Phase III Survey Report #4

WORKER EXPOSURE TO POLYAROMATIC HYDROCARBONS AT SELECTED PETROLEUM REFINERY PROCESS UNITS

SURVEY LOCATION:
Chevron U.S.A. Inc. Refinery
El Segundo, California

SURVEY DATES:
15-17 January 1980

REPORT DATE:
September 1980

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ABSTRACT

This industrial hygiene survey of a petroleum refinery is one of nine performed during Phase III of a NIOSH-sponsored study characterizing worker exposure to polyaromatic hydrocarbons (PAHs) in three different types of process units. Personal and area air samples were collected in the fluid catalytic cracker unit (FCCU) and delayed coker units; the asphalt processing at this refinery was recently discontinued. A silver-membrane filter followed by Chromosorb 102 was used for sampling, and analysis for 23 individual or groups of PAHs was performed by gas chromatography/mass spectrometry. Of the 39 personal and area air samples, 38 had detectable quantities of at least four PAHs or groups of PAHs with the cumulative PAH concentration for individual samples in the low $\mu g/m^3$ concentration range. The highest sample was 145.7 $\mu g/m^3$ for one area location at the FCCU. The average cumulative PAH concentration for the two upwind boundary samples was less than 3 $\mu g/m^3$.

This report was submitted in fulfillment of Contract No. 210-78-0082 by Enviro Control, Inc. under the sponsorship of the National Institute for Occupational Safety and Health (NIOSH).

CONTENTS

FIGURES

CONTENTS (continued)

TABLES

I. INTRODUCTION

Enviro Control, Inc. (Enviro) is under contract to the National Institute for Occupational Safety and Health (NIOSH) to perform a study entitled, "Industrial Hygiene Characterization of Petroleum Refineries." Because petroleum refining is a complex industry involving such a large number of potentially hazardous agents, the study was structured in four progressive phases to enable the development of a meaningful yet manageable study plan. The first two phases of this study have already been completed with the information and resulting recommendations having been presented in the Phase I report (April 1979) and the Phase II report (November 1979). Following is a brief description of these two initial phases as well as descriptions of Phase III and Phase IV.

- Phase I: A detailed literature search was performed including the industrial hygiene aspects and the potential occupational health problems associated with this industry. Preliminary fact-finding surveys were conducted at three refineries. This phase culminated in a preliminary study protocol which recommended the investigation of potential carcinogens in three types of refinery process units: the fluid catalytic cracker unit (FCCU), the delayed coker, and the asphalt processing unit.

- Phase II: An attempt was made to identify specific compounds associated with some degree of cancer-causing potential in the three study process units. Area air samples were collected for a variety of compounds at three refineries, two of which were visited previously during Phase I. Results consistently showed the presence of polyaromatic hydrocarbons (PAHs) in the study process units.

- Phase III: The objective of this main phase of the study is to characterize worker inhalation exposure to PAHs in the study process units. Personal and area air samples will be collected in a total of nine refineries.

- Phase IV: A final report will be prepared integrating the results and information from Phase III and the previous phases.

Phase III is currently in progress. The Chevron U.S.A. Inc. (Chevron) refinery at El Segundo, California was the fourth refinery visited as part of Phase III, and this report presents the information and air sampling data for PAHs collected during this survey.

The Phase III industrial hygiene survey of the Chevron refinery was conducted over a period of 3 days, from January 15 to 17, 1980. Initial contact and arrangements for this visit were made through the refinery Safety Engineer. The opening conference was held with representatives from the refinery, the refinery corporate office, NIOSH, and Enviro (list of attendees in Appendix). The two representatives from Enviro and the Alternate Project Officer from NIOSH described the project, the status, and the specific objectives of the survey. A tentative schedule was agreed upon for the 3 days. After the meeting, the survey team conducted a walk-through of the FCCU and the delayed coker where personal monitoring was scheduled, and the Enviro industrial hygienists explained the sampling procedures to the employees. The asphalt blowing unit, which was originally scheduled to be included in this survey, was permanently shut down on January 1, 1980. Area and personal sampling was conducted on the day shifts of the second and third days at the FCCU and delayed coker unit.

II. DESCRIPTION OF REFINERY

This Chevron refinery is located in El Segundo, California just south of Los Angeles on the Pacific coast. With its crude capacity of 405,000 bbl/day, it is classified as a "large" refinery for the purposes of the study. Since the oil company that owns this refinery and 11 others is one of the largest 15 companies in terms of crude capacity, the company is considered a "major" oil company. The significance of categorizing this refinery by these criteria is explained in the Phase II report.

This refinery was originally built in 1911 by Standard Oil. Currently it occupies over 950 acres and at the time of the survey was processing close to 300,000 barrels of crude a day and producing a full line of petroleum products which included:

- propane
- butane
- jet fuel
- gasolines
- Diesel fuel
- fuel oils (#2, #6)
- lube oils
- #2 (sponge) coke

The domestic crude refined here during the survey was a combination California and Alaskan North Slope crude with a sulfur content of about 1.0% by weight. The API Gravity Index was 25 and the crude was categorized as a "mixed base" type (containing both naphthenes and paraffins). The crude is received by pipeline and offshore tankers. Products are marketed primarily in the local area and are shipped by pipeline; trucks are used for the coke which is taken to the local docks for shipment overseas.

The major process units at the Chevron refinery include:

- four crude distillation units
- three vacuum distillation units
- delayed coker
- three hydrodesulfurization units
- three catalytic reformers
- FCCU
- H_2SO_4 alkylation unit
- polymerization unit

Almost every major process unit has its own control room. Figure II-1 shows a rough refinery plot plan of the area around the units studied during this survey.

There are approximately 1,350 total employees that include production, administrative, and maintenance. Most of the routine maintenance activity is performed in-house; contractors are brought in for tunrarounds and other major maintenance work. At the delayed coker unit, contractors are used for some routine production and maintenance activities. The production units operate 24 hours a day over three work shifts; there are four separate production work crews that rotate weekly.

The safety and health staff at this refinery includes three safety engineers, two occupational physicians, and three occupational health nurses. All are under the direct supervision of the refinery General Manager. The doctors and nurses are on the premises full time during the day shift, 5 days a week. A large number of the refinery employees are trained in first aid and cardiopulmonary resuscitation. The dispensary and treatment room is fully equipped to handle first aid situations and various routine examinations. All of the production and maintenance workers are given preplacement medical examinations, including audiometric testing. There is also a schedule for periodic physical examinations.

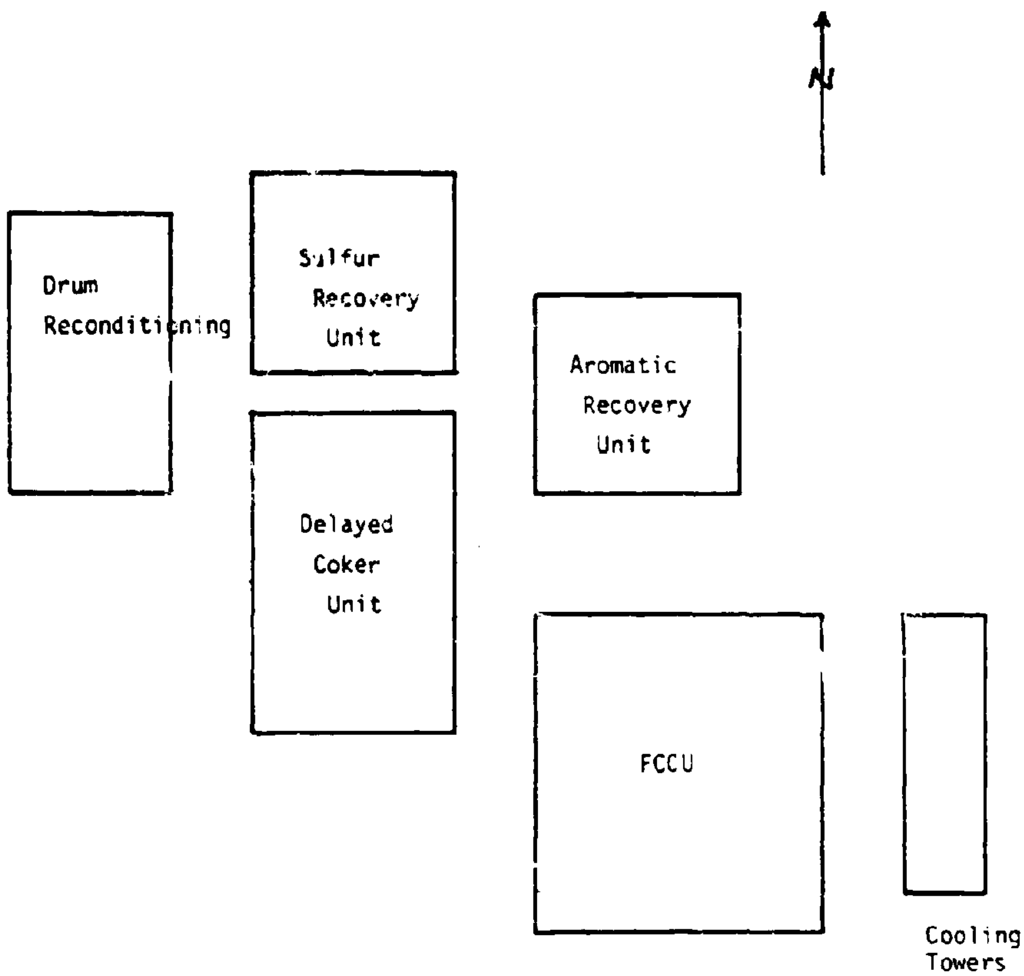

FIGURE II-1. Survey Study Area

As part of good industrial hygiene practice, the use of protective clothing and equipment (e.g., hard hats, safety shoes, rubber gloves, coveralls, slick suits, eye protection) is emphasized. The company provides fresh coveralls daily and laundering service. Eating and smoking are allowed in most control rooms. All new employees attend an extensive training session over a 3-week period which includes information on unit equipment, operations, respirator use, safety hazards, fire protection, and first aid. Formal training continues over the first 3 years. The practice of good personal hygiene such as the washing of hands before eating is also encouraged. Good unit housekeeping is practiced as an important means of minimizing worker exposure to potential hazards. Spills are promptly cleaned up by the unit operators, and any necessary equipment or structure repair is promptly carried out by the unit operators or in-house maintenance crews.

The safety engineers are responsible for the industrial hygiene sampling. Although a routine sampling schedule is not yet established here, a considerable amount of monitoring is conducted, upon request, for compliance purposes and for any other reasons felt necessary by the refinery personnel.

III. STUDY PROCESS UNITS

FLUID CATALYTIC CRACKER UNIT (FCCU)

A. Unit and Process Description

The FCCU is located south of the aromatics recovery unit and southeast of the delayed coker and sulfur recovery units (Figure II-1). The reactor/regenerator (R/R) structure is a side-by-side type with a single riser to the reactor; the height of both the reactor and regenerator is about 50 feet. The unit, designed and installed in the 1950s, has undergone various modifications, the most recent involving the precipitator in 1974 and the deethanizer in 1979. The production capacity of this FCCU is about 55,000 bbl/day; during the survey it was operating at about 90% of capacity.

The unit covers an area of about 400 x 400 feet (Figure III-1). The regenerator, reactor, fractionator, and two rows of pumps run west to east about one-third of the distance from the northern boundary of the unit. The air-conditioned control building along with the compressor platform and H_2S treating area are located in the north area of the unit. The precipitator and CO boiler for the regenerator flue gas are located on the west side of the unit south of the regenerator. The vapor separation and recovery area runs east to west in the central area of the unit.

Fresh feed for the FCCU comes from the crude units (atmospheric gas oil) and vacuum units (light and heavy vacuum gas oils). This fresh feed plus the bottoms (recycle) from the fractionator are injected into the riser where catalytic cracking is initiated as the hot-oil feed contacts the catalyst.

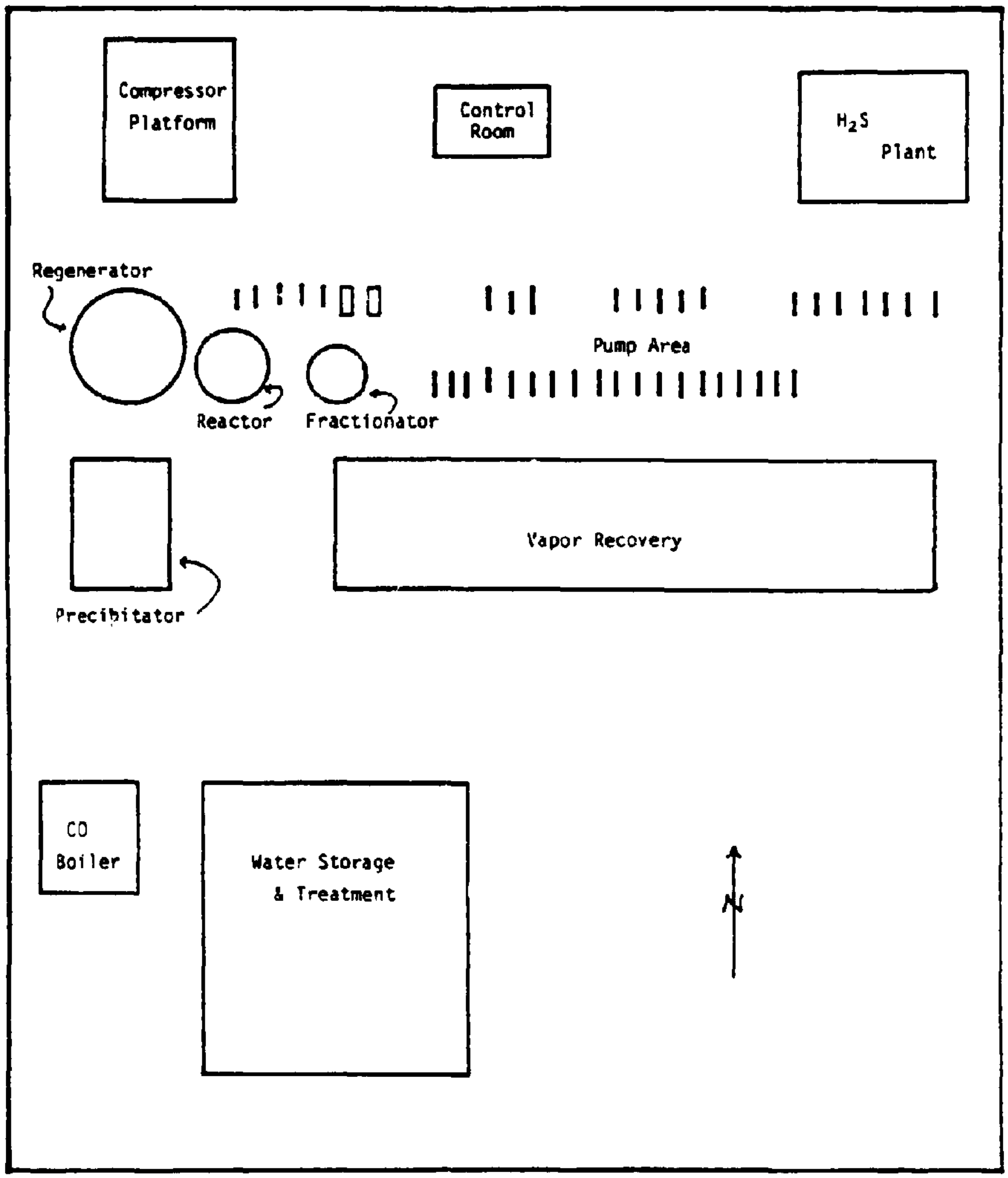

FIGURE III-1. FCCU

The product vapors and the catalyst are separated in the single feed riser line and the reactor itself. The hydrocarbons are taken to the fractionator where the various products are separated. The catalyst is stripped of any remaining oil with steam and delivered to the regenerator where spent catalyst is reactivated by oxidizing the accumulated carbon at a combustion temperature normally greater than 1000°F (538°C). Flue gas from the regenerator goes through a electrostatic precipitator to remove most of the catalyst fines and then to the CO boiler where it is burned before being released to the atmosphere through the stack. The regenerated catalyst is stripped of any absorbed oxygen with steam before being recirculated back to the reactor.

The main products from the fractionator are:

- butane
- propane
- light gas oil
- heavy cat gasoline
- fuel gas

B. Work Force

There are normally six full-time workers assigned to the FCCU during each shift. Following is a brief description of the duties of these workers.

- head operator: Has overall responsibility for the entire unit. This entails working closely with the houseman and supervising outside activities of the four (or more) outside operators. He pays particular attention to any operational difficulties as well as any specific fire or safety hazards, such as gas leaks. He normally spends about 50% of his shift outside the control room in the various production areas.
- unit operator: The primary outside operator who performs routine duties related to the reactor/regenerator (R/R) structure, the fractionator, the compressor deck, the CO boiler, and the pump row (pumps p-119

to p-22) which includes the fractionator bottoms pump and the fresh charge pump. Duties include general inspection of all equipment, meter and gauge reading, pump oiling and routine maintenance. He spends about 60% of his shift outside in the production areas.

- operator I: This outside operator has primary responsibility for the vapor recovery and caustic sections, the pump row which includes pumps p-143 to p-181, and the blow-off tank. Periodically he makes visual inspections, takes meter and gauge readings, gauges tanks, monitors uptake of chemcial additives, keeps pumps oiled, and maintains the unit by general housekeeping. He spends about 60% of his shift outside in the production area.
- operator II: This outside operator has primary responsibility for the FCCU cooling towers, the H_2S treatment plant, and the polyammonia and polysulfide scrubbers. He also acts as an overlap in various other areas of the unit. His duties include periodic inspections, meter and gauge readings, adding chemicals and collecting water samples at the cooling towers.
- houseman (operator III): Spends essentially 100% of his shift inside the control building, monitoring and logging in the various meters and charts on the control board. He works closely with the head operator, as well as with the other outside operators.
- operator IV (CO boiler operator): This outside operator has primary responsibility for the CO boiler and precipitator hoppers. His duties include collecting water samples and adding chemicals, meter and gauge readings, and greasing and lubing equipment. During the survey, he also spent time painting the separate small CO boiler control room located just to the east of the CO boiler. He normally spends about 50% of his shift outside; the rest is spent in the CO boiler control room where he monitors and logs in the various charts on the control board.

In addition to these six workers, occasionally there are one or two helpers that work wherever they are needed during that day. During the first sampling day, the one extra helper spent about 1½ hours at the CO boiler and also did work at the H_2S treatment area. During the second sampling day, the extra helper worked at the chemical shed on the outskirts of the unit and in the CO boiler area.

C. Exposure Control Measures

The primary exposure control measure used at this FCCU is a closed-system process which limits exposure to products, by-products, and intermediates. Also important is a well-organized maintenance program that provides both efficient preventive and repair maintenance services. Under normal operating conditions, exposure to PAHs may occur during sampling of the various streams, during maintenance and housekeeping activities, from fugitive emissions, and from the regenerator flue gas.

The use of sample bombs for collecting process stream samples is a means of minimizing exposure and is used for collecting at least some of the stream samples at this unit. The sample bomb is placed in an auxiliary process line, and the stream is diverted through this line, filling the vessel. The valves at each end of the bomb are closed, and the bomb can be removed with minimum exposure to the collector. Most of the liquid stream samples are collected using the spigot-and-bottle method with sampling loops that eliminate the flushing of lines.

Exposure during routine maintenance is difficult to minimize. The ground level of the unit is constructed of concrete with an efficient sewer system that simplifies cleanup procedures. The refinery has its own craft maintenance crews (e.g., pipefitters, electricians) that provide preventive and repair services. Hard hats, safety shoes, and neoprene gloves are worn routinely, and coveralls and safety or slick suits are available. Disposable earplugs are used when in the compressor areas. There are no routine operations that require the usage of respirators; however, NIOSH-approved air-purifying and self-contained breathing-air respirators are available. These respirators are maintained by the refinery safety department.

The areas of the unit handling heavy fractions, which are more likely to contain the PAHs, are in fairly open areas minimizing potential vapor accumulation. The pumps are south of the control building running in two rows west to east. Several of the heavy-fraction pumps, including the fractionator bottom pump, are located close together around the base of the fractionator tower. This is an area where PAH concentrations might be elevated. The control house, which is air-conditioned but not under positive-pressure ventilation, is occasionally downwind of the R/R or heavy-fraction pumps.

The flue gas from the regenerator passes through an electrostatic precipitator to remove spent catalyst fines and then is burned in the CO boiler with an auxiliary fuel. The heat produced there is used to generate steam. The CO boiler not only removes carbon monoxide from the flue gas, but many other hydrocarbons, making the effluent suitable for discharge to the atmosphere.

DELAYED COKER UNIT

A. Unit and Process Description

The delayed coker unit, as shown in Figure II-1, is located south of the sulfur recovery unit, east of the drum reconditioning plant, and west of the aromatic recovery unit and FCCU. The unit has six 92-foot coke drums with a daily production capacity of 900-2700 tons (one to three drums cut each day). This is one of the larger delayed coker units in terms of coke production that was visited during this study.

The unit, which is about 11 years old, is spread over an area of about 500 x 300 feet (Figure III-2). The ground level of the entire unit is constructed of concrete. The control building is located in the northeast corner of the unit and houses the shift supervisor room, the kitchen, and the locker and shower facilities, as well as the control board room. The coke tower (an open, multilevel structure that includes the six drums) is in the center of the unit running north to south with the coke storage pit just to the west of it. The coke that has been cut is moved

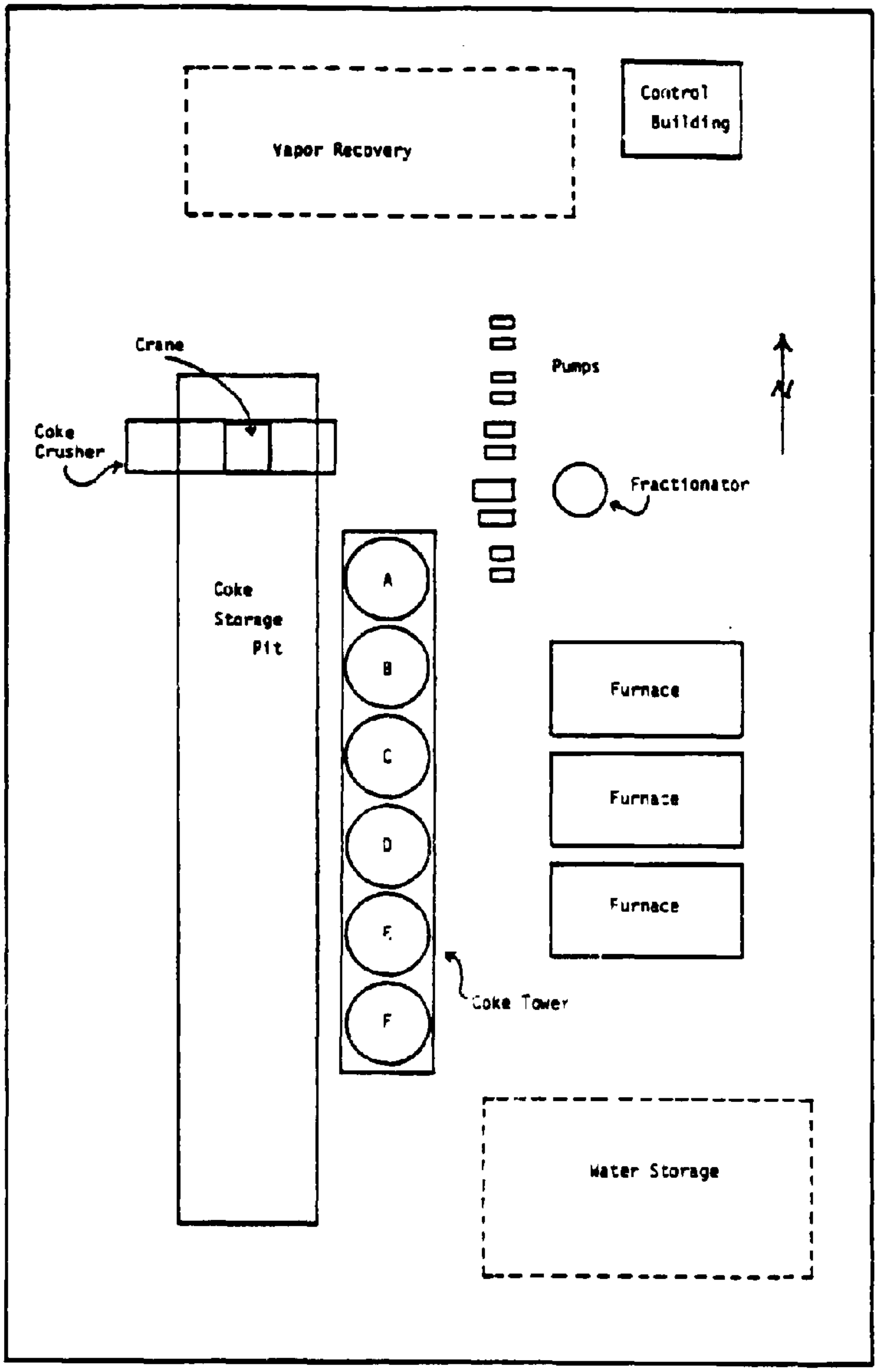

FIGURE III-2. Delayed Coker Unit

by an overhead crane from the pit to a crushing machine located alongside the pit. The crushed coke travels by conveyor belt about 300 yards to the truck-loading hopper and an A-frame storage structure. The coke fills the hopper initially and then is diverted to storage. Trucks are loaded automatically by driving beneath the hopper and selecting the amount of coke to be dropped. The coke is wetted here, but the trucks are not covered. Most of these trucks are not owned by Chevron.

The three gas-fired furnaces and fractionator are located just to the east of the coke tower; the vapor recovery area is on the north side of the unit. The water storage and recovery area and blowdown and quench drums are located in the southeast corner of the unit.

Sponge or No. 2 grade coke was the type produced during the survey and is the predominant type produced at this refinery. The charge stock for sponge coke is primarily residual from the vacuum distillation units. The charge is pumped from storage tanks to the fractionator where the lighter fractions are separated and processed in the vapor recovery area. The bottoms from the fractionator are then pumped (pump p-501) to the series of furnaces where they are heated to a suitable reaction temperature (normally about 900°F or 482°C). The heated charge then goes to one of six coking drums where the thermal cracking process begins. There are three pairs of drums and each drum has a 48-hour cycle with coke formation lasting about 24 hours. Normally one drum is cut each shift. The lighter vapor fractions of the thermal cracking operation are removed from the top of the drum and sent to the fractionator where various products are separated and eventually recovered. Products from this unit, other than coke, include: propane, butane, gas oil, and naphtha.

Routine procedures are used at this unit for preparing each drum for cutting. Coke formation is stopped by switching the feed valve to the other drum of the pair. Steam followed by water is used to cool the drum; this lasts several hours. About 1 hour before cutting is scheduled, the top and bottom of the drum are opened, and the coke is cut with a high-pressure hydraulic bit. An initial hole is bored through the coke, and then the coke is cut from the bottom up. The coke falls down a chute into the coke storage pit. Drilling normally lasts from 3 to 4 hours.

After cutting is completed, the top and bottom of the drum are replaced; the drum is pressure-tested for seal, is heated, and is ready when the charge valve is switched from the other drum to begin coke formation.

B. Work Force

The work force for the coker unit can be divided into two groups, the operations group and the coke-cutting and handling group, both of which are supervised by the division shift supervisor. This supervisor works the normal shift and has a separate office in the control building. During a normal day shift the supervisor spends 50-60% of his time outside monitoring the various operations; he does not usually participate in the work activity. The three-man operations group works the normal 8-hour shift; following is a brief description of their job activities.

- boardman: Spends essentially 100% of his shift inside the control building, monitoring and logging in the various meters and charts on the control board. Works closely with other operational workers.
- head operator: Spends anywhere from 25-75% of his shift outside in the production area depending on operating conditions. During the first sampling day, the head operator was frequently outside (up to 60% of shift) near the crusher and conveyor line because of the problems with the crusher; the second day few problems occurred so he was outside about 30% of his shift. This person is very experienced on the unit and works closely with the other process operators to ensure smooth operating conditions.
- outside operator: Performs most of the routine outside tasks, spending about 50% of his shift in the production area. Conducts periodic tours of the unit taking pressure and flow readings, checking the furnaces, opening and closing various valves, and conducting general visual inspection of all

processes and equipment. He can also oversee maintenance work being done and runs water sample tests in the control building.

The coke-cutting and handling group consists of the driller, driller helper, beltman, deck operator, and crane operator. This group also works the normal 8-hour shift. Several members of this group are employed by an outside contractor (i.e., driller helper, beltman, crane operator) but all work together as a team. Following is a brief description of their job activities.

- driller: Helps with opening and closing the coke drum top and bottom and with positioning the coke chute. Spends most of his shift on the top level where he operates the hydraulic cutting bit. Normal cutting operation lasts about 3-4 hours.
- driller helper: Performs a variety of duties on and around the coke tower which includes relieving the driller during cutting operations, shoveling coke onto the conveyor line, helping to drop the drum bottom and position the chute, and hosing down various areas at the end of a cutting operation. Spends entire shift outside except for breaks which are normally taken in the control room.
- deck operator: Helps with opening and closing the drum and positioning of the chute and transfer line. Performs duties such as valve switching on various decks of the tower (e.g., 23 and 42 deck). Spends about 70% of the shift outside and the rest inside the control room taking care of paperwork (end of shift).
- beltman: Is in charge of the coke crusher, conveyor belt, and A-frame storage structure. Spends about 6 hours each shift in checking the belts, the coke hopper, the amount of coke in the A-frame, and on other outside activities such as shoveling coke onto the

conveyor line and hosing down the ground area. His duties also include relieving the crane operator for 1 hour during lunch. Because of problems with the crusher on the first sampling day, he spent an unusually large percentage of his shift in that area.

- crane operator: Normally spends 7 hours a shift in one of the two overhead crane cabs transferring the cut coke from the pit into the crusher. He takes a 1-hour lunch break in the control building.

During the survey there was also a deck operator trainee. The trainee was in the same area as the deck operator, either performing or assisting in routine duties. During the first sampling day, there were also four contractor maintenance workers cleaning the area around the coke pit. This entailed either shoveling or using a front-end loader to transfer coke back into the pit from which it had spilled. Use of the front-end loader was quite unusual, but these maintenance workers are used about every other day for some cleanup work.

C. Control Measures

The coke-cutting operation is one of the few in a refinery that is not a closed system. Because of this, it is more difficult to minimize worker exposure during this operation. During every cutting cycle the top and bottom of the drum must be opened manually, the coke must be cut by the driller, the operators must clean and lubricate the fittings, and the crane operator must move the coke from the coke pit to the crusher. From here the crushed coke is transported some 300 yards to the A-frame storage structure. Basically the coke-cutting operations at this refinery were similar to those observed at other refineries; however, there were several key points observed related to worker exposure.

The opening of the top and bottom of the drum was done in a time period comparable to that observed at other coke units. The deck operator, trainee, driller, and driller helper worked as a team to complete both openings in about 1 hour. After the bottom plate is moved manually by pully onto a cart (on tracks), a chute extender is lifted from the floor platform to the bottom of the drum and secured. This forms a closed system on this level where the operators spend a good part of their time during the operation.

The top level at this coker unit was very large (about 50 x 13 yards) and totally open, compared to the typical penthouse top level observed at other units. There was a partially enclosed work station for the driller. This open top level and normally high winds minimize the accumulation of vapors. Work areas near the bottom of the drums (23 level) were also fairly open.

The coke crusher itself does not appear to generate large quantities of coke dust. Coke is wet from the pit and the size of the crushed coke is large enough to prevent fine dust generation. However, there were operational difficulties with the crusher during the first cutting shift; apparently this is not uncommon. When this occurs, coke overflows the holding pit necessitating added cleanup. This is normally performed by the contract maintenance group.

Typical protective clothing worn at this unit was hard hats, safety shoes, rubber gloves, and coveralls (provided daily by the company). Several of the coke cutters wore slick suits and rubber boots during deheading and cleanup operations. Showering time was provided at the end of the shift; lockers and shower facilities were in the control building.

The air-conditioned control room was not under positive pressure and was occasionally downwind of the coke tower, furnace, and furnace charge pump. The steam that is used to cool the drums is normally sent through a water scrubbing system before it is vented to the atmosphere.

IV. SAMPLING PROGRAM

PROTOCOL

The sampling protocol for Phase III surveys, detailed in the Phase II report (November, 1979), was followed as closely as possible during the survey of this Chevron refinery. Sampling for airborne PAHs was conducted on the second and third days of the survey in the two study process units. Two locations were chosen at the FCCU and four locations at the delayed coker where area samples were collected. The area sampling cassette contained a silver-membrane filter followed by Chromosorb 102 (Figure IV-1) was used with a portable MSA Model S high-flow pump. To investigate the influence of nonrespirable-size particles, a duplicate sampling setup was used with a cyclone preselector at five of the six area sampling sites. Personal samples were also collected in the FCCU and coker unit. A modified sampling device (Figure IV-2) was used for personal monitoring for PAHs. The Chromosorb was packed in a glass tube following the cassette rather than in the cassette itself. Upwind samples at the refinery boundary line were also collected. A total of 41 samples was collected over the 2 days.

The samples were analyzed by gas chromatography/mass spectrometry which allowed the quantitative analysis of the following 23 individual or groups of PAHs and azo-heterocyclic compounds.

1. naphthalene*
2. quinoline
3. 2-methylnaphthalene
4. 1-methylnaphthalere
5. acenaphthalene
6. acenaphthene
7. fluorene
8. phenanthrene*/anthracene*
9. acridine
10. carbazole
11. fluoranthene
12. pyrene*
13. benzo(a)fluorene/
    benzo(e)fluorene
14. benz(a)anthracene*/
    chrysene*/triphenylene
15. benzo(e)pyrene*/
    benzo(a)pyrene*

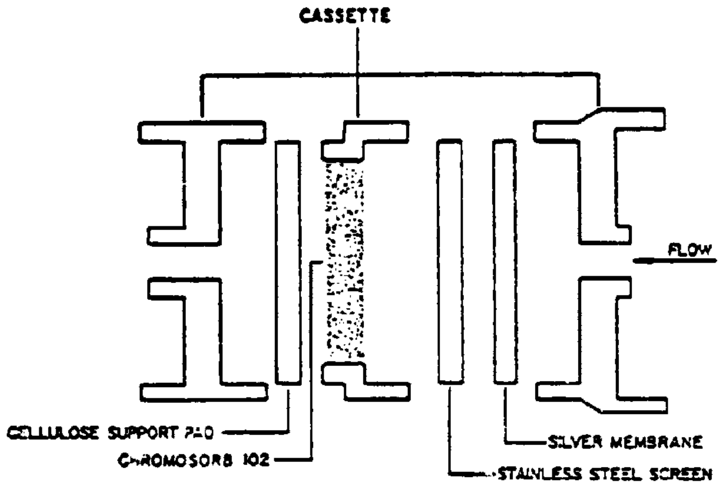

Figure IV-1. Area Monitoring Device for PAHs

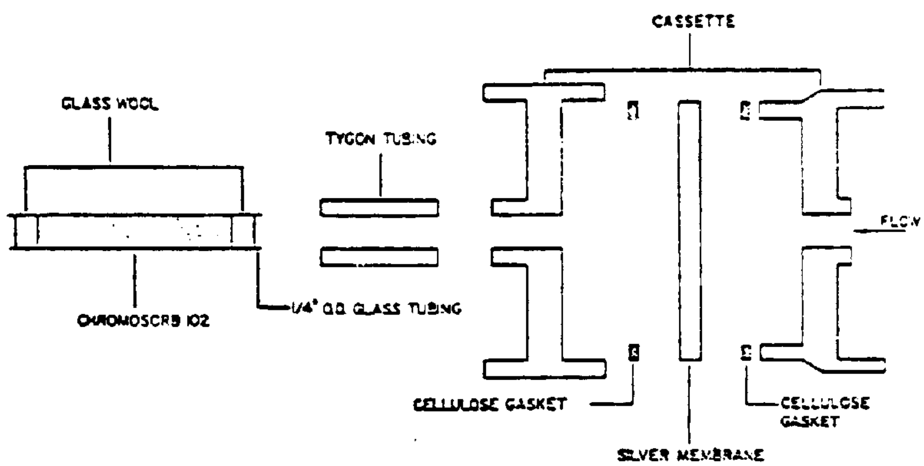

Figure IV-2. Personal Monitoring Device for PAHs

16. perylene
17. dibenz(a,j)acridine*
18. dibenz(a,i)carbazole*
19. indeno(1,2,3-cd)pyrene*
20. dibenzanthracene*
21. benzo(g,h,i)perylene
22. coronene
23. dibenzpyrene*

The "*" designates those compounds considered to have some degree of cancer-causing potential (detailed discussion in Phase II report). Although specific isomers of dibenzanthracene and dibenzpyrene are not distinguishable by the analytical method, one or more of their isomers are potential carcinogens and therefore, the designation is used. There is no definitive information to indicate that the others on this list are potentially carcinogenic. However, the analytical method allowed them to be conveniently included in the analysis, and it was felt that the identification of a large number of PAHs would be beneficial to the study.

SAMPLING CONDITIONS

Weather conditions for the first sampling day (January 16) were mostly cloudy skies with the temperature ranging from 56°F (13°C) in the early morning (0730) to about 70°F (21°C) by early afternoon (1300). The relative humidity during this period ranged from 68% to 85% with some sprinkling in the early afternoon. Until 0900 the winds were generally out of the east at about 6 mph; from 0900, the winds were generally out of the south at 3-5 mph.

Skies were cloudy again on January 17, with the temperature ranging from 60°F (16°C) at 0730 to 70°F (21°C) by 1300. Relative humidity ranged from 70% to 75% with some sprinkling at about noon. During the morning, winds shifted from the southwest to the southeast. At 0800 the wind speed was 3 mph gusting to 8 mph and by 1100 winds were gusting up to 12 mph.

FCCU

A. Area Sampling

Two locations near the fractionator bottoms pump (p-105A) and fractionator were selected to collect area samples in the FCCU (Figure IV-3). Both locations, F-1 and F-2, were sampled on January 16. Location F-1 was about 5 feet above ground on a column support just east of pump p-105A while location F-2, also about 5 feet above ground on a column support, was just west of pump p-105A and north of the fractionator. Pump p-105A is a certrifugal pump that returns the fractionator tower bottoms, including spent catalyst, back to the reactor.

B. Personal Sampling

All six workers assigned full time to the FCCU, as described in Chapter III, were sampled during the day shifts on January 16 and 17. On January 16, sampling was terminated about 2 hours earlier than normally scheduled for most of the workers because of a special training meeting held away from the unit.

DELAYED COKER UNIT

A. Area Sampling

Figure IV-4 shows the four area sampling sites selected in the delayed coker unit. Location C-1, downwind of the bottom of D drum (being cut), was sampled during the day shift on January 16. Sampling pumps were situated 5 feet above ground on a column 10 yards from the coke pit and east of the coke chute for C drum.

Locations C-2, C-3, and C-4 were sampled during the day shift on January 17. Location C-2 was downwind of the coke pit. The sampling pumps were located about 4½ feet above ground on a column about 10 yards north of the pit. Location C-3 was downwind and close to pump p-501, a large centrifugal pump that moves the bottoms from the fractionator to the furnaces. The

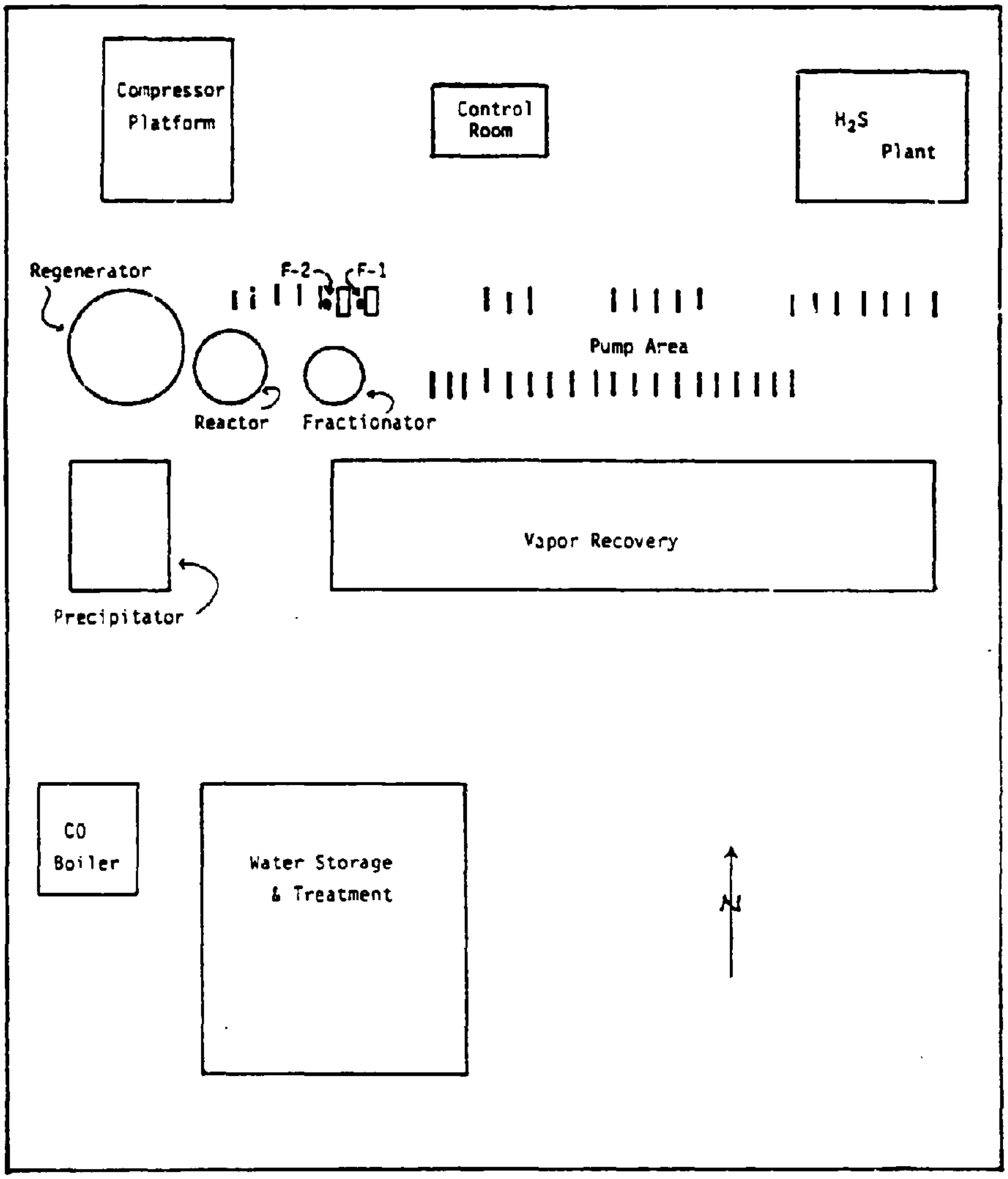

FIGURE IV-3. FCCU Area Sampling Locations

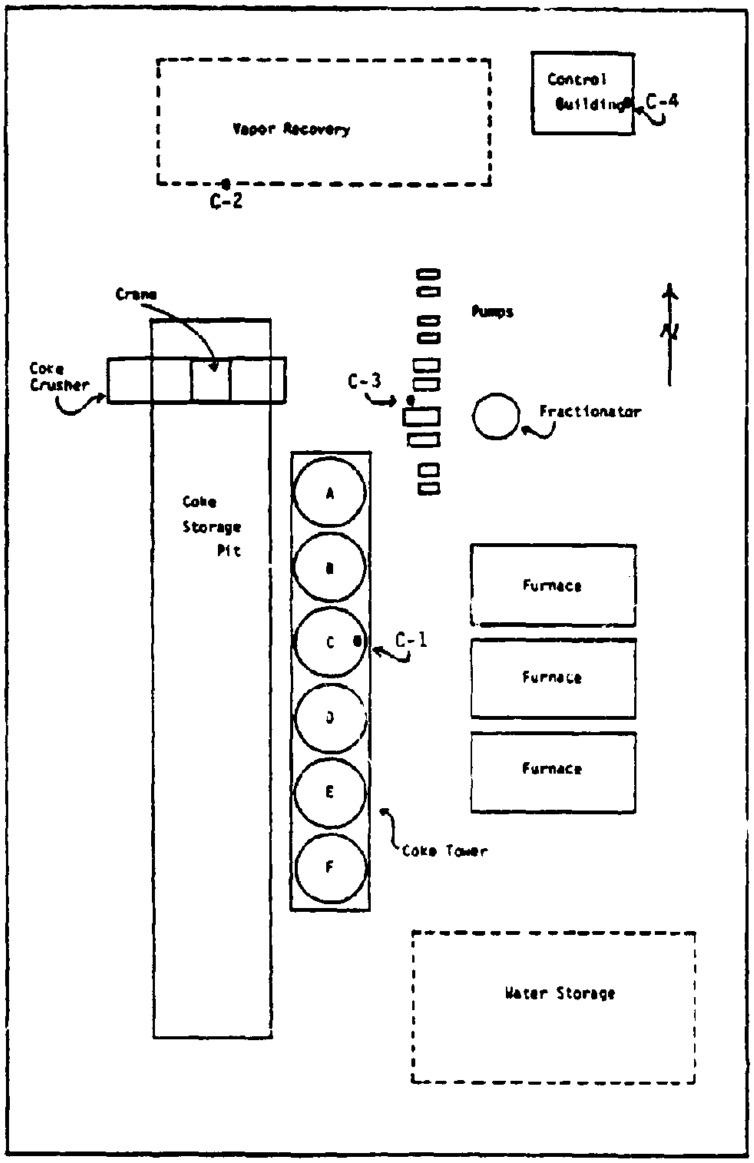

FIGURE IV-4. Delayed Coker Unit Area Sampling Locations sampling pumps were situated about 4 feet above ground west of the fractionator. Location C-4 was located on a table along the east wall of the control room.

B. Personal Sampling

Eight of the nine full-time workers assigned to the delayed coker and described in Chapter III were sampled during the day shifts on January 16 and 17. The boardman, who spends almost 100% of his shift inside the control room was not sampled. Instead, an area sample, as noted above, was situated in the control room. In addition, the deck operator trainee was sampled during the day shift of January 16.

V. RESULTS AND DISCUSSION

The complete results of the area and personal PAH samples collected at this Chevron refinery are presented in Tables V-1 and V-2. Of the 39 personal and area air samples analyzed from the two study process units, 38 had detectable quantities of at least four of the 23 PAHs (or groups of PAHs) for which the samples were tested. The cumulative PAH concentrations for individual samples ranged from none detected for a personal sample from one of the operators at the delayed coker to as high as 145.7 $\mu g/m^3$ for one area sample from the FCCU.

The average of the two upwind boundary samples collected on separate days was 2.7 $\mu g/m^3$. Because of changing wind direction on both days, it was difficult to maintain an upwind location from the refinery. There was also a power plant about ¼ of a mile to the north and another about ½ of a mile to the south of the boundary sampling location. This also may have contributed to the PAHs collected at this location.

A summary of the personal and area sampling results, including the mean (arithmetic) cumulative PAH concentrations for the two types of process units, is presented in Table V-3. On the average, the personal samples at the FCCU were more than five times greater than those from the delayed coker. The two total mass area samples collected in the FCCU were also much higher than those collected in the coker.

The distribution of individual PAHs by ring number was consistent in all samples. The 2-ring compounds were found in the highest concentrations and as the ring numbers increased the concentrations decreased. Only minimal amounts of the 5-ring and no 6- or 7-ring PAHs were found in the samples.

TABLE V-1. PAH Analytical Results (μg/m³) for Personal and Area Samples Collected at the FCCU and Upwind Location[a]

Ring No.		AREA (F-1)		AREA (F-2)		HEAD OPER.		UNIT OPER.		OPER. I		OPER. II		HOUSEMAN		OPER. IV		"EXTRA"		UPWIND	
	Date:	1/16	1/16	1/16	1/16	1/16	1/17	1/16	1/17	1/16	1/17	1/16	1/17	1/16	1/17	1/16	1/17	1/16	1/17	1/16	1/17
	Sample Type:	Total	Resp.	Total	Resp.	Total	b	Total	Total	Total	Total	Total	Total	Total	Total	b	Total	Total	Total	Total	Total
	Sample Volume (ℓ):	733	724	767	750	702		721	940	690	925	726	896	700	517		905	628	936	830	894
	Sample Time:	0746-1457	0746-1457	0751-1457	0751-1457	0653-1228		064--1232	0618-1410	0650-1234	0645-1412	0723-1230	0641-1409	0655-1233	0647-1410		0650-1403	0714-1228	0656-1418	0737-1423	0720-1447
(2)	Naphthalene*	4.56	9.09	17.77	7.01	3.56		3.10	2.46	4.53	2.72	6.71	3.53	3.32	3.63		1.58	3.54	2.01	0.82	1.16
(2)	Quinoline	0.62	1.87	5.20	2.78	0.26		0.48	0.25	0.17	0.19	0.42	0.44	0.29	0.26		0.58	0.44	0.45	0.24	0.24
(2)	2-Methylnaphthalene	12.35	17.99	38.58	22.88	8.21		5.07	4.60	5.55	4.14	7.95	6.29	4.32	6.25		2.45	4.52	3.96	0.56	1.16
(2)	1-Methylnaphthalene	6.98	14.56	32.68	18.80	5.09		2.96	2.16	3.04	2.21	4.12	3.24	2.44	3.39		1.47	2.70	2.20	0.41	0.71
(2)	Acenaphthalene	--[c]	0.31	0.66	0.37	0.15		0.04	0.11	0.27	0.09	0.30	0.11	0.08	0.26		--	0.16	--	<0.01	<0.01
(2)	Acenaphthene	0.61	2.56	9.86	5.24	0.46		0.43	0.29	0.30	0.73	0.75	0.22	0.25	1.29		0.11	0.33	0.19	0.01	--
(3)	Fluorene	0.33	1.94	8.14	4.25	0.24		0.25	0.15	0.43	0.41	0.60	0.10	0.23	0.47		0.03	0.16	0.14	--	--
(3)	Phenanthrene*/Anthracene*	0.80	5.99	25.57	19.14	0.40		0.69	0.37	0.33	0.43	1.10	0.21	0.21	0.55		0.04	0.44	0.32	--	--
(3)	Acridine	0.07	0.63	3.83	--	0.02		0.11	--	0.04	0.04	0.08	--	--	--		--	--	0.02	--	--
(3)	Carbazole	0.08	0.21	1.33	0.63	0.02		0.04	<0.01	<0.01	--	--	--	--	--		--	--	0.02	--	--
(4)	Fluoranthene	0.07	0.52	0.62	0.43	--		0.01	--	--	--	0.05	--	--	--		--	--	--	--	--
(4)	Pyrene*	0.37	1.28	1.10	0.83	<0.01		0.03	<0.01	--	0.01	0.22	--	--	--		--	--	--	--	--
(4)	Benzofluorene	0.14	0.26	0.18	--	--		--	--	--	--	0.01	--	--	--		--	--	--	--	--
(4)	Benz(a)anthracene*/ Chrysene*/Triphenylene	0.53	0.57	0.20	0.15	--		--	--	--	2.22	--	--	--	--		--	--	--	--	--
(5)	Benzo(e)pyrene*/ Benzo(a)pyrene*	--	0.02	--	--	--		<0.01	--	--	0.01	--	--	--	--		--	--	--	--	--
(5)	Perylene	<0.01	<0.01	--	--	--		<0.01	--	--	0.01	--	--	--	--		--	--	--	--	--
(5)	Dibenz(a,j)acridine*	--	--	--	--	--		--	--	--	--	--	--	--	--		--	--	--	--	--
(5)	Dibenz(a,i)carbazole*	--	--	--	--	--		--	--	--	--	--	--	--	--		--	--	--	--	--
(6)	Indeno(1,2,3-cd)pyrene*	--	--	--	--	--		--	--	--	--	--	--	--	--		--	--	--	--	--
(5)	Dibenzanthracene*[d]	--	--	--	--	--		--	--	--	--	--	--	--	--		--	--	--	--	--
(6)	Benzo(g,h,i)perylene	--	--	--	--	--		--	--	--	--	--	--	--	--		--	--	--	--	--
(7)	Coronene	--	--	--	--	--		--	--	--	--	--	--	--	--		--	--	--	--	--
(6)	Dibenzpyrene*[d]	--	--	--	--	--		--	--	--	--	--	--	--	--		--	--	--	--	--
	TOTAL	27.51	57.80	145.73	82.52	18.39		13.21	10.38	14.11	13.19	22.33	14.14	11.14	16.11		6.26	12.29	9.30	2.09	3.27

* Suggested as having some cancer-causing potential.
[a] Blank values have been subtracted from data. Data have not been corrected for temperature and pressure variation; maximum deviation would be within ±2% of actual values.
[b] Sampling pump failed.
[c] "--" designates compounds not detected.
[d] Specific isomers not distinguishable by analytical method; reported value represents any one or combination of existing isomers.

TABLE V-2. PAH Analytical Results (µg/m³) for Personal and Area Samples Collected at the Delayed Coker Unit[a]

Ring No.		AREA							OPERATIONAL						COKE CUTTERS AND HANDLERS										
		(C-1)		(C-2)		(C-3)		(C-4)	Shift Super.		Head Oper.		Outs. Oper.		Driller		Drill Help.		Beltman		Deck Oper.		Crane Oper.		Trainee
	Date:	1/16	1/16	1/17	1/17	1/17	1/17	1/17	1/16	1/17	1/16	1/17	1/16	1/17	1/16	1/17	1/16	1/17	1/16	1/17	1/16	1/17	1/16	1/17	1/16
	Sample Type:	Total	Resp.	Total	Resp.	Total	Resp.	Total	Total	b	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total
	Sample Volume (l):	727	744	724	750	776	724	884	740		892	865	899	879	914	973	930	948	914	926	955	896	943	961	913
	Sample Time:	0720-1423	0720-1423	0729-1435	0729-1435	0718-1439	0718-1439	0702-1424	0757-1407		0637-1403	0651-1357	0639-1404	0641-1350	0702-1417	0643-1431	0640-1418	0635-1429	0644-1410	0632-1408	0624-1401	0620-1348	0642-1420	0640-1420	0646-1405
(2)	Naphthalene*	0.67	1.03	3.30	1.08	0.41	0.51	0.66	0.33		0.26	0.52	0.48	--[e]	1.10	0.55	0.75	1.03	0.60	0.34	1.19	0.54	0.75	0.67	1.04
(2)	Quinoline	0.11	0.10	0.18	0.14	0.24	0.18	0.40	0.26		0.04	0.12	0.06	--	0.20	0.53	0.24	0.13	0.17	0.08	0.25	0.33	0.29	0.26	0.22
(2)	2-Methylnaphthalene	0.72	1.09	3.47	1.30	0.86	0.73	0.42	0.29		0.33	0.52	0.50	--	3.06	0.93	0.72	1.95	0.67	0.43	1.22	0.76	0.87	0.47	1.33
(2)	1-Methylnaphthalene	0.48	0.55	1.43	0.57	0.41	0.48	0.24	0.23		0.36	0.27	0.33	--	1.15	0.37	0.45	0.72	0.40	0.27	0.58	0.29	0.63	0.33	0.55
(2)	Acenaphthalene	0.01	--	--	0.01	--	--	--	--		--	--	--	--	0.04	--	0.02	0.04	<0.01	--	0.02	--	0.03	0.01	0.02
(2)	Acenaphthene	0.02	0.05	0.20	0.08	0.08	0.07	--	--		0.04	--	<0.01	--	0.14	--	0.04	0.16	0.02	--	0.09	--	0.23	0.02	0.07
(3)	Fluorene	--	0.02	0.14	0.11	0.16	0.02	--	--		--	--	--	--	0.18	--	0.06	0.10	--	--	0.04	--	0.04	0.01	0.12
(3)	Phenanthrene*/Anthracene*	--	0.46	0.20	0.41	0.27	0.23	--	--		--	--	--	--	0.43	--	0.04	0.44	--	--	0.26	--	0.14	--	0.36
(3)	Acridine	0.06	0.12	0.06	0.11	0.16	0.08	--	--		--	--	--	--	--	--	--	--	--	--	0.07	--	0.03	--	0.06
(3)	Carbazole	0.02	0.07	0.05	0.07	0.11	0.09	--	--		0.02	--	--	--	0.02	--	0.02	0.04	<0.01	--	0.05	--	0.02	0.01	0.05
(4)	Fluoranthene	--	0.09	--	0.60	0.08	0.02	--	--		--	--	--	--	0.01	--	--	0.03	--	--	0.02	--	--	--	0.03
(4)	Pyrene*	--	0.29	0.02	0.14	0.16	0.11	--	--		<0.01	--	--	--	0.08	0.01	0.01	0.12	--	--	0.06	--	0.02	--	0.11
(4)	Benzofluorene	--	--	0.01	0.03	0.05	<0.01	--	--		--	--	--	--	<0.01	--	--	0.02	--	--	<0.01	--	--	--	0.03
(4)	Benz(a)anthracene*/ Chrysene*/Triphenylene	--	0.03	0.02	0.04	0.09	0.04	--	--		<0.01	--	--	--	0.10	--	--	0.16	--	--	0.02	--	--	--	0.18
(5)	Benzo(e)pyrene*/ Benzo(a)pyrene*	--	--	<0.01	--	--	--	--	--		--	--	--	--	0.01	--	<0.01	0.06	--	--	--	--	<0.01	--	0.10
(5)	Perylene	--	--	0.01	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	<0.01	--	--
(5)	Dibenz(a,j)acridine*	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
(5)	Dibenz(a,i)carbazole*	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
(6)	Indeno(1,2,3-cd)pyrene*	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
(5)	Dibenzanthracene*[d]	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
(6)	Benzo(g,h,i)perylene	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
(7)	Coronene	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
(6)	Dibenzpyrene*[d]	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TOTAL	2.09	3.92	9.09	4.12	3.08	2.56	1.72	1.11		1.05	1.43	1.37	0.00	7.20	2.38	2.30	5.00	1.75	1.08	3.84	1.82	2.52	1.78	4.24

* Suggested as having some cancer-causing potential.
[a] Blank values have been subtracted from data. Data have not been corrected for temperature and pressure variation; maximum deviation would be within ±2% of actual values.
[b] Sampling pump failed.
[e] "--" designates compounds not detected.
[d] Specific isomers not distinguishable by analytical method; reported value represents any one or combination of existing isomers.

TABLE V-3. Summary of PAH Results

	Personal Samples			Area Samples		
	No. of Samples	$\overline{X}$(μg/m³)	No. of PAHs	No. of Samples	$\overline{X}$(μg/m³)	No. of PAHs
FCCU	12	13.4	7-14	2	86.6	14
Coker	15	2.5	0-15	4	4.0	4-14
Total	27	5.3	0-15	6	31.5	4-14

FCCU

The average (arithmetic mean) cumulative PAH concentration ($\overline{X}$) over the two shifts for the seven FCCU workers was 13.4 $\mu g/m^3$ with the number of individual PAHs or groups of PAHs ranging from 7 to 14. Table V-4 shows the the six outside operators were exposed at an average cumulative PAH concentration (13.4 $\mu g/m^3$) almost identical to that for the single inside operator (13.6 $\mu g/m^3$), who spends almost 100% of his shift inside the control room. Even though the cumulative concentrations are similar, in general the outside operators were exposed to a larger number of PAHs (7-14 versus 8).

Table V-4 shows that, although each outside operator has primary responsibility for certain sections or areas of the unit, results for the operators were quite consistent. Results for five of the six outside operators ranged from 10.6 to 18.4 $\mu g/m^3$ (cumulative PAH). The single personal sample collected for operator IV was the lowest (6.3 $\mu g/m^3$) and had the smallest number of PAHs identified. This operator spends most of his shift near the CO boiler and precipitator hoppers and works out of a separate CO boiler control room.

TABLE V-4. Personal Monitoring Results - FCCU

	No. of Samples	$\bar{X}$(μg/m³)	No. of PAHs
Outside Operators	10	13.4	7-14
Head operator (all areas)	1	18.4	11
Unit operator (R/R, compressor, deck, pumps)	2	11.8	10-14
Operator I (vapor recovery, caustic, pumps)	2	13.9	10-13
Operator II (cooling towers, H_2S)	2	18.2	8-12
Operator IV (CO boiler)	1	6.3	7
Extra (CO boiler, outskirts)	2	10.6	8-9
Inside operator (houseman)	2	13.6	8
Total	12	13.4	7-14

The results of the personal monitoring were quite consistent over the 2 days for the FCCU workers. There was less than 38% difference between the duplicate samples collected for all five operators who were sampled on both days. Both day shifts during which sampling was performed were described as routine by the workers. The weather conditions were also fairly similar during the 2 days. A statistical analysis of the data generated from this survey is not presented at this time; such an analysis will be included in the final summary report when data from all nine Phase III surveys are available.

Both area locations selected at the FCCU were sampled during the first sampling shift and both locations were near the fractionator bottoms pump. Results show the sample collected without a cyclone (total mass) on the east side of the pump was 27.5 μg/m³ (14 PAHs identified) while the total mass sample collected on the west side of the pump was 145.7 μg/m³ (14 PAHs identified). For the duplicate sampling units with cyclones, results at these two locations were 57.8 μg/m³ (16 PAHs identified) and 82.5 μg/m³ (12 PAHs identified), respectively.

DELAYED COKER UNIT

Table V-5 gives a summary of the personal monitoring results for the nine coke workers. These values are again average cumulative PAH concentrations ($\overline{X}$) for the 2 sampling days. Table V-5 shows that the six coke cutters and handlers were exposed at higher concentrations than the three operational workers (3.1 versus 1.0 $\mu g/m^3$); the coke cutters and handlers were also exposed to a larger number of PAHs. These results for the delayed coker workers were considerably lower than those for the FCCU workers and were similar to those for the two upwind boundary samples ($\overline{X}$ = 2.7 $\mu g/m^3$). In general, results for the coke cutters and handlers did include a larger number of PAHs than those for the upwind samples. Even though personal sampling results for this unit were quite low, Table V-5 shows that the four coke cutters and handlers who worked on the various levels of the coke tower had the highest cumulative PAH results.

TABLE V-5. Personal Monitoring Results - Delayed Coker Unit

	No. of Samples	$\overline{X}(\mu g/m^3)$	No. of PAHs
Operational	5	1.0	4-8
Shift supervisor	1	1.1	4
Head operator	2	1.2	4-8
Outside operator	2	0.7	0-5
Coke cutters and handlers	11	3.1	4-15
Driller (tower)	2	4.8	5-14
Driller helper (tower)	2	3.7	11-14
Deck operator (tower)	2	2.9	4-14
Trainee (tower)	1	4.2	15
Crane operator	2	2.4	8-13
Beltman	2	1.4	4-7
Total	16	2.4	0-15

Overall, personal sampling results show very little consistency between the two sampling periods. Table V-2 indicates the workers were exposed at higher PAH concentrations and to a larger number of PAHs during the first sampling shift. Comparing the mean cumulative PAH concentrations for the seven workers sampled on both days shows 2.9 $\mu g/m^3$ the first day and 1.9 $\mu g/m^3$ the second day. The results for these same seven showed an average of more than 10 PAHs identified the first day and less than six for the second day. This may be due to the fact that during the first sampling shift there were difficulties with the crusher and conveyor belt. This caused the coke pit to overflow and necessitated additional maintenance operations.

The three area samples taken without cyclones in the coker production area showed cumulative PAH concentrations of 2.1 $\mu g/m^3$ (8 PAHs identified) downwind of the drum being cut, 9.1 $\mu g/m^3$ (14 PAHs) downwind of the coke pit, and 3.1 $\mu g/m^3$ (13 PAHs) near the fractionator charge pump. The duplicate area samples collected with cyclones showed cumulative concentrations of 3.9 $\mu g/m^3$ (12 PAHs), 4.1 $\mu g/m^3$ (14 PAHs), and 2.6 $\mu g/m^3$ (13 PAHs), respectively, for the same locations. The fourth area sample, collected in the control room, showed a cumulative PAH concentration of 1.7 $\mu g/m^3$ with four PAHs identified. A duplicate sample with a cyclone was not collected there.

PAH DISTRIBUTION

Table V-6 shows the percent distribution of PAHs found at the various units and upwind locations by compound ring number. As the table indicates, in all locations, at least 83.7% of the PAHs found were the lighter molecular weight, 2-ring compounds; for the upwind samples this was 100%. Naphthalene and its two methyl derivatives were the compounds found in the highest concentrations.

TABLE V-6. Distribution (%) of PAHs Found by Ring Number

Ring No.	FCCU	Delayed Coker	Upwind
2	83.7	90.2	100
3	14.6	6.9	0
4	1.7	2.6	0
5	0	0.3	0
6	0	0	0
7	0	0	0

VI. CONCLUSIONS

Results of the personal, area, and upwind air samples from the Chevron refinery clearly indicate that workers at the FCCU of this refinery are exposed to numerous PAHs, generally at low $\mu g/m^3$ concentrations. Although not as evident, it appears that the workers at the delayed coker unit were also exposed to low concentrations of PAHs. Concentrations of numerous PAHs were consistently found in the delayed coker air samples; however, they were much lower than those for the FCCU. Many of the personal air samples, especially for the operational group of workers, were similar to the upwind boundary results. In general, the results for the coke cutters and handlers showed larger numbers of PAH present than in the upwind sample results. The upwind boundary results were higher than normally found at other refineries in this study. This may have been due to changing wind directions and the fact that there were also at least two power plants in the vicinity. In attempting to draw conclusions from this survey, one must keep in mind that the samples were only collected over two work shifts during 2 consecutive days. The limitations of such a sampling schedule are recognized; however, there were no unusual operational or environmental conditions during the survey that would cause one to believe that these results were not representative of these units.

It was anticipated that the personal sampling results would show that the outside workers at the coker and FCCU were exposed at much higher PAH concentrations than the inside workers (boardmen), who spend almost 100% of their shift inside the control rooms. However, the results showed that both the variety and concentrations of PAHs to which the boardmen were exposed were greater than anticipated. At the FCCU, the results for the boardman were comparable to those of the outside operators, and at the delayed coker unit, the results for the control room area sample were comparable to those for the operational workers, who spent a good portion of their shift outside in the production area. This clearly indicates that control rooms are definitely not free of contaminants from the production areas.

While the personal sampling data for the FCCU were quite similar over the two sampling shifts, the personal sampling data at the coker varied greatly between the 2 days. This might be explained by the fact that both sampling shifts at the FCCU were considered "routine" by the employees, while as noted, there were difficulties with some of the coke handling equipment during the first sampling day.

The purpose of the limited area sampling at the FCCU and delayed coker unit was to collect samples in areas suspected of having relatively high PAH concentrations, to check suspected major PAH emission sources, and to compare concentrations and PAH distributions with the personal samples. It was anticipated that the area samples would be considerably higher than the personal samples. This was the case at the FCCU as the mean cumulative PAH concentration of the two area samples collected near the fractionator bottoms pump was much higher than the mean cumulative PAH concentration for the 12 personal samples (86.6 versus 13.4 $\mu g/m^3$). This indicates that the fractionator bottoms pump area is a source of PAH emissions. In the coker unit, many of the personal samples, especially those for the coke cutters and handlers, were comparable to the area samples collected near the coke cutting, the coke pit, and the furnace-charge pump. This indicates that these areas were probably not major PAH emissions sources.

As expected from Phase II results, the great proportion of PAHs identified were the lighter 2- and 3-ring compounds. Several of the PAHs identified as being present at this refinery are associated with some degree of cancer-causing potential. However, the lack of existing definitive toxicologic and epidemiologic studies makes an assessment of the actual cancer hazard of this group of compounds outside the scope of this study.

The results of the area samples collected side by side to compare the PAHs present in the total-mass and respirable-fraction (collected with a cyclone preselector) samples were inconclusive. In the coker unit, two of the three area locations sampled with both types of sampling units yielded higher PAH concentrations in the total-mass sample. In the FCCU one of the two locations sampled showed higher concentrations in the total-mass sample and one higher in the respirable-fraction sample. The small number of side-by-side samples collected and the inconsistencies at the two process units make the results for this aspect of the survey inconclusive at this time.

Much of the significance of the data generated during this survey will not be evident until Phase III is completed. At that time the concentrations, PAH distributions, and general tendencies noted at this refinery will be compared for consistency with the other study refineries in the final summary report.

APPENDIX

Opening Conference Attendees

Enviro Control, Inc.

Stan Futagaki	Senior Industrial Hygienist
Edward Haggerty	Industrial Hygienist

NIOSH

Robert Herrick	Alternate Project Officer
Tom Bloom	Industrial Hygienist

Chevron U.S.A., Inc.

C. P. Mehlum	General Manager
R. C. Humphrey	Manager, Operations
Al Edridge	Superintendent, Coker/Sulfuric Acid
Len Course	Superintendent, FCCU/Alkylation Division
Philip McKellar	Safety Engineer
Jerry Walker	Safety Engineer
Norm Zeiser	Corporate Safety and Industrial Hygiene (San Francisco)