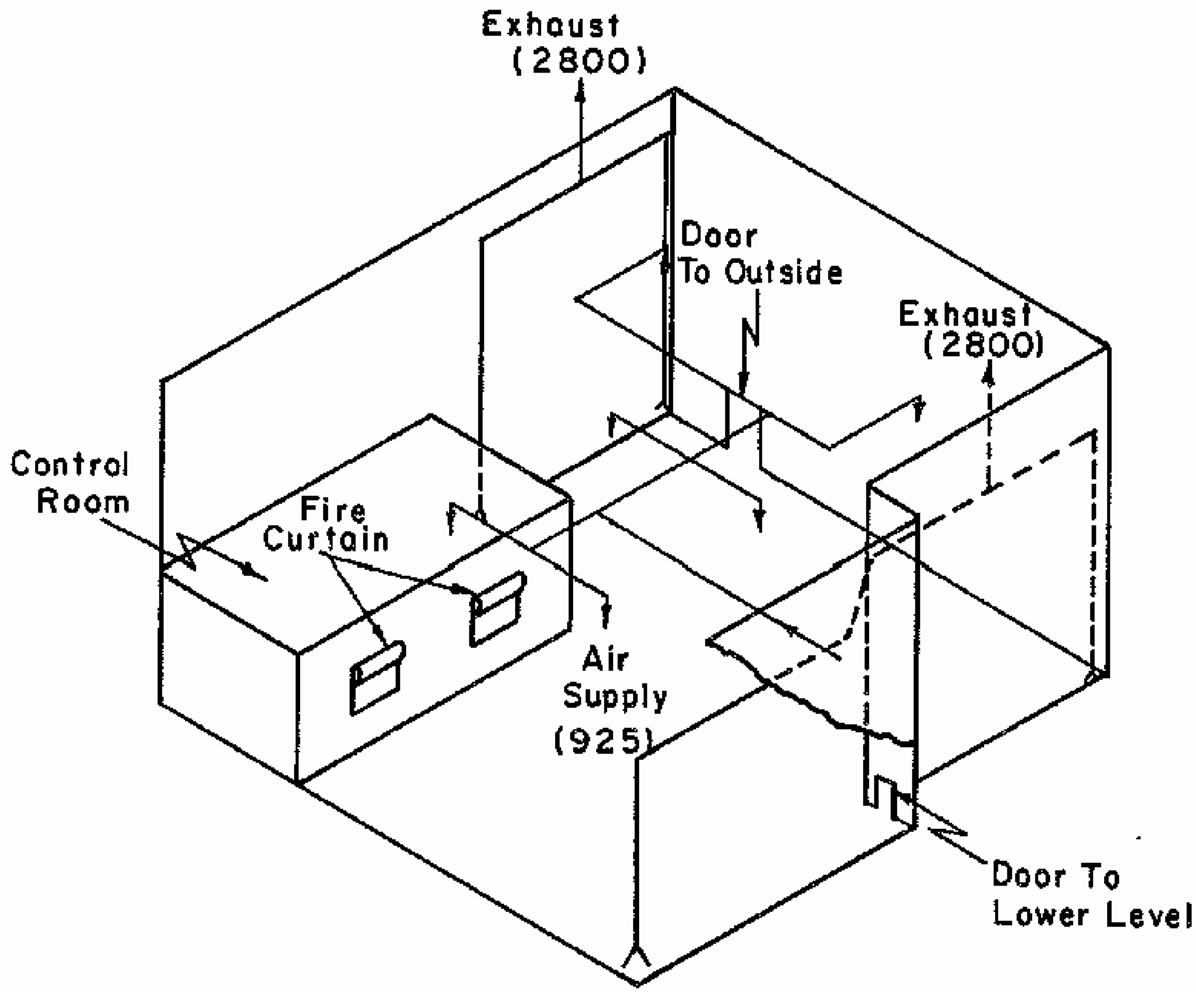

Figure 11. Schematic of Dilution Ventilation System at Drum and Pak Feed System. Numbers are Design Flows in cfm.

If by chance a reclaimed drum catches fire, two fire controls are available to the operator. He can either activate a steam deluge system inside the airlock housing or, if a burning drum emerges from Door A, the visible light sensor, directly above that door, will automatically activate a carbon dioxide deluge system schematically shown in Figure 9.

In the event of fire in the area of the pak feeding system, fire curtains fitted to the control room windows overlooking the area automatically come down. They are held by chains with links that fuse in the presence of extreme heat. The location of these curtains is shown in Figure 11. A rear door permits exit directly to the outside.

Drums are brought to the pak line using a fork lift truck fitted with one of the grabs shown in Figures 7 and 8. The truck is flameproofed for use in hazardous locations and the exhaust gas is water scrubbed.

WORK PRACTICES

Specific Training Programs

A detailed facility operation manual has been written. It describes the job responsibilities of the operator and the operating conditions of the kiln and air pollution control system. It also contains instructions on how to carry out specific operations to avoid injuries and exposures. There are also general instructions on personal hygiene and safety.

The first section of the operations procedure manual describes in detail the incineration process and controls, process conditions, and startup procedures. In another section there is a description of the characteristics and functions of the components of the automatic pak and drum feeder and the sequence of operations in both the reclaim or pumpable mode.

There are specific instructions on how to handle and dispose of special materials safely using the bottle drop. Operating logs are required by the procedures manual. They include hourly information on process parameters (such as temperatures and pressure drops), and the number and origin of drums handled at the pak and drum feeding facility, and the pump room. There are also instructions on how to operate safely the pump room, blend tank, and tank farm pumps, and instructions on how to clean screens safely and how to test the screen housing for leaks.

General Training

A wide variety of audio-visual materials in the form of slides, cassettes, and movies is available from the Safety Department at 3M. Appropriate slides/cassettes for the incinerator operators include those on: (1) Material handling (safety in handling and use of drums, manual lifting, and fork truck operation; (2) use, recharge, inspection, and maintenance of portable, dry chemical fire extinguishers; (3) safe vessel or enclosed space entry procedures; (4) use, inspection, and maintenance of self-contained breathing apparatus; (5) Chemolite incinerator operations and how to properly prepare pumpable and nonpumpable scrap for disposal there. Movies on fire fighting and prevention, flammable liquids, housekeeping, fork lift trucks, manual lifting, and personal protection are also available. Movies on fire fighting explain the causes of various fires and illustrate ways to fight them. Actual case histories are available. The use of "Light Water" brand foaming concentrate and the aqueous, film-forming foam, for solvent and other fires, are illustrated. There are also movies on the use of high expansion foam to protect high piled stock in warehouses.

The fork lift truck is an important tool in material handling at the incinerator. A written manual, for a fork truck training program, is used to determine the suitability of prospective truck drivers for the job. The manual includes a detailed description of the requisite training and specific behind-the-wheel tests that the trainee must undergo to demonstrate his/her ability to perform properly in all possible drum-handling situations.

A training log is maintained for each employee including dates, description of training program, and duration.

Job Duties

The Chemolite incinerator is operated around the clock by a crew of 2 or 3 each shift. There are one incinerator operator (shift foreman) and two assistant operators. One assistant operator works at the pak feed line and the other works in the pump room. Since the quantity and quality of pumpable wastes have declined because of conservation and recycle programs within the company, the pump room operator is a part-time job and is performed on an as-needed basis. The duties of the operator and assistant operator are outlined in Table 3. There is much overlap in the job duties of the operator and assistant operator. This is apparently a deliberate company policy which specifies that "without complete awareness of all operations" by the assistant operator "he (or she) will not function in a safe and efficient manner." While the NIOSH survey team was on-site, the operator on the first day's second shift was carrying out the duties of the assistant operator in the pump room during the first shift on the second day.

Table 3. Summary of job duties.

Duties	Operator	Assistant Operator
Operation of rotary kiln incinerator	X	
Operation of drum feeding and recovery mechanism	X	
Coordinating and directing storage and inspection of material for disposal	X	X
Special bottle drop	X	
Operating logs	X	X
Operation of pumpable waste pumps	X	X
Cleaning pump screens	X	X
Cleaning pumpable waste transfer lines	X	X
Shear pin replacement-residue conveyor	X	X
Calling in such crews or men as necessary for service or maintenance and repairs	X	
Perform maintenance as necessary	X	X
Be responsible for and perform such housekeeping duties as time permits or as directed by supervision	X	X
Operating fork lift truck	X	X
Operation of Gorators	X	X

MONITORING

Monitoring of worker exposures in the pump room has been conducted by 3M industrial hygiene specialists on two occasions. The first series, impinger samples taken in September 1973, were analyzed using ultraviolet and visible light spectrophotometry techniques. The second series of samples were collected on charcoal tubes in February 1976. These were analyzed by gas chromatography techniques. On both occasions, the duration of sampling was 10 to 15 minutes and, in the case of pumpable wastes, covered the entire period while a batch of drums were pumped out. The results of sampling are given in Tables 4 and 5. While a quantitative comparison of the two sets of data is not feasible, because the concentration of species in the wastes were probably not known, the exposures to a given species, reported for 1973, were generally higher than those found in 1976. Aside from any changes in prevailing conditions, such as the rate of general ventilation in the pump room, it is possible that the analytical technique employed in 1973 may have yielded values that were generally higher than those obtained in 1976 with charcoal and analyzed by GC.

As seen in Tables 4 and 5, exposures ranged between 10 and 42 percent of the allowable TLV's at that time, assuming that exposures are additive and that the same operation continued for eight hours. These values, however, represent peak exposures because the pump room operator does not perform the task of opening drums and pumping them out for the whole shift. Actual time-weighted average exposures could be one-third to one-tenth those reported since the assistant operator performs other tasks such as cleaning strainers, drum handling operations, etc. It is noteworthy that exposures occurring when opening and pumping out drums with bungs ranged between 3 and 8 percent of allowable, and were one-fifth to one-eighth those occurring when handling materials in drums with lids.

As seen in Table 5 exposures of the assistant operator working on the pak and drum conveyor were equal to or less than 2 percent. Physical examinations were administered to the workers on a yearly basis. These were recently discontinued.

Table 4. Solvent exposures, in ppm, of assistant operator in pump room using impingers.*

Date		MEK (200)***	Toluene (100)***	Other	% of Allowable Level**
9-11-73	Pumping 8 open head drums	55	5	-	33
9-11-73	Pumping 10 open head drums	12	2	8 isopropanol (400) 50 heptane (400)	22
9-11-73	Pumping 12 open head drums	15	2	15 isopropanol (400) 60 heptane (400)	30
9-13-73	Pumping 7 closed head drums	-	1.5	27 isopropanol (400)	8
9-13-73	Pumping 8 closed head drums	-	2	4 ethylacetate (400) 20 hexane (500)	7
9-13-73	Pumping 7 closed head drums	-	Trace	15 hexane (500)	3
9-13-73	Pumping 4 closed head drums	-	Trace	30 acetone (1000) 10 hexane (500)	5
9-17-73	Pumping 4 closed head drums	-	2	13 isopropanol (400)	5
9-17-73	Pumping 4 open head drums	20	17	-	27
9-17-73	Pumping 6 open head drums	37	24	-	42
9-17-73	Pumping 6 open head drums	26	17	-	30

*10-15 minute breathing zone samples during drum opening, pumping, etc.
**% allowable exposure is calculated on basis of additive effect and assuming that exposure to the same level continued for 8 hours.
***TLV in parenthesis.

Table 5. Solvent exposures, in ppm, of assistant operators in the pump room and at the pak and drum feed line February 23, 1976.*

Location	Sample Type	MEK (200)**	Toluene (100)**	Xylene (100)**	Heptane (400)**	1,2-Dichloro-ethane (50)**	% of Allowable Exposure***
Pump Room	Breathing zone	27	2.5	0.3	4.7	--	17
Pump Room	Breathing zone	11	5.1	0.1	2.1	--	11
Pump Room	Breathing zone	3.4	6.3	0.8	8.3	--	10
Pump Room	Breathing zone	12	3.8	1.1	2.9	5.6	23
Pack and drum con-veyor	Breathing zone	1	1	0.1	0.5	--	2
Pack and drum con-veyor	Breathing zone	0.6	0.5	0.1	1.6	--	2
Pack and drum con-veyor	Breathing zone	1.5	0.5	0.3	1.2	--	2
Pack and drum con-veyor	Breathing zone	0.8	0.4	0.1	1.1	--	1
Pack and drum con-veyor	Breathing zone	1.0	0.2	0.1	0.2	--	1

*Charcoal tube samples.
**Applicable TLV in parenthesis.
***Assuming the additive effect and that exposure to the same level continued for 8 hours.

PERSONAL PROTECTIVE EQUIPMENT

Hard hats, safety glasses, company-provided uniforms, and safety shoes are routinely worn by workers at the incinerator site. All-cotton work gloves are used by workers who come in contact with drums of hazardous wastes. Rubber suits, face shields, and Norton half-face piece respirators are worn when handling special materials.

Two respirators were available in the control room for use in emergencies. The first was an air-supplied MSA air mask, Model 401. The second was an MSA all service gas mask with a type "N" canister. Personal protective equipment were found in a special room shown in Figure 1. Norton half-face piece respirators (Model 7500-30L) for use with organic vapor cartridges (Model 7500-3) were available. Also, there were available MSA full-face respirators (all service gas mask) and with type N canisters and the Model 401 SCBA.

EVALUATION OF HAZARD CONTROLS

OBJECTIVES AND METHODS

An in-depth survey, to collect and evaluate data and information on effective occupational hazard control techniques was performed and covered three shifts on three consecutive days (9/14 through 9/16/82). The evaluation of the controls included: (1) The collection of personal breathing zone and general area samples using NIOSH Method P&CAM 127 for organic solvents; (2) observation of work practices and collection of information on training and education programs; (3) observation of, collection of data on, and description of the engineering controls; and (4) collection of information on personal protective equipment in use.

SAMPLING AND ANALYTICAL METHODS

The personal and general area samples were obtained using charcoal tubes (SKC 100/50 Lot No. 120) and MDA Accuhaler pumps calibrated at a nominal 50 cc/min. An HNU Model PI 101 photoionization analyzer fitted with an 11.7 ev lamp, was used to estimate the levels of total hydrocarbons in each area. It was determined that an air sample size of about 10 liters was adequate to prevent breakthrough. A number of charcoal tubes were selected for preliminary qualitation of air contaminants present. These tubes represented general area samples taken at the end of conveyor No. 1 and in the pump room. The locations of these samples are designated ACF and AP in Figures 9 and 5, respectively.

These samples were desorbed with 1 mL carbon disulfide spiked with 0.1 percent tridecane as an internal standard. The solution was analyzed by gas chromatography (flame ionization detector) and reanalyzed by gas chromatography mass spectrometry techniques. The columns used consisted of 30 meter DB-1 bonded phase fused silica capillary columns (splitless mode).

The rest of the samples were analyzed for specific solvents using gas techniques in accordance with NIOSH Method P&CAM 127 with the following modifications being typical:

Desorption Process:	1 hour in 1 mL carbon disulfide containing 1 uL/mL decane as an internal standard.
Gas Chromatograph:	Hewlett-Packard Model 5711A equipped with a flame ionization detector.
Column:	30m X 0.31 mm ID fused silica capillary with an inner coating of 1.0 um DB-1.
Oven Conditions:	2 minutes at 70°C programmed at 8°C/min to 140°C.
Other:	Helium was used as the carrier gas in the split mode of operation with a split ratio of 20 to 1.

RESULTS OF AIR MONITORING

Personal samples were obtained for the operator and the two assistant operators working the pak feed system and the pump room. As an aid in the determination of species to which the workers were exposed, area samples were taken simultaneously. In the pump room, the area samples were located to the left and right of the operator (8-feet above floor level) in the immediate vicinity of the drums to be pumped out (AP1 and AP2 in Figure 5). In the area of the pak feed system area air samples were obtained at two locations. The first was 4 feet above and towards the end of conveyor No. 1 (ACF in Figure 9). The other location was 4 feet above and at the beginning of conveyor No. 4 (ACR in Figure 9). The results of the sampling are shown in Tables 6 and 7.

Table 6. Exposures and concentration levels in pump room.

Date and Shift	Operator or Area Sample	Duration of Sample (min).	Volume of Sample (liters)	Air Concentrations, ppm							Percent[d] Allowable
				Acetone	n-Heptane	MEK[a]	2, 3-Methyl Hexanes	THF[b]	Toluene	Xylenes	
9/15/82 7a-3p	Operator A	227	11.4	15.6	0.2	8.5	N.D.[c]		3.7	N.D.	8.0
	Area 1	209	12.5	N.D.	N.D.	0.3	N.D.	---	0.2	N.D.	---
	(AP1)	221	13.2	2.5	N.D.	1.5	N.D.	---	1.2	N.D.	---
	Area 2	220	14.2	N.D.	0.3	0.9	0.3	---	0.6	0.2	---
	(AP2)	225	13.7	10.4	0.3	5.2	0.5	---	2.8	0.4	---
9/16/82	Asst. Operator E	209	4.0	2.1	---	20.8	---	N.D.	N.D.	---	10.6
7a-3p	Asst. Operator F	132	7.7	10.8	---	15.2	---	8.2	5.4	---	15.5
	Area 2	264	13.9	1.2	---	3.2	---	N.D.	0.9	---	---
	(AP2)	164	8.0	7.0	---	7.7	---	5.4	5.5	---	---
OSHA TWA				1000	500	200	500	200	200	100	

a. Methyl ethyl ketone.
b. Tetrahydrofuran.
c. N.D. for nondetectible.
d. Assuming additive effect.

Table 7. Summary of exposures and concentration levels in the vicinity of the drum and pak feed system.

Date and Shift	Operator or Area Sample		Duration of Sample (min).	Volume of Sample (liters)	Contaminant Concentration, ppm: Acetone	Ethyl Acetate	n-Heptane	MEK[a]	2-Methyl Hexane	3-Methyl Hexane	MIBK[b]	THF[c]	Toluene	Xylenes	Percent[d] Allowable
9/14/82 3p-11p	Operator	A-1	243	14.6	--	N.D.	N.D.	0.5	N.D.	N.D.	N.D.	--	N.D.	0.2	1
		-2	208	8.8	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	--	N.D.	N.D.	--
	Asst. Operator	B-1	229	11.5	--	N.D.	N.D.	0.5	N.D.	N.D.	N.D.	--	N.D.	0.4	1
		-2	213	11.0	--	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	--	N.D.	N.D.	--
	Above Conveyor (ACF)	1-1	230	10.9	--	0.6	0.3	5.0	N.D.	0.7	0.9	--	2.0	8.5	--
		-2	217	10.3	--	1.6	0.5	1.3	N.D.	0.7	N.D.	--	1.8	1.3	--
	Above Conveyor (ACR)	4-1	223	10.4	--	N.D.	N.D.	1.3	N.D.	N.D.	N.D.	--	N.D.	0.6	--
		-2	223	8.1	--	N.D.	N.D.	0.4	N.D.	N.D.	N.D.	--	N.D.	0.3	--
9/15/82 7a-3p	Operator	C-1	216	10.3	N.D.	--	N.D.	0.6	N.D.	N.D.	--	--	N.D.	0.2	1
	"	C-2	234	11.0	N.D.	--	N.D.	0.6	N.D.	N.D.	--	--	N.D.	N.D.	1
	Asst. Operator	D-1	232	10.6	N.D.	--	N.D.	0.6	N.D.	N.D.	--	--	0.3	0.2	1
	" "	D-2	220	10.3	0.8	--	N.D.	1.6	N.D.	N.D.	--	--	0.8	0.4	1.6
	Above Conveyor (ACF)	1-1	198	10.0	--	--	N.D.	5.0	N.D.	N.D.	--	--	1.6	5.2	--
		-2	234	11.5	--	--	N.D.	4.9	N.D.	N.D.	--	--	1.4	2.6	--
9/16/82 7a-3p	Operator	C-1	435	27.0	--	--	--	0.9	--	--	N.D.	0.4	0.2	N.D.	1
	Asst. Operator	D-1	265	13.0	--	--	--	5.9	--	--	0.2	2.3	1.2	1.4	6.1
	" "	D-2	183	8.8	--	--	--	2.3	--	--	N.D.	N.D.	1.2	N.D.	1.7
	Above Conveyor (ACF)	1-1	197	12.4	--	--	--	6.0	--	--	0.3	2.1	1.3	2.4	--
		-2	235	8.4	--	--	--	4.8	--	--	N.D.	N.D.	1.2	N.D.	--
	OSHA TWA				1000	400	500	200	500	500	410	200	200	100	

a. Methyl ethyl ketone.
b. Methyl isobutyl ketone
c. Tetrahydrofuran
d. Assuming additive effect and exposure to these levels for 8-hours.
e. Breakthough occurred.

Exposures in both areas were much lower than applicable standards (assuming the additive effect). In the pump room the exposures were of the order of 10 percent of allowable as a maximum. Exposures in the pak feed area were mostly of the order 1 to 2 percent with only one-half shift showing an exposure of 6 percent of allowable.

On 9/15/82, the pump room operator spent only 46 percent of the time pumping out drums. the rest of the time he performed other tasks including cleaning out the line strainer between one of the blend tanks and a storage tank and returning empty drums to a trailer. A total of 33 drums were handled in the pump room on that shift. On 9/16/82, two operators emptied drums. Twenty-seven drums were pumped out by operator E. Labels on the drums indicated the presence of MEK, acetone, toluene, xylene, methanol, and chlorinated species such as perchloroethylene and chlorothene. Methanol and chlorinated species were not detected on the samples used for qualitation. Most of the drums had bungs instead of lids. The operator was in the vicinity of the drums for about 90 minutes. Operator F emptied drums for the second part of the shift. A total of 36 drums were pumped out. Drum labels indicated the presence of acetone, methyl ethyl, ketone, THF, and paint solvent. The paint solvent may have been mostly toluene as operator F's exposure shows.

In the area of the pak and drum feed system, observations indicated that the operator is likely to have very low exposure as he spends most of his time in the control room. He leaves the control room occasionally at his option to activate the manual controls of the feed system during a reclaimable cycle to assure himself that the cycle proceeded normally. The assistant operator normally spends one-third of the time on the line removing or puncturing lids, preparing drums for feedings, and tightening lids on reclaimed drums. The rest of the time he or she is away from the sources of exposure using the fork lift truck to stack pallets in the warehouse; placing drums on conveyor No. 1; or returning reclaimed drums to the trailer.

ENGINEERING CONTROLS

Pump Room

General ventilation and, to a lesser extent, local exhaust ventilation are the primary controls used to suppress the levels of air contaminants in the pump room. In order to characterize the dilution system, an air balance was determined for the entire room using a rotating vane anenometer. The results of the balance are as follows.

Supply (cfm)		Exhaust (cfm)	
Ceiling diffusers	8,000	Exhaust air grills (400 ea.)	1,600
Additional air supply	6,000	Booth for viscous liquids	4,900
		East door	3,900
		North door	2,500
		Unaccounted losses, 5% of air supply	700
	14,000		13,600

Only the air supply from the diffusers was not measured. A design value of 1,000 cfm per diffuser was assumed. Since the volume of the room was approximately 56,000 cubic feet, the supply was such that 15 room changes per hour were obtained.

The booth in which viscous liquids are dumped was not used during the survey. Measurements indicated an average face velocity of 135 ft/min, which is adequate for this application. The velocity distribution was such that velocities almost double the average were obtained in the area of the booth where the dumping would occur.

The drum residue dumping mechanism contributes to reducing exposures by removing the assistant operator from the source of exposure. It contributes to a reduction in the need for manual lifting.

PAK AND DRUM FEED SYSTEM

The general dilution ventilation system in the area is the primary control contributing to reducing levels of contaminants. No measurements were made as the HNU direct reading instrument showed total levels to be much below those in the pump room. This was borne out by the air monitoring data. The design supply and exhaust air flow rates are reported in Figure 11.

The pak and drum feed system may be considered an advanced engineering control which, in addition to the ancillary controls, (CO_2 deluge system and overhead vent) effectively displace and protect the worker from potential fire and explosion hazards in addition to eliminating need for manual handling of drums.

WORK PRACTICES

In general, the two operators and the four assistant operators who were observed during the survey displayed skill and efficiency in the performance of their job duties. Grossly unsafe acts were not observed. Most of the workers have been working at this site for at least a few years. They were knowledgeable in interpreting the information on the drum labels - especially those items pertaining to toxicity, flammability, and compatibility. On one occasion, a pallet with three drums containing aniline, acetic-, and acid chloride was brought to the pump room. The assistant operator immediately recognized that these highly toxic and water reactive (acid chloride) wastes were not appropriate for pumping out in the pump room but rather should be dumped directly into the kiln through the automatic feed system.

The kiln operators are certified boiler operators. Since the kiln temperature should be maintained within narrow limits and the BTU contents of the wastes being burned are not known with a great deal of certainty, safe and efficient operation require skillful interpretation of instrument readings in the control room. In addition to manipulating the airflow through the kiln it appears that the operator coordinates the feedings of high, medium, and low BTU materials with the assistant operator to achieve an even rate of heat release. When such is not possible, auxiliary fuel oil is relied upon for temperature control. Even though the operator has the capability to initiate the drum reclaim cycle from the control room, the two operators, who were observed, frequently initiated such cycles using controls close to conveyor No. 4 in order to correct any unusual situations such as a drum catching on fire after being reclaimed. No such unusual episodes were observed during the survey. The operator also performs routine maintenance, such as replacement of thermocouples, as needed.

The assistant operators observed working the pak and drum feed system were skillful in the operation of the fork lift truck. No mishaps occurred. When on one occasion a drum slipped through the drum grab and a small spill occurred because the lid partially came off, the assistant operator skillfully recovered the drum, placed it on conveyor No. 1, and immediately proceeded to cover the spilled liquid with "Quick-Dry" - an absorbent clay used to clean up spills. When working to remove lids from drums and/or otherwise prepare them for disposal into the kiln, the assistant operators used spark-proof tools to remove the lids. By rapping the side of the drum they could tell what the level of material inside the drum was, and whether there was any free standing liquid in the drum. This helped the assistant operator to determine how the drum should be prepared as previously described. It was noted that the assistant operators frequently changed their work gloves.

The assistant operators working in the pump room also displayed skill in use of the fork lift truck. Spark-proof tools were used in removing the lids or bungs from the drums. It is required to attach the ground wire to the drum as soon as the aluminum probe is inserted. After the assistant operator has completed pumping out a batch of drums, he is required to clean the pump screen (in-line strainers). This task can be a significant source of exposure when improperly performed. On one occasion the task of cleaning the screens was observed at this site. The assistant operator donned rubber gloves, then vented the screen into a small bucket to relieve fluid pressure. The cover plate was removed and the screen, a perforated small bucket, was then cleaned using a "spatula." The coverplate was replaced and the screen pot checked for leaks using partial stream pressure. Cleaning of pumpable waste transfer lines with steam may occur before and after a batch of drums is pumped out, if there is concern that the wastes are incompatible.

CONCLUSIONS

The Chemolite hazardous waste incineration facility is a technically advanced and flexible system that routinely and effectively handles 55-gallon steel drums or small "paks." The routinely handled wastes contain organic solvents with OSHA PEL standards between 25 to 1,000 ppm. Special materials which represent a much more significant hazard are also disposed of using the bottle drop on a much less frequent basis and only in prepackaged small quantities not exceeding 5 gallons.

In addition to exposure to chemical species, other hazards for which controls exist at this site include the potential for injury from fire and explosion and manual handling of heavy objects. The hazard controls associated with the handling of pumpable wastes include: (1) Dilution and local exhaust ventilation which contribute to reducing ambient levels; (2) mechanical devices and motorized equipment for handling drums; (3) grounding devices to assure the nonoccurrence of sparks caused by flowing liquids; (4) work practices enforced to minimize contact with solvents and the potential for injury; (5) a facility design which conforms to best practices described in the National Electrical Code for hazardous locations and adopted by OSHA in 1972; and (6) use of protective clothing and equipment to minimize inhalation and skin exposures.

Exposures to solvents when handling nonpumpable wastes include: (1) Dilution ventilation; (2) work practices which effectively reduce the potential for the occurrence of episodes that may adversely affect worker safety and well being; (3) automation that is designed to displace the worker from sources of exposure and the potential for fire and explosion; and (4) a facility design which conforms to best practices set forth in the National Electrical Code for hazardous locations.

Monitoring by the company and by NIOSH have indicated that exposures were much lower than applicable OSHA standards. Grossly unsafe acts were not observed. It was obvious during the NIOSH survey that the workers were familiar with their job duties and performed them with skill. It can be concluded that the

Company's training and education programs are effective. It is noteworthy that in the 11-year-span since this facility has been in operation, only very minor injuries have occurred.

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