101-18

IN-DEPTH SURVEY REPORT:

CONTROL TECHNOLOGY FOR

CHEMICAL PROCESS UNIT OPERATIONS

AT

ICI AMERICAS INC.

BAYPORT, TEXAS

REPORT WRITTEN BY
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DATE OF REPORT
March 1985

REPORT NO 101-18B

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
Division of Physical Sciences and Engineering
Engineering Control Technology Branch
4676 Columbia Parkway
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PLANT SURVEYED	ICI Americas Inc Bayport, Texas
SIC CODE	2869
SURVEY DATE:	March 19-23, 1984
SURVEY CONDUCTED BY:	Phillip A. Froehlich Harold Van Wagenen Mazen Anastas James Woodfin
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CONTENTS

I. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational safety and health research. Located in the Department of Health and Human Services (formerly DHEW), it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, ECTB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of these completed studies include the foundry industry; various chemical manufacturing or processing operations, spray painting; and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury

II. PLANT AND PROCESS DESCRIPTION

DESCRIPTION

ICI Americas Inc., a subsidiary of one of the world's major chemical firms, Imperial Chemical Industries, PLC of England, operates a number of chemical processing sites in the United States from their Wilmington, Delaware headquarters. The Agricultural Chemicals and Chemical Divisions have separate processing installations on a 430-acre site located in the Bayport Industrial Park about 25 miles south of Houston, Texas and near the Johnson Space Center.

The Petrochemicals Division operates a new, continuous chemical processing facility, featuring state-of-the-art equipment and technology, to produce ethylene oxide (EO). In an adjacent continuous processing unit, derivatives are prepared from EO by (1) hydrolysis with water to form various glycols; (2) reaction with methanol, ethanol, and butanol to provide glycol ethers; and (3) reaction with ammonia to provide mono-, di-, and triethanolamines. Glycol ether acetates are prepared in a separate batch unit where acetic acid is reacted with selected glycol ethers.

The subject of this survey was the EO manufacturing unit. It has a nameplate capacity to produce 450 million pounds of EO annually. The major portion is reacted to ethylene glycols, utilized in the on-site production of the EO derivatives, or shipped by rail car to an ICI facility at New Castle, Delaware for condensation to various long chain ethoxylates. The remainder is available for merchant trade and is shipped in dedicated rail cars. The EO/derivatives complex was put on stream in September, 1981.

Of approximately 200 ICI site employees, about 115 are assigned to production units and the others to personnel, engineering, and purchasing departments. In addition, about 110 Brown and Root Corporation workers provide contract maintenance services. Both ICI and Brown and Root employees are non-union and work under the safety and occupational procedures and requirements of ICI. There has been very little turn-over of the workforce (including contract employees) since the Agricultural Chemicals Division plant was started in 1977.

PROCESSING

EO is produced by vapor phase oxidation of ethylene with oxygen at moderate pressure and temperature over a silver catalyst in accordance with the following exothermic reaction*.

$$\underset{\text{Ethylene}}{7\ H_2C = CH_2} + \underset{\text{Oxygen}}{6\ O_2} \xrightarrow{\text{Ag Catalyst}} \underset{\text{Ethylene oxide}}{6\ H_2C \underset{O}{-} CH_2} + 2\ CO_2 + 2\ H_2O$$

EO is recovered by water scrubbing as a fairly dilute solution. The scrubbed gas, virtually free of EO, is recompressed. A drag stream is diverted from the main flow through a CO_2 removal system where CO_2 reacts with potassium carbonate to form the bicarbonate. The bicarbonate solution, in turn, is regenerated with steam to free the CO_2. After return of the CO_2-free side stream, the main flow is topped up with ethylene and oxygen and recycled to the oxidizer.

*Kirk-Othmer, Encyclopedia of Chemical Technology, 1980, Volume 9, p. 441.

The dilute EO solution is steam stripped to enrich the concentration and the concentrated solution is then degassed to remove soluble gases. A portion of this solution is purified by distillation to remove water, formaldehyde, acetaldehyde, and other impurities. The essentially aldehyde-free, dry EO is sent to storage for rail car loading or put into a distribution system to feed various EO derivative processes within the facility. Because of its tendency to polymerize, EO is stored at 60°F maximum (chilled water refrigeration) for normally, no longer than one week.

The degassed solution not fed to the EO purification column is mixed with more water, heated in the glycol reaction system, and hydrolyzed to form a mixture of glycols. This is a time-temperature relationship. The dilute glycol solution is dehydrated and then distilled to separate mono, di, tri, and heavy glycol as products. The reaction kinetics result in approximately 90% mono, 9% di, and 0.9% triethylene glycol.

The Derivatives plant is a multipurpose unit in which, on a campaign basis, ethanolamines, glycol ethers (of methyl, ethyl, and butyl alcohols) are produced. The process is similar to the ethylene glycol process except that higher temperatures and longer residence times are employed. The chemistry is identical except for the substrate: ammonia, water, or ethyl, methyl, or butyl alcohols. Acetates of monoethyl ether glycol are produced in a separate batch unit. ICI is preparing to produce monoethyl butyl acetate. In response to toxicity concerns about monoethers, they are shifting production from the ethyl and methyl glycol ethers to less volatile acetates.

The raw materials, ethylene and oxygen, are supplied from underground pipe grids which supply the entire Houston area petrochemical complex. Multiple suppliers feed these pipe grids and cross connections between companies on the pipe grids can be made if an underground pipe is broken or torn up during excavation. The redundancy of supply sources is a major help in maintaining continuous operation. Because of this assured supply, the gases flow directly to the facility's continuous reactor without intermediate storage.

Although most of the newer EO facilities are oxygen based, older units use air as an oxygen source. The oxygen process is relatively simple as compared to an air based plant where there is a multiplicity of reactors in series and much more complicated turbo compressor equipment. The energy efficiency, capital cost, and the selectivity (or yield conversion) is also superior for oxygen based plants as compared to air based plants. Almost all new plants are oxygen based. Where pure oxygen is unavailable, the cost of constructing and operating an oxygen supply plant can favor the air oxidation process.

For each shift, there is one inside operator (who seldom leaves the control room) and two outside operators. Duties shared by the outside operators include EO rail car loading, quality control sampling, and patrolling, monitoring, and adjustment of utility, EO, and glycol reaction equipment. Under storage conditions some EO may flash, but a leak would be noticed primarily as a liquid stream. The four crews of operators work 12-hour shifts four successive days and then are off, but on call for replacement or emergency duties, for 4 days. After another 4-day duty tour, they have four days off with no recall requirements.

POTENTIAL HAZARDS

This survey was limited to control technology related to potential EO exposure as this is the the primary occupational health hazard in the unit surveyed. There is limited by-product formation of formaldehyde, acetaldehyde, vinyl chloride monomer, and oxalic acid, and process chemicals such as caustic and ethylene dichloride for which minimal occupational exposure may occur.

EO is a colorless gas, condensing at low temperatures to a mobile liquid. The normal boiling point is 10.4°C, and the vapor pressure at 20°C is 1093.5 mm Hg. The vapors are flammable and explosive; the Tag open cup flash point is below -112.5°C, the lower explosive limit in air is 3%, and the upper explosive limit is 100% by volume. It is miscible in all proportions with water, ether, alcohol, and most organic solvents. The closed cup flash point of a 1 percent solution of EO in water is 31°C.

On June 15, 1984, the OSHA permissible exposure limit (PEL) for EO was lowered from 50 ppm to 1 ppm as a time-weighted-average (TWA) concentration over an 8-hour period. The promulgation of a short-term exposure limit or a ceiling limit is currently unresolved, but OSHA rule making on the issue is continuing. Routes of entry are by inhalation, ingestion, and skin or eye contact. Acute exposure can result in eye irritation, corneal burn, skin burn (frostbite), irritation of the respiratory tract and lungs, and depression of the central nervous system. Nausea and vomiting may be delayed and may be followed by convulsive seizures and profound weakness of the extremities. Target organs are the eyes, blood, respiratory system, kidneys, liver, and the central nervous system. It is also a suspected carcinogen. Evidence concerning EO as a potential human carcinogen is presented in the NIOSH Current Intelligence Bulletin No. 35, dated May 22, 1981 (DHHS-NIOSH-Publication No. 81-130).

III. CONTROL TECHNOLOGY

INTRODUCTION - PRINCIPLES OF CONTROL

Occupational exposures can be controlled by the application of a number of well-known principles, including engineering measures, work practices, personal protection, and monitoring. These principles may be applied at or near the hazard source, to the general workplace environment, or at the point of occupational exposure to individuals. Controls applied at the source of the hazard include engineering measures (material substitution, process/equipment modification, isolation or automation, local ventilation) and work practices, these are generally the preferred and most effective means of control in terms of both occupational and environmental concerns Controls which may be applied to hazards that have escaped into the workplace environment include dilution ventilation, dust suppression, and housekeeping. Control measures may also be applied near individual workers, including the use of remote control rooms, isolation booths, supplied-air cabs, work practices, and personal protective equipment.

In general, a system comprised of the above control measures is required to provide worker protection during normal operating conditions, as well as under conditions of process upset, failure, and/or maintenance. Process and workplace monitoring devices, personal exposure monitoring, and medical monitoring are important mechanisms for providing feedback concerning effectiveness of the controls in use. Ongoing monitoring and maintenance of controls to insure proper use and operating conditions and the education and commitment of both workers and management to occupational health are also important ingredients of a complete, effective, and durable control system.

These principles of control apply to all situations, but their optimum application varies from case-to-case. The application of these principles is discussed below.

In the ICI EO/derivatives facility, occupational exposure is most likely for the workers involved with rail car loading, quality control sampling, facility equipment disassembly and decontamination, laboratory analysis, and control instrumentation repair and maintenance. Hazard control successfully employed by ICI will be discussed under the following component headings engineering controls, monitoring, and work practices.

ENGINEERING CONTROLS

Design Considerations

EO is explosive and hazardous on occupational exposure; therefore, production is conducted in an outdoor facility using tightly closed and highly automated process equipment. Because the processing is largely automated, operators are few in number and spend a substantial part of their time inside ventilated, enclosed control stations located away from the processing equipment.

The physical layout of the facility was planned with consideration of the prevailing wind which generally blows in a northwesterly direction. Therefore, EO storage and rail car loading are located at the northeast end of the plant. The manufacturing facilities are south of the tank farm, the laboratory and control rooms are south of these, and the general offices are in the southern most sector. Thus the concentration of personnel is away from sites where a break down could cause potential exposures.

ICI PLC, the parent company, uses hazard analysis as a tool to develop a balance between safety and cost. This plant was designed with this balance in mind. For instance, the size of the EO vessels was based on the probability that they may explode and attendant costs which would be incurred if they did. To deter such potential calamities, a large investment was made in redundant and instrumented controls to provide the current level protection. Further expenses are incurred to maintain a staff of highly trained instrument technicians to frequently trip test and troubleshoot the equipment to ensure that all are functioning properly.

Trip testing is done according to a written procedure. Plant personnel audit these procedures and, on a periodic basis, corporate auditors interview the technicians, examine historical data, witness actual trip testing, and review maintenance records. The concepts and the necessary hardware were an integral part of the design of the plant. The need to trip test a particular instrument monthly was developed and documented well before the plant was erected. Since the best people to write operating instructions are the people who use them, the actual procedure was written by the instrument foreman who would have to implement it, in conjunction with a hazard analyst and the instrument engineer who designed the system.

Another example of how hazard analysis affected the process design is in the selection of the method used to move the EO distillation column bottoms into the glycol reactor feed system. A minimum pressure must be achieved to conduct this operation. The conventional way is to elevate the distillation column sufficiently to install a pump and a spare beneath it. For such an installation, the base equipment cost includes a 200' high distillation column, two pumps, and the auxiliary equipment needed to meet the ICI standards for the level of protection required for such a pump. Additionally, the yearly costs of operating and maintaining the pump must be factored into the cost comparison. (During the design of the plant, an economic system to project average cost to present value was developed so that both operating costs and investment costs can be updated.)

An alternate approach is to increase the elevation of the column to provide the hydrostatic head necessary to gravity feed the still bottoms to the glycol reactor feed system. This would increase the foundation and the structural steel costs, however, it would avoid the costs of the pump and the related instrumentation and safety gear. At the level of accuracy of the cost estimating, costs of either choice were equivalent. Hazard analyses revealed two major ways of causing a catastrophic occurrence in an EO plant. 1) poor control over the oxygen and hydrocarbon ratios and 2) an EO pump problem. Both can lead to a fire which then propagates as an explosion. However, by selecting the second choice, the need for a pump was avoided and a safer and maintenance free operation was obtained at no added cost. The comment was made: "If you don't have something, it won't go wrong!"

Since processing risks are high, ICI has incorporated a proprietary High Integrity Protective System (HIPS) to protect the EO plant. Briefly, it monitors critical process parameters with three separate instrument loops. This is similar to the control philosophy on atomic submarines or power plants. If two of the three instrument loop monitors show that a critical control condition has drifted outside the control parameter, the HIPS system will automatically shut down oxygen feed to the plant. The trip initiators are intended: 1) to prevent detonatable mixtures of oxygen and hydrocarbons, 2) to protect equipment in the plant, and 3) prevent carry over of product (such as by foaming or relief to the atmosphere).

The HIPS monitors over 50 parameters, all in triplicate. It has the great advantage that an instrument or control feature can be tested on line without the need to defeat or short circuit a trip. To ensure that a channel is functioning from a sensing point in the process all the way through to the safety alert system in the control room, a technician using a prescribed procedure can trip and cause an instrument to think it is in trouble. When the alarm flashes on the panel in the control room, the channel is shown to be working effectively. This trip testing can be done on a routine basis without losing production, since it takes two out-of-range measurements to initiate a plant shutdown. Although very expensive, ICI management believes the HIPS setup met the objective of the hazard analysis made at the design stage in 1979 and has more than paid for itself in preventing production losses over the period the EO facility has been in operation. In over two years of operating experience, during which the HIPS components have been tested on a monthly basis, only five failures have occurred, none of which impacted on the safety of the plant.

In the event of a large leak in the oxygen supply line or a long term plant shutdown, all lines devoted to oxygen usage can be carefully flushed using high purity nitrogen. The oxygen supply pipe coming into the grounds has a main isolation valve at the entry area. Just downstream, a stainless steel tube joins this line and is used to inject nitrogen into the oxygen line after the main isolation valve is closed. The nitrogen purges the oxygen line on into the processing equipment.

Plant operations are monitored, but not computer controlled, on a Taylor Mod 3 electronic control system in the control room. This system collects information from the various control loops and displays it in an efficient manner on video screens. It presents tabulations and summaries of data on the process control parameters To supplement this analog system, an adjacent computer computes graphs, accounting reports, and summaries of all analytical results on the various intermediate and product streams for management perusal. Because of the hazard of runaway heat buildup, the temperature profiles for the reactors and related equipment are carefully monitored by the control room operators. They check over 300 temperature points in the plant EO reactors. The economics of the plant also can be monitored constantly: the amount of steam, ethylene, and oxygen being fed, and the amounts of product streams being produced. ICI has reduced the paper work required by older systems, data are recorded on cassettes and printouts so that the operators actually log very little written data.

Piping and Gasketing

As much as possible, all piping is welded. Where flanges are required to connect valves, nozzles, etc., written specifications and procedures for installation were prepared by Davy-McKee, the construction contractor. As an example, ANSI (American National Standards Institute), carbon steel, 600 psi, raised face, socketweld and buttweld flanges with Grafoil® gaskets are specified for EO service of greater than 1 percent concentration. Conformation to these piping specifications has resulted in generally trouble free operation.

Some of the original specifications have been modified and elaborated upon by ICI engineers based on actual experience. For instance, 1/16" Grafoil® grade GHE with 3/16" SS ring type gaskets were installed. Grafoil® is a Union Carbide product made of compressed carbon with a stainless steel mesh inside, compressed graphite is very brittle and must be backed up. However, ICI found ring type gaskets are very susceptible to flange blowouts from overpressure in the line. Therefore, the specification was changed to spiral wound Grafoil® 2. This has the Grafoil® between stainless steel rings. Spiral wound flange gasketing is more expensive than ring gaskets, but the stainless steel provides some resiliency to the flange. They can also be centered in the flange more easily so that the mating surfaces can be lined up properly. A typical 3-inch spiral wound gasket made by Sepco Flex Seal, Houston, Texas is identified as: 3", 150 API-601, 3/16" Grafoil®.

The torquing procedure used to tighten the flanges is as important as the choice of gaskets. Flange bolts are pulled to the specific tension values recommended by ANSI for each flange size. Figure 1 is a procedure used by Brown and Root for bolt tightening. ICI has recommended the following be incorporated also: 1) Bolting should be well lubricated with a suitable graphite oil. 2) A time period between each of the bolt tightening cycles (ten minutes suggested) should be allowed for initial relaxation. 3) The bolt tightening sequence should be staggered in a cross or star pattern at diametrically opposed bolt locations. 4) The torque at all flanged joints should be checked at least annually.

Flanges are 'sealed' with sheetmetal enclosures which have 'leak' or drain tubes that penetrate the insulation. If a flange leaks, liquids and vapors are captured by the enclosure and the technician is alerted to the flange seal failure by observing fluids draining from the 'leak' tubes. Hot equipment and flanges are heavily insulated not only to conserve energy, but also to eliminate heat sources which might ignite EO vapors should a major leak occur.

EO Sewer System

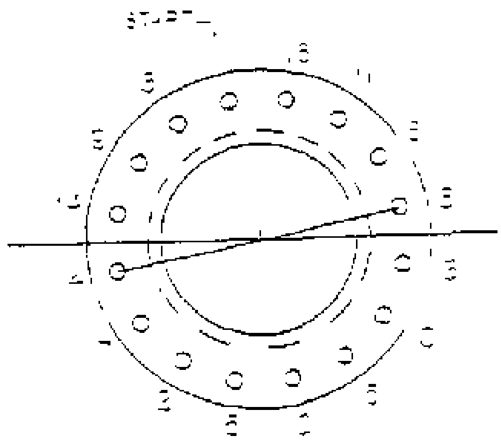
In addition to a normal surface water sewer system throughout the plant, there is a completely separate EO sewer system. Pump seal and flange emissions, drips, and spills of EO all go to this special sewer system which incorporates the following design features:

1. The pump and drain lines all contain gooseneck loops to prevent back flow.

BROWN AND ROOT PROCEDURE FOR BOLT TIGHTENING

1. The bolts shall be tightened incrementally to the stress required for hydrotest in a series of three cycles as per Table using a suitable torque wrench or other controlled torque device.

2. A staggered sequence shall be used to tighten bolting in each cycle in accordance with the following illustration



3. In any cycle, the entire sequence must be completed before the next cycle is started.

4. After Cycle 3 is completed, each bolt shall be checked for relaxation by re-torquing to the appropriate value for Cycle 3 shown in Table. Do not use a staggered sequence in this operation Experience has shown that best results are obtained by moving from bolt to adjacent bolt around the flange Continue this operation until all relaxation has stabilized and a uniform torque exists for each bolt.

TORQUE - FT LB

Bolt Diam.	Thread Per In.	Cycle 1 Stress 30 ksi	Cycle 2 Stress 45 ksi	Cycle 3 Stress 60 ksi	Maximum Stress 84 ksi
3/4	10	100	150	200	280
7/8	9	160	240	320	448
1	8	245	368	490	687
1-1/8	8	355	533	710	993
1-1/4	8	500	750	1,000	1,400
1-3/8	8	680	1,020	1,360	1,904
1-1/2	8	800	1,200	1,600	2,240
1-5/8	8	1,100	1,650	2,200	3,080
1-3/4	8	1,500	2,250	3,000	4,200
2	8	2,200	3,300	4,400	6,200

The above table applies to SA-193-B7 bolting

Figure 1 Flange Installation Instructions

2. The sumps (Figure 2) are automatically pumped out as the level control dictates (water may be added to keep pumps operating).

3. The sumps are continuously purged with nitrogen to maintain an inert blanket over the liquid in the sump.

4. The sump lids are checker plate lids. They are gasketed and all pipe entry points are welded. All other possible emission points in the sewer sump surface are sealed with mastic.

5. Each sump is vented to a high point away from other equipment. EO is a reactive chemical and disappears quickly in the atmosphere.

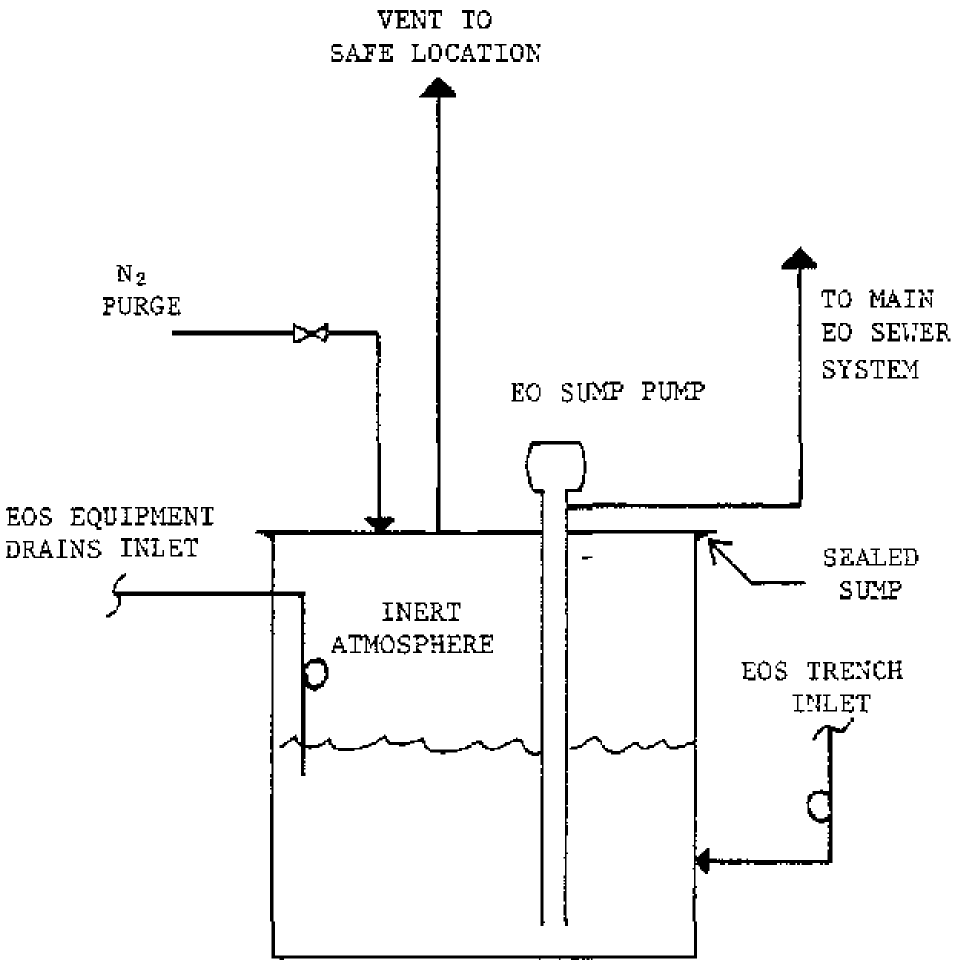
Pump Seals

Figure 3 illustrates mechanical seal arrangements, classified by positional arrangement. Double mechanical seals (bottom illustration) are used in this facility for dirty services, such as pumping salts and dirty fluids. In this arrangement, the two single seals are mounted back to back and the stationary seal members are at opposite ends of the seal chamber. The seal flush or buffer fluid is at a higher pressure than the pump discharge and is contained in a seal pot. Circulation is through Connection A and C. If the primary seal fails, the higher pressure seal flush will leak into the liquid being pumped. This can create a contamination problem depending on the seal flush fluid being employed.

Tandem mounted mechanical seals (Figure 3, middle drawing) are used on all the EO centrifugal pumps. In this arrangement, the two single mechanical seals are mounted so that both sealing elements face the outboard end of the seal chamber. The tandem seal flush fluid pressure is either lower than or equivalent to that of the pump discharge. If the primary seal fails, leakage is into the seal pot. If a secondary seal failure occurs, the seal flush normally leaks to the atmosphere, however, in the EO plant, pump seal leakage is piped to the EO sewer sump system. The chance for simultaneous failure of both the primary and secondary seals is very low. Failed seals are returned to the manufacturer for reworking.

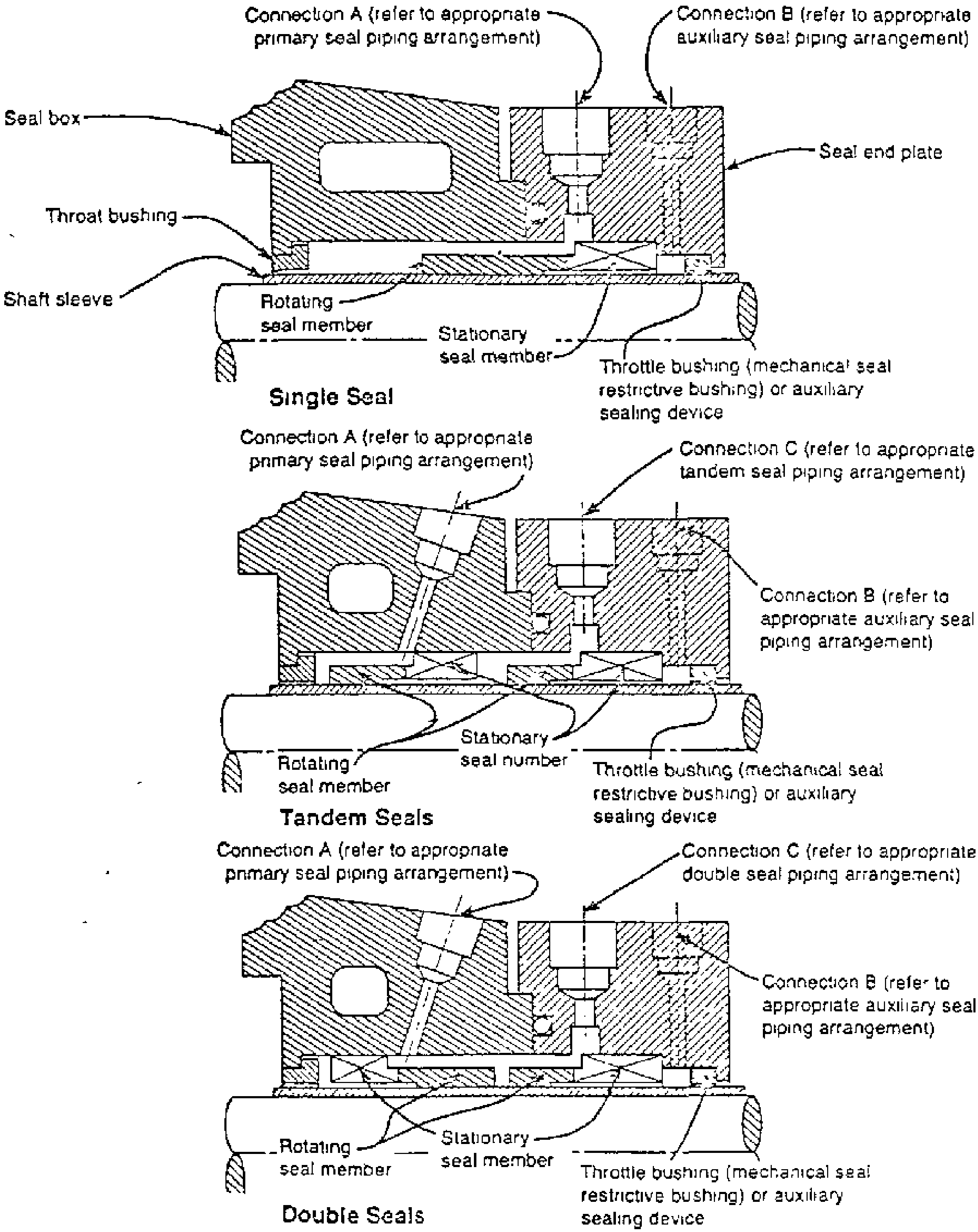
Sundyne centrifugal pumps are utilized for high pressure EO service. These are high speed (ca 12,000 rpm), vertical pumps which are sealed with John Crane tandem mounted, type 8 mechanical seals; a balanced, pusher type seal. The seal comprises a compressed carbon ring and a hardfaced surface. For the EO facility, the hardface surface is normally stainless steel treated with carborundum. The two O-rings are made of Kalrez® (duPont). The usual sealing materials supplied by Crane such as Viton® or polytetrafluoroethylene (PTFE) (the ICI equivalent is Fluon®) are not true elastomers, they deform and remain deformed. Also, PTFE will cold flow and assume the shape of the piece. Kalrez® is a true elastomer which has the chemical inertness of PTFE.

The facility uses the same general seal flush hookup for all centrifugal pumps: an API Standard 610 Plan 11 for the primary seals and a modified Plan 52 for the secondary seals. This consists of a bypass from the pump discharge which directs the fluid being pumped through a restricting orifice to Connection A (Figure 3, middle drawing) to provide lubrication and cooling for the seal.



1) Sump pump operates on automatic level control

Figure 2 EO Sump Schematic



NOTE These illustrations are typical and do not constitute any specific design

Figure 3. Mechanical Seal Configurations

Plan 52 utilizes Connection C to introduce a buffer fluid to the sealing chamber and another connection (not shown) to return it to the seal pot. The design of the seal flush circulation system provides not only a seal pot (reservoir) for the fluid but also a means of cooling the fluid to reduce the operating temperature of the seals. At this site, the seal flush is a 50 percent solution of ethylene glycol in water. As the flush fluid in the cavity between the primary and secondary seals heats up, the warmer fluid moves by convection into the seal pot. The return leg from the seal pot to the pump contains a cooling device. Depending on the service, it may be a water cooled coil or a section of finned tube which will dissipate some of the heat. The low velocity flow through the seal system will maintain the seal flush temperature under normal operating conditions.

At the top of the seal pot is a vent/overflow drain line which leads through a restriction orifice and an open valve to a vent header. This open line relieves overpressure due to seal failure or other causes without need for a relief valve on the seal pot. The header discharges to the EO sewer system through a dip tube submerged below the water surface in a sump. If EO leaks through the seal, it will vaporize into the seal pot and flow through the vent line to the EO sewer. The restriction orifice in the vent line confines the flow and enough back pressure is created to trip the pressure switch. This will flash an alarm in the control room to indicate a seal leak condition.

Spurious trips occurred during early production. These were thought to be seal failure, but were actually caused by overpressure of the nitrogen blanketing the sump system. The excessive pressure backed up through the dip tube, into the seal pot, and tripped the pressure alarm. The dip tube discharged into the sump several feet below surface and water displacement by the nitrogen was about equivalent to 5 psig. This situation was remedied by shortening the length of the tube extending below the surface of the water in the sump.

The instrumentation on the seal pots activates alarms in the control room when several conditions go out of a normal parameter: 1) pressure, both high pressure and high, high pressure; 2) level, and 3) temperature on the seals. The high pressure alarm is set to alarm at 5 psi, the high, high pressure alarm, actuated at 6 psi, is considered redundant and sets off an alarm only when tripped. When the high pressure alarm goes off in the control room, an operator goes out to investigate the pump. If there is a primary seal leak on an EO pump, the pot surface usually becomes very cold or even frozen. If the seal pot level drops, the trip signals an alarm in the control room. If the level goes too high, there is a HIPS trip. High temperature in the pump shaft bearings does not cause an immediate trip and alarm, but indicates probable future bearing failure. The instrumentation is periodically checked by the outside operator.

On a two day schedule, two millwrights check all rotating equipment in the facility, giving special attention to the bearings. IRD spike energy monitoring equipment is used to monitor vibrations in the rotating equipment. Using trend analysis from past data, ICI can predict about which month the rotating equipment should be taken out of service for overhaul. Predictions are made from a plot of the noise data, when an IRD reading of around 4 is reached, the equipment is shut down. Overhauls are performed as needed, rather than on a time-based schedule.

Decontamination of Pumps

The most frequent reason for pump decontamination are seal failures. In this case, it is necessary to clear EO from the pump case, the associated pipework within the isolations, the seal pot, and the seal cavity. The objective of decontamination is to flush out the normal contents of this equipment and replace it with nitrogen containing less than 1 ppm EO at atmospheric pressure before releasing the pump for maintenance.

The normal isolation used at this plant on EO or high pressure steam lines is a double block and bleed: two manual shutoff valves with a bleed valve between them. This redundancy ensures that the equipment is isolated from the process and also provides an indicator as to whether or not either of the block valves is leaking. This arrangement also provides valves for the introduction of purging materials for decontamination.

Typically, decontamination has been performed by connecting the required utility with tubing to the bleed valve of the double block and bleed on the suction side of the pump. Tubing connections were also made from the discharge bleed valve to the EO sump. No specific physical arrangement was employed and technicians made flex hose connections on a spot basis.

First, the material between the isolations was flushed out with water to clear as much EO from the pump as possible. Even though the tubing was inserted fairly deeply into the sewer, excessive EO vapors could be emitted from the sewer; workers were cautioned to stay away from that area.

Second, the pump was flushed with low pressure steam, or steam condensate. This is the most important part of the decontamination. There are two ways of removing the EO: one is to pressurize the system with cold water and absorb or scrub out the EO, the other is to heat it up at a low pressure, vaporize it, and sweep it away. Steam and condensate were put through the pump for varying lengths of time, up to 6 hours. This may have been longer than was necessary to decontaminate the parts in which there was flow, but there were various dead spaces in the system that did not become part of the circulation. Enough time was allowed for the heat to spread throughout the pipework and vaporize all of the EO. Also, heat tends to break up EO polymers which may form in the system so that these can be flushed out.

Finally, nitrogen was used to force out the contaminated condensate and clear the pump in preparation for removing it and to provide a gas phase medium for testing for EO contamination. A high flow rate was used initially to sweep out the pump, then it was reduced to a trickle flow to get as objective a measure of EO contamination as possible, using Gastech detection tubes.

Although the temperature of the condensate is about 250°F, hot surfaces have not been a major problem for maintenance personnel. Typically, the pump is decontaminated during the night shift and completed by two or three o'clock in the morning. It has several hours to cool off before the maintenance crew arrives on the day shift.

At the time of the survey, this decontamination method was being revised, although no employee had been grossly overexposed, improvements are desirable. A new, 26-point procedure has been written and final approval status is anticipated shortly. Many of the concepts used to develop the proposed decontamination method were discussed with the NIOSH research team.

In addition to reducing occupational exposure to EO during decontamination, the system has economic advantages . Depending on the geometry of the specific pump, 60 to 1800 pounds of EO is contained within the isolations. This has been lost in the EO sump, but with the proposed procedure, it can be recovered by diversion to the EO stripper feed line. The energy value of the condensate may also be recovered by returning the condensate to the process. (It is estimated that each pump will be decontaminated between 1.5 and 2.5 times a year, based on past performance.)

A typical installation for aqueous EO is a Sundyne vertical, centrifugal pump operating at about 12,000 rpm with 50 to 100 psi suction and 600 psi discharge. It includes a kick-back flow control valve (FCV) using an automatic flow controller, that allows the pump to maintain a constant minimum flow. If a kick-back situation occurs, e.g. the downstream piping is blocked, the kick-back valve opens to allow a portion of the pump discharge to be returned to the intake side. A kick-back cooler (a fairly standard item in this plant) is also in the circuit. The cooler is to assure that the heat of pumping is removed from the loop, to prevent the temperature of the recirculating fluid from increasing to the point at which the EO will polymerize. Figure 4 is a sketch of the set-up and illustrates the changes proposed for improved decontamination.

Manifold A will be constructed having three small (ca. 3/4-inch) valves and check valves at one end for connecting the utilities (water, condensate, and nitrogen) and stainless flex hoses at the other end for connection to the pump and to the seal pot so that both can be flushed at the same time (Connections 1 and 2). For the aqueous pumps, a third flex hose is connected to the high point of the kick-back system (Connection 3) to eliminate an otherwise dead leg (a shutoff is provided for this flex hose when a non-aqueous pump is decontaminated). Manifold B will be constructed with three flex hoses at one end for connection to the pump suction low point and the seal pot drains and (for aqueous pumps) the pump discharge (Connections 4, 5, and 6, respectively). At the other end is a block valve and a pipe union for connection to the EO stripper feed line (Connection 7). To simplify access to the EO stripper feed line, a central drop will be hard piped from this line to the pump alley and a flex hose will be used to reach the desired pump. Also, a cart will be designed to store and transport the manifolds and attendant equipment to the desired location.

With this set-up, aqueous EO can be forced from the top of the pump system (both kick-back loop and seal pot) and drained from the low points. Decontamination is accomplished by first isolating the pump at the double block and bleeds in the pump suction (1) and discharge lines (6) and the seal pot vent line from the vent header (8) to prevent wash from entering the header. After the two manifolds are connected as described above, the pump system is sequentially flushed with the three services fifteen minutes with water, thirty minutes with 130# condensate, and sufficiently long with

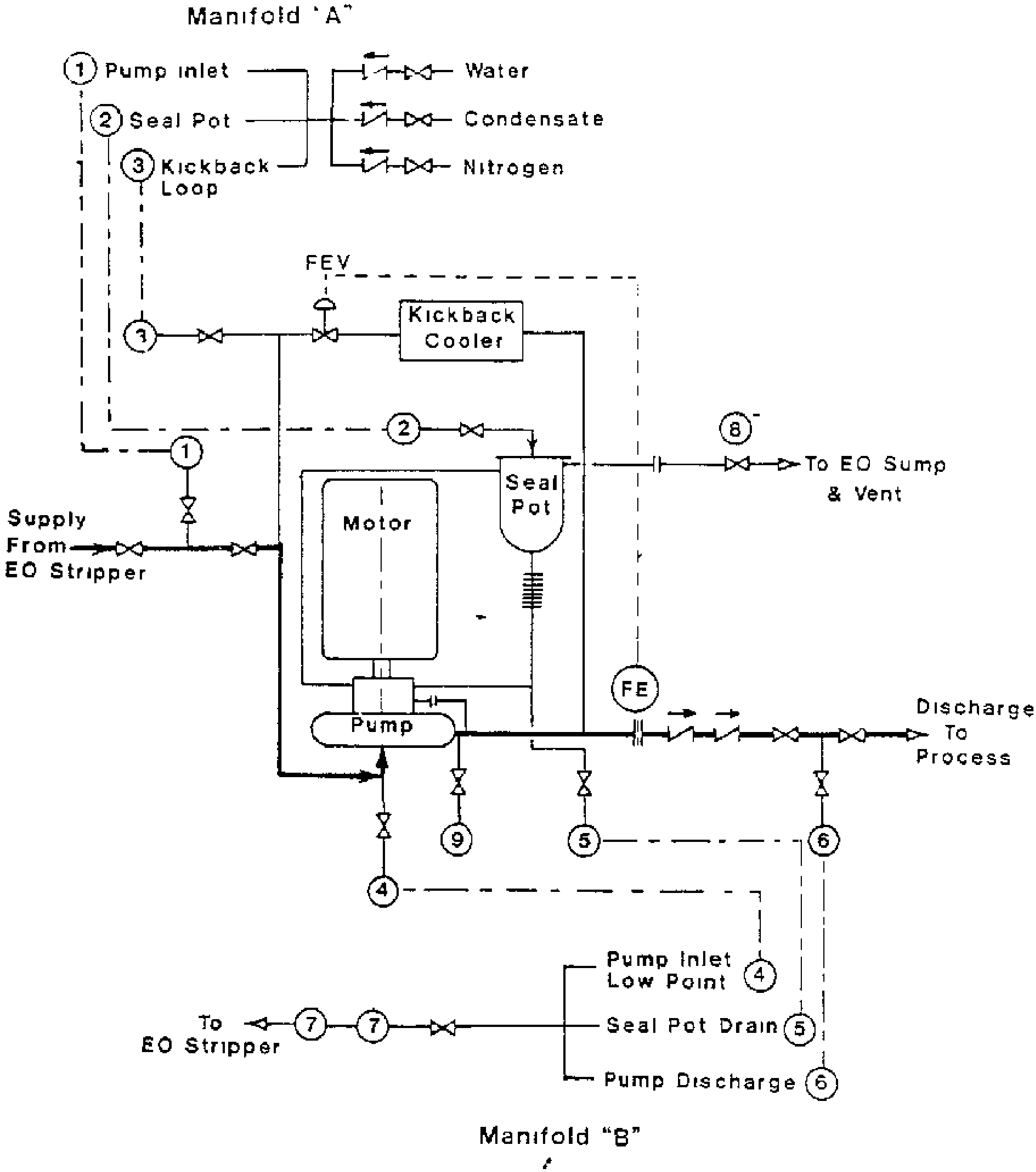


Figure 4. Proposed Decontamination Set-Up

nitrogen to force the liquid from the system. At this point, the flow to the EO stripper feed header is cut off (7) and the valve in the seal pot vent line (8) is opened so that the nitrogen is purged to the EO sewer for thirty minutes. These are arbitrary times that will be adjusted appropriately with experience. The nitrogen flow is then reduced to a minimum and the gas is sampled at the pump case drain (9) with a Gastech detector tube. If the EO content is greater than 1 ppm, decontamination is repeated, otherwise, the supply hoses are depressured and disconnected and the pump is turned over to maintenance for removal and repair. During the hot condensate flush, a technician is required to probe the entire system to ensure that all pipe work is hot. Cold spots would indicate blockage or poor circulation and an alternate method of flushing may be necessary. When purging with nitrogen, slugging will occur in the hoses when most of the liquid is forced from the system; the resultant jumping of the flex hose will indicate when this stage is reached. The gas flow should then be directed to the EO sewer in order not to upset the EO stripper. Blowing is continued to sweep out any vaporized EO remaining in the system.

Instrument Decontamination

ICI is currently investigating means to further minimize exposure during instrument maintenance. This is a difficult problem because the instruments are so widely dispersed that the cost of applying engineering controls to provide a uniformly low level exposure would be prohibitive.

If an instrument must be removed from the process for recalibration or repair, it may be undesirable to shut down and decontaminate the entire plant. Two alternatives exist. 1) provide the means to decontaminate the instrument in place or 2) protect the instrument technician from the short term exposure using personal protective equipment-and also provide a centralized decontamination facility for such events. If decontamination can be done in place, there is no need to carry the instrument back to the central decontamination facility. It is anticipated that on a case-by-case basis the decision will be made to accept a dead instrument until the campaign is completed, then decontaminate and fix it. Or, if it is truly indispensable, e.g., an input to the control system, the necessary line connections will be installed so that condensate and nitrogen can be flushed through the instrument while the process remains in line. There is usually enough diversity in the instrumentation system that a loop can be run on manual operation (while carefully watching the other control parameters) long enough to decontaminate that instrument and install a warehouse spare in its place. Subsequently, the decontaminated instrument can be repaired in the shop and then put into the warehouse stock. A third alternative is to provide an installed spare instrument, but this is even more expensive than providing for the ability to decontaminate the control instrument.

Where instruments which require frequent maintenance are concentrated in a relatively small area, the expenses for installing engineering controls can be justified. In one area in the EO derivatives facility product change-overs occur on a weekly or monthly basis. The need to check or recalibrate the instruments as required for the different products creates a large number of potential exposures per year and an engineering hardware solution is justified ICI proposes to modify the installation so as to decontaminate the instruments and the process pipe at the same time. An instrument header will be installed so that the sensing cells can be flushed with nitrogen to a common header to the EO drain system. At the end of a campaign, when the pipework is emptied by nitrogen pressure, the instruments will also be cleared. Both control valves and the check valves will be opened following a prescribed procedure and the lines will be blown directly to the EO sewer system. After washing with condensate the lines will be blown dry with nitrogen. The cleanout will be relatively easy because the pipes are of small diameter and the volume of EO held up in the system is relatively small. The purpose is to prevent EO polymers from forming due to contact with water or rust. Experience has shown that when metal surfaces are cleaned and passivated (washed with hot condensate, then blown dry with nitrogen), the probability of having polymer cause a plug, a jammed control valve, or a valve to stick partially open is minimized.

Two general principles incorporated in the design are to make the system as free draining as possible and to get as close as practicable. In other words, the installation will be made so that flushing is always in a downward direction and the instrument sensing cells are mounted proximate to the metering device. For instance, differential pressure cells are mounted as close to the orifice taps as possible to minimize the length of the impulse lines.

Pressure Relief Systems

Because the original design of the equipment allowed a comfortable margin between the normal operating pressure and the relief valve set pressures, the plant has not had a relief valve-open during plant operation. For this reason, the relief valves vent directly to the atmosphere and are not put into a collector system. The relief valves have carbon steel bodies and stainless trim in the seats. Each valve in service is removed, tested, and recertified as to lift pressure at least every two years. All parts of the plant which are on line continuously have dual relief valves and isolation systems so that a relief valve is always available for switching when necessary. Flammable vapor and EO relief valves have tail pipe systems for the addition of snuffing steam to prevent the venting of explosive mixtures.

The EPA permit issued when the plant was constructed limited the maximum EO concentration in any vent gas stream to 50 ppm. There are two main points at which the process routinely vents to the atmosphere. One is from the EO purification column where the small load of non-condensables which accompany the EO feed to this column is purged. Nitrogen is added to the column to combine with the non-condensables so that the pressure control valve is activated. The nitrogen and non-condensables pass through the valve into an EO scrubber before release to the atmosphere. The only time the discharge from the column, scrubber, and vent approaches 50 ppm EO level is during a plant startup, about once a year. The other vent to the atmosphere is off the EO rail car vent scrubber. When rail cars are pressurized with nitrogen, up to 10 cfm of nitrogen is blown back through the supply line to empty the car of any heel. This can overload the scrubber and cause EO to escape through the vent. The vent is connected to a stack that is 100 feet high, 20 inches in diameter, and has a corona discharge shield at the top to prevent the accumulation of a static charge. These vents are quite distant from normal work areas and present minimal potential for occupational exposure.

Rail Car Loading

EO is shipped in dedicated rail cars, usually 20,000 gallon cars containing 170-190,000 pounds EO. They are filled and shipped under a nitrogen pad at 60 psig. The nitrogen provides a nonflammable vapor space above the EO liquid in the car. The rail cars should be returned by customers empty and under 30 psig, however, many have a small heel of EO remaining. On return, the car is first weighed to determine amount of EO "heel" and the air space contents are tested for oxygen content.

Nitrogen is used to sweep air from the various transfer and venting lines and provide an inert pad for the storage tanks and rail cars. All aspects of EO tank car loading are detailed in a written procedure.

After the car is spotted at the loading station and grounded, both vapor recovery and loading arms are attached. These overhead arms are provided with OPW Dover Kamvalok® dry (dripless) disconnects and the mating parts are affixed to the tank car fittings with stainless steel pipe nipples and ells so that the coupling or adaptor face upward. Threaded fittings are wrapped with PTFE tape to provide tight, leakproof connections.

Nitrogen is introduced to the car through the vapor recovery arm until the pressure reaches 60 psig. This pressure is maintained while the lines are checked for leaks and then reduced to 30 psig by release through the loading arm to a knockout pot and a vent stack. This pressure/depressure step also empties the car of any residual EO 'heel'. The venting gas is sampled for oxygen content, if the level is over 1 percent, the car is purged with nitrogen until the oxygen content is 1 percent or less at 30 psig. About 5,000 pounds of certified EO is pumped into the car, then some of the car contents are pushed into the knockout pot and sampled. If the sample indicates contamination, the fluid in the car is emptied, and another 5,000 flush added and sampled. The contaminated flush is pumped to a hold tank and from there fed to the ethylene glycol unit.

When loading is approved, EO is pumped into the car through a totalizing meter which stops the flow after the preset volume has been delivered. A final sample is obtained by pushing an aliquot of the car contents into the knockout pot with nitrogen. Nitrogen is then blown through the loading arm to pressurize the car to 50 psig while at the same time displacing the liquid from the loading arm and associated pipe work. Finally, the rail car loading valve(s) are closed and nitrogen is blown through the vapor recovery arm to force any liquid out of that system and to increase the car pressure to 60 psig. Then the car is isolated with the vapor line valve on the car and the pressure in the loading arm system is reduced to 15 psig through the knockout pot vent. Finally, the loading arm and vent spool pieces are vented to a scrubbing pot on the ground level and removed.

A rail car checklist is filled out and signed by the loader and the panelman (in the control room) for each shipment. It includes checking yes/no answers to such things as placement of car chocks, visible damage to car, inspection date expiration, removal of spool pieces and railing guard, and sealing and placarding of the car. Data recorded includes car number, EO lot number, EO sample numbers, oxygen content, volume of EO loaded, final car pressure, and seal number. Although some of this information is for accounting purposes, many of the items listed serve as reminders to the operator for the proper loading procedure.

The following instrumentation associated with the loading operation will activate trips which stop the EO flow to the loading area·

Trip Title	Function
High Level in EO Vent Knockout Drum	A high liquid level in the knockout drum can lead to carryover to the rail car or interfere with the flow of nitrogen. This trip also prevents the back flow of liquids into the nitrogen system.
Rail Car Combustibles	This sensor is located below the rail car and monitors emission of combustible gases from the loading area.
Rail Car High Temperature	A UV heat and flame detector is used to monitor the rail car loading area.
Rail Car Ground	This assures the integrity of the rail car grounding circuit during the loading operation.
Flow Totalizer	The flow is shut off when the total reaches a set point value to prevent overfilling a rail car.

Two other trips are associated with the nitrogen supply system to prevent the backflow of EO into the plant nitrogen system and to assure sufficient nitrogen volume for padding in case the plant nitrogen flow is interrupted.

Quality Control Sampling

A great deal of planning and design have gone into minimizing occupational exposure during sampling. About eight to ten EO-containing samples are taken each day. Sampling circuits are installed in lines across pumps, control valves, or between vessels where the pressure differential creates sufficient flow to obtain representative samples. At these places, closed loop piping is installed and 1/4-inch diameter lines with 1/4-inch valves provide a secondary loop in which the sampling bombs are inserted. The nominally one-half to one liter bombs are provided with internal dip tubes so that they can not be completely filled, thus adequate head space is provided for expansion if the liquid is warmed. The sample bombs are kept in the laboratory and are specially coded and labeled. The bombs are constructed with instrument class valves which have stainless steel bellow-seals to prevent leakage through packing glands. The bellows are quite fragile and since each valve costs $250, safe alternatives are being sought.

Sampling is performed in accordance to written procedures which also specify the personal protective equipment required. The procedures vary depending on the material being sampled. In general, the operator starts flow through the sampling loop about 20 minutes before inserting the empty bomb in the secondary loop. The bomb is first pressurized with nitrogen to ensure that the connections are not leaking and to purge the bomb of residual materials. After the bomb is filled, the valves are closed and the bomb is pressurized to 60 psig with nitrogen. Before the sealed bomb is removed, the contents of tubing leading to both ends of the bomb are blown back into the sample loop with nitrogen. The filled sample bomb is carefully conveyed to the laboratory. Laboratory handling is under ventilated hoods and also in accordance with detailed written procedures

MONITORING

In additional to the HIPS, two other monitoring systems are installed at this facility. These are for detection and automatic action in event of: (1) excessive leakage from lines feeding ethylene to the continuous reactor, and (2) fugitive emissions from within the facility.

The flammable vapor monitoring system is an explosion preventive system for immediately suppressing gross emissions of ethylene and/or ethylene oxide as gases. Sensors are installed at appropriate locations. The system alerts the technicians to manually trip the deluge system and take other appropriate actions if necessary. For both ethylene and ethylene oxide the LEL is in the range of 3.0-3.5 percent gas in air mixture.

Fugitive Emission Monitoring System (FEMS)

The Texas Air Control Board requires monitoring of fugitive emissions from the plant because it is in a non-attainment area for photo-reactive pollutants; therefore, ICI must demonstrate that it is running a tight plant. Knowing they had to provide an expensive monitoring system for fugitive emissions, ICI designed it for occupational health considerations as well. Forty-one points are monitored where fugitive emissions are both possible and must be guarded against. Typical sampling point locations are at the loading station, at the storage tank and process sampling units, on top of the storage tanks, near pump seals, etc. An alarm horn sounds and a panel light flashes in the control room when the EO level exceeds 10 ppm. These alarms are also logged in by the control room terminal.

The FEMS is useful not only from the industrial hygiene standpoint but also as a maintenance tool. Although there have been few leaks, the system has tripped twice so far when flanges have opened up

The FEMS is composed of one Applied Automation GC (gas chromatography) microprocessor based programmer and 2 GC's. The GC's monitor 20 and 21 sample points, respectively, in two separate analyzer houses. Samples are drawn continuously through stainless steel tubing by an eductor system which produces about 5" Hg negative pressure. The sampling lines from the field to the analyzers are typically about 200 feet long, but vary, the longest is about 320 feet. The flow rate through the tubing is controlled and the variation in the length of the sampling lines is compensated for by creating a higher flow rate for the sampling points which are at a greater distance from the respective analyzer houses. Because they are under negative pressure, it is important that the sampling line tubing and connections from the sensing points to the analyzer houses are leak tight.

As illustrated in Figure 5, a filter is installed at the sampling point to keep dust and dirt out of the sampling line. In the analyzer house one eductor pulls samples for a group of up to four sampling point units. A Whitey® sample bomb with a 1/16" diameter capillary tube is attached to each sampling line to form a sample reservoir. Samples for analysis are drawn from these bombs by means of a pump which operates at a 20" Hg vacuum. When an analysis cycle is initiated, a solenoid valve opens and the sample is pulled from the bomb through the sample pump. The sample is directed through a rotometer (to show flow is occurring) and a filter. About 10-15 seconds later, a sample shutoff is initiated which allows the sample loop to come to atmospheric pressure, then the sample is injected into the GC analyzer. When the shutoff occurs, the pressure in the bomb is about 20" Hg vacuum. While analyses are made for the other 19 or 20 points (about 20 minutes), the bomb will draw in a sample through the capillary until the pressure rises to 5" Hg vacuum.

For analysis, the sample passes through a drying column to remove the water and heavy ends, through a Poropack gas chromatographic column, and then passed through a flame ionization detector (FID). This is done automatically on the basis of one sample per minute. The range of EO detection is from 300 ppm ± 10 ppm down to 0.5 ppm.

Several ICI management personnel noted that they have observed ambient monitoring systems where improper installation resulted in false sample analyses. Frequently, this occurred when the eductor was placed downstream from the analyzer. As a result, when sample cutoff was performed, the eductor evacuated the sample loop and left very little in it for analysis. It is essential that the portion of the sample loop just upstream of the analyzer be isolated and equalized to atmospheric pressure before the sample is injected.

The analytical data from all of the FEMS sensing points are recorded on cassette tapes. It is possible to report each sampling result, however, the unit is now programmed to calculate a TWA reading from the approximately 24 readings taken for each sensing point during an 8-hour period. Because of the limited memory in the microcomputer, information other than the 8-hour averaged value is then cleared from the system. Recorded values are printed at a terminal in the central control room. If any reading exceeds the set alarm level, both an audible alarm and panel light are activated to identify the area, and the sampling point can be located from the terminal. The current set point for the FEMS is 10 ppm but it can be set as low as 1 ppm. When the FEMS indicates an emission problem, technicians check the vicinity of the sampling point to determine the cause and repair needs. A portable Organic Vapor Analyzer (OVA) made by Foxboro is used to help locate the source of the emissions.

The GC analyzer is calibrated at 1/2 the alarm level (5 ppm EO). Plastic bags, filled with a known 5 ppm EO gas concentration, are tied around the various emission sampling points so that samples are pulled from the bags. By this means, a properly calibrated system will confirm the 5 ppm concentration in the bags. In addition, 1 ppm and 20 ppm standard samples are used occasionally to check the linearity of the response.

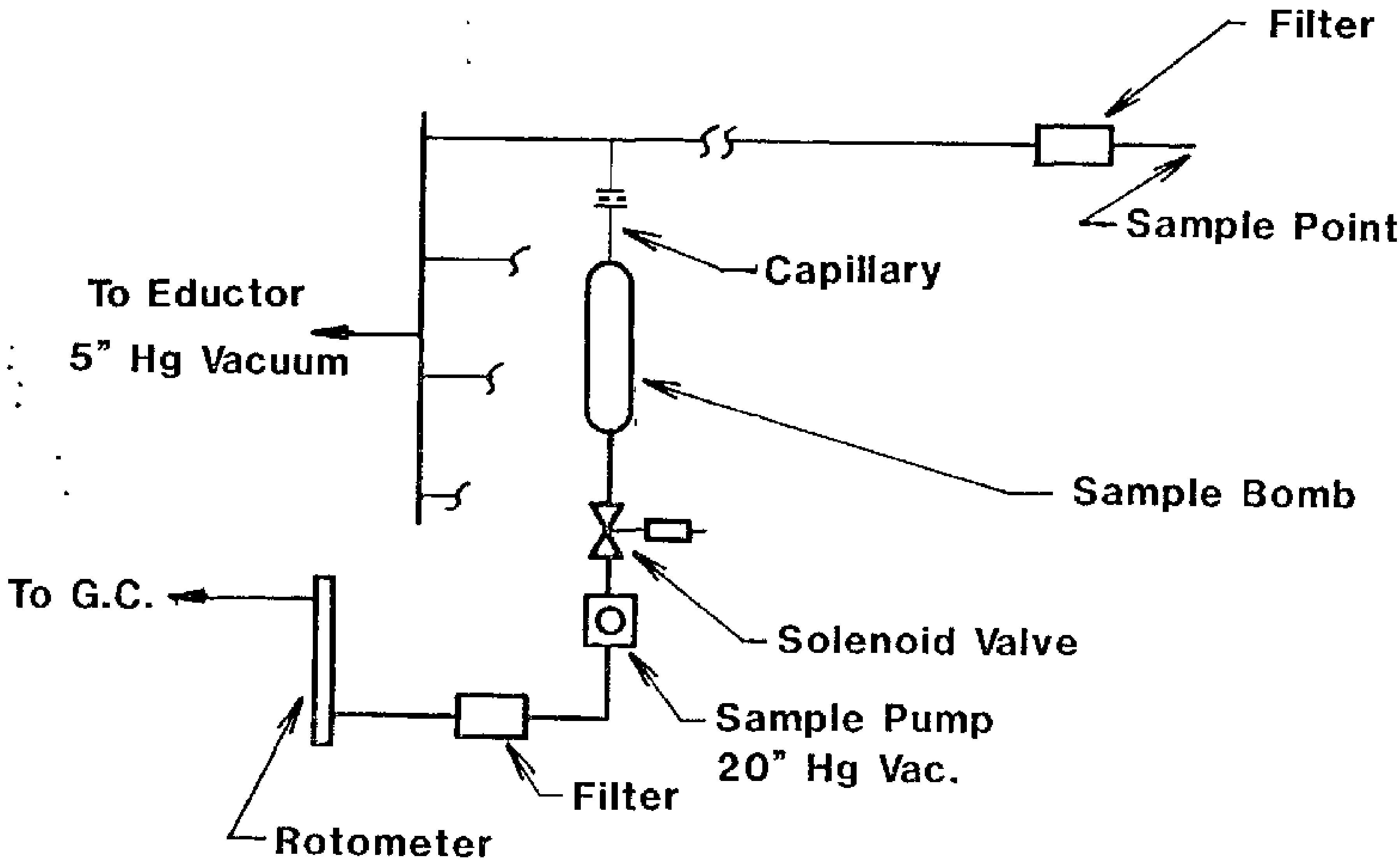


Figure 5   Schematic of FLMS Sampling System

The FEMS is included in the written preventive maintenance program used at this facility. The components are inspected daily by a contract instrument mechanic to ensure that the pumps are running and that analyses are being made and entered. Every two weeks a calibration standard check is made on the system to confirm that the response factors are the same. The Teflon® backed neoprene diaphragm in the piston-type sampling pump, becomes torn, probably due to the mechanical stress generated by the pump action rather than reaction with EO. To preclude pump failure, the diaphragms are replaced monthly. The sensor points are also checked on a regular schedule by the plastic bag method.

If there are no GC problems, general maintenance for the two FEMS systems takes not more that 10 hours per month. Because they are operating at such high sensitivity and flow rates, the analyzers occasionally show erratic responses. Frequently this is caused by compounds emitted from chemical processing plants adjacent to the ICI facility entering the system. No maintenance is performed on the microprocessor. This and the sampling transport equipment (except for the pump diaphragms) are essentially trouble-free.

It took about a year to solve all the problems and get the FEMS operation in accordance with the ICI requirements. Presently, the FEMS is operational at least 95% of the time, including downtime for testing and calibration. The experience at this site is that dedicated and skilled people are required to put the systems into acceptable and effective operation, and to maintain them at high effectiveness over time. Trouble shooting is not routine; there are many facets to the overall operation of this analytical warning system -- mechanical, electronic, computer, software, etc. 'Cookbook' instructions or formulations can not be followed to install and maintain a FEMS, installation and maintenance personnel must know the field thoroughly through hands-on experience and must be able to train others.

The following 1981 costs were estimated by the instrument maintenance contractor. Each of the two analyzer houses, including the structure, all the sampling equipment within the house, and the GC analytical equipment, cost about $40,000. Utilities (including field tubing, sensing elements, etc.) are about $20,000 per house. The FEMS programmer for both systems cost $10,000 and includes the microprocessor and software. The additional development costs after the installation were about $10,000 for the two systems. The total estimate for the present 41-point emission point FEMS installation is about $135,000. The maintenance cost for system operation is 10 x $30/hr or $300/month labor. To that must be added costs of carrier gases, air, hydrogen to analyzers, paper, etc.

Medical Monitoring

The Bayport site has a comprehensive medical program. The facilities are staffed by a part-time contract physician and a full-time registered nurse. The Health Services Supervisor is also a registered nurse. Medical policies are basically established by corporate management. Medical records are entered into a computer at the Corporate Office and may be integrated with industrial hygiene and production data at a later date.

All employees must pass a preemployment physical examination. The policy of the Medical Department is to not recommend for employment persons who have pre-existing physical conditions which may later cause problems for either the potential employee or the company.

In addition to the normal body function tests performed by the physician, the preemployment examination includes: blood and urine tests, eye examination and vision testing, inner ear inspection and audiometric testing, an EKG, a pulmonary functions test, and a chest x-ray. An extensive medical history is elicited which includes personal family history, illnesses, exercise and eating habits, chemical exposures, and other previous problems of the employee. The ICI management believes that a most important part of the health assessment is past history information and emphasize to employees that this applies to both work and off-work situations, as well as close family history. The history forms are designed for computer data entry.

Once hired, employees receive an annual examination almost identical to the preemployment physical with the exception of the chest x-ray which is given every three years. Inoculation records are also reviewed at that time. Retirees may currently receive similar medical health exams at no charge.

The initial preemployment physical exam is mandatory for obtaining a position with ICI. An employee could refuse further testing thereafter, however, no refusals have occurred as yet. If there were such a protest, it would be entered in the medical records to satisfy corporate requirements.

The average noise level to which a worker is exposed is also included with the audiometric test results. The Industrial Hygiene Department performs an annual audit of the noise level in the facility for each job category and also provides information as to the kind of hearing protection the worker wears, if any. This information is entered into the computer and stored.

Sinus infection is common in the Houston area and can affect a pulmonary functions test, therefore, a short history section (smoking experience, chemical exposures, allergies, etc.) is included in the pulmonary function test report of the annual physical exam. Changes in the lungs caused by such things as smoking, exposure to allergens, dust either in the work or home environment, etc., can be detected more readily by a pulmonary function test than on x-ray. The medical field, in general, has turned away from the annual chest x-ray, however, the latter is useful for detecting such things as a massive scar in the chest cavity, or an enlarged heart.

An EKG is performed during the preemployment physical exam and is repeated every one to five years based on age. It is normally given annually at this site because little additional time or expense is involved. The output of the computerized EKG machine is transmitted by telephone to California, examined there, and a report is returned within three minutes, if irregularities are noted, a cardiologist in Berkeley will review the printout, on request, and promptly forward an opinion.

EO is known to affect the liver and kidneys (the filtering systems) and the blood producing organs (marrow of the bone). To determine whether such changes might occur on the job, additional lab blood work is performed for the EO facility technicians, including a CBC with a differential (counting some of the blood platelets). If overexposed to EO, some of the blood producing mechanisms could be destroyed and leukemia might develop. White blood cell and the platelet counts can indicate if the individual is being affected. In the Chemscreen or the Smac test, there are about 26 different tests which determine liver function, kidney function, and the fat levels in the blood. Also, a chest x-ray is repeated every three years. The blood testing was originally scheduled for every six months. Since no trends in the blood work test results, up or down, have been observed, blood testing is now on a yearly basis. Based on this experience and reports in the medical literature, the company believes that blood tests every six months are unwarranted because of the risk of causing an infection whenever the body is entered.

Workers in the EO facilities are required to wear respirators in certain situations. The physician is required to complete a clearance form which states the individual is approved to wear a respirator before they can be used. This is a requirement for the preemployment physical exam and also the following annual exams. If the worker has a problem, the physician may specify which type of respirator can be worn, or whether the individual should be transferred to a job requiring no respirator usage. Copies of the respiratory clearance go to the employee, the file, the Industrial Hygiene Dept., the facility management, and corporate headquarters. In the Industrial Hygiene Dept., this clearance is added to the employee's file concerning respiratory facial fit test information. If a facility operator were to be shifted from one job to another because of lack of respirator clearance, there would probably be no change in pay. This site has a rather youthful workforce and the issue has not yet occurred.

Because EO is a suspected carcinogen, the workers must have special medical clearance to work in the EO facility. If there is evidence of blood levels dropping etc., the doctor will note this on the medical records and notify the facility manager to move the individual from the EO facility. Again, this has not yet occurred.

A unique form of medical monitoring conducted by the ICI Medical Department is called The General Health Index. It is not related specifically to occupational health, but rather a general health survey performed every six months for EO employees and four times a year for Agricultural Chemical facility employees. Site employees who presumably experience no hazardous exposures in their normal job routines and contract employees are included in these evaluations. It is intended to evaluate the overall physical condition and evaluate changes with time. The General Health Index includes blood pressure, pulse, and weight determinations and a general questioning about the person's physical status. have they had any skin problems, felt excessively weak, chest tightness, nose bleeds, sore throats, etc. Physical problems occurring during non-working hours are discussed and possible relationship to the individual's work situation analyzed. By this means, possible delayed occupational exposure symptoms may be discovered. (In a plant with a limited size workforce, such as this, the medical staff learns much about the individual workers, their lifestyle, etc.) During the various stages of the physical examinations, conversations with the nursing staff reveal concerns (what is happening in the plant and also what may be happening at home) that may have a bearing on an individual's General Health Index.

The General Health Index is probably most valuable to the contractors' employees, they tend to be an older population than the ICI site employees and, therefore, more subject to aging problems. This is the only medical review that ICI makes available to contractor personnel, the contractor or private physicians must provide all other health testing. The contractor employees are directed to seek medical help if the General Health Index testing indicates they suffer from high blood pressure or other anomalies.

At the end of the year copies of the General Health Index sheets are sent to corporate headquarters. Employee medical records are restricted. Employees must provide written approval to the Medical Dept for others see the their medical records. They can request that copies of their medical file be given their doctor, family, lawyer, etc., if they so desire; a simple release form is available for this purpose. The medical records are kept on site as long as the employee works at the site. They are microfilmed and stored at least thirty years, generally at the corporate headquarters in Wilmington, upon cessation of employment,

WORK PRACTICES

When new hires or contract employees first come to the company they are given an orientation in the Safety Division office. It includes a discussion of the ICI philosophy on safety. Training films covering both corporate and facility goals and procedures are viewed. The potential for occupational exposures and the effects of these chemicals on the body are discussed by the industrial hygienist. General policies regarding eating and smoking facilities, uniforms, safety equipment, etc., are also delineated. Eating and smoking is forbidden in any process area and in the control rooms, except in designated lunch areas.

All personnel, including contractor employees, are furnished with uniforms and safety equipment. Prescription safety glasses are provided to facility employees who require corrective lenses. Individuals entering the operating areas must wear long sleeve uniforms, safety shoes, and hard hats. Uniforms are changed daily and laundered by ICI. The purpose of the uniforms and possible exposure or contamination of uniforms or shoes is fully discussed.

Contract employees must follow all ICI safety and occupational exposure rules and procedures. They are not permitted to work on any of the operating equipment until a rigorous decontamination procedure has been completed by ICI operations personnel.

Training

This facility is very new and employee turnover has been minimal, the training procedures described below were used in staffing this grass roots facility. It was assumed that the newly hired trainees were inexperienced and knew nothing about the subject. For about three weeks fundamental principles were explained: some basic chemistry and physics -- chemical reactions, pressure, temperature, flow, etc., and hardware -- what a valve is, how it works, the kinds of valves, etc. The trainees were then divided into smaller groups for training in specific job assignments. Those assigned to the EO area received a nine week training program which consisted mostly of reviewing what are known as General Instructions (GI's).

Before completion of the EO plant, the operations were broken down into 108 process subsystems; as an example, the EO purification unit is considered to be one subsystem. The design team then wrote GI's for each subsystem. They contain a description of what the subsection was intended to do, why and how it was designed, the optimum product rate, and options on how it can be operated. Each control loop was described with its range of control and normal operating point. A set of drawings for each subsystem was used in operator training. The first drawing was a simplified flow diagram, the next drawing showed all the control loops superimposed on the simplified flow diagram. A third drawing showed the relief device setups: relief valves, rupture discs, vent valves, etc., these devices were described, the limits outlined, and the sizing explained. Each GI served as a complete description of the process subsection and how it should be operated from a design point of view -- not a detailed, step-by-step procedure, but a general operating description. Each subsystem was assigned to a shift supervisor or process engineer whose was responsible for developing additional training material, to train the technicians, and finally test them for adequacy of knowledge. Certain parts, such as the control loops, were considered more important and thus received greater emphasis. Each EO technician comprehensively studied about 45 or 50 of the 108 subsystems for the EO/derivatives facility.

Initial training of new facility operators also included study and use of a company prepared manual of material safety data sheets for all chemicals employed, a detailed emergency procedures manual, and written job descriptions outlining good procedures and work practices. Occupational exposure possibilities were thoroughly discussed. For personal protective equipment, mandatory use of specific equipment was detailed in a written chart which outlined requirements for various work areas, specific material handling, and specific job tasks.

Prior to the initial startup, cold water trials were made to clean out the system, check out control loops, and to aid operator training. A valve-by-valve procedure had been written for the original startup, but this was discarded. A list of all controllers in the EO production area has been assembled and a valve setting assigned to each controller for operation both in startup and continuous operations. On a startup, the list of controller settings (15-20 pages) serves as a check list. Since all of the system downstream of the oxidizer can be charged with water and/or pressurized with nitrogen to simulate operating conditions, a list of subsystems to be started and the time to start them is issued on a daily basis. The very last step is to give the panelman the list of cold, ready for oxygen conditions, when he gets the plant to these conditions, oxygen and ethylene feed can be started.

Specific instructions have been completed for both starting up and for shutting down. Instructions for continuous operation, when there are no interruptions, deal with the subtleties of keeping the plant tuned to the optimum temperatures, pressures, and flow rates desired. If the temperature goes up, how can it be returned to normal? Which of several options should be tried first and which next? These are essentially 'tweeking' instructions; ways to optimize a certain parameter. There are also specific instructions for batch operations, such as rail car loading.

Currently, utility technicians who wish to become panel operators no longer receive extensive classroom training. They study the various subsection GI's individually and are tested for their understanding of the basic functions of the subsystems. This study can be performed during slack periods in their duty cycles. They are required to draw simplified diagrams of the various subsections, to identify and explain the function of each control loop and relief device, and to discuss the significance of other equipment items in the facility with the shift supervisor. They attend approximately eight formal, all-day classroom sessions which provide an overall process view of the EO manufacturing system. They also learn how to deal with important possible system upset conditions, such as an oxygen or a glycol reaction trip, upset operation of the Mod 3 control system, computer display problems, trouble shooting of an instrument loop, and the process background of the HIPS.

Housekeeping

The state of the housekeeping is frequently an indication of the effectiveness of work practices and of management leadership and concern for safety and occupational exposures to hazardous chemicals. Housekeeping at this site was excellent. Each of the production supervisors has prepared a written action routine so that each shift has a housekeeping responsibility and each operator on that shift has an area of responsibility. The day shift makes sure one part of the plant is clean, and the night shift another. Dirt and debris accumulate most frequently from maintenance operations. Before a maintenance work order can be closed out, the production shift supervisor is required to inspect the area thoroughly. If things are not cleaned up, the supervisor will not sign that the work has been completed and the maintenance organization then has the problem of closing out the work order. Infrequently, under the pressure of time and extra work, plant cleanliness does deteriorate. If so, a crew of maintenance and production people is organized to perform a top to bottom cleanup and haul away all the accumulated materials.

Empty drums of minor processing chemicals are gathered together, quarantined, triple rinsed, and put into a central pickup area for proper disposal. Normally the area operator is responsible for assembling empty drums at the proper pickup point from which the utility operators remove them to the central pickup area.

Incident Reports

Anyone (manager, supervisor, technician, contractor employee) can report an unsafe condition, an unsafe action, or an accident by completing an Accident/Incident (AI) Report. Instructions on the form indicate that a report can be written when: 1) an employee experiences or could have experienced a job related injury or illness, 2) there is equipment or property damage, 3) there is a fire, 4) there is a spill or release of materials; 5) a fire extinguisher, five-minute escape pack, or other life saving device is used, or 6) an undesired event occurs which, under slightly different circumstances, could have led to an accident. These are quadruplicate carbonless forms. Within twenty-four hours of the completion of the report, one copy each is sent to the safety and medical departments, and the third to the staff person responsible for that area. The original copy is routed for investigation and action. Recommendations to prevent a recurrance are entered on this copy and signed off by the plant manager. Then an action list is generated, how the problem is to be resolved, who is responsible for that action, and when it will be accomplished. A running log of every incident reported and who is responsible for carrying out the action items is generated and tracked by the safety department.

REACT Reports

Another method for reducing hazards used at this site, though not in the EO plant, is the REACT system (Review activity, Evaluate responsibility, Audit area, Correct Hazards, Tell). A "Code or Description of Act (or Condition)" is entered on the left side of the REACT card, and the "Action Taken" on the right. Cards are dated and signed by the originator and a reviewer. It is similar to the duPont STOPS program in which supervisors evaluate work areas and the actions of the hourly workers, but has a broader base. Not only supervisors, but anyone can and is encouraged to fill out REACT cards. In one production area, a series of incidents occurred. To increase awareness, each technician is now required to submit one REACT card every four shift cycle worked. The technicians are utilized because their presence in the field provides more opportunity for observation. Because technicians at this facility can initiate work orders, they can take care of things which may not be allowed at other plants. In addition to filling out the card, the originator is required to contact and communicate with others who may be affected by the action or condition. If there are no unsafe acts during those four cycles, they may write "NONE". However, management believes that in four days, something should be reportable, that no one is infallible, nor that the workplace is perfection.

Safety Meetings

A monthly safety meeting is conducted by the Safety Engineer. Each meeting is an open discussion of a different topic, some are process related, some are safety procedure items, and a few are off-the-job safety topics. All employees participate and make suggestions or bring up problems related to the particular safety topic.

Emergency Response Procedures

Presently, the emergency response (fire, explosion, medical) procedures are being revised and rewritten. Employees receive training one full day every eight weeks. At the time of this survey, training was being conducted for fire hose handling and water supply. Monthly fire drills are scheduled for each shift, which means four drills a month. These are performed at night or on weekends when fewer extraneous people are on the site and to avoid conflicts with maintenance work. The fire chiefs are shift supervisors; they have separate classes, an eight-hour class each month.

Fire drills consist of a simulated incident conceived by the Safety Department, for instance, a gasoline spill at the gasoline pumps at the warehouse. After first checking to assure that the operations are stable enough to have a drill, the Safety Engineer discusses the scenario with the fire chief, a description of the incident, the wind direction, potential exposures, etc. There are many things that must be accomplished. Most important is communicating, contacting people on the emergency frequency of the portable radio system and instructing them what to do. There are designated positions on the emergency response teams (ERT) eg, a certain job title is the pumper driver, another job title, perhaps in a different production unit, is a fire monitor operator. The chief has to bring the people and equipment together at an assembly point, then go to the scene and relieve the situation. Sometimes the crews will set hoses to hydrants and actually flow water to fill a 55-gallon drum that was set out by the Safety Engineer. An unforeseen bonus of these 'spontaneous drills' is the enthusiasm shown by the ERT's, as demonstrated by a spirit of competitiveness between shifts with regard to speed of response and performance during the incident, etc.

Confined Space Entry Procedures

Employees receive an annual review of confined space entry procedures. Except for the medical team, there have been no rehearsals in the field. Appropriate employees practice putting on self contained breathing apparatus (SCBA), hooking up to the air lines, and go over the use of the emergency 5-minute escape bottles, however, they have not rehearsed actually removing someone from a vessel.

A written procedure for cleaning and isolating specific equipment before entry has been prepared. This is called a safe work file procedure on isolating equipment and it documents exactly which valves are to be opened, which valves are to be closed, which lines are to be disconnected, etc. Equipment tagging and electrical lockout procedures are also delineated.

After the vessel is prepared for entry, oxygen level and the flammability tests are performed at various levels of the vessel, the results are written on the work permit. Entry is not permitted unless the flammable vapor is below 10% of the lower explosive limit, and the oxygen content is above 19.5 percent. If EO is involved, Gastech detector tubes are used to assure that levels are 1 ppm or less.

Explosion proof, electric air movers are normally used to purge the vessels. Pneumatic systems are not used unless hooked up to an air compressor because the plant air system is backed up with high pressure nitrogen. It could potentially be switched over to nitrogen at any time. Depending on the vessel, purging is started at least 24-hours before entry. The policy is to pull air into the top of the vessel, usually by putting an air mover at the bottom of the vessel to suck the air out. This is to prevent leaks of hydrocarbons or other heavier-than-air substances from being pulled in.

During an entry, two people must be in attendance, with at least one person outside. Although everyone has a radio, the outside person also has a freon operated air horn, this provides an alternate form of communication in case the radio or the battery should fail. Anyone entering must wear a harness with a lifeline and also a personal oxygen/LEL monitor, even when they are using a supplied air respirator. The breathing air is normally supplied from a two-cylinder bottle cart. If the low oxygen alarm sounds, workers inside must get out immediately. When two or more people are working in the same area on one level, an oxygen/LEL monitor must be worn by at least one of these persons. If there is a multiple entry of a column, there must be one person with an oxygen monitor for each level, with the geometry of the trays in some of the columns, it may be possible that a pocket of hydrocarbon or inerts could accumulate.

The oxygen and LEL are tested every four hours. Each shift that comes on is required to verify this information, take responsibility for the condition of the equipment, and sign the permit. Work permits expire after 24 hours and a new permit must be written for work to continue past that time.

Work permits are written by persons of various levels of authority, depending on the circumstances. For instance, a technician can write a permit for outside work with hand tools, but the shift supervisor is the lowest level of authority that can sign a work permit. A production supervisor, the next level above a shift supervisor, must sign for confined space entry. For some potentially very hazardous confined space or other operations, the site manager is the only authority. For instance, during a turn around there was an entry in a vessel for welding with an argon purge, and the argon displaced the oxygen. The welder wore a supplied-air, full facepiece respirator and had an emergency egress bottle; however, the work permit could only be authorized by the site manager.

Emergency egress packs provide five minutes of breathing air for escape in case the normal air supply is interrupted. It must be worn when an entry is made. There are some exceptions, for instance, in a column where there are very close clearances because of the trays or other obstructions, but these must be recognized and signed off by the site manager. No entries into flammable atmospheres are permitted.

IV. CONTROL EFFECTIVENESS

Air contaminant measurements can be used to determine the efficacy of hazard controls. Low levels in the proximity of potential emission points indicate that chemical substances are effectively contained within the processing equipment. Personal samples in the breathing zone of employees reflect the effectiveness of both equipment and work practices in preventing occupational exposure. Personal (breathing zone) and area air samples were collected and analized according to NIOSH Method 1607. The samples were collected on 400 mg and 200 mg of activated coconut shell charcoal contained in separate glass tubes (6 mm inside diameter by 8.5 cm long) connected in series. The sampling train was contained in a plastic holder and DuPont P-125 pumps calibrated at approximately 20 milliliters of air per minute (ml/min) were used to draw air through the sampling train for various periods of time. In most cases, the ICI industrial hygienist collected duplicate samples according to a modified Qazi-Ketcham method (AIHA Journal, Nov 1977, pp 635-647) also at about 20 ml/min. All electrical equipment used was certified as Class 1B because of the highly explosive properties of EO.

During the survey, weather conditions were mostly fair and temperatures were in the 55 to 80°F range. At the beginning of the week the wind varied in direction and gusted to 20 mph and higher; towards the end of the survey, it had abated to gentle breezes and returned to the prevailing southerly direction.

The two ICI job categories having the greatest potential for EO exposure are the outside technician and the laboratory analyst. The outside EO technician patrols the EO facility looking for problems and/or possible trouble spots two or three hours per shift, takes quality control and in-process samples, and fills rail cars. The technician is required to be in the immediate area during the two or more hours required to prepare and load a rail car. At least one tank flushing sample and a shipment quality control sample are obtained for each car loaded, up to three rail cars may be loaded on one shift. The number of other quality control and in-process samples vary from day to day depending on how well the facility is operating. The laboratory technician performs various analytical tests on the samples, such as water content, specific gravity, color, acidity, impurities, etc., the specific tests performed, hence the potential exposure, depend upon the type of sample.

The survey team conducted approximate full-shift sampling to document levels of exposure at the time of the survey. To develop statistically valid average exposures that reflect the variability of meteorological and processing conditions would require a much extended study. The personal air sampling results are shown in Table 1.

Area samples were obtained using the same methods and equipment as for personal sampling. Low sampling flow rates are prescribed by these methods because EO is not readily adsorbed onto the sampling medium, therefore, short term or peak exposures cannot be determined in this manner. To perform short term sampling, some area samples were collected in Tedlar® bags for varying times using DuPont pumps calibrated at approximately 50 ml/min and 1 liter/min and on a few occasions, gas syringe samples were used to obtain instantaneous samples. These were analyzed in the quality control laboratory using a Photovac 10A10 Portable Photoionization Gas Chromatograph. Area sampling results are presented in Table 2.

Discussion of Air Sampling Results

Although it is obvious by inspection that results of side-by-side sampling using the Qazi-Ketcham and the NIOSH Method 1607 are equivalent, a Matched Pair T-Test indicates no significant difference at the 95% confidence level.

The results of personal sampling indicate that the TWA exposure for the workers most at risk were below the current PEL (1 ppm EO). The laboratory technicians apparently had very minimal exposure. A short term sample during rail car loading indicated a 4-hour TWA exposure of 1.5 ppm for the outside technician. Another short time excursion above 1 ppm occurred during a 4.3 hour sampling period in which a pure EO sample was obtained. Nonetheless, the overall TWA exposures for the shift worked during these incidents were less than 1 ppm.

Area samples proximate to pump seals indicate that minimal leakage occurs from these devices. Results from the gas bag and charcoal tube samples are equivalent. The gas syringe samples taken the next day, when wind conditions were calmer, indicate somewhat higher concentrations but still less than 1 ppm.

Since the startup of this facility, monitoring of air contamination has been performed at various times to attempt to measure normal exposures and also to determine potential exposures from known leaks or upset conditions. Sampling was performed using the modified Qazi-Ketcham method and Minnesota Mining and Manufacturing Company (3M) No. 3550 passive monitoring badges. About 80 percent of the passive monitor results were made in tandem with a charcoal tube sample; the two sampling media were mounted side-by-side either on a worker's lapel or at the area sampling point. Although the passive monitors are now used occasionally as a matter of convenience, the experience at this and other sites, lead ICI industrial hygienists to believe the results are not as reliable as the charcoal tube method. In addition, the charcoal tubes are extracted and analyzed at the facility, thus results can be obtained shortly after the sampling is completed. The passive monitors are sent to 3M labs for analysis and results are not available for two or more weeks. The badges could be analyzed on site, however, the fee charged by 3M for this service is considerably less than ICI costs.

All of the company EO exposure data were discussed with the survey team. The results of personal sampling were reported as a best effort to adjust them to an 8-hour TWA basis (about 10 of the values included are for short-term samples, an hour or less). For instance, if a sample was taken over a 4-hour period and it was known that no further exposure occurred during the subsequent 4-hour period, the value reported was adjusted to an 8-hour basis by dividing the 4-hour exposure result by two.

A summary of the plant data is shown in Table 3. These data show 87 percent (84 out of 96) of the personnal exposures, as measured by the Qazi Ketcham method, were less than 1 ppm EO. Furthermore, 75 percent of these were less than 0.5 ppm. In general, the reported exposure results tend to be on the high side because many are for less than 8-hour periods. The technicians may

TABLE 1. RESULTS OF PERSONAL MONITORING FOR ETHYLENE OXIDE

Job Class	Tasks Performed	Day	Sampling Time of Day	Time (min)		Results (ppm) NIOSH	ICI
EO Tech	Took compressor readings, loaded rail car (leak developed on loading arm during final purge)	3/20	0614-1041	267		1.50	1.60
	Lunch, routine activities		1041-1450	249		0.33	0.50
	Loaded rail car		1450-1741	171		0.65	0.65
			Total	11h 27m	TWA	0.86	0.96
EO Tech	Took samples; helped load rail car	3/20	0614-1043	269		0.61	0.60
	Lunch, routine activities		1043-1451	267		0.05	0.06*
	Helped load rail car		1451-1651	120		0.03	0 12*
			Total	10h 56m	TWA	0.28	0.29
EO Tech	Took samples, including pure EO	3/22	0617-1035	258		1.36	1.07
	Hooked up rail car, took flush sample		1035-1516	281		0.01*	0.05*
			Total	8h 59m	TWA	0.66	0.54
EO Tech	Took samples (non-EO), repaired sample bomb	3/22	0620-1034	254		0.12	0.12
	Hooked up rail car, helped take flush sample		1034-1517	283		0.03	0.05*
			Total	8h 57m	TWA	0.07	0.08
Lab Tech	Analyzed pure EO and rail car samples	3/20	0714-1103	229		0.05	0.06*
	Analyzed rail car flush sample		1103-1455	232		0.25	0.08
	Routine activities		1457-1751	174		0.23	0.13
			Total	10h 35m	TWA	0.17	0.09
Lab Tech	Analyzed pure EO sample	3/22	0643-1053	250		0.02	0.05*
	Analyzed rail car flush sample		1055-1530	275		0.03	0.05*
			Total	8h 45m	TWA	0.03	0.05*

* less than indicated value

TABLE 2. RESULTS OF AREA MONITORING FOR ETHYLENE OXIDE

Area	Type of Sample	Time of Day	Time (min)	Results (ppm) NIOSH	ICI
Analyzer house #1	CT[a]	1329-1739	241 (4h 1m)	0.59	0.45
	TB[b]	0850-0900	10	0.64	
	TB	1730-1740	10	0.82	
Near seal on aqueous EO pump	CT	1151-1633	282 (4h 42m)	0.16	0.12
	TB	1340-1350	10	0.07	
	TB	1630-1640	10	0.13	
Near seal of pump feeding pure EO to derivatives facility	CT	1205-1645	280 (4h 40m)	0.22	
	TB	1410-1420	10	0.10	
	TB	1636-1646	10	0.20	
Near seal of purification column reflux pump	CT	1155-1637	282 (4h 42m)	0.11	0.14
	TB	1355-1405	10	0.07	
	TB	1633-1643	10	0.13	
Purification column pump seal	GS[c]	0850		0.81	
At FEMS sensor ca. 10 feet from purification column pump	GS	0852		0.52	
About 3 feet downwind of rail car cupola during final loading and disconnection	TB	1630-1750	80 (1h 20m)	1.08	

a Charcoal Tube
b Tedlar® Bag
c Gas Syringe

TABLE 3. EO EXPOSURE RESULTS (ppm)[a]

Personal Samples[b]	Charcoal Tube Number	Charcoal Tube Percent	Passive Monitor Number	Passive Monitor Percent
Below LOD[c]	28	29	32	52
Between LOD and 0.5	46	48	4	7
Between 0.5 and 1.0	10	10	15	25
Between 1.0 and 50.0	12[d]	13	8	13
Above 50.0	0	0	2	3
Total	96	100	61	100
Area Samples[e]				
Below LOD	8	28	8	47
Between LOD and 0.5	10	34	1	6
Between 0.5 and 1.0	2	7	6	35
Between 1.0 and 50.0	8	28	1	6
Above 50.0	1	3	1	6
Total	29	100	17	100

a Data from ICI sampling 1982 - 1983

b Derived as 8-hour TWA for most samples

c Level of Detection estimated at about 0.03 ppm for a 10 liter sample

d Maximum concentration = 7.13 ppm

e Average over sampling time

do several specific outside tasks during the sampling period and then spend several hours in the control room, if the latter time period is unknown, the result from the short-term sampling period is treated as the 8-hour TWA. Only when specific times for differing exposures could be identified were the short-term results factored down to provide a lower 8-hour TWA value.

Many of the high exposure levels occurred in initial start-up of the facility or shortly thereafter, while operating conditions were somewhat unsettled. The conditions causing some of these high EO exposure values were determined and have since been corrected. For example, a number of the early samples from the analyzer houses were well over 1 ppm. After the ventilation rates in these houses were increased, the sampling results were much lower.

Of the 96 personal samples, 42 were for EO technicians or supervisors working in the plant, several of these were taken at times when decontamination and/or equipment repairs were being performed. Eight samples exceeded 1 ppm, three were short term samples and two exposures (6.7 and 7.1 ppm) occurred during decontamination of the purification column. At the time that this operation was performed, effluent from the column was allowed to drain across the pad to the EO sewer. This is no longer permitted and connections have been made to ensure that drainage goes to the EO stripping column or directly to the sump. Sixteen personal samples were for laboratory technicians of which 2 exceeded 1 ppm, one was a short term sample and the other an 8-hour TWA of 1.90 ppm.

V. CONCLUSIONS

Based on the results of air sampling performed during this survey and those previously obtained by the company, employee exposure to EO from routine operations can be controlled within the new OSHA PEL. Proposed engineering and work practice modifications for decontamination of pumps and related equipment appear well designed to protect workers during such operations. Both management and employees are well informed and trained to react to emergency and nonroutine operations, such as turnarounds, so that excessive exposure will be potentially circumvented. To date, medical monitoring of employees working with EO has revealed no detriment to the health of the workers either from chronic exposure to the low levels of contamination which exist at this facility or to the very few instances when acute overexposure has occurred.

As yet, OSHA has not set limits for short term exposures. It was observed that in spite of the elaborate procedure for rail car loading described in this report, a few drops of EO escaped from the Kamvaloc® dry disconnects when the loading arms were detached. In addition, as a result of minor mechanical failures excursions above 1 ppm (averaged over various time periods) have been obtained both for personal and area air contamination samples. During a recent visit at another facility, the survey team observed the use of a venturi blower directed at the dome of the car to help dissipate fumes from the loading zone. This may also be useful during rail car loading at other facilities; however, such factors as the effect of additional equipment in a cramped location or of an additional noise source, must be considered.

Two areas of research have been suggested to improve occupational health at this and similar facilities. One is the development of 'pocket-size', direct reading instruments for the detection and measurement of EO such as those available for hydrogen sulfide. With such a device it is possible to obtain instantaneous readouts of contaminant levels which can be used to perform real time monitoring of exposures encountered. They can also be used to locate emission sources and trace the plumes or estimate dissipation rates. Another general need for the chemical industry is the development of economical devices and methods to safely detoxify laboratory wastes.

In conclusion, good safety and health practices are the result of full commitment by both management and employees. Such is the case at the ICI Americas Bayport facility. In this respect it is one of the best facilities the writer has visited. This is perhaps best demonstrated by the fact that this facility was designed to limit EO exposure to 1 ppm or less at a time when the OSHA limits were 50 ppm. The unique on-line air contaminant monitoring system and the well-designed medical surveillance are also evidence of the care and respect this company has for occupational health and safety.