

AD-A157 308

A CREW EXPOSURE STUDY PHASE II VOLUME 2 AT SEA PART B  
(U) SOUTHWEST RESEARCH INST SAN ANTONIO TX DIV OF  
ENGINEERING AND... M J ASTLEFORD ET AL. APR 85

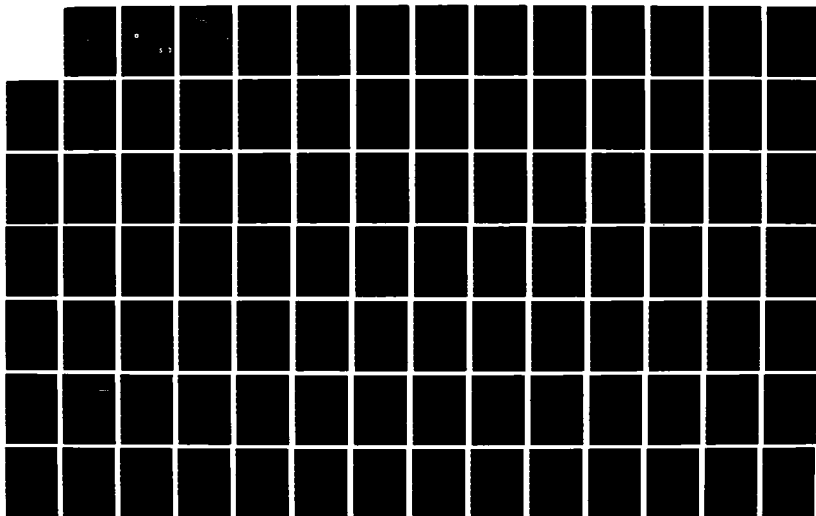
1/5

UNCLASSIFIED

USCG-D-12-85 DTCG23-80-C-20015

F/G 6/10

NL





MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A157 308

2

Report No.

CG-D-12-85

A CREW EXPOSURE STUDY - PHASE II  
VOLUME II - AT SEA  
PART B

W. J. Astleford  
J. C. Buckingham  
H. L. Kaplan  
R. J. Maggot  
J. P. Riegel



Final Report  
April 1985

This document is available to the U.S. public through the National  
Technical Information Service, Springfield, Virginia 22161

DTIC  
ELECTE  
JUL 15 1985  
S D  
G

Prepared for:

U.S. Department of Transportation  
United States Coast Guard

Office of Research and Development  
Washington, D.C. 20593

DTIC FILE COPY

85 06 21 006

SOUTHWEST RESEARCH INSTITUTE  
Post Office Drawer 28510, 6220 Culebra Road  
San Antonio, Texas 78284

**A CREW EXPOSURE STUDY - PHASE II  
VOLUME II - AT SEA  
PART B**



by  
William J. Astleford  
J. Christopher Buckingham  
Harold L. Kaplan  
Raymond J. Magott  
John P. Riegel

FINAL REPORT  
Contract No. DTCG23-80-C-20015  
SwRI Project No. 06-6177

|                    |                                     |
|--------------------|-------------------------------------|
| Accession For      |                                     |
| NTIS GRA&I         | <input checked="" type="checkbox"/> |
| DTIC TAB           | <input checked="" type="checkbox"/> |
| Unannounced        | <input type="checkbox"/>            |
| Justification      |                                     |
| By _____           |                                     |
| Distribution/      |                                     |
| Availability Codes |                                     |
| Dist               | Avail and/or Special                |
| A/1                |                                     |

Prepared for  
Commandant (G-FCP-22F/64)  
U.S. Coast Guard  
2100 Second Street, S.W.  
Washington, D.C. 20593

April 1985

Approved:

Robert L. Bass, Director  
Department of Mechanical Sciences



|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                      |                                                                                       |                                                |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|---------------------------------------------------------------------------------------|------------------------------------------------|
| 1. Report No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 2. Government Accession No.<br><b>AD-A157 308</b>    | 3. Recipient's Catalog No.                                                            |                                                |
| 4. Title and Subtitle<br>A CREW EXPOSURE STUDY - PHASE II<br>VOLUME II - AT SEA<br>PART A AND PART B                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                      | 5. Report Date<br>April, 1985                                                         | 6. Performing Organization Code<br>06          |
| 7. Author(s) W. J. Astleford, J. C. Buckingham, H. L. Kaplan,<br>R. J. Magott and J. P. Riegel                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                      | 8. Performing Organization Report No.<br>06-6177                                      |                                                |
| 9. Performing Organization Name and Address<br>Southwest Research Institute<br>Division of Engineering and Materials Sciences<br>P. O. Drawer 28510<br>San Antonio, Texas 78284                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                      | 10. Work Unit No. (TRIS)                                                              | 11. Contract or Grant No.<br>DTCG23-80-C-20015 |
| 12. Sponsoring Agency Name and Address<br>U. S. Department of Transportation<br>U. S. Coast Guard<br>2100 Second Street, S.W.<br>Washington, D. C. 20593                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                      | 13. Type of Report and Period Covered<br>Final Report - Phase II<br>5/15/82 - 4/12/85 |                                                |
| 15. Supplementary Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                      | 14. Sponsoring Agency Code                                                            |                                                |
| 16. Abstract<br><p>The objective of this effort was to implement the Phase I test plan for characterizing occupational exposures of crew members on bulk liquid tankers to chemical substances, primarily cargo vapors. Additional chemical substances included nuisance dust, asbestos fibers, oil mist and silica dust. This report documents the measurement and monitoring data that were collected on six at-sea voyages that involved tankers carrying Subchapter O, Subchapter D and unregulated liquid products. The interpretation of these occupational exposures was based on a conservative method that makes use of the medical monitoring response level concept and current values of the ACGIH TLVs. This method was developed because the work routine that forms the basis for TLVs is not generally applicable to marine operations. Noise dosimetry was performed on two voyages in order to characterize the environment in an Engine Room and in the Deck Department of a state-of-the art product tanker.</p> <p>This study concluded that the potential for unacceptable inhalation exposures is greatest during open tank gauging and entry into product tanks. Volume II, Part A represents the body of the Final Report. The detailed voyage reports are contained in Volume II, Part B. <i>Keywords</i></p> |                                                      |                                                                                       |                                                |
| 17. Key Words<br>Tankers;<br>Chemicals;<br>Crude Oil;<br>Deck Department;<br>Marine Transport;<br>Vapors;<br>Occupational Exposures;<br>Noise;<br>Engine/Pump Room.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                      | 18. Distribution Statement                                                            |                                                |
| 19. Security Classif. (of this report)<br>Unclassified                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 20. Security Classif. (of this page)<br>Unclassified | 21. No. of Pages                                                                      | 22. Price                                      |

## TABLE OF CONTENTS

|                                       | <u>Page</u> |
|---------------------------------------|-------------|
| Appendix A - Voyage Report - Voyage 1 | A-1         |
| Appendix B - Voyage Report - Voyage 2 | B-1         |
| Appendix C - Voyage Report - Voyage 3 | C-1         |
| Appendix D - Voyage Report - Voyage 4 | D-1         |
| Appendix E - Voyage Report - Voyage 5 | E-1         |
| Appendix F - Voyage Report - Voyage 6 | F-1         |

**APPENDIX A**  
**VOYAGE REPORT - VOYAGE 1**

## VOYAGE 1 REPORT OUTLINE

- I. Vessel Description
- II. Deckhouse Configuration and Ventilation
- III. Engine Room Configuration and Ventilation
- IV. Cargo Description
- V. Watch Composition and Work Schedules
- VI. Trip Overview
- VII. Sampling Strategy and Sample Analysis
- VIII. Activities of Selected 3/M
- IX. Activities of Selected A/B
- X. Activities of Various Crew Members
- XI. Deckhouse and Engine Room Environments

I. Vessel Description

- I.1 Dimensions
  - o Length Overall - 630 ft
  - o Length between perpendiculars - 600 ft
  - o Breadth (mid) - 100 ft
  - o Depth (mid) - 45 ft
- I.2 Tonnage - 39,000 DWT (summer mark)
- I.3 Propulsion - 14,000 hp diesel
- I.4 Cargo Tanks - 18 (six rows of three across, wing capacities symmetric about center longitudinal)
- I.5 Cargo Pumps - five 4500-gpm self priming, diesel driven deepwells; one 2500-gpm self priming diesel driven deepwell
- I.6 Cargo Loading Method - open drop, open loading
- I.7 Cargo Gauging Method - open gauging with Lufkin tape and crucifix through deck riser tubes. The deck riser tubes extend 28 in. upward from the deck plate. Tube inside diameter is 8 inches. The gauging tubes are not classified as a restricted gauging system.
- I.8 Vapor Venting System - Vapors are vented through open ullage ports and open riser tubes during loading. Vapors are vented from secured tanks through VAC-REL P/V valves on each expansion trunk. The pressure-vacuum settings are 1.0 psi and 0.5 psi, respectively. The center of the P/V valve discharge is 42 in. above deck level.
- I.9 Tank Cleaning Method - non-rotating water spray nozzle and water driven air blowers.
- I.10 Expansion Trunk Layout - The expansion trunks for the starboard wing tanks are colinear and parallel with the ship's longitudinal axis on the starboard side. The expansion trunks for the center tanks are colinear, as are the port wing trunks, both sets being located on the port side of the vessel.

## II. Deckhouse Configuration and Ventilation

### II.1 Deckhouse Configuration

The deckhouse consisted of three levels:

1. Main deck level - housed the galley, mess, engine control room, and quarters for unlicensed crew members.
2. Boat deck level - housed the hospital room and quarters for the licensed crew members.
3. Navigation bridge.

Access to the deckhouse from the forward deck was provided by two doors (port and starboard) on the main deck level and one door on the boat deck. Three doors, similarly located, provided access to the stern deck.

### II.2 Deckhouse Ventilation

Conditioned air was provided to the main and boat deck areas by a central, closed-return heating and cooling unit. The compressor for the cooling unit was housed in the engine room. Air discharge grills were located in the ceilings of individual rooms with return air grills located in the interior doors.

Although the system had the capability of drawing in fresh air from the boat deck, this duct was normally kept shut. Therefore, the air conditioning system should not communicate with the outside ambient air unless the external air infiltrates into the deckhouse through the access doorways. This same system provided air conditioning to the bridge, where a window unit was also located. Due to the mild temperatures, the doors to the bridge wings were normally open.

An exhaust fan was located in the galley over the grill. This was strictly an exhaust fan with no makeup air capabilities.

### III. Engine Room Configuration and Ventilation

#### III.1 Engine Room Configuration

The engine room consisted of four levels, the first one being a level below the main deck. The control room was located on the main deck level in the very front of the deckhouse and centrally located between the forward deck access doors.

#### III.2 Engine Room Ventilation

Primary ventilation for the four-level engine room was provided by a push-pull system. Supply air was provided by two separate blowers, whose inlets were located on the central surfaces of the fairing supports for the flying bridge. Exhauster discharge grills were located on the aft end of these fairings.

Supply air was ducted to the first and second below-deck levels in the engine room. Forced ventilation for the forward third level was provided by one of the second level supply ducts located directly over the diesel engine. Air from the second level was transported to the third level through open floor gratings. Forced ventilation was confined primarily to the forward portions of the engine room that housed the main engine and other heat-producing pieces of equipment. The aft end of the first level, which housed the hydraulic steering mechanism as well as a welding shop and a general work shop, was separated from the forward portion of the engine room by a bulkhead with a hatch for access. Ventilation for this room consisted of infiltration through the door and natural ventilation as provided by a vertical duct that opened onto the main deck level aft of the deckhouse. The third and fourth levels housed the clutch, reducer gear assembly, and the drive shaft. A mechanical ventilation outlet was located over the propeller shaft assembly.

#### IV. Cargo Description

The cargo consisted of jet fuel and regular, unleaded, and super unleaded gasoline. During loading, these products were distributed according to Table I.

TABLE I. CARGO DISTRIBUTION PLAN

| Tank No. | Quantity (bbls) | Product                 |
|----------|-----------------|-------------------------|
| 1P       | 12,800          | Super Unleaded Gasoline |
| 1C       | 28,410          | Super Unleaded Gasoline |
| 1S       | 12,800          | Super Unleaded Gasoline |
| 2P       | 14,200          | Regular Gasoline        |
| 2C       | 22,350          | Regular Gasoline        |
| 2S       | 14,200          | Regular Gasoline        |
| 3P       | 18,730          | Unleaded Gasoline       |
| 3C       | 39,680          | Unleaded Gasoline       |
| 3S       | 18,730          | Unleaded Gasoline       |
| 4P       | 13,080          | Jet Fuel                |
| 4C       | 27,720          | Jet Fuel                |
| 4S       | 13,080          | Jet Fuel                |
| 5P       | 9,330           | Jet Fuel                |
| 5C       | 15,580          | Jet Fuel                |
| 5S       | 9,250           | Jet Fuel                |
| 6P       | 8,450           | Unleaded Gasoline       |
| 6C       | 18,260          | Unleaded Gasoline       |
| 6S       | 8,450           | Unleaded Gasoline       |

These products were subsequently discharged in two ports. The port times for loading and discharge are noted below.

| <u>Port No.</u> | <u>Operation</u> | <u>Duration (hrs)</u> |
|-----------------|------------------|-----------------------|
| 1               | Loading          | 32.0                  |
| 2               | Discharge        | 12.0                  |
| 3               | Discharge        | 52.5                  |



V. Watch Composition and Work Schedules

Excluding the Master, the Deck Department consisted of three licensed Mates and six unlicensed personnel (i.e. A/B's and O/S's).

At sea, all three Mates stand a 4-on, 8-off navigation watch. During off-watch hours at sea, each Mate may perform additional work activities on an overtime basis, if he so chooses. In part, the Mates stand a 4-on, 8-off deck watch during cargo transfer. Overtime work is also conducted off-watch. This overtime work may include "all hands" in preparation for docking and undocking, extending the deck watch hours if the Chief Mate's work load is too great, especially during the critical stages of cargo handling, and a variety of maintenance and house-keeping tasks.

At sea, the A/B's stand a navigation watch. In port, they stand deck watches. The watch shifts of the three A/Bs were scheduled such that they could also work a full 8-hour maintenance and repair shift. Opportunities for overtime exist such as mandatory "all hands" for docking and undocking if it occurs outside of the regular work hours and assisting with heel washing of tanks and flushing of cargo discharge lines. The A/Bs are required to work a "bow watch" during channel navigation. This requires them to work 2 hours after their normal 4-hour shift.

The O/Ss do not stand navigation watch. At sea, they perform deck work and general maintenance (0800-1700) as directed by the Bosun, who received his daily work list from the Chief Mate. In port, the O/Ss stand deck watches. The O/S also has opportunities for overtime such as "bow watch" during channel navigation and tank cleaning work at night or engine room maintenance. For "bow watch" the O/S must report 2 hours before his regular 4-hour shift. While in port, the deck watch work unit consists of a Mate, an A/B, and an O/S.

It is to be noted that all work schedules include frequent, short, rotating work breaks for rest and mess time.

## VI. Trip Overview

According to the test plan, two Deck Department employees were to be identified for the monitoring program. Based on the desire to monitor individuals that would be primarily involved with cargo transfer operations and most especially tank topoffs, the third mate (3/M) and his corresponding A/B (A/B1), both on the 0800-1200 and 2000-2400 shift, were chosen. The work activities and occupational exposures for these two individuals were monitored during the entire voyage.

When the two selected employees were either off duty or in an environment where occupational exposure information was not warranted (based on OVA surveys), the activities of other workers were monitored. This enabled documentation of a wider range of work activities and additional information for activities of particular interest.

Figure 1 presents the durations of terminal dockings as well as the regular work shifts of the 3/M and A/B1 for the entire twelve-day voyage. As is noted in this figure, the trip consisted of loading at one terminal, discharge at two terminals, and return to the loading terminal. Time gaps between terminals represent transit times from one berth to the next.

The major deck work activities for each day of the voyage are listed in Table II. The work activities and occupational monitoring of these documented activities for the 3/M, A/B1, and the various additional employees are thoroughly presented in Section VIII, IX, and X, respectively.

TABLE II

| Day | Major Deck Work Activities          |
|-----|-------------------------------------|
| 1   | Periodic tank gauging, tank topoffs |
| 2   | Periodic tank gauging, tank topoffs |
| 3   | Post-loading deck work              |
| 4   | Rust chipping, painting             |
| 5   | Rust chipping, painting             |
| 6   | Discharge gauging, ballasting       |
| 7   | Rust chipping, painting             |
| 8   | Discharge gauging                   |
| 9   | Discharge gauging, ballasting       |
| 10  | Rust chipping, painting             |
| 11  | Washing and blowing all wing tanks  |
| 12  | Pre-loading deck work               |

#### Topoff of 4P

The topoff of 4P was completed using a crucifix. The ullage readings are summarized below:

| <u>Encounter No.</u> | <u>Time</u> | <u>Duration (sec)</u> |
|----------------------|-------------|-----------------------|
| 1                    | 0957:00     | 10                    |
| 2                    | 1002:40     | 6                     |
| 3                    | 1005:00     | 5                     |
| 4                    | 1006:50     | 2                     |
| 5                    | 1007        | 180                   |
|                      | 1010        | Stopped 4P            |

#### Topoff of 4S

The topoff of 4S was completed using a tape and then the crucifix. The ullage readings are summarized below:

| <u>Encounter No.</u> | <u>Time</u> | <u>Duration (sec)</u> |
|----------------------|-------------|-----------------------|
| Using tape           |             |                       |
| 1                    | 1013        |                       |
| 2                    | 1019        | 5                     |
| 3                    | 1020        | 10                    |
| 4                    | 1025        | 2                     |
| 5                    | 1028:30     | 8                     |
| Using crucifix       |             |                       |
| 6                    | 1031:35     | 7                     |
| 7                    | 1032:40     | 5                     |
| 8                    | 1033:31     | 3                     |
| 9                    | 1033:50     | 3                     |
| 10                   | 1034:00     | 3                     |
| 11                   | 1034:10     | 3                     |
| 12                   | 1034:25     | 3                     |
| 13                   | 1034:45     | 3                     |
|                      | 1034:55     | Stopped 4S            |

#### Topoff of 4C

The topoff of 4C was completed using a crucifix. The ullage readings are summarized below:

| <u>Encounter No.</u> | <u>Time</u> | <u>Duration (sec)</u> |
|----------------------|-------------|-----------------------|
| 1                    | 1042:00     | 3                     |
| 2                    | 1043:00     | 3                     |
| 3                    | 1044:00     | 3                     |
| 4                    | 1045:00     | 3                     |
| 5                    | 1045:17     | 3                     |
| 6                    | 1045:47     | 3                     |
|                      | 1046        | Stopped 4C            |

### Topoff of 2C

Tank 2C was short loaded and stopped at an ullage of 10 feet. The readings were taken with a regular ullage tape and are summarized below.

| <u>Encounter No.</u> | <u>Time</u> | <u>Duration (sec)</u> |
|----------------------|-------------|-----------------------|
| 1                    | 0804:30     | 15                    |
| 2                    | 0805:48     | 12                    |
| 3                    | 0806:50     | 10                    |
| 4                    | 0809:40     | 7                     |
| 5                    | 0811:30     | 8                     |
| 6                    | 0814:40     | 10                    |
| 7                    | 0816:40     | 10                    |
| 8                    | 0817:50     | 15                    |
| 9                    | 0818:46     | 38                    |
| 10                   | 0819:55     | 10                    |
| 11                   | 0820:30     | 3                     |
| 12                   | 0821:00     | 4                     |
| 13                   | 0821:50     | 4                     |
| 14                   | 0822:23     | 9                     |
| 15                   | 0822:48     | 7                     |
|                      | 0823        | Stopped 2C            |

All of these ullages were taken from the upwind side of the deck riser.

### Topoff of 6C

Tank 6C was topped off using first a tape and then a crucifix. A summary of the ullages is given below.

| <u>Encounter No.</u> | <u>Time</u> | <u>Duration (sec)</u> |
|----------------------|-------------|-----------------------|
| Using tape           |             |                       |
| 1                    | 0851:30     | 3                     |
| 2                    | 0857:17     | 31                    |
| 3                    | 0901:20     | 23                    |
| 4                    | 0902:08     | 15                    |
| 5                    | 0902:30     | 13                    |
| 6                    | 0903:00     | 4                     |
| 7                    | 0904:00     | 4                     |
| 8                    | 0904:40     | 5                     |
| Using crucifix       |             |                       |
| 9                    | 0908:40     | 8                     |
| 10                   | 0909:25     | 5                     |
|                      | 0910        | Stopped 6C            |

Deck Watch Period 2 (0800-1200, Day 2)

The major activities during this period were tank toffs and periodic tank gauging. Exposure monitoring samples were collected to correlate with specific activities as summarized below.

| <u>Time</u> | <u>Activity</u>       | <u>Sample Number</u> |
|-------------|-----------------------|----------------------|
| 0800-0830   | Topoff of 2S, 2C      | SB-42<br>60385       |
| 0830-0915   | Topoff of 6C          | SB-60<br>60386       |
| 0915-1050   | Topoff of 4P, 4S, 4C  | SB-48<br>60387       |
| 1050-1200   | Periodic Tank Gauging | SB-49                |

The following summarizes the specific details of these activities, i.e. the toffs and tank gaugings.

Topoff of 2S

Tank 2S was to be filled to a 98% full ullage of 3'8". The tank toff procedure when filling a tank to an ullage of less than four feet, as measured from the 28" high deck riser, was accomplished using a wooden crucifix. The shaft that extended into the tank was about four and one-half feet long and the cross piece was long enough to rest on the deck riser. Once the product level reached the bottom of the stick, this crew member never moved more than three feet away from the riser. Little time was spent with the breathing zone directly over the top of the riser. He was usually there just long enough to drop the crucifix in and then pull it out. He would then step back, standing upwind or crosswind, and look at the liquid level mark on the stick.

The series of ullage measurements during toff of tank 2S are listed below:

| <u>Encounter No.</u> | <u>Time</u> | <u>Duration (sec)</u> |
|----------------------|-------------|-----------------------|
| 1                    | 0756:40     | 5                     |
| 2                    | 0757:08     | 4                     |
| 3                    | 0757:30     | 3                     |
| 4                    | 0757:40     | 2                     |
| 5                    | 0758:30     | 2                     |
| 6                    | 0759:11     | 7                     |
|                      | 0759:20     | Stopped 2S            |

All of these ullages, except for Encounter No. 1 which was taken from downwind, were taken from crosswind of the deck riser.

| <u>Start Time<br/>of Round</u> | <u>Tank</u> | <u>Duration (sec)</u> | <u>Breathing Zone<br/>Vapor Conc.<br/>(ppm gasoline)</u> |
|--------------------------------|-------------|-----------------------|----------------------------------------------------------|
| 2158                           | 6S          | 20                    | 300                                                      |
|                                | 6C          | 30                    | 415-700                                                  |
|                                | 6P          | 15                    | 45-65                                                    |
|                                | 3P          | 17                    | 1750-2000                                                |
|                                | 3C          | 14                    | 4300                                                     |
|                                | 3S          | 20                    | 1500                                                     |
| 2229                           | 4S          | 56 F*                 | 16-115                                                   |
|                                | 4C          | 60 F                  | 115                                                      |
|                                | 4P          | 30 F                  | 730                                                      |
|                                | 5P          | 40                    | 160-480                                                  |
|                                | 5S          | 30 F                  | 70-6000                                                  |
|                                | 5C          | 20                    | NM **                                                    |
| 2258                           | 6P          | 20 F                  | NM                                                       |
|                                | 6C          | 20 F                  | NM                                                       |
|                                | 6S          | 20 F                  | NM                                                       |
|                                | 3S          | 25 F                  | NM                                                       |
|                                | 3C          | 15 F                  | NM                                                       |
|                                | 3P          | 20 F                  | NM                                                       |
| 2329                           | 5S          | 16                    | NM                                                       |
|                                | 5C          | 21                    | NM                                                       |
|                                | 5P          | 27                    | NM                                                       |
|                                | 4P          | 27                    | NM                                                       |
|                                | 4C          | 30                    | NM                                                       |
|                                | 4S          | 32                    | NM                                                       |
|                                | 2S          | 20                    | NM                                                       |
|                                | 1S          | 26                    | NM                                                       |

The 3/M's body position was usually either upwind or crosswind of the deck riser during ullage readings, but he sometimes stood downwind because of convenience.

For the time between periodic rounds, the 3/M sat or stood at various places on the deck. These locations included:

- o the starboard rail upwind of the vapors,
- o the 4S hatch cover facing stern (downwind of the vapors from the open ullage cap on the expansion trunk), and
- o the steps downwind of the starboard manifold drip tray.

---

\* F indicates that 3/M held flashlight for A/B taking actual ullage reading.

\*\* NM indicates not measured.

TABLE III. SUMMARY OF ACTIVITIES AND EXPOSURES FOR THE 3/M (CONT'D)

WORKER TITLE: 3rd Mate (Page 3 of 3)

WATCH: 0800-1200, 2000-2400

| Voyage Day | Voyage Leg | Worker Activities          | Time of Observation | Regular Time (RT)<br>Overtime (OT)<br>or OFF | Sample Number | Exposure              | Exposure Concentration |              | Exposure Duration (min) |
|------------|------------|----------------------------|---------------------|----------------------------------------------|---------------|-----------------------|------------------------|--------------|-------------------------|
|            |            |                            |                     |                                              |               |                       | ppm Benzene            | ppm Gasoline |                         |
| 10         | Ballast    | In Deckhouse               | 0000 - 0200         | OFF                                          | None          | None                  | --                     | --           | --                      |
|            |            | Wheelhouse for Maneuvering | 0200 - 0400         | OT                                           | None          | None                  | --                     | --           | --                      |
|            |            | In Deckhouse               | 0400 - 0800         | OFF                                          | None          | None                  | --                     | --           | --                      |
|            |            | Wheelhouse Watch           | 0800 - 1200         | RT                                           | None          | None                  | --                     | --           | --                      |
|            |            | In Deckhouse               | 1200 - 1300         | OFF                                          | None          | None                  | --                     | --           | --                      |
|            |            | Fire Line Maint.           | 1300 - 1700         | OT                                           | None          | None                  | --                     | --           | --                      |
|            |            | In Deckhouse               | 1700 - 2000         | OFF                                          | None          | None                  | --                     | --           | --                      |
|            |            | Wheelhouse Watch           | 2000 - 2400         | RT                                           | None          | None                  | --                     | --           | --                      |
|            |            | In Deckhouse               | 0000 - 0600         | OFF                                          | None          | None                  | --                     | --           | --                      |
|            |            | Wheelhouse Relief for C/M  | 0600 - 0800         | OT                                           | None          | None                  | --                     | --           | --                      |
| 11         | Ballast    | Wheelhouse Watch           | 0800 - 1200         | RT                                           | None          | None                  | --                     | --           | --                      |
|            |            | In Deckhouse               | 1200 - 2000         | OFF                                          | SB-9          | Gasoline Infiltration | ND                     | 1.08         | 247                     |
|            |            | Wheelhouse Watch           | 2000 - 2400         | RT                                           | None          | None                  | --                     | --           | --                      |
|            |            | In Deckhouse               | 0000 - 0800         | OFF                                          | None          | None                  | --                     | --           | --                      |
| 12         | Ballast    | Wheelhouse Watch           | 0800 - 1200         | RT                                           | None          | None                  | --                     | --           | --                      |
|            |            | In Deckhouse               | 1200 - 1300         | OFF                                          | None          | None                  | --                     | --           | --                      |
|            |            | General Pump Maint.        | 1300 - 1500         | OT                                           | None          | None                  | --                     | --           | --                      |
|            |            | Wheelhouse for Maneuvering | 1500 - 1600         | OT                                           | None          | None                  | --                     | --           | --                      |
|            |            |                            |                     |                                              | None          | None                  | --                     | --           | --                      |

TABLE III. SUMMARY OF ACTIVITIES AND EXPOSURES FOR THE 3/H (CONT'D)

WORKER TITLE: 1st Mate (Page 2 of 3)

WATCH: 0800-1200, 2000-2400

| Voyage Day | Voyage Log                                 | Worker Activities                         | Time of Observation | Regular Time (RT)<br>Overtime (OT)<br>or OFF | Sample Number | Exposure        | Exposure Concentration |              | Exposure Duration (min) |
|------------|--------------------------------------------|-------------------------------------------|---------------------|----------------------------------------------|---------------|-----------------|------------------------|--------------|-------------------------|
|            |                                            |                                           |                     |                                              |               |                 | ppm Benzene            | ppm Gasoline |                         |
| 5          | Laden No. 1                                | In Deckhouse                              | 0000 - 0800         | OFF                                          | None          | None            | --                     | --           | --                      |
|            |                                            | Wheelhouse Watch                          | 0800 - 1200         | RT                                           | None          | None            | --                     | --           | --                      |
|            |                                            | In Deckhouse                              | 1200 - 1530         | OFF                                          | None          | None            | --                     | --           | --                      |
|            |                                            | General Pump Maint.                       | 1530 - 1700         | OT                                           | None          | None            | --                     | --           | --                      |
| 6          | Laden No. 1                                | In Deckhouse                              | 1700 - 2000         | OFF                                          | None          | None            | --                     | --           | --                      |
|            |                                            | Wheelhouse Watch                          | 2000 - 2400         | RT                                           | None          | None            | --                     | --           | --                      |
|            |                                            | In Deckhouse                              | 0000 - 0800         | OFF                                          | None          | None            | --                     | --           | --                      |
|            |                                            | Wheelhouse Watch                          | 0800 - 1200         | RT                                           | None          | None            | --                     | --           | --                      |
| 7          | Disch. No. 1<br>Laden No. 2<br>Laden No. 7 | In Deckhouse                              | 1200 - 2000         | OFF                                          | None          | None            | --                     | --           | --                      |
|            |                                            | Wheelhouse Watch                          | 2000 - 2400         | RT                                           | None          | None            | --                     | --           | --                      |
|            |                                            | In Deckhouse                              | 0000 - 0800         | OFF                                          | None          | None            | --                     | --           | --                      |
|            |                                            | Wheelhouse Watch                          | 0800 - 1200         | RT                                           | None          | None            | --                     | --           | --                      |
| 8          | Discharge No. 2                            | In Deckhouse                              | 1200 - 1330         | OFF                                          | None          | None            | --                     | --           | --                      |
|            |                                            | General Pump Maint.                       | 1330 - 1500         | OT                                           | None          | None            | --                     | --           | --                      |
|            |                                            | In Deckhouse                              | 1500 - 2000         | OFF                                          | None          | None            | --                     | --           | --                      |
|            |                                            | Wheelhouse Watch                          | 2000 - 2400         | RT                                           | None          | None            | --                     | --           | --                      |
| 9          | Discharge No. 2<br>Ballast                 | In Deckhouse                              | 0000 - 0800         | OFF                                          | None          | None            | --                     | --           | --                      |
|            |                                            | Discharge Gauging and<br>2P, 2S Stripping | 0800 - 0930         | RT                                           | SB-78         | Gasoline Vapors | ND                     | 5.16         | 94                      |
|            |                                            | Discharge Gauging                         | 0930 - 1200         | RT                                           | SB-109        | Gasoline Vapors | ND                     | 18.88        | 125                     |
|            |                                            | In Deckhouse                              | 1200 - 2000         | OFF                                          | SB-116        | Gasoline Vapors | 0.11                   | 2.17         | 488                     |
| 9          | Discharge No. 2                            | Discharge Gauging                         | 2000 - 2200         | RT                                           | SB-102        | Gasoline Vapors | ND                     | 8.02         | 240                     |
|            |                                            | Stripping of 6S                           | 2100 - 2200         | RT                                           | SB-31         | Gasoline Vapors | ND                     | 8.91         | 65                      |
|            |                                            | In Deckhouse                              | 0000 - 0800         | OFF                                          | SB-33         | Gasoline Vapors | ND                     | ND           | 420                     |
|            |                                            | Discharge Gauging                         | 0800 - 1200         | RT                                           | None          | None            | --                     | --           | --                      |
| 9          | Ballast                                    | In Deckhouse                              | 1200 - 2000         | OFF                                          | None          | None            | --                     | --           | --                      |
|            |                                            | Ballast Gauging                           | 2000 - 2400         | RT                                           | SB-111        | Gasoline Vapors | 1.11                   | 122.23       | 231                     |



TABLE III. SUMMARY OF ACTIVITIES AND EXPOSURES FOR THE 1/H

WORKER TITLE: 3rd Mate (Page 1 of 3)

WATCH: 0800-1200, 2000-2400

| Voyage Day | Voyage Leg                            | Worker Activities      | Time of Observation | Regular Time (RT)<br>Overtime (OT)<br>or OFF | Sample Number | Exposure              | Exposure Concentration |              | Exposure Duration (min) |
|------------|---------------------------------------|------------------------|---------------------|----------------------------------------------|---------------|-----------------------|------------------------|--------------|-------------------------|
|            |                                       |                        |                     |                                              |               |                       | ppm Benzene            | ppm Gasoline |                         |
| 1          | Loading                               | Periodic Tank Gauging  | 2000 - 2250         | RT                                           | SB-47         | Gasoline Vapors       | 1.18                   | 107.00       | 177                     |
|            |                                       | Periodic Tank Gauging  | 2250 - 2400         | RT                                           | 60382         | Gasoline Vapors       | ND                     | 82.88        | 183                     |
|            | Loading                               | In Deckhouse           | 0000 - 0800         | OFF                                          | SB-50         | Gasoline Vapors       | 1.19                   | 296.12       | 57                      |
|            |                                       | Tank Topoff 2S, 2C     | 0800 - 0830         | RT                                           | 60383         | Gasoline Vapors       | ND                     | 265.83       | 54                      |
| 2          | Loading                               | Tank Topoff 6C         | 0830 - 0915         | RT                                           | SB-64         | Gasoline Infiltration | 0.18                   | 19.22        | 483                     |
|            |                                       | Tank Topoff 4P, 4S, 4C | 0915 - 1050         | RT                                           | SB-42         | Gasoline Vapors       | 20.80                  | 4839.10      | 31                      |
|            | Periodic Tank Gauging<br>In Deckhouse | Periodic Tank Gauging  | 1050 - 1200         | RT                                           | 60385         | Gasoline Vapors       | 19.72                  | 5758.70      | 39                      |
|            |                                       | In Deckhouse           | 1200 - 2000         | OFF                                          | SB-60         | Gasoline Vapors       | 16.49                  | 2997.10      | 47                      |
| 3          | Laden<br>No. 1                        | Prepare to Sail        | 2000 - 2400         | RT                                           | 60386         | Gasoline Vapors       | 13.61                  | 4367.30      | 47                      |
|            |                                       | In Deckhouse           | 0000 - 0800         | OFF                                          | SB-48         | Gasoline Vapors       | 0.67                   | 81.32        | 88                      |
|            | Laden<br>No. 1                        | Wheelhouse Watch       | 0800 - 1200         | RT                                           | 60387         | Gasoline Vapors       | ND                     | 129.71       | 85                      |
|            |                                       | In Deckhouse           | 1200 - 2000         | OFF                                          | SB-49         | Gasoline Vapors       | ND                     | 4.96         | 56                      |
| 4          | Laden<br>No. 1                        | General Pump Maint.    | 1300 - 1700         | OT                                           | SB-44         | Gasoline Infiltration | ND                     | 1.21         | 481                     |
|            |                                       | In Deckhouse           | 1700 - 2000         | OFF                                          | None          | None                  | ---                    | ---          | ---                     |
|            | Wheelhouse Watch                      | Wheelhouse Watch       | 2000 - 2400         | RT                                           | None          | None                  | ---                    | ---          | ---                     |
|            |                                       | Wheelhouse Watch       | 0000 - 0800         | OFF                                          | None          | None                  | ---                    | ---          | ---                     |

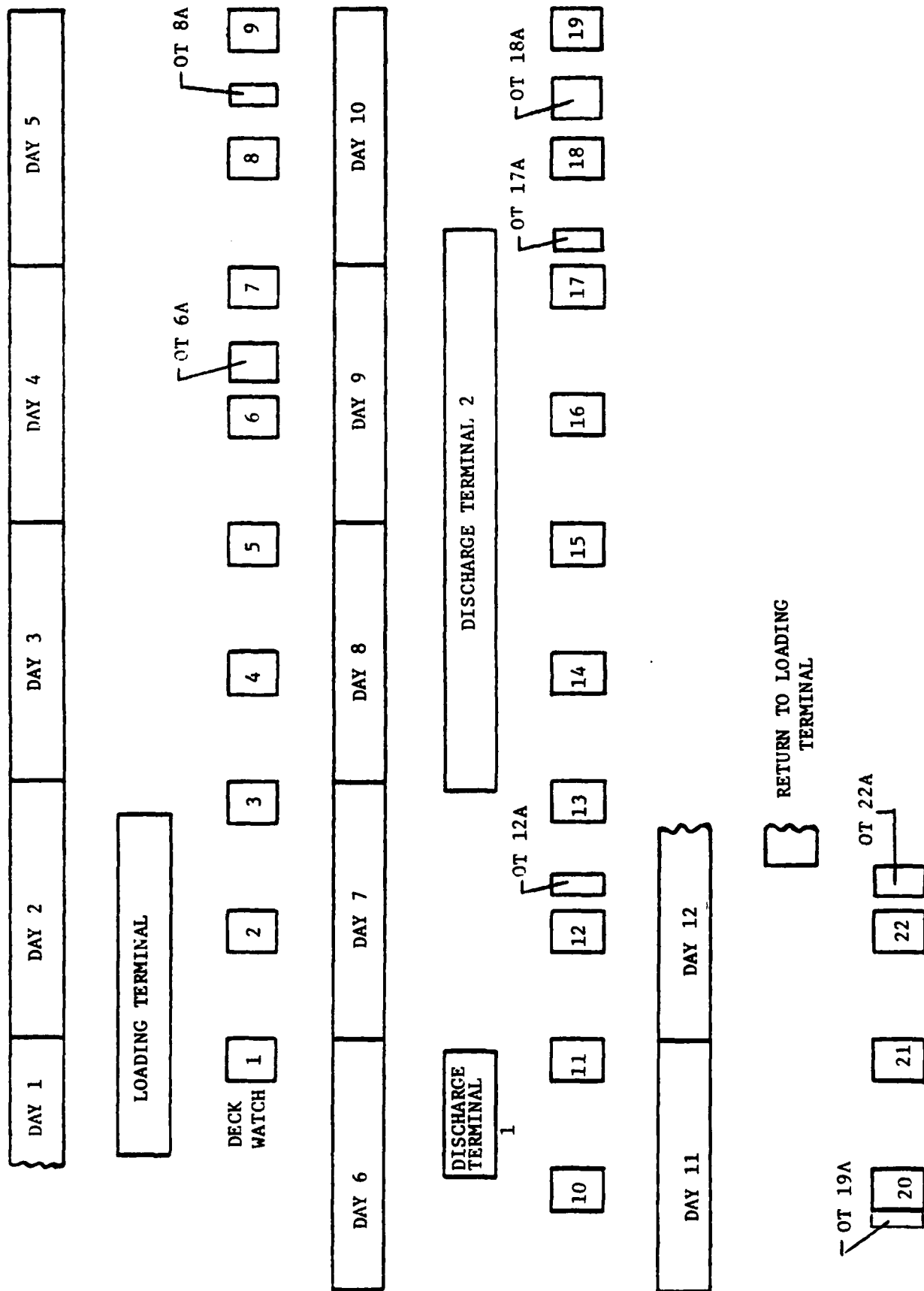


FIGURE 2. REGULAR AND OVERTIME WORK SHIFTS FOR 3/M

VIII. Summary of Activities and Occupational Exposures for the 3/M

The 3/M's normal watch hours were 0800-1200 and 2000-2400. These regular work shifts as well as overtime worked by the 3/M are presented and labelled in Figure 2.

Table III summarizes the 3/M's activities during the entire voyage. For each activity, the time of observation and whether it was regular time (RT), overtime (OT), or off period (OFF) are noted. For times when samples were collected, the sample numbers, exposures, exposure concentrations, and durations are also tabulated.

The activities and occupational exposures for the 3/M during the entire voyage will be discussed in detail in this section.

Deck Watch Period 1 (2000-2400, Day 1)

The loading of regular, unleaded, and super unleaded gasoline into tanks 1, 2, 3, and 6 across had begun at 1930. The loading of jet fuel into tanks 4 and 5 across began at 2000.

The major activity of the 3/M during this watch was periodic tank gauging. Since it was so close to the beginning of loading, very few ullage readings were taken. Two sequential exposure samples were taken during this shift and are summarized below.

| <u>Time</u> | <u>Activity</u>       | <u>Sample Number</u> |
|-------------|-----------------------|----------------------|
| 2000-2250   | Periodic Tank Gauging | SB-47 *              |
|             |                       | 60382 **             |
| 2250-2400   | Periodic Tank Gauging | SB-50                |
|             |                       | 60383                |

Gauging rounds usually involved two people, especially at night when use of a flashlight was necessary. The gauging rounds for the 3/M during watch period 1 are summarized below.

---

\* SB-xx indicates active charcoal tube samples

\*\* A five digit number indicates passive charcoal badge samples

Respirable sandblasting exposure samples were collected using a cyclone separator and 37 mm, 0.8  $\mu$  MEC filters in cassettes. Sampling flow rate was nominally 1-1.5 Lpm

The filter media was not appropriate to quantitative X-ray diffraction or colorimetric analysis as recommended by NIOSH. Therefore, the following semi-quantitative analysis procedure was employed.

- o A bulk sample of the sandblasting feed stock and a rafter sample (sandblasting debris) were both analyzed sequentially for
  - weight loss upon dehydration at 110°C,
  - weight loss on ignition to remove organics, and
  - weight loss on Aqua Regia treatment to remove non-silica inorganics.
- o This analysis indicated that the feed stock was 99.71 percent silica by weight and that the rafter sample was 99 percent silica by weight (one percent contamination).
- o The feed stock was then analyzed by X-ray diffraction, without internal standards, over the emission range of quartz, tridymite and cristobalite. Only quartz was detected.

Based on the above analyses, it was assumed that quartz was the only silica compound on the respirable sandblasting filters, and it was present on the filter in the same proportion by weight as was determined from the rafter sample (99 percent).

The exposure filters were weighed, and the quartz exposure concentrations were calculated as follows.

$$C = \frac{0.99 (W_F - W_I)}{Q_t}$$

where  $W_F$  = weight of respirable material (quartz plus debris) on the filter plus filter weight  
 $W_I$  = pre-test filter tare weight  
 $Q_t$  = as defined earlier.

o Passive Dosimeters

$$C \text{ (ppm)} = \frac{[W_{CF} + 2.2 W_{CB}]}{\eta(SR) t} \left( \frac{24.45}{MW} \right) \left( \frac{T + 273}{298} \right) \left( \frac{760}{P} \right)$$

where

$W_{CF}$  = weight of analyte on exposed front strip corrected for blank, ng

$W_{CB}$  = weight of analyte on backup strip corrected for blank, ng

SR = passive sampling rate,  $\text{cm}^3/\text{min}$ .

(= 35.6 for benzene and 21.9 for gasoline according to manufacturer's data)

Other quantities are as defined for the adsorbent tubes.

Respirable paint and rust chipping samples were collected using (1) a cyclone separator having a  $10\mu$  cutoff on particle size, and (2) filter cassettes containing 37 mm,  $0.8\mu$  MEC filters. All filters were conditioned and weighed prior to sampling. Sampling flow rate was within the accepted 1-2 Lpm range. The Material Safety Data Sheets for the paint primer, thinner and finish coat did not include the presence of chromates, lead, barium or strontium compounds. Therefore, the contaminants of interest were identified as zinc and iron.

Visually, all of the chipping sample filters had extremely light loading. Therefore, a two-step analysis procedure was defined.

- o The most heavily loaded filter was weighed, and the exposure concentration was calculated. If the concentration was less than  $5 \text{ mg/m}^3$ , which is the TLV-TWA for respirable nuisance zinc oxide dust and iron oxide, then the remaining filters would be analyzed gravimetrically.
- o If the most heavily loaded filter produced an exposure concentration greater than  $5 \text{ mg/m}^3$ , then all filters would be analyzed by atomic absorption to quantify the zinc and iron levels according to NIOSH Method P&CAM 173.

In the final analysis, all filters were analyzed gravimetrically, and exposure concentrations were calculated as follows:

$$C = \frac{(W_F - W_I)}{Qt}$$

where  $W_F$  = post-test weight of conditioned filter  
 $W_I$  = pre-test filter tare weight  
 $Q$  = sampling flow rate  
 $t$  = sampling time.

o Charcoal Sampling Tubes

| <u>Chemical</u> | <u>Tube Size</u> | <u><math>\eta</math></u> |
|-----------------|------------------|--------------------------|
| Benzene         | small (100/50)   | 0.984                    |
|                 | large (400/200)  | 0.984                    |
| THC(gasoline)   | small (100/50)   | 1.005                    |
|                 | large (400/200)  | 0.950                    |
| Isobutanol      | large (400/200)  | 0.82                     |
| MEK             | large (400/200)  | 0.801                    |
| MIBK            | large (400/200)  | 0.880                    |
| N-Butanol       | large (400/200)  | 0.88                     |
| Xylene          | large (400/200)  | 0.981                    |

o Passive Charcoal Badges

| <u>Chemical</u> | <u><math>\eta</math></u> |
|-----------------|--------------------------|
| Benzene         | 0.947                    |
| THC (gasoline)  | 1.010                    |

Ambient vapor concentrations were calculated using the following analytical expressions.

o Absorbent tubes

$$C \text{ (ppm)} = \frac{W_c}{\eta Q t} \left( \frac{24.45}{MW} \right) \left( \frac{T + 273}{298} \right) \left( \frac{760}{P} \right)$$

where

- $W_c$  = cumulative weight of analyte on the tube corrected for blank,  $\mu\text{g}$
- $\eta$  = desorption efficiency as a decimal
- $Q$  = sampling flow rate, LPM
- $t$  = sample duration, min.
- $MW$  = analyte molecular weight
- $T$  = sampling temperature,  $^{\circ}\text{C}$
- $P$  = sampling barometric pressure, mm Hg

## VII. Sampling Strategy and Sample Analysis

All of the products that were loaded and discharged during the observation period were various types of gasolines. Since there is no recommended NIOSH sampling procedure for gasolines, the sampling was based on benzene. The recommended NIOSH sampling procedure for benzene is as follows:

|                                    |                                                                      |
|------------------------------------|----------------------------------------------------------------------|
| TWA <sup>(1)</sup>                 | 10ppm                                                                |
| Ceiling <sup>(1)</sup>             | 25ppm                                                                |
| NIOSH Method Number <sup>(2)</sup> | S311                                                                 |
| Absorbent Type                     | Activated Charcoal                                                   |
| Absorbent Size                     | L = 7cm<br>OD/ID = 6/4 mm<br>20/40 mesh<br>100/50mg                  |
| TWA Concentration:                 | Sample Volume 12l<br>Sample Flow Rate 0.2l/min<br>Sample Time 60 min |
| Ceiling Concentration:             | Sample Volume 2l<br>Sample Flow Rate 0.2l/min<br>Sample Time 10 min  |

In addition to the conventional sampling methods that employ pumps and tubes, passive dosimeters were also utilized. The badges contained two adsorption elements; one element served as a backup section. All tubes and passive dosimeters were analyzed by an AIHA accredited laboratory.

For the gasoline samples, nitrobenzene was used to desorb the charcoal tubes because it is superior to carbon disulfide in two areas and has desorption efficiencies comparable to carbon disulfide. No temperature program was needed for nitrobenzene, and greater analytical precision was possible since no gasoline peaks are obscured, as is the case when carbon disulfide is used. Nitrobenzene was not used to desorb the badges since it dissolved a component of the badge material.

For the paint samples, carbon disulfide was used to desorb the charcoal tubes, as recommended by NIOSH. No badges were used to monitor paint exposure.

The following summarizes the desorption efficiencies reported by the laboratory.

- (1) ACGIH Exposure Limits
- (2) NIOSH Manual of Analytical Methods, Volumes 1-7.

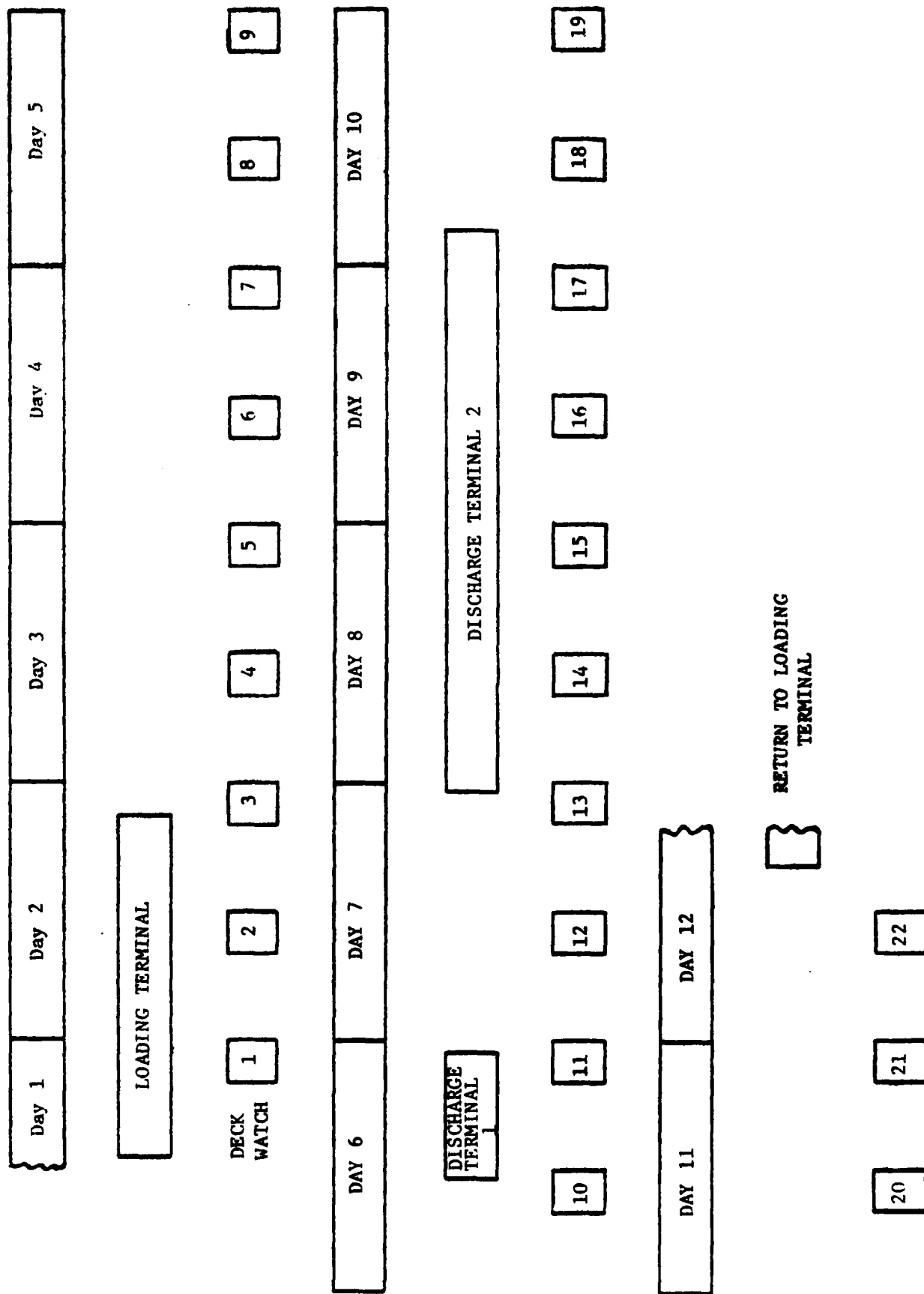


FIGURE 1. DURATION OF TERMINAL DOCKINGS AND REGULAR WORK SHIFTS



At 1100 of this shift, the 3/M completed one ullage round of tanks 3C, 3S, and 3P, then went into the deckhouse to recalculate finishing times of the various tanks and take a break. From 1130 until the end of the shift he was on the deck but in areas where he had little potential for exposure.

Deck Watch Periods 3 (2000-2400, Day 2)  
4 (0800-1200, Day 3)  
5 (2000-2400, Day 3)  
6 (0800-1200, Day 4)  
7 (2000-2400, Day 4)  
8 (0800-1200, Day 5)  
9 (2000-2400, Day 5)

The major activity for Period 3 was to prepare the ship's bridge for sailing. This included updating books and preparing charts. Occupational exposure monitoring was not performed on this shift because of the lack of potential for exposure, based on OVA survey information.

The deck watches for periods 4 through 9 were spent entirely in the wheelhouse navigating. Occupational exposure monitoring was also not performed for these six shifts.

Overtime Periods 6A (1300-1700, Day 4)  
8A (1530-1700, Day 5)

During these overtime periods, the 3/M performed maintenance activities on the diesel pumps on deck in preparation for discharge. His activities included checking water and oil levels and adding ethylene glycol. Exposure monitoring was not justified based on an OVA survey of the areas in which the 3/M worked.

Deck Watch Period 10 (0800-1200, Day 6)

From 0800-1030 the 3/M was in the wheelhouse for maneuvering and docking activities. He then went out onto the deck to start the cargo transfer. His major activities included preparing valves for discharge, starting the diesels, and engaging pumps when the dock was ready for the transfer to begin. Exposure monitoring was not performed during this period because the 3/M was not near any of the open tanks and ambient concentrations were low during the short time he spent on deck.

Deck Watch Periods 11 (2000-2400, Day 6)  
12 (0800-1200, Day 7)  
13 (2000-2400, Day 7)

The deck watches for periods 11, 12, and 13 were spent entirely in the wheelhouse navigating. Occupational exposure monitoring was not performed because of the lack of potential for exposure.

Overtime Period 12A (1330-1500, Day 7)

General maintenance on the deck diesel pumps, as discussed for periods 6A and 8A, was performed during this period. Exposure monitoring was again not justified.

Deck Watch Period 14 (0800-1200, Day 8)

The major activities during this period were discharge gauging and the stripping of two tanks. Exposure monitoring samples were collected to correlate with specific activities as summarized below.

| <u>Time</u> | <u>Activity</u>                              | <u>Sample No.</u> |
|-------------|----------------------------------------------|-------------------|
| 0800-0930   | Discharge Gauging and Stripping of 2P and 2S | SB-78             |
| 0930-1200   | Discharge Gauging                            | SB-109            |

A summary of the periodic ullage readings taken between 0800 and 0930 is presented below.

| <u>Tank</u> | <u>Time</u> | <u>Duration (sec)</u> |
|-------------|-------------|-----------------------|
| 1P          | 0832:30     | 36                    |
| 1C          | 0833:25     | 95                    |
| 1S          | 0835:20     | 40                    |
| 5C          | 0844:00     | 20                    |
| 6S          | 0845:30     | 13                    |
| 2P          | 0859:24     | 26                    |

Stripping of product tanks was achieved by looking down into either a Butterworth opening or the ullage hatch and watching the liquid level in relation to the suction lines in the bottom of the tank. Various valves were opened or closed in an effort to pump the maximum amount of liquid out of the tank without losing suction on the pump.

A summary of the times when the 3/M was looking into the tanks to strip 2P and 2S is listed below.

Stripping of 2P

| <u>Encounter No.</u> | <u>Time</u> | <u>Duration (sec)</u> |
|----------------------|-------------|-----------------------|
| 1                    | 0905:30     | 30                    |
| 2                    | 0906:10     | 30                    |
| 3                    | 0906:45     | 25                    |
| 4                    | 0907:30     | 40                    |
| 5                    | 0908:30     | 60                    |
| 6                    | 0910:00     | 17                    |
| 7                    | 0910:36     | 78                    |
|                      | 0912:00     | Stopped 2P            |

Stripping of 2S

| <u>Encounter No.</u> | <u>Time</u> | <u>Duration (sec)</u> |
|----------------------|-------------|-----------------------|
| 1                    | 0912:30     | 30                    |
| 2                    | 0913:22     | 10                    |
| 3                    | 0913:35     | 25                    |
| 4                    | 0914:47     | 8                     |
| 5                    | 0915:20     | 16                    |
| 6                    | 0915:52     | 13                    |
| 7                    | 0916:35     | 4                     |
| 8                    | 0916:58     | 22                    |
| 9                    | 0917:30     | 22                    |
| 10                   | 0918:00     | 9                     |
| 11                   | 0918:22     | 8                     |
| 12                   | 0919:45     | 25                    |
| 13                   | 0920:25     | 4                     |
| 14                   | 0920:45     | 5                     |
| 15                   | 0922:00     | 16                    |
| 16                   | 0923:07     | 13                    |
| 17                   | 0924:14     | 17                    |
| 18                   | 0924:35     | 12                    |
| 19                   | 0924:52     | 14                    |
| 20                   | 0925:10     | 15                    |
| 21                   | 0925:28     | 14                    |
| 22                   | 0925:52     | 16                    |
| 23                   | 0926:10     | 17                    |
| 24                   | 0926:30     | 20                    |
|                      | 0927:00     | Stopped 2S            |

A summary of the periodic ullage readings taken between 0930 and 1200 is presented below.

| <u>Tank</u> | <u>Time</u> | <u>Duration (sec)</u> |
|-------------|-------------|-----------------------|
| 6S          | 1005:50     | 25                    |
| 6C          | 1006:25     | 23                    |
| 6P          | 1007:18     | 32                    |
| 5P          | 1008:20     | 30                    |
| 5C          | 1009:20     | 18                    |
| 5S          | 1009:53     | 30                    |

Only minimal gauging was necessary because this shift was so close to the beginning of discharge, and most of the tanks were still over half full. These gaugings were mainly for determining discharge rates which were used to calculate the ship departure time.

Deck Watch Period 15 (2000-2400, Day 8)

Although there were many tanks discharging simultaneously during this watch period, the only gauging that was done was to strip 6S. Two different exposure samples were collected, one over the entire shift and one during the hour that it took to strip 6S. These samples are summarized below.

| <u>Time</u> | <u>Activity</u>   | <u>Sample No.</u> |
|-------------|-------------------|-------------------|
| 2000-2400   | Discharge Gauging | SB-102            |
| 2100-2200   | Stripping of 6S   | SB-31             |

The following summarizes the times when the 3/M was looking into 6S for stripping.

Stripping 6S

| <u>Encounter No.</u> | <u>Time</u> | <u>Duration (sec)</u> |
|----------------------|-------------|-----------------------|
| 1                    | 2102:35     | 10                    |
| 2                    | 2105:00     | 10                    |
| 3                    | 2115:00     | 45                    |
| 4                    | 2125:20     | 47                    |
| 5                    | 2130:50     | 50                    |
| 6                    | 2135:00     | 60                    |
| 7                    | 2142:36     | 34                    |
| 8                    | 2144:00     | 30                    |
| 9                    | 2144:40     | 6                     |
| 10                   | 2146:00     | 29                    |
| 11                   | 2146:33     | 38                    |
| 12                   | 2156:20     | 10                    |
| 13                   | 2158:00     | 120                   |
|                      | 2200:00     | Stopped 6S            |

Deck Watch Period 16 (0800-1200, Day 9)

The major activity during this watch period was discharge gauging. Exposure monitoring was not conducted because it was raining and the high humidity can cause invalid results. Also, OVA surveys indicated that there was little potential for exposure.

Deck Watch Period 17 (2000-2400, Day 9)

The major activity during this shift was ballast gauging. Sample SB-111 was collected over the entire watch period.

The following summarizes the ballast gauging performed by the 3/M.

| <u>Tank</u> | <u>Time</u> | <u>Duration (sec)</u> |
|-------------|-------------|-----------------------|
| 1C          | 2042:15     | 45                    |
| 3C          | 2048:10     | 45                    |
| 4C          | 2050:00     | 30                    |
| 4C          | 2150:00     | 20                    |
| 3C          | 2151:00     | 20                    |
| 1C          | 2152:00     | 30                    |
| 1C          | 2242:00     | 30                    |
| 3C          | 2247:00     | 30                    |
| 5C          | 2253:00     | 35                    |
| 6C          | 2255:00     | 25                    |

The 3/M spent the rest of the time during this shift away from these sources, usually by the rail upwind of the vapors.

Overtime Period 17A (0200-0400, Day 10)

The 3/M spent this entire overtime period in the wheehouse for maneuvering during undocking. Exposure monitoring was not performed.

Deck Watch Periods 18 (0800-1200, Day 10)

19 (2000-2400, Day 10)

20 (0800-1200, Day 11)

21 (2000-2400, Day 11)

22 (0800-1200, Day 12)

The deck watches for periods 18 through 22 were spent entirely in the wheelhouse navigating. No exposure monitoring was performed.

Overtime Period 18A (1300-1700, Day 10)

For this overtime period, the 3/M completed work on fire line maintenance replacing valve wrenches and relettering the pipes. Exposure monitoring was not justified.

Overtime Period 19A (0600-0800, Day 11)

Since the C/M was leading the tank cleaning efforts on deck, the 3/M reported for his normal watch two hours early. He was navigating in the wheelhouse for the entire period and monitoring was not performed.

Overtime Period 22A (1500-1600, Day 12)

The 3/M spent this entire overtime period in the wheelhouse for maneuvering during docking. Exposure monitoring was not justified.

IX. Summary of Activities and Occupational Exposures for  
Selected Crewman 8-12 A/B

The second crewman whose activities and occupational exposures were documented during the entire voyage was the A/B whose normal watch hours coincided with that of the 3/M (0800-1200 and 2000-2400). A chronological description of the regular work hours for A/B1 along with his overtime shifts are shown in Figure 3. The overtime shifts occurred only while the ship was in transit. At no time while the ship was docked for either loading or discharging of cargo did the selected A/B become involved in extended work activities.

A composite list of the A/B's activities during the entire voyage is shown in Table IV. Occupational exposure samples are also shown in the table and were collected during those activities in which higher than normal levels of contaminants were anticipated. On certain occasions, samples were also collected in the A/B's quarters to determine his exposure during off hours as a result of vapor infiltration.

The types of exposures sampled consisted of both cargo (gasoline) and non-cargo (paint) vapors as well as exposures to dust. The paint exposures are presented in Table V. The dust exposures were sampled during chipping of paint or sand blasting.

TABLE V. OCCUPATIONAL EXPOSURE TO PAINT VAPORS  
FOR SELECTED A/B (A/B1)

| Sample No. | Exposure Duration (min) | Xylene (ppm) | Isobutanol (ppm) | Methyl Isobutyl Ketone (ppm) | Methyl Ethyl Ketone (ppm) |
|------------|-------------------------|--------------|------------------|------------------------------|---------------------------|
| SB-97      | 34                      | 10.44        | 4.10             | ND                           | ND                        |
| SB-93      | 13                      | 5.10         | ND               | ND                           | ND                        |

In the remaining part of this section, a detailed discussion of the A/B's activities and occupational exposures noted in Table IV will be presented.

Deck Watch Period 1 (2000-2400, Day 1)

The responsibility of the A/B during this workshift was to assist the mate on watch (3/M) in periodic tank gauging. On most of the gauging rounds, the A/B's functions consisted of holding a flashlight and recording the ullage measurements that were being read by the 3/M. The A/B, however, did perform the actual ullage measurements on one of the gauging rounds during this period. Summarized below are the gauging rounds for which the 8-12 A/B was involved, with notation of the duration of time spent near each tank.

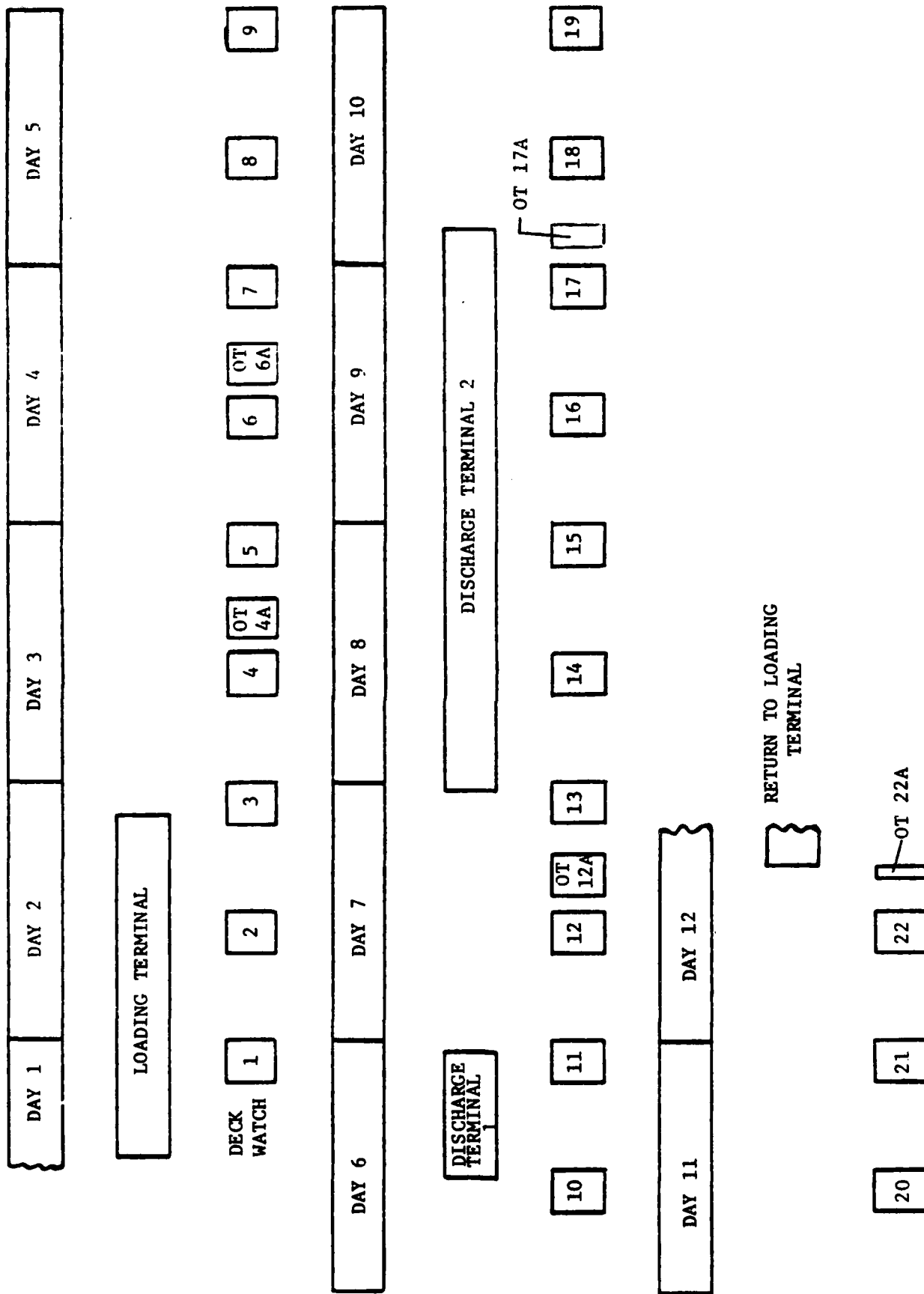


FIGURE 3. REGULAR AND OVERTIME WORK SHIFTS FOR A/B1



TABLE IV. SUMMARY OF ACTIVITIES AND EXPOSURES FOR A/R1

WORKER TITLE: A/R

WATCH: 0800 - 1200; 2000 - 2400

| Voyage Day | Voyage Log  | Worker Activities      | Time of Observation | Regular Time (RT)<br>Overtime (OT)<br>or OFF | Sample Number           | Exposure                                              | Exposure Concentration                               |                                                      | Exposure Duration (min) |
|------------|-------------|------------------------|---------------------|----------------------------------------------|-------------------------|-------------------------------------------------------|------------------------------------------------------|------------------------------------------------------|-------------------------|
|            |             |                        |                     |                                              |                         |                                                       | ppm Benzene                                          | ppm Gasoline                                         |                         |
| 1          | Loading     | Periodic Gauging       | 2000 - 2300         | RT                                           | SB-65                   | Gasoline Vapors                                       | 1.10                                                 | 199.35                                               | 173                     |
|            |             | Periodic Gauging       | 2300 - 2400         | RT                                           | 63761<br>SB-69<br>63763 | Gasoline Vapors<br>Gasoline Vapors<br>Gasoline Vapors | ND<br>5.70<br>5.91                                   | 221.12<br>907.47<br>1297.40                          | 173<br>43<br>45         |
|            | Loading     | In Deckhouse           | 0000 - 0800         | OFF                                          | SB-66                   | Gasoline Inflation                                    | 0.13                                                 | 17.88                                                | 450                     |
|            |             | Tank Top Off (General) | 0800 - 1100         | RT                                           | SB-58<br>63764          | Gasoline Vapors<br>Gasoline Vapors                    | 0.27<br>1.95                                         | 428.30<br>638.18                                     | 171<br>171              |
| 2          | Loading     | Tank Top Off (General) | 1100 - 1200         | RT                                           | SB-59                   | Gasoline Vapors                                       | ND                                                   | 46.86                                                | 50                      |
|            |             | In Deckhouse           | 1200 - 2000         | OFF                                          | SB-52                   | Gasoline Inflation                                    | ND                                                   | 3.06                                                 | 471                     |
|            | Laden No. 1 | Undocking              | 2000 - 2130         | RT                                           | SB-85                   | Gasoline Vapors                                       | 1.73                                                 | 19.9                                                 | 80                      |
|            |             | Wheelhouse Watch       | 2130 - 2400         | RT                                           | None                    | None                                                  | --                                                   | --                                                   | --                      |
| 3          | Laden No. 1 | In Deckhouse           | 0000 - 0800         | OFF                                          | None                    | None                                                  | --                                                   | --                                                   | --                      |
|            |             | Wheelhouse Watch       | 0800 - 1200         | RT                                           | None                    | None                                                  | --                                                   | --                                                   | --                      |
|            | Laden No. 1 | Chipping Paint         | 1200 - 1300         | OFF                                          | None                    | None                                                  | --                                                   | --                                                   | --                      |
|            |             | In Deckhouse           | 1300 - 1700         | OT                                           | None                    | None                                                  | --                                                   | --                                                   | --                      |
| 4          | Laden No. 1 | In Deckhouse           | 1700 - 2000         | OFF                                          | None                    | None                                                  | --                                                   | --                                                   | --                      |
|            |             | Wheelhouse Watch       | 2000 - 2400         | RT                                           | None                    | None                                                  | --                                                   | --                                                   | --                      |
|            | Laden No. 1 | In Deckhouse           | 0000 - 0800         | OFF                                          | None                    | None                                                  | --                                                   | --                                                   | --                      |
|            |             | Wheelhouse Watch       | 0800 - 1200         | RT                                           | None                    | None                                                  | --                                                   | --                                                   | --                      |
| 5          | Laden No. 1 | Chipping Paint         | 1200 - 1300         | OFF                                          | None                    | None                                                  | --                                                   | --                                                   | --                      |
|            |             | In Deckhouse           | 1300 - 1530         | OT                                           | None                    | None                                                  | --                                                   | --                                                   | --                      |
|            | Laden No. 1 | Spray Painting         | 1530 - 1615         | OT                                           | SB-D-5                  | Rust (Paint & Rust)                                   | Non Detectible                                       | Non Detectible                                       | 127                     |
|            |             | Spray Painting         | 1615 - 1700         | OT                                           | SB-97<br>SB-93          | Paint (constituents)<br>Paint (constituents)          | See Paint Exposure Table<br>See Paint Exposure Table | See Paint Exposure Table<br>See Paint Exposure Table | 34<br>13                |

TABLE IV. SUMMARY OF ACTIVITIES AND EXPOSURES FOR A/M1 (CONT'D)

WORKER TITLE: A/R

WATCH: 0800 - 1200; 2000 - 2400

| Voyage Day    | Voyage Leg      | Worker Activities | Time of Observation | Regular Time (RT)<br>Overtime (OT)<br>or OFF | Sample Number | Exposure            | Exposure Concentration |              | Exposure Duration (min) |
|---------------|-----------------|-------------------|---------------------|----------------------------------------------|---------------|---------------------|------------------------|--------------|-------------------------|
|               |                 |                   |                     |                                              |               |                     | ppm Benzene            | ppm Gasoline |                         |
| 4<br>(cont'd) | Laden<br>No. 1  | In Deckhouse      | 1700 - 2000         | OFF                                          | None          | None                | --                     | --           | --                      |
|               |                 | Wheelhouse Watch  | 2000 - 2400         | RT                                           | None          | None                | --                     | --           | --                      |
|               | Laden<br>No. 1  | In Deckhouse      | 0000 - 0800         | OFF                                          | None          | None                | --                     | --           | --                      |
|               |                 | Wheelhouse Watch  | 0800 - 1200         | RT                                           | None          | None                | --                     | --           | --                      |
| 5             | Laden<br>No. 1  | In Deckhouse      | 1200 - 2000         | OFF                                          | None          | None                | --                     | --           | --                      |
|               |                 | Wheelhouse Watch  | 2000 - 2400         | RT                                           | None          | None                | --                     | --           | --                      |
|               | Misch.<br>No. 1 | In Deckhouse      | 0000 - 0800         | OFF                                          | None          | None                | --                     | --           | --                      |
|               |                 | Wheelhouse Watch  | 0800 - 1000         | RT                                           | None          | None                | --                     | --           | --                      |
| 6             | Laden<br>No. 1  | In Deckhouse      | 1000 - 1200         | RT                                           | SB-63         | Gasoline Vapors     | ND                     | 4.72         | 29                      |
|               |                 | Hose - Connect    | 1200 - 2000         | OFF                                          | None          | None                | --                     | --           | --                      |
|               | Laden<br>No. 1  | In Deckhouse      | 2000 - 2300         | RT                                           | None          | None                | --                     | --           | --                      |
|               |                 | Undocking         | 2300 - 2400         | RT                                           | None          | None                | --                     | --           | --                      |
| 7             | Laden<br>No. 2  | In Deckhouse      | 0000 - 0800         | OFF                                          | None          | None                | --                     | --           | --                      |
|               |                 | Wheelhouse Watch  | 0800 - 1200         | RT                                           | None          | None                | --                     | --           | --                      |
|               | Laden<br>No. 2  | In Deckhouse      | 1200 - 1300         | OFF                                          | None          | None                | --                     | --           | --                      |
|               |                 | Chipping Paint    | 1300 - 1700         | OT                                           | SB-D-16       | Dust (Paint & Rust) | Non-Detectible         | --           | 93                      |
| 8             | Laden<br>No. 2  | In Deckhouse      | 1700 - 2000         | OFF                                          | None          | None                | --                     | --           | --                      |
|               |                 | Hose Connect      | 2000 - 2300         | RT                                           | SB-10         | Gasoline Vapors     | 1.55                   | 96.78        | 42                      |
|               | Misch.<br>No. 2 | In Deckhouse      | 2300 - 2400         | RT                                           | None          | None                | --                     | --           | --                      |
|               |                 | Periodic Gauging  | 0000 - 0800         | OFF                                          | None          | None                | --                     | --           | --                      |
| 9             | Laden<br>No. 2  | In Deckhouse      | 0800 - 1200         | RT                                           | SB-90         | Gasoline Vapors     | ND                     | 3.52         | 215                     |
|               |                 | Periodic Gauging  | 1200 - 2000         | OFF                                          | SB-108        | Gasoline Inflation  | 0.11                   | 1.37         | 464                     |
|               | Laden<br>No. 2  | In Deckhouse      | 2000 - 2400         | RT                                           | SB-99         | Gasoline Vapors     | ND                     | 2.21         | 60                      |
|               |                 | Periodic Gauging  |                     |                                              |               |                     |                        |              |                         |

TABLE IV. SUMMARY OF ACTIVITIES AND EXPOSURES FOR A/R1 (CONT'D)

WORKER TITLE: A/R

WATCH: 0800 - 1200; 2000 - 2400

| Voyage Day | Voyage Leg                | Worker Activities                   | Time of Observation | Regular Time (RT)<br>Overtime (OT)<br>or OFF | Sample Number  | Exposure                           | Exposure Concentration |                | Exposure Duration (min) |
|------------|---------------------------|-------------------------------------|---------------------|----------------------------------------------|----------------|------------------------------------|------------------------|----------------|-------------------------|
|            |                           |                                     |                     |                                              |                |                                    | ppm Benzene            | ppm Gasoline   |                         |
| 9          | Disch. No. 2              | In Deckhouse                        | 0000 - 0800         | OFF                                          | SB-100         | Gasoline Infiltration              | ND                     | ND             | 430                     |
|            |                           | Periodic Gauging                    | 0800 - 1200         | RT                                           | None           | None                               | --                     | --             | --                      |
|            |                           | In Deckhouse                        | 1200 - 2000         | OFF                                          | None           | None                               | --                     | --             | --                      |
|            |                           | Periodic Gauging<br>Hose Disconnect | 2000 - 2400         | RT                                           | SB-53<br>SB-22 | Gasoline Vapors<br>Gasoline Vapors | 0.25<br>ND             | 40.98<br>34.65 | 225<br>67               |
| 10         | Disch. No. 2<br>& Ballast | In Deckhouse                        | 0000 - 0200         | OFF                                          | None           | None                               | --                     | --             | --                      |
|            |                           | All Hands                           | 0200 - 0400         | OT                                           | None           | None                               | --                     | --             | --                      |
|            |                           | In Deckhouse                        | 0400 - 0800         | OFF                                          | None           | None                               | --                     | --             | --                      |
|            |                           | Wheelhouse Watch                    | 0800 - 1200         | RT                                           | None           | None                               | --                     | --             | --                      |
| 11         | Ballast                   | In Deckhouse                        | 1200 - 2000         | OFF                                          | None           | None                               | --                     | --             | --                      |
|            |                           | Wheelhouse Watch                    | 2000 - 2400         | RT                                           | None           | None                               | --                     | --             | --                      |
|            |                           | In Deckhouse                        | 0000 - 0800         | OFF                                          | None           | None                               | --                     | --             | --                      |
|            |                           | Wheelhouse Watch                    | 0800 - 1200         | RT                                           | None           | None                               | --                     | --             | --                      |
| 12         | Ballast                   | In Deckhouse                        | 1200 - 2000         | OFF                                          | None           | None                               | --                     | --             | --                      |
|            |                           | Wheelhouse Watch                    | 2000 - 2400         | RT                                           | None           | None                               | --                     | --             | --                      |
|            |                           | In Deckhouse                        | 0000 - 0800         | OFF                                          | None           | None                               | --                     | --             | --                      |
|            |                           | Wheelhouse Watch                    | 0800 - 1200         | RT                                           | None           | None                               | --                     | --             | --                      |
|            |                           | In Deckhouse                        | 1200 - 1500         | OFF                                          | None           | None                               | --                     | --             | --                      |
|            |                           | All Hands                           | 1500 - 1600         | OT                                           | None           | None                               | --                     | --             | --                      |
|            |                           |                                     |                     |                                              | None           | None                               | --                     | --             | --                      |

| <u>Start of Gauging Round</u> | <u>Tank</u> | <u>Duration (sec)</u> |
|-------------------------------|-------------|-----------------------|
| 2200                          | 6S          | 25 F*                 |
|                               | 6C          | 30 F                  |
|                               | 6P          | 20 F                  |
|                               | 3P          | 20 F                  |
|                               | 3C          | 15 F                  |
|                               | 3S          | 20F                   |
| 2231                          | 4S          | 60                    |
|                               | 4C          | 60                    |
|                               | 4P          | 52                    |
|                               | 5S          | 30                    |
|                               | 5C          | 90                    |
|                               | 5P          | 30                    |
| 2333                          | 5S          | 15 F                  |
|                               | 5C          | 25 F                  |
|                               | 5P          | 20 F                  |
|                               | 4P          | 25 F                  |
|                               | 4C          | 35 F                  |
|                               | 4S          | 30 F                  |
|                               | 2S          | 25 F                  |
|                               | 1S          | 27 F                  |

The majority of the time he was 1 - 1.5 feet upwind or crosswind of the gauging standpipe. During the 2231 gauging round, he stood closer to the standpipe than before in order to read an accurate ullage.

When the A/B was not making gauging rounds, his activities were somewhat random and consisted of:

- o checking tension of the mooring lines,
- o being on standby upwind of the expansion trunk of the last tank gauged during a particular gauging round,
- o being on standby upwind of the loading manifold, and
- o being on break in deckhouse for approximately 20 minutes each on two occasions.

Two sets of sequential occupational exposure samples were collected during this 4-hour watch with both active (pump and tube) and passive dosimeters. The time periods corresponding to the samples are noted below.

---

F\* indicates that A/B held flashlight for 3/M who took actual ullages

| <u>Time</u> | <u>Activity</u>  | <u>Sample Number</u> |
|-------------|------------------|----------------------|
| 2200-2300   | Periodic Gauging | SB-65 *<br>63761 **  |
| 2300-2400   | Periodic Gauging | SB-69<br>63763       |

Deck Watch Period 2 (0800-1200, Day 2)

The primary activities occurring during watch No. 2 consisted of the toff of 6 of the ships 18 cargo tanks and one periodic gauging round of tanks 3P, 3C, and 3S. The A/B's work activities, as noted previously, were again one of assistance to the 3/M. A/B1 did not toff any of the tanks. Instead, his normal duty was to be in closed proximity of the particular tank being topped off waiting for orders from the 3/M to close down on the product valve to that tank. These locations varied from sitting on the ship's center pipeway, when a center tank was being topped off, to actually manning the tank's product valve. These were usually areas that were either upwind or crosswind of the particular tank being topped off but still downwind of other tanks not yet finished loading.

When not directly assisting the 3/M on tank toff, A/B1 either made several rounds of the ship's deck checking on mooring lines, was on break (total of two, 20 minutes each), or sat near the starboard loading manifold.

Two sets of sequential exposure samples were taken during this watch as noted below.

| <u>Time</u> | <u>Activity</u> | <u>Sample Number</u> |
|-------------|-----------------|----------------------|
| 0759-1050   | Tank Toff       | SB-58<br>63764       |
| 1100-1150   | Tank Toff       | SB-59                |

Deck Watch Period No. 3 (2000-2400, Day 2)

Since all loading had finished on the previous watch period (1600-2000 watch), the major activities performed by A/B1 were concerned with preparing the ship for sailing. Some of the tasks that the A/B was involved in were:

- o storing of safety equipment and gear,
- o being on standby near the half full loading manifold drip tray waiting for shore analysis of final ullage samples, and
- o retrieval of the mooring line during undocking.

\* active charcoal sample

\*\* typical five digit number indicates passive charcoal sample badges

These tasks lasted for approximately 40% of his third watch period. The remaining portion was spent in the wheel house on navigation duty.

The A/B's occupational exposure was monitored only during the initial part of the watch and was collected on sample SB-85.

Deck Watch Periods    4 (0800-1200, Day 3),    5 (2000-2400, Day 3),  
                                  6 (0800-1200, Day 4),    7 (2000-2400, Day 4),  
                                  8 (0800-1200, Day 5),    9 (2000-2400, Day 5).

While the ship was in transit, A/B1 usually spent his watch period in the wheel house navigating the ship at the direction of the 3/M. In fact, during his 4-hour night shift (2000-2400 hrs), he did not leave the wheel house. During the day shift (0800-1200), however, he occasionally left the wheel house to perform various housekeeping chores such as washing down both the deck outside the wheel house and the boat deck, which was just below the wheel house. He was allowed to do these activities during the day watch provided the ship was far enough away from shore and other ship traffic was low.

OVA surveys of the wheel house and those areas that the A/B worked outside of the wheel house indicated normal hydrocarbon background concentrations of ambient air, 5 ppm as methane. Consequently, exposure samples were not collected during these six watch periods.

Overtime Periods    4A (1300-1700, Day 3),  
                                  6A (1300-1700, Day 4)

During the off-watch day hours of the laden voyage, A/B1 performed ship maintenance activities, including paint and rust chipping, brush painting, and spray painting.

A/B1's major activities during period 4A were paint and rust chipping and brush painting with primer. Because occupational exposure monitoring was already being conducted on other crewmen performing similar activities, A/B1 was not monitored. See Chapter X for these similar exposures.

A/B1's major activities during period 6A were paint and rust chipping and spray painting. A summary of the exposure samples collected is presented below.

| <u>Time</u> | <u>Activity</u>         | <u>Sample Number</u> |
|-------------|-------------------------|----------------------|
| 1300-1530   | Paint and Rust Chipping | SB-D-5               |
| 1530-1615   | Spray Painting          | SB-97                |
| 1615-1700   | Spray Painting          | SB-93                |

All of the mixing of the two-part paint was done by hand in small cans. This A/B stood downwind of the paint he was mixing, and his breathing zone was approximately 2 feet from the paint can. This mixing lasted from 1024-1035.

The first item he painted was the port stern deckhouse entry door. Because of its location on the back of the deckhouse, there was recirculation of the paint mist in the area. Paint vapors infiltrated into the deckhouse hallway. The total time to paint the door was 3 minutes.

Next, the A/B painted the port stern railing and port starboard bits. He normally stood upwind or crosswind of the objects being painted, and because they were in open areas, the excess spray was rapidly blown away.

Spray Painting-O/S (1132-1140, Day 5)

The activity during this work period consisted of spray painting the surfaces that were sandblasted during the 0844-1115 work period of day 5. The overall activity lasted a short time. Sample SB-56 was collected on the O/S during this time period.

Gauging Round with the Q.C. Inspector-C/M (1020-1045, Day 6)

During this time period, the C/M went on a gauging round with a quality control inspector who took ullage measurements on each tank. Exposure sample SB-77 was collected on the C/M during this entire period.

A summary of the gauging times is given below.

| Tank | Time    | Duration<br>(sec) | Gauging Location                               |
|------|---------|-------------------|------------------------------------------------|
|      |         |                   | DW (Downwind)<br>UW (Upwind)<br>CW (Crosswind) |
| 3S   | 1030:00 | 20                | DW                                             |
| 3C   | 1030:30 | 20                | UW                                             |
| 2S   | 1031:10 | 15                | UW                                             |
| 2C   | 1031:35 | 15                | UW                                             |
| 1S   | 1032:00 | 27                | UW                                             |
| 1C   | 1032:40 | 45                | UW                                             |
| 1P   | 1033:44 | 41                | DW                                             |
| 2P   | 1034:54 | 35                | DW                                             |
| 3P   | 1035:50 | 31                | CW                                             |
| 4P   | 1036:50 | 44                | DW                                             |
| 5P   | 1037:54 | 30                | DW                                             |
| 6P   | 1038:37 | 23                | CW                                             |
| 6C   | 1039:20 | 20                | DW                                             |
| 6S   | 1039:57 | 21                | DW                                             |
| 5S   | 1040:32 | 28                | CW                                             |
| 5C   | 1041:10 | 25                | CW                                             |
| 4S   | 1041:51 | 24                | UW                                             |
| 4C   | 1042:25 | 25                | UW                                             |

Sandblasting-O/S (0844-0955, 1053-1115, Day 5)

During these two periods, an O/S sandblasted those deck surfaces that had undergone rust chipping the day before. A portion of the time was spent sandblasting near the wall of the deckhouse on the ship's stern. The other surfaces that were sandblasted included the mooring line guide and a bit. One cumulative dust sample (SB-D-12) was collected during this activity. Sampling was stopped from 0955-1053 during the crew member's work break.

While he was sandblasting, the O/S wore a hood that draped over his head and down to the middle of his chest. While the hood protected his eyes from the flying sand, its loose fit at the bottom, allowed the fine sand from the visible dust cloud to enter underneath the hood. To counteract this, the O/S also wore a filter mask over his nose and mouth. However, the filter\* was approved for organic vapor instead of dust.

He normally sat upon a milk crate while he was sandblasting the deck surfaces. Because the dust cloud was so concentrated, he also had to bend over to see what he was doing. His posture caused the front lower portion of the hood to lean away from his chest and allowed the dust cloud to enter the breathing zone.

The dust sampler was attached to the O/S's lapel underneath the hood.

Rust Chipping-A/B (0900-0935), Day 5)

During this time period, an A/B chipped rust with a needle gun on the port stern deck and rail downwind of sandblasting activities. For the entire time he wore headphone type ear protection and sunglasses. Because he was sometimes working outside the railing, he also wore a life jacket and belt harness. Dust exposure sample SB-D-7 was collected from 0900-0935 on this A/B.

Most of the time he chipped from downwind, in order to see his work, approximately 2 feet from his face.

Spray Painting-A/B (1020-1125, Day 5)

During this time period, an A/B mixed paint, cleaned sand off the areas to be painted, and painted the stern port entry door, stern bits, and railing. For this entire time he wore sunglasses and cloth work gloves. Exposure sample SB-81 was collected from 1024-1125 on this A/B.

---

\* Pulmosan Safety Equipment Filter No. TC-236-81.



| <u>Time</u> | <u>Activity</u> | <u>Sample No.</u> |
|-------------|-----------------|-------------------|
| 0845 - 1015 | Rust Chipping   | SB-D-6            |
| 1100 - 1200 | Rust Chipping   | SB-D-18           |

He chipped steadily from 0836 - 1000 and 1100 - 1200. Most of the time, he chipped from crosswind or upwind approximately 1½ - 2½ feet from his face. Sometimes it was necessary for him to be downwind of the chipping in order for him to see his work.

\*Run-around Changeover-O/S (0825-0922, 0923-0954, Day 4)

During this time period, two run-arounds were transferred from the port loading manifold to the starboard manifold. Two sequential exposure samples were collected on one of the two individuals involved in this activity. The first sample, SB-88, was obtained from 0825-0922 during run-around removal from the loading manifold on the port side. The second sample, SB-95, was collected while the run-around was being bolted onto the starboard manifold (0923-0954).

The O/S's activity on the port side consisted of unbolting the two flanged connections between the run-around and the mating flanges of the manifold valves. Prior to loosening the bolts, small drain valves were opened to drain the product in the run-around into the drip pan. When the first bolts were loosened, more product spilled out. Since the drip tray was approximately half-full, the O/S connected a drain hose to the drip tray and discharged its contents overboard.

Once the run-around was detached, blind flanges were bolted onto the open manifold valve flanges, and the run-around removal was completed.

The distance from the O/S's breathing zone to the source of gasoline vapors varied from 2 - 6 feet during most of the activity. Most of his work was performed while he was standing on the deck leaning over the drip tray. The top of the drip tray was approximately 3.5 feet above the deck. At times, he would get on top of the pan grating and assume either a squatting or standing position.

The overall activity conducted on the starboard side in attaching the run-around was very similar except it was performed in the reverse order.

---

\* A run-around is a U-shaped section of piping used to allow:

1. product loading through one hose from shore into two series of ship tanks, or
2. product discharge from two series of ship tanks through one hose to the shore.

When not gauging, the C/M stood upwind or crosswind of the deck riser with his breathing zone approximately 5 feet from the riser opening.

Spray Painting-O/S (1023-1150, 1300-2400, Day 3)

During these two work periods, an O/S mixed paint in the fore-castle and spray painted the stern port and starboard engine room machinery hatches. One occupational exposure sample, SB-84, was collected for both work periods. During the 1150 and 1300 lunch break, the sampling pump was turned off. The following summarizes the O/S's activities during this observation period.

1. Approximately 30 minutes of his time was spent mixing the two-component paint in the fore-castle.
2. The total time that he spent spray painting was 43 minutes. Most of the time he stood upwind or crosswind of his work, but sometimes he stood downwind in order to see the area he was spraying.
3. The remainder of the sampling time was spent:
  - o in transit between the paint mixing area and the stern, or
  - o cleaning equipment.

Rust Chipping-O/S (1410-1455, Day 3)

During this period, the O/S chipped rust from the port mooring line guide with a pneumatic impacting tool. He started the chipping without any dust protective equipment, but after approximately eight minutes, he went forward and returned with a surgical type dust mask and gloves. He resumed the activity and spent the remaining portion of the period chipping rust from the same deck fixture.

He was normally in a prone position while performing this activity. His breathing zone distance from the object was approximately 1 - 2-1/2 feet.

One dust sample was collected, SB-D-13, on the O/S to determine his exposure to airborne particulate.

Rust Chipping-A/B (0800-1200, Day 4)

During this time period, an A/B chipped rust on the starboard stern deck using an air powered needle gun. For the entire time he wore goggles and headphone type ear protection, but no respiratory protection. The following dust exposure samples were taken during this time period.

TABLE VII. OCCUPATIONAL EXPOSURES TO PAINT VAPOR  
FOR VARIOUS CREWMEN

| Sample<br>No. | Exposure<br>Duration<br>(min) | Xylene<br>(ppm) | Isobutanol<br>(ppm) | Methyl<br>Isobutyl<br>Ketone<br>(ppm) | Methyl<br>Ethyl<br>Ketone<br>(ppm) |
|---------------|-------------------------------|-----------------|---------------------|---------------------------------------|------------------------------------|
| SB-84         | 142                           | 5.04            | 1.82                | ND                                    | ND                                 |
| SB-56         | 8                             | 9.68            | ND                  | ND                                    | ND                                 |
| SB-55         | 141                           | 3.16            | 1.20                | --                                    | --                                 |
| SB-61         | 68                            | 1.89            | 3.25                | --                                    | --                                 |
| SB-201        | 130                           | 6.78            | 3.25                | --                                    | --                                 |
| SB-81         | 61                            | 5.92            | 3.01                | --                                    | --                                 |

TABLE VI. SUMMARY OF ACTIVITIES AND EXPOSURES MONITORED FOR VARIOUS CREWMEN (CONT'D)

WORKER TITLE: Various Crewmen

WATCH: As noted

| Voyage Day | Voyage Leg | Worker Title | Worker Activities      | Time of Observation | Regular Time (RT)<br>Overtime (OT)<br>or OFF | Sample Number | Exposure        | Exposure Concentration |              | Exposure Duration (min) |
|------------|------------|--------------|------------------------|---------------------|----------------------------------------------|---------------|-----------------|------------------------|--------------|-------------------------|
|            |            |              |                        |                     |                                              |               |                 | ppm Benzene            | ppm Gasoline |                         |
| 11         | Ballast    | A/R          | Tank Washing & Blowing | 0600 - 1200         | OT 0600 - 0800<br>RT 0800 - 1200             | SB-117        | Gasoline Vapors | 0.73                   | 146.83       | 354                     |
|            |            | A/R          | Tank Washing & Blowing | 0600 - 1200         |                                              | 60389         | Gasoline Vapors | 0.71                   | 223.06       | 354                     |
|            |            | O/S          | Tank Washing & Blowing | 0600 - 1200         | OT 0600 - 0800<br>RT 0800 - 1200             | SB-119        | Gasoline Vapors | 0.66                   | 143.15       | 333                     |
|            |            | O/S          | Tank Washing & Blowing | 0600 - 1200         |                                              | 60390         | Gasoline Vapors | ND                     | 197.33       | 333                     |
|            |            | O/S          | Tank Washing & Blowing | 1200 - 1710         | RT                                           | SB-110        | Gasoline Vapors | 0.34                   | 63.54        | 309                     |
|            |            | O/S          | Tank Washing & Blowing | 1200 - 1710         | RT                                           | 60391         | Gasoline Vapors | 0.97                   | 55.99        | 309                     |
|            |            | A/B          | Tank Washing & Blowing | 1250 - 1710         | RT                                           | SB-205        | Gasoline Vapors | 0.64                   | 63.33        | 261                     |
|            |            | A/B          | Tank Washing & Blowing | 1250 - 1710         | RT                                           | 60392         | Gasoline Vapors | ND                     | 86.31        | 261                     |
|            |            | O/S          | Tank Cleaning          | 0600 - 1200         | OT 0600 - 0800<br>RT 0800 - 1200             | SB-209        | Gasoline Vapors | 0.21                   | 42.40        | 341                     |
|            |            | C/M          | Tank Cleaning          | 0600 - 1200         |                                              | 63766         | Gasoline Vapors | ND                     | 55.95        | 296                     |
| 11         | Ballast    | O/S          | Tank Cleaning          | 1215 - 1700         | OT 0600 - 0800<br>RT 0800 - 1200             | SB-103        | Gasoline Vapors | 2.08                   | 201.50       | 344                     |
|            |            | C/M          | Tank Cleaning          | 1215 - 1700         |                                              | 63765         | Gasoline Vapors | 0.90                   | 241.68       | 309                     |
|            |            | O/S          | Tank Cleaning          | 1215 - 1700         | OT 1215 - 1300<br>RT 1300 - 1700             | SB-207        | Gasoline Vapors | 0.48                   | 83.58        | 285                     |
|            |            | C/M          | Tank Cleaning          | 1241 - 1405         |                                              | 63775         | Gasoline Vapors | ND                     | 64.06        | 265                     |
|            |            |              |                        |                     | RT                                           | 63777         | Gasoline Vapors | 6.10                   | 409.44       | 84                      |

TABLE VI. SUMMARY OF ACTIVITIES AND EXPOSURES MONITORED FOR VARIOUS CREWMEN (CONT'D)

WORKER TITLE: Various Crewmen

WATCH: As noted

| Voyage Day | Voyage Leg   | Worker Title | Worker Activities     | Time of Observation | Regular Time (RT) Overtime (OT) or OFF | Sample Number | Exposure                             | Exposure Concentration   |              | Exposure Duration (min) |
|------------|--------------|--------------|-----------------------|---------------------|----------------------------------------|---------------|--------------------------------------|--------------------------|--------------|-------------------------|
|            |              |              |                       |                     |                                        |               |                                      | ppm Benzene              | ppm Gasoline |                         |
| 7          | Laden No. 2  | O/S          | Spray Painting        | 0927 - 1148         | RT                                     | SB-55         | Paint Constituents & Gasoline Vapors | See Paint Exposure Table | 9.48         | 141                     |
|            |              | O/S          | Spray Painting        | 1329 - 1437         | RT                                     | SB-61         | Paint Constituents & Gasoline Vapors | See Paint Exposure Table | 156.51       | 68                      |
|            |              | O/S          | Spray Painting        | 1440 - 1650         | RT                                     | SB-201        | Paint Constituents & Gasoline Vapors | See Paint Exposure Table | 2.34         | 130                     |
| 7          | Laden No. 2  | O/S          | Changing Run-around   | 1740 - 1825         | OT                                     | SB-120        | Gasoline Vapors                      | 6.42                     | 501.30       | 41                      |
|            |              | O/S          | Run-around Changeover | 1742 - 1820         | OT                                     | SB-104        | Gasoline Vapors                      | 2.7                      | 315.99       | 38                      |
|            |              | A/B          | Hose Connect          | 2310 - 2350         | OT                                     | SB-83         | Gasoline Vapors                      | ND                       | 21.48        | 42                      |
| 8          | Disch. No. 2 | 2/M          | Stripping 6P          | 1200 - 1230         | RT                                     | SB-80         | Gasoline Vapors                      | 7.00                     | 166.91       | 21                      |
|            |              | 2/M          | Stripping 6C          | 1230 - 1315         | RT                                     | SB-79         | Gasoline Vapors                      | ND                       | 147.51       | 45                      |
| 8          | Disch. No. 2 | C/M          | Stripping 1C          | 1607 - 1630         | RT                                     | SB-114        | Gasoline Vapors                      | ND                       | 135.6        | 23                      |
|            |              | --           | Area Sample ①         | 1612 - 1631         | --                                     | SB-76         | Gasoline Vapors                      | 4.5                      | 610.78       | 19                      |
|            |              | C/M          | Stripping 1S          | 1634 - 1649         | RT                                     | SB-107        | Gasoline Vapors                      | ND                       | ND           | 15                      |
| 9          | Disch. No. 2 | --           | Area Sample ②         | 1635 - 1650         | --                                     | SB-74         | Gasoline Vapors                      | ND                       | ND           | 15                      |
|            |              | O/S          | Hose Disconnect       | 2225 - 2341         | RT                                     | SB-202        | Gasoline Vapors                      | 0.38                     | 22.06        | 76                      |
| 10         | Ballast      | A/B          | Sandblasting          | 1035 - 1115         | RT                                     | SB-D-19       | Sand                                 | 6.73 mg/m <sup>3</sup>   | (Quartz)     | 40                      |

① Taken at Butterworth opening of 1C where tank gaugings were made during stripping.  
 ② Taken at Butterworth opening of 1S where tank gaugings were made during stripping.

TABLE VI. SUMMARY OF ACTIVITIES AND EXPOSURES MONITORED FOR VARIOUS CREWMEN

WORKER TITLE: Various Crewmen

WATCH: As noted

| Voyage Day | Voyage Log      | Worker Title | Worker Activities                                                     | Time of Observation        | Regular Time (RT)<br>Overtime (OT)<br>or OFF | Sample Number     | Exposure                           | Exposure Concentration           |                  | Exposure Duration (min) |
|------------|-----------------|--------------|-----------------------------------------------------------------------|----------------------------|----------------------------------------------|-------------------|------------------------------------|----------------------------------|------------------|-------------------------|
|            |                 |              |                                                                       |                            |                                              |                   |                                    | ppm Benzene                      | ppm Gasoline     |                         |
| 2          | loading         | C/H<br>C/H   | Tank Topoff 1P, 1S, 1C                                                | 0525 - 0620                | RT                                           | SB-67<br>60184    | Gasoline Vapors                    | 16.47<br>79.50                   | 2661.9<br>5115.0 | 52<br>52                |
| 1          | laden<br>No. 1  | O/S          | Spray Painting                                                        | 1000 - 1200<br>1300 - 1400 | RT<br>RT                                     | SB-84             | Paint Constituents                 | See Paint Exposure Table         |                  | 142                     |
| 4          | laden<br>No. 1  | O/S          | Rust Chipping                                                         | 1400 - 1500                | RT                                           | SB-D-13           | Rust Dust                          | Non-Detectible                   |                  | 45                      |
| 4          | laden<br>No. 1  | A/B<br>A/B   | Rust Chipping<br>Rust Chipping                                        | 0845 - 1015<br>1100 - 1200 | OT<br>OT                                     | SB-D-6<br>SB-D-18 | Rust Dust<br>Rust Dust             | Non-Detectible<br>Non-Detectible |                  | 84<br>54                |
| 4          | laden<br>No. 1  | O/S          | Run-around Changeover:<br>Port Side Removal<br>Starboard Side Connect | 0825 - 0922<br>0923 - 0954 | RT<br>RT                                     | SB-88<br>SB-95    | Gasoline Vapors<br>Gasoline Vapors | ND<br>ND                         | 14.62<br>ND      | 57<br>11                |
| 5          | laden<br>No. 1  | O/S          | Sandblasting                                                          | 0844 - 0955<br>1053 - 1115 | RT<br>RT                                     | SB-D-12           | Sand                               | 7.37 mg/m <sup>3</sup>           | (partic)         | 94                      |
| 5          | laden<br>No. 1  | A/B          | Rust Chipping                                                         | 0900 - 0935                | OT                                           | SB-D-7            | Rust Dust, Sandblasting            | Non-Detectible                   |                  | 28                      |
|            |                 | A/B          | Spray Painting                                                        | 1020 - 1125                | OT                                           | SB-81             | Paint & Thinner Vapors             | See Paint Exposure Table         |                  | 61                      |
|            |                 |              | Spray Painting                                                        | 1132 - 1140                | RT                                           | SB-56             | Paint Constituents                 | See Paint Exposure Table         |                  | 8                       |
| 6          | Disch.<br>No. 1 | C/H<br>Z/H   | Gauging Round with Q.C.<br>Stripping 2C                               | 1020 - 1045<br>1530 - 1600 | OT<br>OT                                     | SB-77<br>SB-82    | Gasoline Vapors<br>Gasoline Vapors | ND<br>ND                         | 73.26<br>ND      | 25<br>11                |
|            | Disch.<br>No. 1 | A/B          | Hose Disconnect                                                       | 1630 - 1710                | RT                                           | SB-46             | Gasoline Vapors                    | ND                               | 5.97             | 40                      |
|            |                 | C/H          | Ballasting Gauging 2C                                                 | 1645 - 1800                | OT                                           | SB-101            | Gasoline Vapors                    | ND                               | ND               | 76                      |

X. Summary of Monitored Activities and Occupational Exposure for Various Deck Department Personnel

The following is a detailed discussion of the activities and occupational exposures for workers other than the 3/M and the designated A/E. These observations were conducted in order to document a more complete set of work activity scenarios that occurred during this voyage, some of which never involved the 3/M or A/B1.

Table VI summarizes the activities for workers other than the 3/M or A/B1. Table VII presents the occupational exposures to paint vapors for these workers.

Tank Topoff - C/M (0500-0630, Day 2)

During this time period, the C/M topped off tanks 1P, 1S, and 1C. Due to the short duration of each topoff, only one set of samples, SB-87 and 60384, was taken to encompass all three topoffs.

The topoff of 1P was very short and lasted only 5 minutes (0525-0530). The C/M used a crucifix to take continual readings while standing crosswind of the hatch or gauging tube.

The entire topoff of 1S lasted approximately 20 minutes (0530-0550). The time between 0430 and 0544 was spent waiting for the liquid to reach the bottom of the crucifix. The topoff gauging with the crucifix then lasted six minutes (0544-0550). During this time, continual readings were taken from crosswind of the deck riser.

The topoff of 1C took considerably longer than 1P or 1S mainly because the tank was short-loaded and had to be gauged using a tape. The following summarizes the ullages taken during the topoff of 1C.

| <u>Encounter No.</u> | <u>Time</u> | <u>Duration (sec)</u> |
|----------------------|-------------|-----------------------|
| 1                    | 0555:40     | 10                    |
| 2                    | 0558:30     | 4                     |
| 3                    | 0559:28     | 7                     |
| 4                    | 0601:45     | 7                     |
| 5                    | 0603:15     | 5                     |
| 6                    | 0603:34     | 6                     |
| 7                    | 0604:45     | 6                     |
| 8                    | 0605:00     | 2                     |
| 9                    | 0606:00     | 3                     |
| 10                   | 0606:57     | 2                     |
| 11                   | 0607:24     | 2                     |
| 12                   | 0608:20     | 4                     |
| 13                   | 0610:35     | 3                     |
| 14                   | 0610:40     | 10                    |
| 15                   | 0615:50     | 8                     |
| 16                   | 0616:52     | 14                    |
|                      | 0617:10     | Stopped 1C            |

Deck Watch Periods 18 (0800-1200, Day 10)  
                          19 (2000-2400, Day 10)  
                          20 (0800-1200, Day 11)  
                          21 (2000-2400, Day 11)  
                          22 (0800-1200, Day 12)

During these five regular watch periods, the A/B performed typical wheelhouse navigation duties and exterior house cleaning chores, similar to those described for watches 4 through 9. Exposure monitoring was not performed.

Overtime Period 22A (1500-1600, Day 12)

During this overtime period, A/B1 was in the wheelhouse for maneuvering activities while docking. Exposure monitoring was not performed.



Two occupational exposure samples were collected on the A/B during this watch. One of the samples was a full watch sample, while the other was collected concurrently with the shorter duration hose disconnect activity. The sample numbers and sampling periods are presented below.

| <u>Time</u> | <u>Activity</u> | <u>Sample Number</u> |
|-------------|-----------------|----------------------|
| 2002-2347   | Complete Watch  | SB-53                |
| 2225-2347   | Hose Disconnect | SB-22                |

The first hour of the A/B's watch was spent cleaning up the wheel house. Following this task, he came back out onto the deck to assist the 3/M. Although tanks were being ballasted, the A/B did not gauge any of the tanks. Instead, he spent most of his time at the fore and aft tie line winches taking the slack out of the mooring lines.

A/B1 and one other crewman disconnected the discharge hoses. The normal procedure for each hose was as follows:

- o The valve on the ship's manifold was opened to drain the residual product from the line into the drip pan.
- o The loading hose was secured to the ship's boom.
- o One or both crewmen unfastened all but one of the bolts connecting the ship's flange to the loading hose flange.
- o The boom was activated to raise or lower the hose to free the last bolt.
- o A blind was attached to the hose flange and the hose was lowered to the dock.
- o A blind was bolted to the ship's valve flange.

Four hoses in all were disconnected with each hose removal requiring about 8-10 minutes each. A substantial amount of liquid was released into the drip pan during the line draining step. The A/B's distance from the drip pan varied from two feet when he was bolting the blind to the ship's flange to approximately eight feet when he was near the railing guiding the hose onto the dock.

Overtime Period 17A (0200-0400, Day 10)

During this overtime period, the A/B assisted in undocking activities. Since all hatches had been secured, the potential for exposure was minimal, and no exposure samples were collected.

The A/B made two gauging rounds during this watch. On some of the tanks he had trouble determining the ullage, and stuck his face against the open gauging standpipe to visually check the cargo level. The tanks that the A/B gauged during these two rounds along with the gauging durations are shown below.

| <u>Tank</u> | <u>Time</u> | <u>Duration (sec)</u> |
|-------------|-------------|-----------------------|
| 1P          | 1008:20     | 30                    |
| 1C          | 1009:10     | 420                   |
| 1S          | 1016:20     | 80                    |
| 1C          | 1017:50     | 20                    |
| 5C          | 11:09:25    | 15                    |
| 5S          | 11:09:48    | 12                    |
| 6P          | 11:22:10    | 40                    |

The remaining portion of his time was spent sitting on the center deck piping or port side railing or in the deckhouse on break (twice, 20 minutes each).

One personal sample (SB-90) was collected on the A/B during this watch to monitor his exposure to gasoline vapor.

Deck Watch Periods 15 (2000-2400, Day 8)  
16 (0800-1200, Day 9)

Heavy rains occurred during both of these watch periods and altered the work activities of the A/B as compared to the tasks he performed during his previous watch. The A/B spent most of his time inside one of the six pump houses. Although tanks were being gauged, the 3/M was the only one performing this activity. The A/B periodically checked the status of the bow and stern mooring lines.

Exposure sample SB-99 was collected on A/B1 during the first hour of watch period 15. His exposure was not monitored during watch period 16.

Deck Watch Period 17 (2000-2400, Day 9)

Product discharge was completed during the previous watch period (1600-2000). Therefore, the A/B's major activities consisted of assisting the 3/M in ballast gauging, housekeeping chores in the wheel house, and assisting in hose disconnect.

Overtime Period No. 12A (1300-1700, Day 7)

During this period, the A/B performed paint and rust chipping activities on the starboard railing near midship. Since this activity generated dust, an exposure sample was collected. The exposure sample was SB-D-16.

Deck Watch Period 13 (2000-2400, Day 7)

A/B1's activities during this watch period were similar to watch period No. 10 and involved a combination of wheel house navigation duty, docking and hose hookup at discharge terminal No. 2. The procedures that were used to connect the hoses were described earlier. On this occasion, however, A/B1 was the person who was standing on top of the drip pan while unbolting the product piping flanges. Some product drained from the ship's product piping into the drip pan when flanges were removed. A total of three hoses were connected.

As compared to the hose hookup activities that were performed in watch period No. 10, the A/B was in closer proximity to the gasoline vapors emitting from the drip pan and was there for a longer period of time. His exposure during this hose hookup was collected on Sample SB-10.

Deck Watch Period 14 (0800-1200, Day 8)

During this watch period, all of the remaining product was being discharged to shore. Initially, most of the tanks were still quite full. Activities performed by the A/B consisted of deck cleaning, manning product valves during the stripping of tanks 2P and 2S, and periodic gauging.

The deck cleaning activity resulted from a slight leak at the check valve on pump 4. Although the leak was repaired immediately, a portion of the deck near the check valve still contained liquid cargo. The A/B spent the first hour of his watch cleaning up the deck spill by spreading adsorbent over it and then sweeping it up.

Following the deck cleanup operation, A/B1 assisted the 3/M in the stripping of tanks 2S and 2P. His main activity was to man the product valves and stand ready for orders from the 3/M to close them.

Deck Watch Period No. 10 (0800-1200, Day 6)

The A/B's activities during this watch period were split between wheel house watch duties and deck work involving docking and subsequent hose hookup at the first discharge terminal. During the initial stages of docking, he was involved in handling the ship's mooring lines. After the ship was secured to the dock, he along with five other unlicensed crewmen connected the discharge hoses to the ship's loading/discharge manifold product piping. A total of three hoses were connected to the ship at this terminal.

The sequence of steps that were followed to connect each loading hose to the ship are summarized below:

- o One of the crewmen sat or stood on the manifold drip pan and removed the product piping blind.
- o A shore winch raised the discharge hose onto the ship's deck.
- o The other crewmen, standing on deck, then aligned the hose flange with the ship flange and bolted them together.

The time spent connecting each hose was approximately 6 to 7 minutes. During the hose connecting activity, the A/B stood crosswind of the drip pan and helped to align the hose and ship flanges. On occasion, he got on top of the drip pan to assist in attaching the bolts. Since there was a potential for exposure from cargo liquid in the drip pan, a personal sample (SB-63) was collected on A/B1 during the hose connection activity.

The remaining part of his watch was spent either in the deck house on break or checking the mooring lines.

Deck Watch Period 11 (2000-2400, Day 6)

Prior to the start of this watch period, product discharge had been completed, and all hoses had been disconnected. Consequently, the A/B's watch consisted of undocking activities and wheel house navigation duty. Due to the low levels of hydrocarbons on the deck where the A/B was located, no exposure samples were collected.

Deck Watch Period 12 (0800-1200, Day 7)

Because the ship was underway enroute to the second discharge port, the A/B was in or near the wheel house on navigation watch. His activities during this period were similar to those discussed for watch periods No. 4 through No. 9 and did not warrant exposure monitoring.

#### Discharge Stripping-2/M (1530-1602, Day 6)

During this time period, the 2/M stripped the product from tank 2C. Exposure sample SB-82 was collected on the 2/M during this activity.

For the time period 1530-1544, the 2/M was waiting for the product level to drop to the point where he needed to slow the pump and/or close valves. During this time he checked the product level three times as summarized below.

| <u>Encounter No.</u> | <u>Time</u> | <u>Duration (sec)</u> |
|----------------------|-------------|-----------------------|
| 1                    | 1535        | 60                    |
| 2                    | 1538        | 20                    |
| 3                    | 1542        | 10                    |

These checks were performed by kneeling or leaning over a Butterworth opening with the breathing zone immersed in the opening.

Between 1544 and 1557, the 2/M knelt next to the opening, watched the product, and instructed the A/B and O/S to close valves. At 1557, the stripping was stopped.

After looking into the tank for approximately one additional minute, the 2/M decided to strip more product out of the tank. The tank was finally stripped from 1558 to 1600.

#### Hose Disconnect-A/B (1630-1710, Day 6)

During this time period, the A/B attached the sling from the shore side boom to the three discharge hoses. Exposure sample SB-46 was collected on the A/B during this time period.

The A/B's main function was to connect the sling from the shore side boom to the discharge hose and then direct the dock personnel on the maneuvering of the hose. This maneuvering enabled the other crewmen to disconnect the hoses at the ship's manifold. Since he had to be in sight of the dock personnel, this A/B stood by the ship railing approximately six feet from the manifold drip tray.

#### Ballast Gauging-C/M (1644-1800, Day 6)

During this time period, tank 2C was ballasted to an ullage of 40 feet. Exposure sample SB-101 was collected on the C/M during this entire period.

Since this was the only tank being ballasted and the ship was almost totally full, no ullage readings were taken. Instead, the C/M used the ship's load computer to determine when ballasting should terminate. Actually, the C/M spent only a few minutes by tank 2C. The rest of the time he was either in the deckhouse, which was upwind, or walking around the deck upwind of 2C.

Spray Painting-O/S (0927-1148, Day 7)  
(1329-1437, Day 7)  
(1440-1650, Day 7)

Extensive spray painting was performed by this O/S during the entire day work shift. His task was to spray paint all 18 of the ship's expansion trunks, hatches and product valve stems. In addition to a potential exposure to paint vapors, the O/S also was in the vicinity of gasoline vapors vented through P/V valves from partially filled or empty tanks. Three personal samples were collected on the O/S to monitor his exposure to both paint and gasoline vapors. The sample numbers and corresponding sampling periods are listed below.

| <u>Time</u> | <u>Sample Number</u> |
|-------------|----------------------|
| 0927 - 1148 | SB-55                |
| 1329 - 1437 | SB-61                |
| 1440 - 1650 | SA-201               |

The spray painting activities on Day 7 are summarized on the following page.

| <u>Time</u> | <u>Activity</u>                                                       |
|-------------|-----------------------------------------------------------------------|
| 0927 - 0951 | mixing paint in forecastle and preparing spray paint equipment        |
| 0951 - 1025 | break                                                                 |
| 1025 - 1045 | connecting spray gun air line to on deck compressed air source        |
| 1048 - 1112 | spray painting fixtures                                               |
| 1112 - 1120 | moving spray gun air lines to on deck air source close to No. 2 tanks |
| 1120 - 1148 | spray painting No. 2 across tank fixtures                             |
| 1329 - 1346 | air drying No. 3 across tanks                                         |
| 1346 - 1402 | spray painting No. 3 across tank fixtures                             |
| 1402 - 1409 | mixing paint                                                          |
| 1409 - 1436 | spray painting No. 3 across tank fixtures                             |
| 1426 - 1437 | mixing paint and moving spray gun air line to vicinity of No. 4 tanks |
| 1440 - 1500 | spray painting No. 4 across tank fixtures                             |
| 1500 - 1530 | break                                                                 |
| 1530 - 1534 | mixing paint                                                          |
| 1534 - 1540 | spray painting No. 4 across tank fixtures                             |
| 1540 - 1547 | spray painting No. 5 across tank fixtures                             |
| 1547 - 1602 | mixing paint                                                          |
| 1602 - 1616 | spray painting No. 5 tank fixtures                                    |
| 1616 - 1620 | mixing paint                                                          |
| 1620 - 1630 | moving spray gun airline to vicinity of No. 6 tanks                   |
| 1630 - 1654 | spray painting No. 6 across tank fixtures                             |

Changing Run-around-O/S (1740-1825, Day 7)

During this time period, two ordinary seamen (O/S) changed a run-around from the port to the starboard manifold. Exposure samples were collected on both O/S's as noted below.

| <u>O/S No.</u> | <u>Sample</u> |
|----------------|---------------|
| 1              | SB-120        |
| 2              | SB-104        |

O/S1 first opened the small drain valves on the manifold pipes that were connected to the run-around. While the product was draining into the drip pan, O/S1 stood back against the rail approximately 10 feet upwind. When the product flow had reduced to a trickle, he loosened the bolts of the flanges and dropped the run-around onto the grate in the drip pan. When the flanges were loosened, more product poured out of the piping. This sequence lasted from 1740 to 1754.

After bolting the blanks on the pipe flanges on the port side, O/S1 carried the run-around to the starboard side. When the starboard flange on pipe 6 was loosened, once again liquid poured into the drip pan. Because of the placement of the drip tray, the O/S was standing directly downwind at this point. Product poured into the drip pan for two minutes (1800-1802).

The run-around was then bolted into place with O/S1 standing on the grate in the drip tray. General cleanup of the bolts laying in the two drip trays and removal of the starboard blank for pipe 5 occupied O/S1's time to the end of this period.

The activities of O/S2 were similar to O/S1. While O/S1 handled the unbolting of the run-around and blanking off of the manifold valve flange, O/S2 was performing the same tasks on the other end of the run-around. His (O/S2) position relative to the drip tray varied as did O/S1 from leaning against the tray during removal of run-around to near the ship's railing while the product piping was drained.

One major difference between this run-around changeover and the one conducted during Day 4 was that in this case, the drip tray was not drained. Whatever product was drained from the product piping during this second changeover was present in the drip pans during the remainder of the activity.

#### Hose Disconnect-A/B (2309-2357, Day 7)

During this time period, an A/B connected product hoses to the port manifold for tanks 1, 2, and 3 across. Exposure sample SB-83 was collected on the A/B.

The A/B went through the same procedure for each hose. He would

- o unbolt the blank from the manifold flange,
- o unbolt the blank from the product hose, then
- o bolt the product hose to the manifold pipe.



All of this work was performed while standing or squatting on the grate in the drip pan. In the latter case, his breathing zone was approximately 2½ to 3 feet above the liquid in the pan.

Discharge Stripping-2/M (1200-1315, Day 8)

During this time period, the 2/M stripped tank 6P from 1200 to 1230 and tank 6C from 1230 to 1315. Two exposure samples were collected on the 2/M. Sample No. SB-80 corresponded to the stripping of tank 6P, and Sample No. SB-79 corresponded to the stripping of tank 6C.

To view the liquid level in the tank bottom, the 2/M laid on the deck and inserted his head in a Butterworth opening. When not viewing the liquid level, he continued to lay on the deck and propped himself up on his elbows making his breathing zone one foot above the tank opening. The following tables summarize the times that the 2/M viewed the liquid level for the stripping of 6P and 6C.

Stripping of 6P

| <u>Encounter No.</u> | <u>Time</u> | <u>Duration (sec)</u> |
|----------------------|-------------|-----------------------|
| 1                    | 1207:50     | 69                    |
| 2                    | 1209:11     | 30                    |
| 3                    | 1210:50     | 21                    |
| 4                    | 1211:15     | 45                    |
| 5                    | 1212:20     | 20                    |
| 6                    | 1212:45     | 26                    |
| 7                    | 1213:17     | 30                    |
| 8                    | 1213:50     | 60                    |
| 9                    | 1214:57     | 20                    |
| 10                   | 1215:20     | 32                    |
| 11                   | 1215:55     | 35                    |
| 12                   | 1216:40     | 17                    |
| 13                   | 1217:30     | 30                    |
| 14                   | 1218:18     | 48                    |
| 15                   | 1220:13     | 30                    |
| 16                   | 1220:50     | 80                    |
| 17                   | 1222:22     | 56                    |
| 18                   | 1223:20     | 6                     |
| 19                   | 1223:29     | 28                    |
| 20                   | 1224:50     | 8                     |
| 21                   | 1225:01     | 33                    |
| 22                   | 1225:38     | 52                    |

Stripping of 6C

| <u>Encounter No.</u> | <u>Time</u> | <u>Duration (sec)</u> |
|----------------------|-------------|-----------------------|
| 1                    | 1230:58     | 47                    |
| 2                    | 1234:45     | 18                    |
| 3                    | 1238:40     | 30                    |
| 4                    | 1241:12     | 23                    |
| 5                    | 1241:40     | 10                    |
| 6                    | 1241:58     | 63                    |
| 7                    | 1243:12     | 146                   |
| 8                    | 1246:40     | 29                    |
| 9                    | 1248:35     | 18                    |
| 10                   | 1249:00     | 27                    |
| 11                   | 1249:30     | 16                    |
| 12                   | 1250:50     | 21                    |
| 13                   | 1251:17     | 39                    |
| 14                   | 1252:00     | 18                    |
| 15                   | 1252:25     | 39                    |
| 16                   | 1253:14     | 64                    |
| 17                   | 1254:22     | 13                    |
| 18                   | 1254:40     | 88                    |
| 19                   | 1259:10     | 17                    |
| 20                   | 1259:40     | 90                    |
| 21                   | 1301:25     | 112                   |
| 22                   | 1303:25     | 25                    |
| 23                   | 1303:54     | 94                    |
| 24                   | 1306:00     | 14                    |
| 25                   | 1308:00     | 40                    |
| 26                   | 1308:49     | 215                   |
| 27                   | 1312:40     | 14                    |

Discharge Stripping-C/M (1607-1630, Day 8)

During this time period, the C/M was involved in the stripping of product from tank 1C. In order to see into the tank, the C/M would lie down on the deck and place his face directly into a Butterworth opening. As the level dropped, he would periodically raise his head and signal the A/B on standby to close down on the product valve. The number of times and the durations when he checked the level is summarized on the following page.

| <u>Time</u> | <u>Duration (sec)</u> |
|-------------|-----------------------|
| 1608:08     | 117                   |
| 1611:25     | 15                    |
| 1613:05     | 5                     |
| 1613:50     | 25                    |
| 1614:15     | 55                    |
| 1615:10     | 40                    |
| 1617:05     | 35                    |
| 1617:40     | 70                    |
| 1618:13     | 60                    |
| 1620:00     | 40                    |
| 1621:54     | 26                    |
| 1622:53     | 12                    |
| 1623:20     | 15                    |
| 1624:13     | 60                    |
| 1625:40     | 15                    |
| 1626:30     | 45                    |
| 1627:30     | 20                    |
| 1627:55     | 20                    |
| 1628:20     | 60                    |

Two exposure samples were obtained during this activity. Sample SB-114 was a personal sample that was collected on the C/M. Sample SB-76 was an area sample, which was collected at the opposite edge of the Butterworth opening from where the C/M was positioned.

#### Discharge Stripping-C/M (1634-1649, Day 8)

After stripping tank 1C, the C/M moved over to tank 1S to perform the same activity. The major difference between stripping tank 1S and tank 1C was that the level sightings were made through the ullage opening on the tank hatch rather than the Butterworth opening. This procedure was necessary because the pump suction was located directly under the tank hatch. The durations of the sightings at tank 1S are shown below.

| <u>Time</u> | <u>Duration (sec)</u> |
|-------------|-----------------------|
| 1637:05     | 12                    |
| 1639:55     | 5                     |
| 1644:15     | 5                     |
| 1644:45     | 25                    |
| 1645:18     | 12                    |
| 1645:46     | 120                   |

One personal (SB-107) and one area (SB-74) sample were collected during this discharge stripping activity. The area sample was collected at the ullage opening on the tank hatch.

Hose Disconnect-O/S (2225-2341, Day 9)

This hose disconnect operation occurred in conjunction with A/B1's regular watch No. 17 (2000-2400, Day 9). The activities of the O/S were very similar to those described for A/B1, and thus will not be repeated here.

Exposure sample, SB-202, was collected on the O/S during this activity.

Sandblasting-A/B (1035-1115, Day 10)

During this period, an A/B sandblasted surfaces on the stern of the ship. His activities and protective equipment were similar to those noted in the O/S sandblasting documentation on day 5 (0844-1115). A dust exposure sample, SB-D-19, was collected on this A/B.

Tank Washing and Ventilating-A/B and O/S (0600-1710, Day 11)

During this time period, an A/B and an O/S assisted in tank washing and ventilation. The exposure samples that were collected are summarized below.

| <u>Worker</u> | <u>Sample No.</u> | <u>Time</u> |
|---------------|-------------------|-------------|
| A/B           | SB-117            | 0600-1200   |
|               | 60389             | 0600-1200   |
|               | SB-205            | 1250-1710   |
|               | 60392             | 1250-1710   |
| O/S           | SB-119            | 0600-1200   |
|               | 60390             | 0600-1200   |
|               | SB-110            | 1200-1710   |
|               | 60391             | 1200-1710   |

This A/B - O/S team was responsible for washing and ventilating tanks 1P, 1S, 2P, 2S, and 3S. The procedure for each tank was the same, and it included:

- o opening forward, center, and aft Butterworth covers,
- o dropping the wash hose 15 feet into the forward, center, and aft Butterworth opening for about 15 minutes each,
- o setting up the discharge pump to strip wash residue from the tank and discharge it overboard.

- o stripping the remaining liquid from the tank after washing had been completed,
- o setting up a water driven blower on the Butterworth opening furthest from the man entry hatch, and
- o closing of the man entry hatch and all of the Butterworth openings.

The A/B and O/S were exposed to product vapors primarily while gauging during the stripping of the tanks. These gauging activities are summarized below.

A/B Gauging Activity During Tank Washing

| <u>Encounter No.</u> | <u>Tank</u> | <u>Time</u> | <u>Duration (sec)</u> |
|----------------------|-------------|-------------|-----------------------|
| 1                    | 1P          | 0630:10     | 10                    |
| 2                    | 1P          | 0635:00     | 60                    |
| 3                    | 1P          | 0639:20     | 100                   |
| 4                    | 2C          | 0648:12     | 26                    |
| 5                    | 2C          | 0700:00     | 10                    |
| 6                    | 2P          | 0833:00     | 120                   |

O/S Gauging Activity During Tank Washing

| <u>Encounter No.</u> | <u>Tank</u> | <u>Time</u> | <u>Duration (sec)</u> |
|----------------------|-------------|-------------|-----------------------|
| 1                    | 1P          | 0652:00     | 60                    |
| 2                    | 2C          | 0655:00     | 300                   |
| 3                    | 2S          | 1102:00     | 60                    |

These gauging activities were performed at the open expansion trunks. The A/B or O/S would kneel or lean over by the hatch. In this position, their breathing zones were roughly six inches below the top lip of the expansion trunk. A mirror or a flashlight was used to illuminate the bottom of the tank.

Tank Cleaning-C/M and O/S (0600-1700, Day 11)

The tank cleaning activities performed by the C/M and O/S were very similar to those discussed previously for the A/B and O/S team during this same time period. The C/M and O/S, however,

cleaned all tanks aft of the loading manifold (No. 3, No. 4, No. 5, and No. 6 tanks). Both active and passive occupational exposure samples were collected on the C/M and O/S as summarized below.

| <u>Worker</u> | <u>Sample No.</u> | <u>Time</u> |
|---------------|-------------------|-------------|
| C/M           | SB-103            | 0600-1200   |
|               | 63765             | 0600-1200   |
|               | 63777             | 1240-1405   |
| O/S           | SB-209            | 0600-1200   |
|               | 63760             | 0600-1200   |
|               | SB-207            | 1215-1700   |
|               | 63775             | 1215-1700   |

During the first time period both individuals were involved in washing the tanks (blowers were not connected until after lunch). For the tank washing and blowing procedure, see the previous section entitled "Tank Washing and Blowing-A/B and O/S (0600-1170, Day 11)".

Except for the No. 6 wing tanks, the liquid level was sighted through the tank hatches. For 6S and 6P the C/M looked through the Butterworth opening directly above the pump suction.

Tank washing and stripping of the No. 6 wings occurred during the initial portion of the second sampling period.

Ambient hydrocarbon concentrations on the deck were 10-20 ppm as methane with excursions to 200-300 ppm as methane. Hydrocarbon levels at the tank hatches and Butterworth openings, where the C/M made his sightings, usually exceeded 1000 ppm as methane.

## XI. Deckhouse and Engine Room Environments

### Deckhouse Environment

OVA surveys were conducted at all levels of both the deckhouse and engine room throughout the voyage to allow assessment of the relative potential for vapor infiltration into living spaces.

The deckhouse vapor concentrations for loading, laden, discharging, and tank cleaning are presented in Table VIII. These concentration values represent the average of the measurements taken during the various surveys. The deckhouse surveys indicated a general increase in vapor concentration during cargo loading and tank cleaning, which could be a result of infiltration through incompletely closed forward or aft access doors, or both. During loading, the odor of gasoline was noticeable, especially in the hallway to the boatdeck leading to the forward access door.

In addition to the OVA surveys during tank washing and blowing, continuous concentration measurements were made in the SwRI quarters, which was believed to contain typical deckhouse vapor levels, using an OVA connected to a strip chart recorder. This concentration time history is included as Figure 4. On this figure, the higher concentration periods are correlated with specific events. Since washing or blowing of the aft tanks did not necessarily raise the vapor concentration in the deckhouse, it seems that factors such as wind speed, wind direction, and how tightly the doors are sealed are the determining factors in the infiltration into the deckhouse.

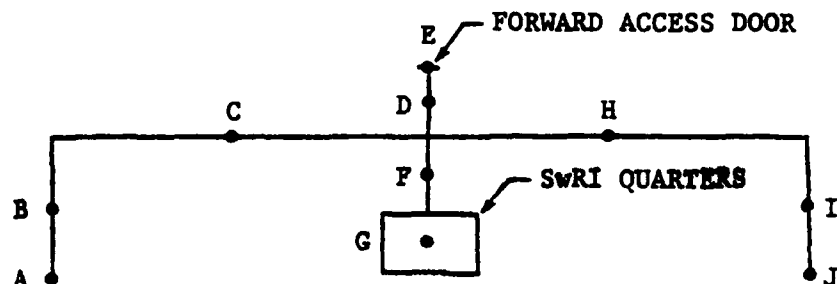
During tank washing and blowing, area samples were placed both in the SwRI quarters and engine control room, and they are designated in Table VIII as boat deck level G and main deck level F, respectively. The samples collected are summarized in Table IX.

TABLE IX. AREA SAMPLES FOR TANK WASHING AND BLOWING

| <u>Voyage<br/>Day</u> | <u>Location</u>       | <u>Sample<br/>Time</u> | <u>Sample<br/>No.</u> | <u>Concentration</u> |            | <u>Duration<br/>(min)</u> |
|-----------------------|-----------------------|------------------------|-----------------------|----------------------|------------|---------------------------|
|                       |                       |                        |                       | <u>BNZ</u>           | <u>THC</u> |                           |
| 11                    | SwRI Qrtrs.           | 0600 - 1430            | SB-94                 | 0.30                 | 5.80       | 482                       |
| 11                    | Engine<br>Control Rm. | 0600 - 1430            | SB-91                 | 0.36                 | 9.14       | 489                       |
| 11                    | SwRI Qrtrs.           | 1430 - 1820            | SB-9                  | ND                   | 1.08       | 247                       |
| 11                    | Engine<br>Control Rm. | 1430 - 1820            | SB-5                  | ND                   | ND         | 238                       |

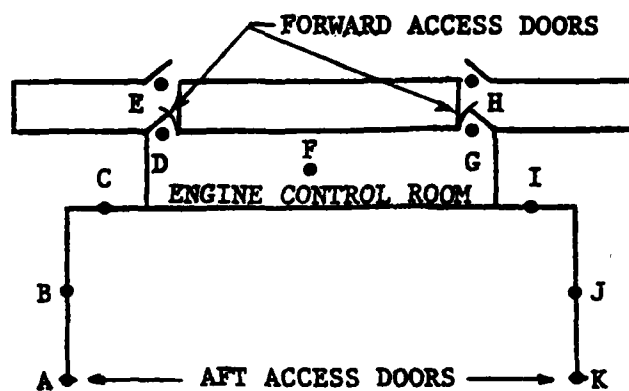
TABLE VIII. OVA SURVEYS OF DECKHOUSE

## BOAT DECK LEVEL

Vapor Concentrations (ppm Gasoline)

| <u>Point</u> | <u>Tank Cleaning</u> | <u>Loading</u> | <u>Laden</u> | <u>Discharging</u> |
|--------------|----------------------|----------------|--------------|--------------------|
| A            | 12.5                 | 25             | 10           | 5                  |
| B            | 12.5                 | 26             | 10           | 5                  |
| C            | 12.5                 | 26             | 10           | 5                  |
| D            | 10                   | 43             | 11           | 5                  |
| E            | 11                   | 45             | 11           | 5                  |
| F            | 11                   | 36             | 10           | 5                  |
| G            | 11                   | 33             | 10           | 5                  |
| H            | 11                   | 30             | 10           | 6                  |
| I            | 12.5                 | 27             | 10           | 7                  |
| J            | 11                   | 27             | 11           | 11                 |

## MAIN DECK LEVEL

Vapor Concentrations (ppm Gasoline)

| <u>Point</u> | <u>Tank Cleaning</u> | <u>Loading</u> | <u>Laden</u> | <u>Discharging</u> |
|--------------|----------------------|----------------|--------------|--------------------|
| A            | 12.5                 | -              | 10           | 5                  |
| B            | 12.5                 | 23             | 10           | 5                  |
| C            | 11                   | 23             | 10           | 5                  |
| D            | -                    | -              | 10           | 5                  |
| E            | -                    | -              | 7            | 7                  |
| F            | 7                    | 26             | 10           | 5                  |
| G            | 18.5                 | -              | 7            | 5                  |
| H            | -                    | -              | 7            | 7                  |
| I            | 7                    | 30             | 11           | 5                  |
| J            | 11                   | 27             | 10           | 5                  |
| K            | 10                   | -              | 10           | 5                  |



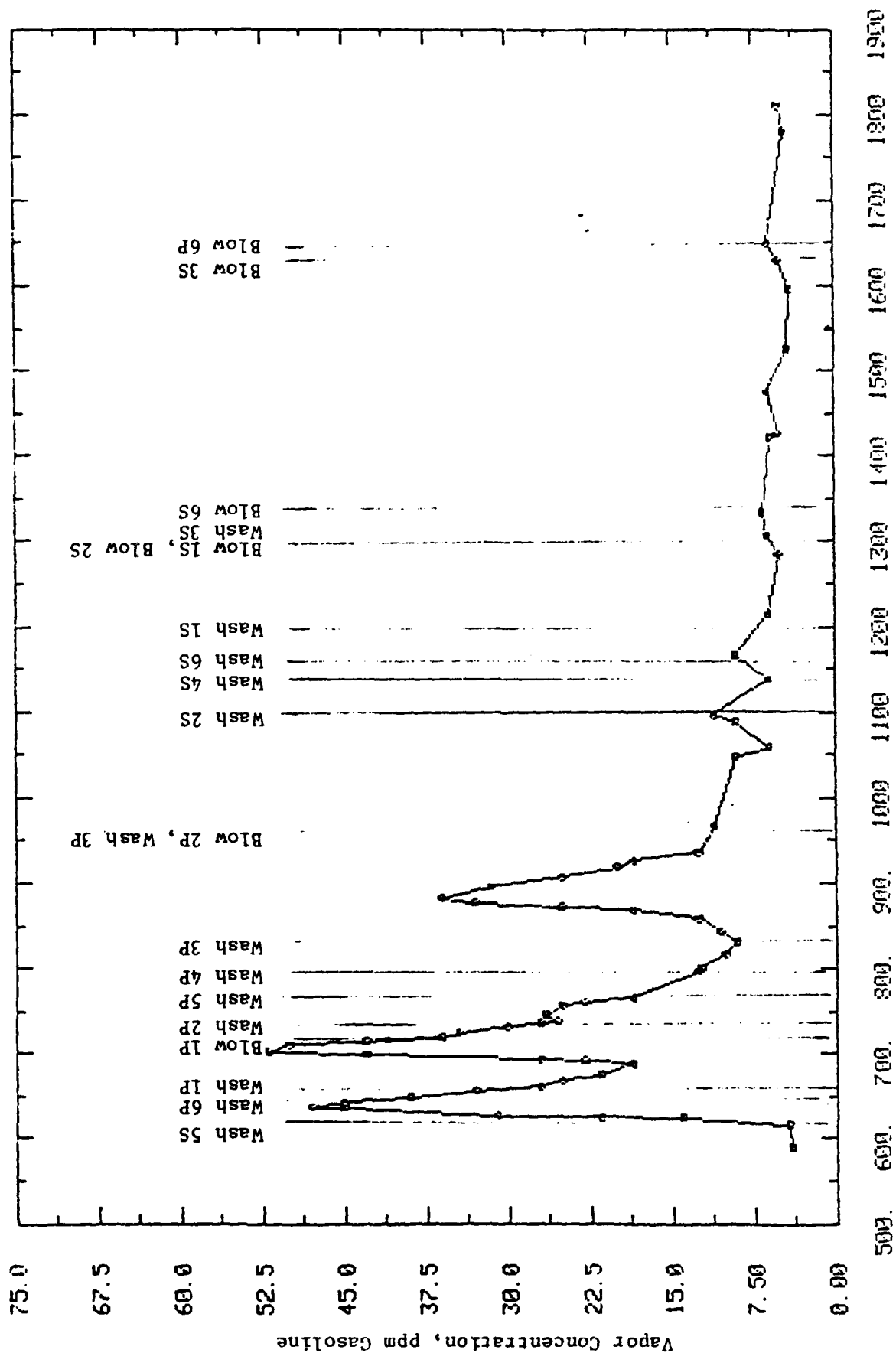


FIGURE 4. VAPOR CONCENTRATION IN SWRI QUARTERS DURING TANK WASHING AND BLOWING

The deckhouse vapor concentrations during ballasting are presented in Table X (on the following page). Because of the variation over time of these values, they are presented at the times the surveys were taken and have not been averaged. Continuous concentration measurements in the SwRI quarters were also recorded during ballasting and appear as Figure 5. Significant events designated on this figure indicate that:

- (1) vapor concentrations in the deckhouse continually increased during ballasting,
- (2) the peak concentration coincides with the end of ballasting, and
- (3) at least two hours were necessary after ballasting was completed for the vapor concentration in the deckhouse to drop to its initial background level.

An area sample was placed in the SwRI quarters during ballasting activities. The relevant data is presented below.

| Voyage<br>Day | Sample Time | Sample No. | Concentration<br>(ppm) |       | Duration<br>(min) |
|---------------|-------------|------------|------------------------|-------|-------------------|
|               |             |            | BNZ                    | THC   |                   |
| 9 - 10        | 2000-0400   | SB-212     | 0.20                   | 21.42 | 484               |

The bulk fuel oil sample was analyzed qualitatively for the 16 PNAs designated by the EPA. This list of compounds is partially duplicated the combined lists from NIOSH P&CAM 183 and 184. Quantitative analysis was then conducted on four of these PNAs that have ACGIH TLVs. These compounds were o-Terphenyl, Chrysene, Benzo(a)pyrene, and Naphthalene.

The analysis of charcoal tubes for total hydrocarbon (THC) involved absorption with nitrobenzene followed by summation of gas chromatograph integrated counts through xylene. Nitrobenzene was used because it eluted from the column after xylene and thus did not obscure low molecular weight volatile components as did carbon disulfide. Total hydrocarbon content was quantified against a hexane standard. Gasoline vapor concentration was calculated using an average molecular weight of 72.5.

The results of the x-ray diffraction analysis of the bulk insulation are summarized below.

| <u>Sample No.</u> | <u>Weight Percent Asbestos form</u> |                   |
|-------------------|-------------------------------------|-------------------|
|                   | <u>Amosite</u>                      | <u>Chrysotile</u> |
| S-14              | -                                   | 20-22             |
| S-18              | 2-3                                 | 3-4               |
| S-26              | ND                                  | ND                |
| S-39              | ND                                  | ND                |
| S-44              | 1                                   | 3                 |

The designator ND signifies that the asbestos form was not detected.

The quantitative results for PNAs in the bunker fuel oil are presented below.

| <u>Component</u> | <u>Weight Percent</u> | <u>Detection Limit (ug/g)</u> |
|------------------|-----------------------|-------------------------------|
| Naphthalene      | 0.088                 | 500                           |
| Chrysene         | 0.074                 | 50                            |
| Benzo(a) Pyrene  | 0.003                 | 20                            |
| o-Terphenyl      | 0.180                 | 50                            |

concentrations at the most frequently visited location and real-time environmental surveys using an Organic Vapor Analyzer (OVA). Occupational and area vapor samples were collected on charcoal tubes and were analyzed for benzene content and total hydrocarbon content through xylene. Short-term (15 minute) vapor sampling was not appropriate because (1) pumproom entry durations were nominally less than 15 minutes and (2) OVA surveys did not suggest that the TLV-STEL for gasoline and hence benzene would be exceeded. Work activity documentation included work task identification and duration. On selected occasions, the pumpman's noise environment was characterized. Noise dosimetry equipment was worn by SwRI project personnel.

In the engine room, full-watch occupational exposures were monitored for noise, asbestos and total hydrocarbon vapors. As in the pump room, engine room noise dosimetry was conducted for comparison against the U. S. Coast Guard Naval Vessel Circular 12-82. Asbestos was collected and analyzed using NIOSH P&CAM Z39. Vapor samples were collected on charcoal and were analyzed for total hydrocarbon content through xylene. A separate analysis for benzene was not warranted because of the low vapor concentrations as determined by OVA surveys. The three dosimetry methods were distributed between the Assistant Engineer, Fireman and Oiler. The watch-to-watch distribution between personnel was varied according to a systematic plan. The motivation for vapor monitoring was possible gasoline vapor infiltration through the engine room's positive pressure dilution ventilation system.

Bulk samples of degraded insulation and bunker fuel oil were collected in the engine room. The insulation samples were analyzed by x-ray diffraction for weight percent content of various asbestos forms. The bunker fuel was analyzed for weight percent of selected polynuclear aromatic hydrocarbons. Oil mist area samples were collected on mixed esters of cellulose filters and were analyzed by infrared spectroscopy for mist concentration as mineral oil.

#### IV. Sampling Strategy and Sample Analysis

Prior to initiation of sampling, walk-through surveys were conducted in both the engine and pump rooms. The purpose of these surveys was to become familiar with equipment location, work stations and potential sources of airborne contaminants. Based on these surveys it was concluded that

- o neither location contained easily-identified, discrete sources of contaminant emission that would be analogous to the vapor plume that is discharged from a cargo tank during open gauging,
- o the positive pressure ventilation system in the engine room was conducive to promoting a nearly uniform distribution of contaminants within the work space,
- o pumproom operations could be controlled primarily from the deck level control console thus necessitating only brief entries to the pump/bilge level, and
- o the suction ventilation system in the pumproom was conducive to generating vertical vapor concentration gradient as opposed to a more homogenous atmosphere.

Two sampling strategies were devised prior to the test. As a result of the above observation, the following strategy was used.

In the pump room, full-shift occupational vapor exposure samples were collected on the first and second pumpman. These samples were supplemented by area vapor monitoring at the pump/bilge level to characterize the

### III. Cargo Description

The cargo consisted of regular, unleaded and aviation gasolines as well as aviation jet fuel. These products were distributed as indicated in Table III.1. Loading of the entire ship took place at one terminal. Six tanks (3P, 3C, 3S, 6P, 6C, 6S) of jet fuel were discharged at anchorage to a lightering barge. The remaining products were then discharged in port.

TABLE III.1. CARGO DISTRIBUTION PLAN

| Tank No. | Quantity (bbls) | Product           |
|----------|-----------------|-------------------|
| 1P       | 4363            | Aviation Gas      |
| 1C       | 12615           | Aviation Gas      |
| 1S       | 4363            | Aviation Gas      |
| 2P       | 5557            | Unleaded Gas      |
| 2C       | 12611           | Unleaded Gas      |
| 2S       | 5557            | Unleaded Gas      |
| 3P       | 5795            | Jet Fuel          |
| 3C       | 12612           | Jet Fuel          |
| 3S       | 5795            | Jet Fuel          |
| 4P       | 5812            | Regular Gasoline  |
| 4C       | 12610           | Regular Gasoline  |
| 4S       | 5812            | Regular Gasoline  |
| 5P       | 5811            | Regular Gasoline  |
| 5C       | 12604           | Regular Gasoline  |
| 5S       | 5811            | Regular Gasoline  |
| 6P       | 5812            | Jet Fuel          |
| 6C       | 12594           | Jet Fuel          |
| 6S       | 5812            | Jet Fuel          |
| 7P       | 5792            | Jet Fuel          |
| 7C       | 12575           | Jet Fuel          |
| 7S       | 5792            | Jet Fuel          |
| 8P       | 4244            | Unleaded Gasoline |
| 8C       | 9429            | Unleaded Gasoline |
| 8S       | 4244            | Unleaded Gasoline |
| 9P       | 5150            | Unleaded Gasoline |
| 9C       | 12594           | Unleaded Gasoline |
| 9S       | 5150            | Unleaded Gasoline |

operation by providing tools and operating a winch to support and remove the pipe fixture. During the laden voyage, the pump room was checked daily for leaks by either the first or second pumpman. When the vessel was discharging cargo, the operation of the cargo pumps was monitored almost continuously by one of the pumpmen.

Shifts also varied during the voyage. While the vessel was loading or discharging, the pumpmen staggered their shifts. During the laden voyage both pumpmen worked day shifts.

#### II.4 Deck Work

During periods of minimal cargo related activities, ship's personnel were monitored while they performed deck work. The results of this sampling are included in this report.

Substances might include paints, degreasers, asbestos lagging, etc. Alternatively, exposure might occur due to infiltration of cargo vapors into the engine room. This condition should appear on dosimetry samples as a function of voyage leg and cargo handling activities. The former type of exposure should remain more constant throughout the entire voyage.

Engine room personnel worked shifts of 4-on, 8-off during the voyage. Several individuals also worked overtime. During normal four-hour shifts, the work followed a routine, repetitive schedule of activities. For example, the oiler was required to make "rounds" every hour while underway. He inspected everything quickly, paying particular attention to gauge readings throughout the engine room. These rounds took the oiler from the propellar shaft to the stack in a period of 5 to 10 minutes. On the last round of his shift, the oiler would make sure that the personnel coming on duty for the next shift were awake.

The engineers and firemen also followed fairly routine schedules much of the time. The engineer stood near the control console almost continuously when the ship was maneuvering. In open waters, the engineers were able to move away from the control panel to supervise work, perform monthly duties, etc. (Monthly duties for the engineers are given in Section V.II.) The firemen stood near the boiler control panel most of the time. They periodically moved away from the panel to check gauge readings, replace fuel injection tips and adjust valves.

### II.3 Pump Room

Activities in the pump room varied considerably. During loading operations, there was generally no need to use the pump room cargo pumps. On this voyage, maintenance workers came on board to remove a faulty line from one of the pumps. The pumpman on duty assisted the



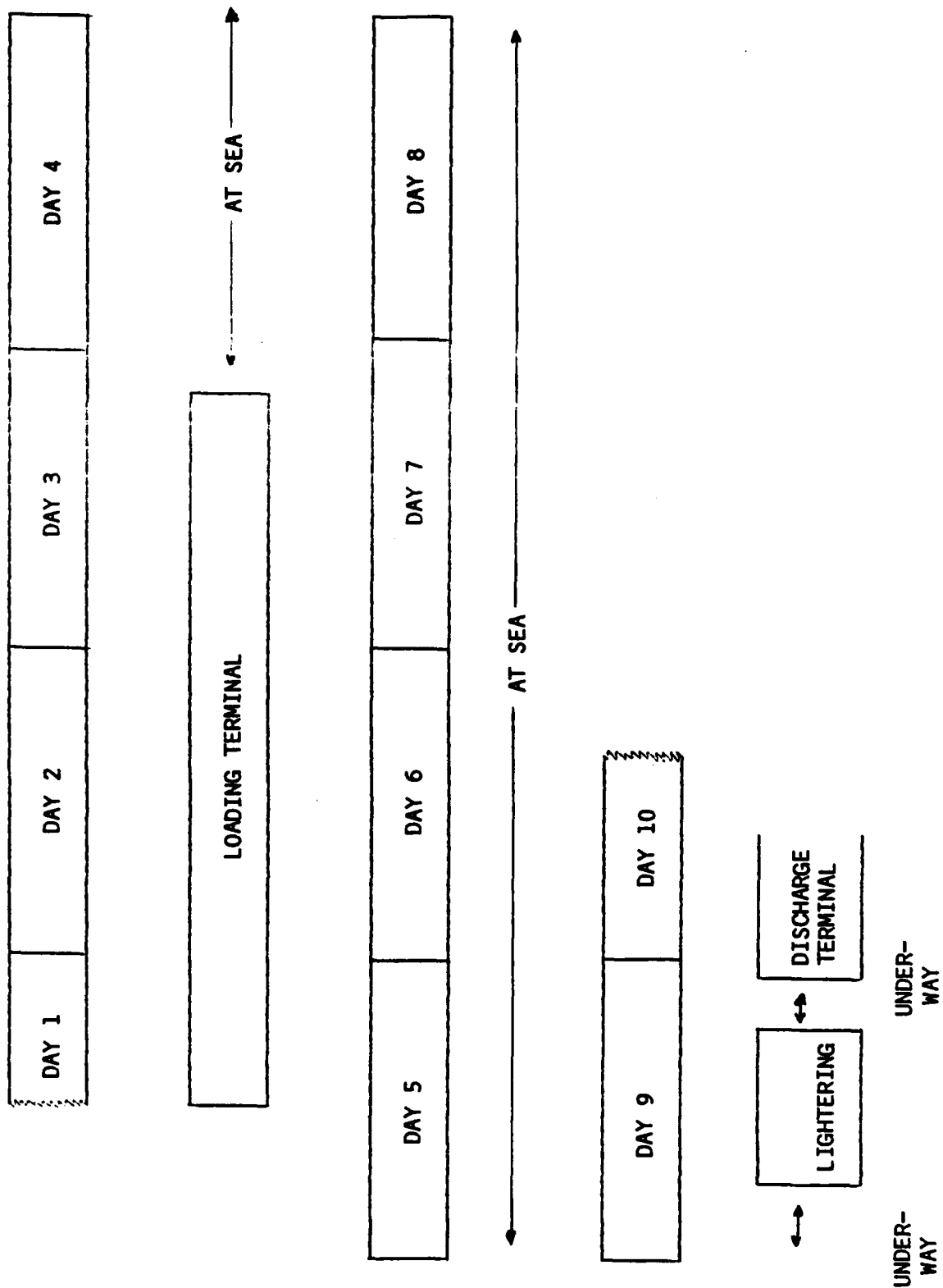


FIGURE II.1. OVERVIEW OF TIME SPENT LOADING, LADEN, AND DISCHARGING

## II. Trip Overview and Objectives

### II.1 General

The primary purpose of this trip was to monitor engine room and pump room personnel during various legs of the voyage. Based on prior observations on board other vessels, the loading, laden voyage, discharge, ballasting, tank cleaning, and gas freeing operations could produce a wide range of vapor concentrations on deck, and possibly inside the engine room. The objective was to monitor the engine room during each of the operations listed. However, changes in the ship's schedule precluded monitoring during ballasting, tank cleaning, or gas freeing.

Most of the pump room monitoring was conducted during the loading and discharging of cargo. During the laden voyage deck work was monitored, including chipping and painting. This monitoring was conducted during periods when sampling in the engine room and the pump room was not expected to provide additional exposure information. Figure II.1 provides an overview of the duration of each leg of the voyage. The vessel was docked at the loading terminal for approximately two full days. During this time, loading was interrupted due to electrical storms in the area. The laden voyage spanned a period of approximately 5-1/2 days. The ship was lightered to a barge for approximately 12 hours and then sailed for several hours to the discharge terminal.

### II.2 Engine Room

Activities in the engine room generally follow a fairly routine schedule. Therefore, exposure to a hazardous substance was expected to occur in one of two ways. First, a normal activity might result in exposure to a hazardous substance carried in the engine room.

I. Vessel Description

I.1 Dimensions

- o Length Overall - 604'
- o Length between perpendiculars - 573'
- o Breadth (mid) - 78'
- o Depth (mid) - 44'

I.2 Tonnage - 27,000 DWT

1.3 Propulsion - Steam-turbine; 15,000 horsepower

1.4 Cargo Tanks - 27 (nine rows of three across, wing capacities symmetric about center longitudinal

1.5 Cargo Pumps - Five steam driven pumps in pumproom

1.6 Cargo Loading Method - Closed Drop

## VOYAGE 2 REPORT OUTLINE

- I. Vessel Description
- II. Trip Overview and Objectives
- III. Cargo Description
- IV. Sampling Strategy and Sample Analysis
- V. Engine Room
- VI. Pump Room
- VII. Miscellaneous

APPENDIX B  
VOYAGE REPORT - VOYAGE 2

### Engine Room Environment

The engine room vapor concentrations during loading and at sea are presented in Table XI. Due to these low concentrations and spot OVA checks during other phases of the voyage, personal sampling was not justified.

TABLE XI

#### Engine Room Vapor Concentration Measurements (ppm as Methane)

| <u>Level</u> | <u>Location</u>           | <u>Loading</u> | <u>At Sea</u> |
|--------------|---------------------------|----------------|---------------|
| I            | Spare Parts Room          | 8              | 6             |
|              | Compressor                | 8              | 5             |
|              | Engine Exhaust Ducts      | 8              | 7             |
|              | Fuel Separator            | 8              | 6             |
|              | Hydraulic Steering Room   | 8              | 6             |
| II           | Work Bench and Tool Rack  | 8              | 6-7           |
|              | Engine Cylinder Covers    | 8              | 6-7           |
|              | Engine Cooling Air Outlet | 8              | 6-7           |
| III          | Forward Transfer Pump     | 8              | 6-7           |
|              | Bucket of Degreaser       | 8              | 6-7           |
|              | Engine Fuel Racks         | 8              | 6-7           |
|              | Clutch and Reducer        | 8              | 6-7           |
| IV           | Propeller Drive Shaft     | 8              | 6-7           |

- NOTES: 1. Within a given level, locations progress from forward to aft end of engine room.  
 2. Measurements made with OVA.  
 3. Vapors were not analyzed for composition.

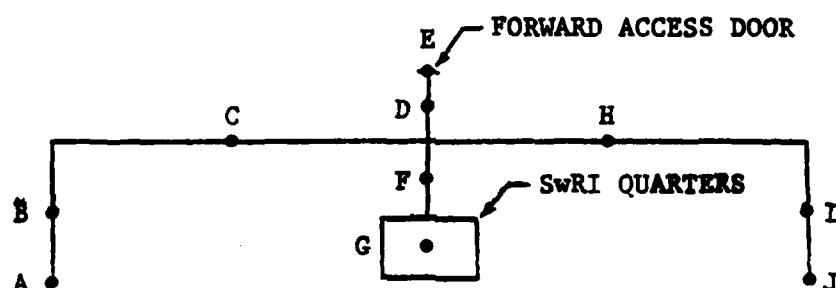
One area sample was collected in the engine room during a laden leg of the voyage. The sample was placed above the engine cylinder covers on level II, on the recommendation of the 1st Engineer. The relevant data is presented below.

| <u>Voyage</u><br><u>Day</u> | <u>Sample Time</u> | <u>Sample No.</u> | <u>Concentration</u> |            | <u>Duration</u><br><u>(min)</u> |
|-----------------------------|--------------------|-------------------|----------------------|------------|---------------------------------|
|                             |                    |                   | <u>BNZ</u>           | <u>THC</u> |                                 |
| 5                           | 1134 - 2056        | SB-62             | ND                   | 0.34       | 562                             |



TABLE X. OVA SURVEYS OF DECKHOUSE DURING BALLASTING, DAY 10

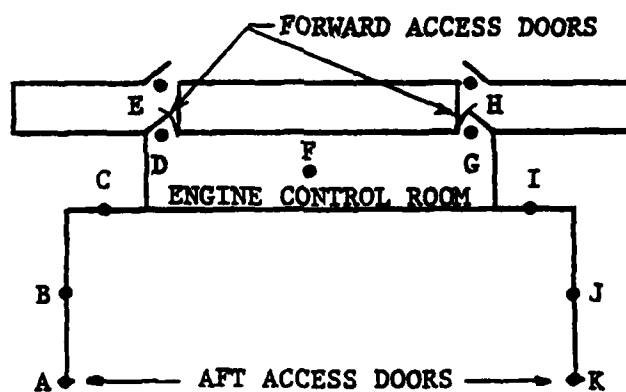
## BOAT DECK LEVEL



Vapor Concentrations (ppm Gasoline) At Times:

| Point | 0023 | 0100 | 0135 | 0210 | 0303 | 0345 |
|-------|------|------|------|------|------|------|
| A     | 54   | 50   | 151  | 190  | 21.5 | 14   |
| B     | 45   | 86   | 145  | 190  | 46   | 17   |
| C     | 43   | 86   | 145  | 168  | 48   | 17   |
| D     | 86   | 102  | 260  | 285  | 31   | 14   |
| E     | 145  | 104  | 285  | 235  | 31   | 11   |
| F     | 41   | 88   | 145  | 185  | 48   | 15.5 |
| G     | 38   | 88   | 145  | 178  | 50   | 15.5 |
| H     | 45   | 88   | 149  | 190  | 45   | 18.5 |
| I     | 45   | 92   | 151  | 190  | 41   | 18.5 |

## MAIN DECK LEVEL



Vapor Concentrations (ppm Gasoline) At Times:

| Point | 0023 | 0100 | 0135 | 0210 | 0303 | 0345 |
|-------|------|------|------|------|------|------|
| A     | 63   | 102  | 140  | 168  | 30   | 12.5 |
| B     | 63   | 99   | 170  | 190  | 33   | 14   |
| C     | 63   | 97   | 140  | 168  | 33   | 14   |
| D     | 60   | 99   | 178  | 155  | 30   | 14   |
| E     | 190  | 102  | 122  | 140  | 25   | 12.5 |
| F     | 82   | 102  | 190  | 168  | 20   | 11   |
| G     | 99   | 122  | 285  | 132  | 10   | 12.5 |
| H     | 145  | 155  | 850  | 190  | -    | -    |
| I     | 58   | 97   | 138  | 122  | 33   | 14   |
| J     | 60   | 95   | 138  | 140  | 33   | 12.5 |
| K     | 72   | 112  | 140  | 155  | 31   | 11   |



## V. Engine Room

### V.1 Configuration and Ventilation

The engine room consisted of three primary levels. These levels included the "shaft level", the "control room level", and the "workshop level". The aft section of the shaft level contained steam condensers, lube oil coolers and purifiers, gear boxes, and the propeller shaft. The forward section contained five motors for driving discharge pumps located in the pump room. The motor shafts passed through a bulkhead separating the engine room and the pump room. The aft room on the control level contained a low pressure and a high pressure turbine, two steam turbines and alternators, an electrical breaker panel, and the control console. The fire room was forward of the control room. It housed the low pressure and high pressure boilers, a condensate box, a fuel oil heater, a storage area enclosed with expanded metal, and a fire control panel. The workshop level contained a storage area for tools, reference books, pipes, circuit breakers, etc. The forward portion of this level provided access to the upper half of the boilers.

Supply air for engine room ventilation was brought in through four inlets located two levels above the "poop deck". Figure V.1 shows the geometry of the air intake vents for the engine room. These vents were located one level below the engine exhaust stack level. The exhaust vents in Figure V.2 were located on the engine exhaust stack level. Figure V.3 shows the locations of the engine room inlet and exhaust vents in planview. Table V.1 shows the air flow velocities measured at an inlet and at an exhaust vent. The measurements were made by holding a mechanical vane anemometer in the flow at the locations indicated in Figures V.1 and V.2. These locations were roughly at the centers of equal areas. Ventilation flow rate based on inlet conditions was about 9300 cfm. The calculated discharge flow rate was close to 1050 cfm. The difference between these numbers represents the flow rate of air that was discharged from the engine room through other openings such as the access opening to the stack shroud.

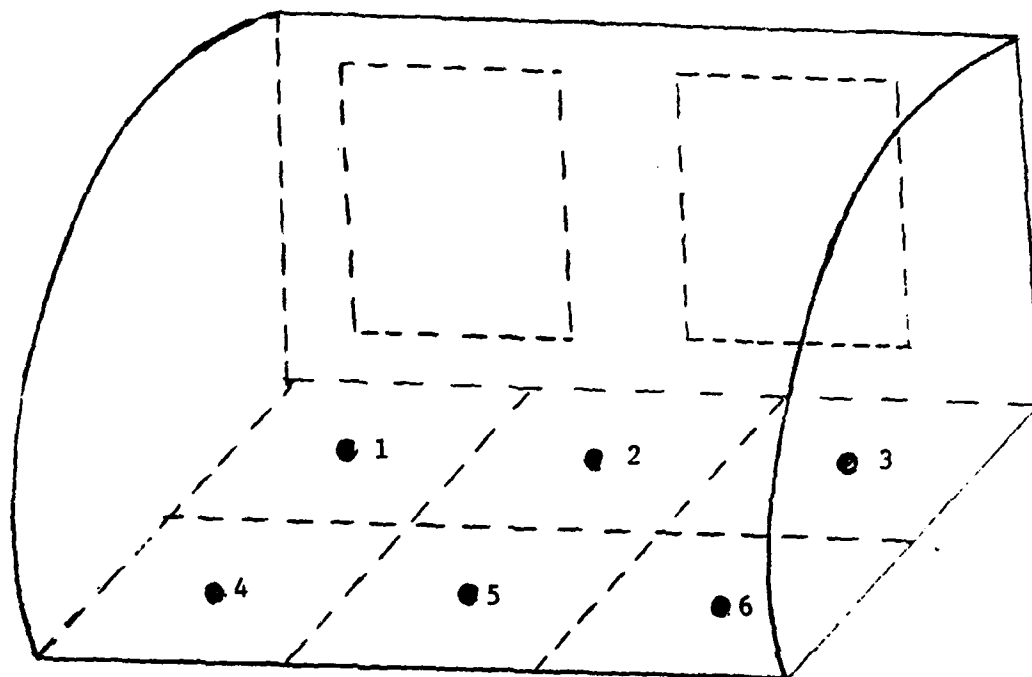
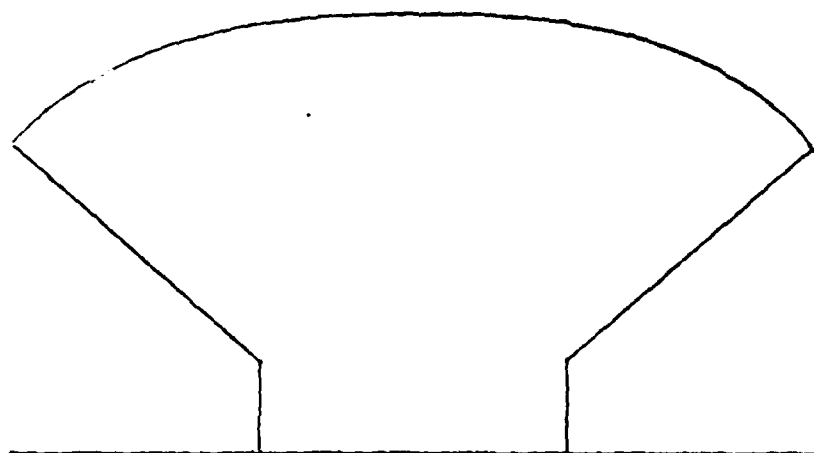
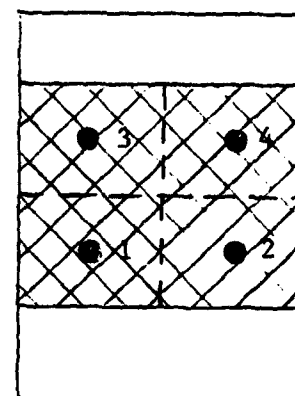


FIGURE V.1. INLET GEOMETRY

● VELOCITY  
MEASUREMENT  
LOCATIONS



FORE-AFT VIEW



EXHAUST  
GRILL

END VIEW

FIGURE V.2. OUTLET GEOMETRY

● VELOCITY  
MEASUREMENT  
LOCATIONS

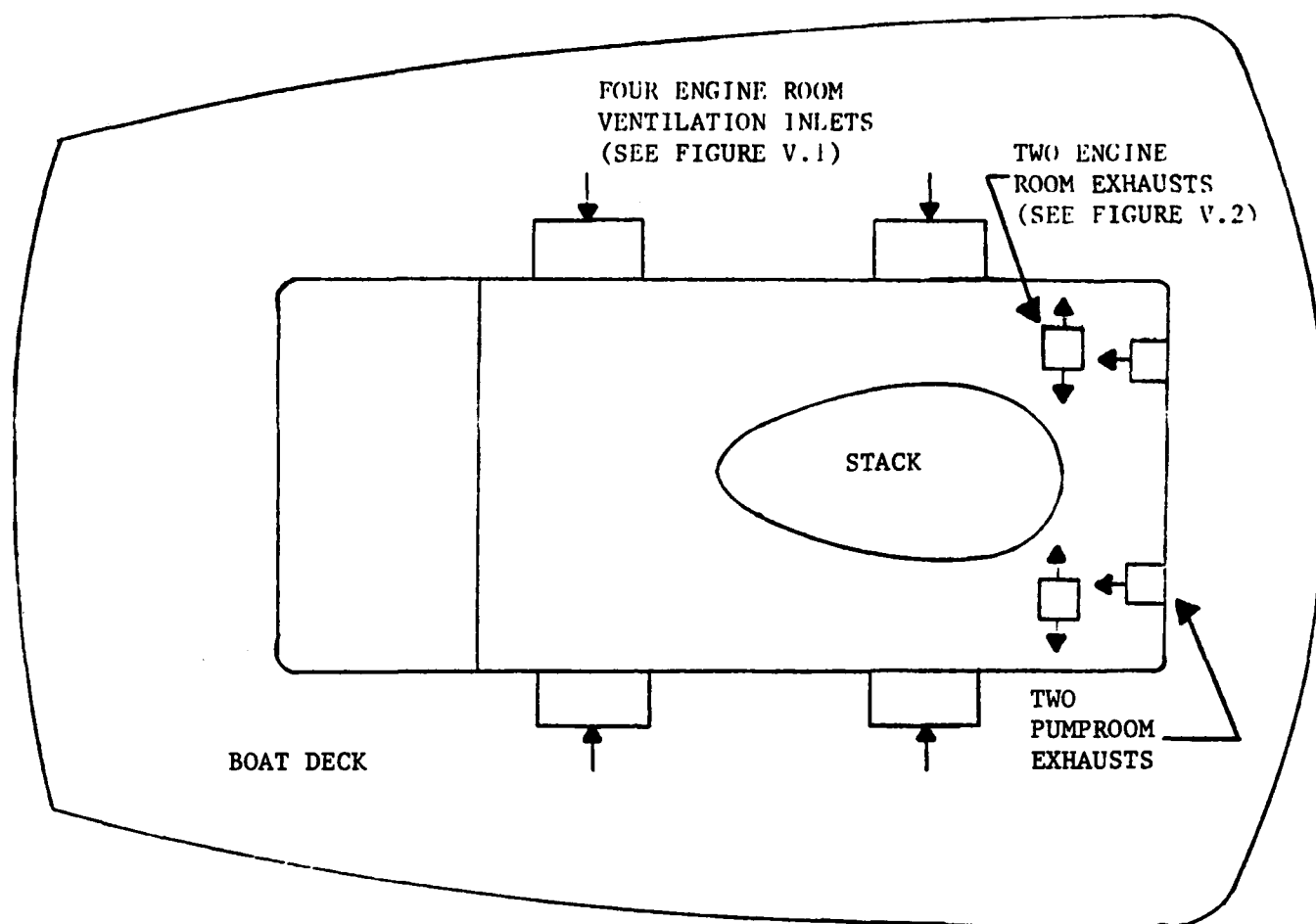


FIGURE V.3. ENGINE ROOM VENTILATION INLETS AND EXHAUSTS

TABLE V.1. VENTILATION AIR FLOW VELOCITIES (m/sec)

| Location | Inlet | Exhaust    |
|----------|-------|------------|
| 1        | 4.9   | 2.1        |
| 2        | 5.9   | 1.4 (2.0)* |
| 3        | 5.8   | 2.2        |
| 4        | 5.2   | 2.8 (3.2)* |
| 5        | 2.8   | --         |
| 6        | 3.7   | --         |

\*Numbers in parenthesis indicate the velocity recorded on a second measurement.

Inside the engine room, spot ventilation was provided in areas where the men normally stood during a watch. Air flow velocities were measured at head level (approximately 5-1/2 to 6 feet) for several of these vents. The measurements were made at locations where the engineers, oilers, and firemen stood during their watches. The location of the measurement points in the control room and in the fire room are shown in Figure V.4. The corresponding flow velocities are given in Table V.2. The location of sample points in the shaft level of the engine room are indicated in Figure V.5. Table V.3 shows the velocities measured on the shaft level.

TABLE V.2. SPOT VENTILATOR FLOW RATES - CONTROL ROOM AND FIRE ROOM

| Location ID | Description                                                                               | Flow Rate, m/s |
|-------------|-------------------------------------------------------------------------------------------|----------------|
| A           | Ventilator for fireman; used occasionally while monitoring fire control panel             | 2.6            |
| B           | Fireman's normal position while monitoring fire control panel; temperature at panel 110°F | 6.7            |
| C           | Control console; steam control position                                                   | 1.4            |
| D           | Control console; duplexer position                                                        | 1.4            |
| E           | Seat (measurement taken at head level while seated)                                       | 6.5            |
| F           | Seat (measurement taken at head level while seated)                                       | 5.8            |

TABLE V.3. SPOT VENTILATOR FLOW RATES - SHAFT LEVEL OF ENGINE ROOM

| Location ID | Description                                                                                                                                                                                                                                                               | Flow Rate, m/s |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| A           | (Ventilators A, B, C, and D were located in the room directly below the boilers. This room contained low pressure feed water pumps and the cargo discharge pump motors. Temperature in the room was 106°F. Temperature in the air flow of the spot ventilators was 93°F.) | 2.4            |
| B           |                                                                                                                                                                                                                                                                           | 4.4            |
| C           |                                                                                                                                                                                                                                                                           | 1.9            |
| D           |                                                                                                                                                                                                                                                                           | 4.2            |
| E           | Forward of condensers; above port side of watertight door; temperature 100°F.                                                                                                                                                                                             | 3.8            |
| F           | Forward of condensers; above starboard side of watertight dock; temperature 100°F.                                                                                                                                                                                        | 2.8            |

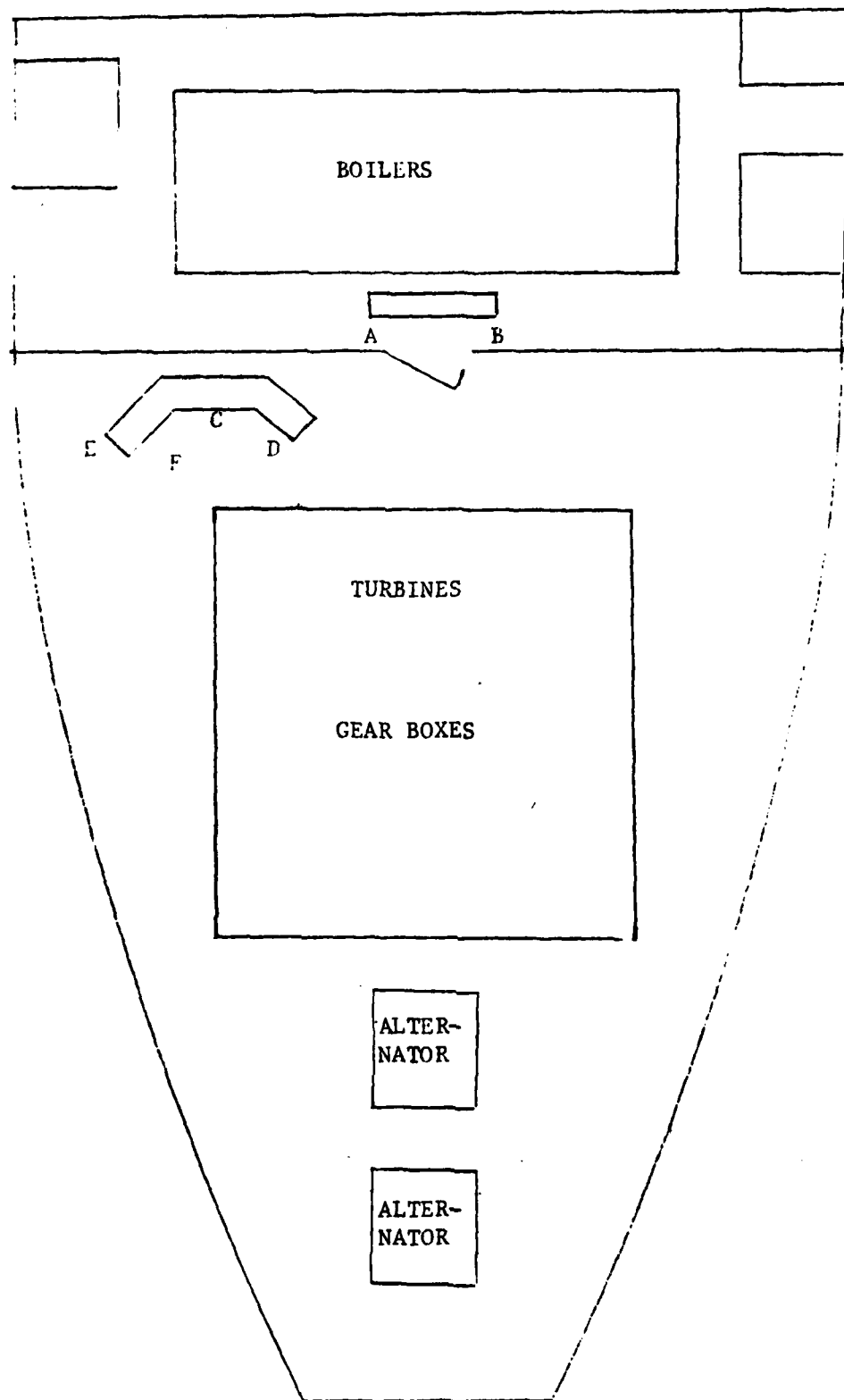


FIGURE V.4. SPOT VENTILATOR LOCATIONS - CONTROL ROOM AND FIRE ROOM

# DISCHARGE PUMP MOTORS

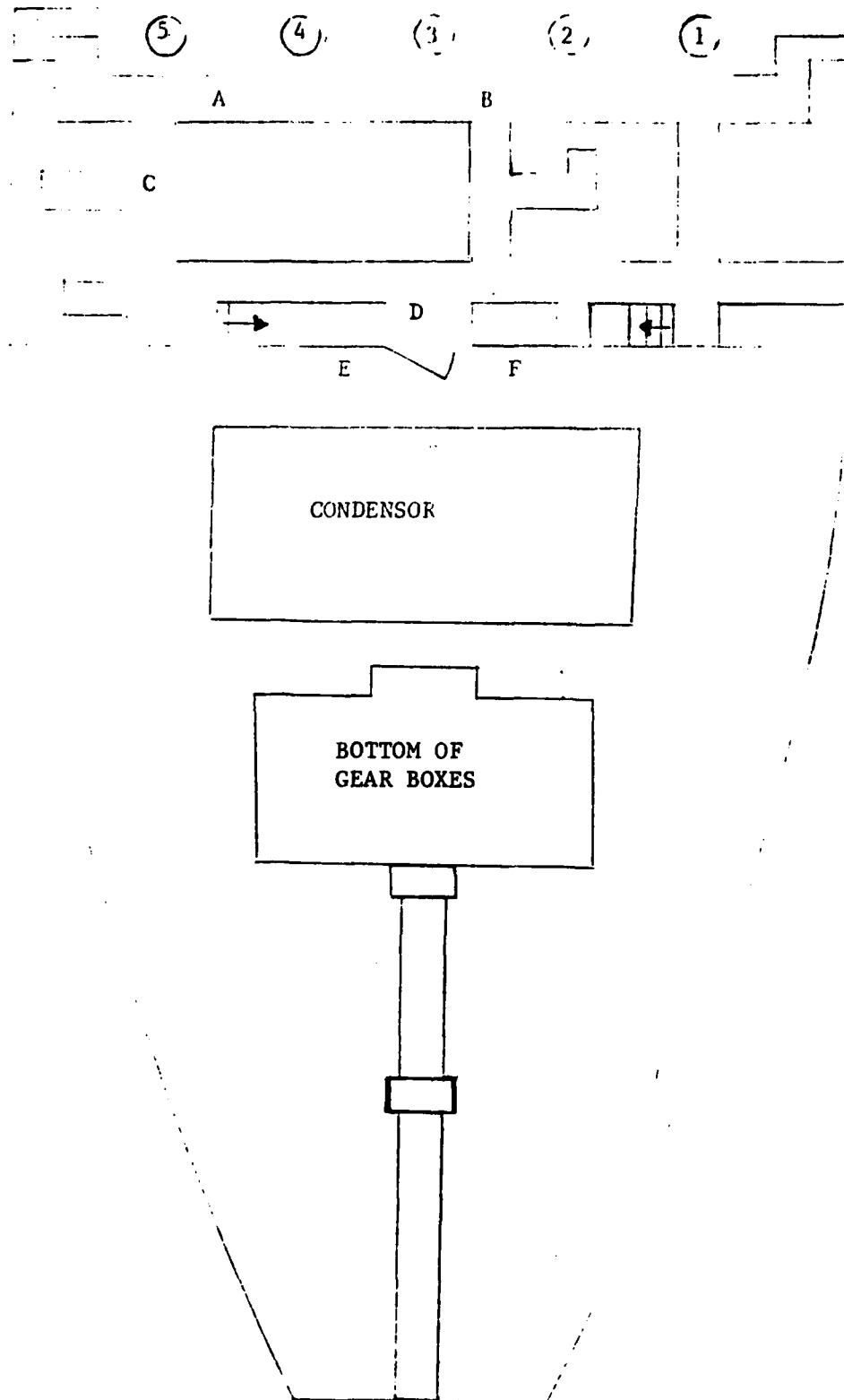


FIGURE V.5. SPOT VENTILATOR LOCATIONS - SHAFT LEVEL OF ENGINE ROOM

## V.2 Schedules and Responsibilities

### a. Watch Composition and Schedules

The Engineering Department consisted of:

- o Chief Engineer
- o 1st Assistant Engineer
- o 2nd Assistant Engineer
- o 3rd Assistant Engineer
- o Three Oilers
- o Three Firemen
- o Chief Wiper
- o Two Wipers

At sea, the assistant engineers work watches of 4-on, 8-off. An oiler, a fireman, and a wiper work the same shift schedule. During off-watch hours, additional work may be performed on an overtime basis. The engineers perform many of their "monthly duties" on overtime. General responsibilities and monthly duties are described in the next section.

### b. Responsibilities and Duties

Duties are assigned to engine room personnel, but the duties may not be performed on every voyage. For example, the assistant engineers have a list of monthly duties which may be performed over a period of several voyages. Therefore, the exposures monitored on different voyages may differ. Tables V.4 through V.6 summarize the monthly responsibilities assigned to the first, second, and third assistant engineers.



TABLE V.4. FIRST ASSISTANT ENGINEER - MONTHLY DUTIES

1. Lubricate generator trips and governor assemblies. Test trips and log.
2. Lubricate main engine throttles and inspect tightness of holding screws.
3. Test emergency diesel speed control and trip.
4. Change over all equipment.
5. Clean faces on all thermometers and gauges.
6. Operate and free-up, if required, all salt water valves.
7. Clean stack, fwd fan room and after fan room - chip and paint, as required.
8. List brass pipe fitting requirements.
9. List tool requirements.
10. List packing requirements.
11. List oil and grease requirements.
12. List requirements of iron stock, nuts and bolts, screws and stud stock.
13. List valve requirements.
14. List paint requirements.
15. Clean and lubricate machine shop equipment.

TABLE V.5. SECOND ASSISTANT ENGINEER - MONTHLY DUTIES

1. Secure and blow down both boilers. Log. (Meg forced draft fan motor, or arrange for Third Assistant Engineer to meg it, while boiler is secured.)
2. Blow down feed water regulator, as per instruction manual; also, blow down regulator, any time the boiler is back on line after a shutdown.
3. Test run boiler test pump and log.
4. Clean ALL sootblower air filters and lubricators.
5. Take a boiler water sample from each main boiler, L.P.S.G. and condensate, just before entering Port Arthur, for analysis by Maintenance Engineering.
6. Change over feed pump, when directed by First Assistant Engineer. Change oil immediately after securing. Check for cleanliness of oil or evidence of water. Test L.O. alarm and log. See that all valves operate freely and do not leak.
7. Change over L.P. feed pump. If required, repack immediately after securing.
8. Change over fuel oil service pump, when directed by First Assistant Engineer.
9. Change over fuel oil heater, in rotation, when directed by First Assistant.
10. Clean salt water strainer on feed pump lube oil coolers supply. Log.
11. Grease soot blowers (Thermotex).
12. List requirements of high pressure pipe fittings.
13. List requirements of high pressure valves.
14. List requirements of high pressure gaskets.
15. List requirements of water test and treatment chemicals for boilers and evaps.
16. List requirements of boiler gauge glass parts and boiler gaskets.

TABLE V.6. THIRD ASSISTANT ENGINEER - MONTHLY DUTIES

1. MEGGER REPORT: Submit to Chief Engineer by the 15th of each month. Close and open main condenser overboard valve, when megging main circulator. Arrange with the Second Assistant Engineer to obtain meg on forged draft fan motors, when boilers are secured. Remove all fuses when megging running lights, and meg both lamps in each circuit. The generators are not to be cleaned or megged. (This is handled by shore staff.)
2. Check galley equipment wiring and controls, when directed.
3. Check pump room bilge alarm, with assistance of Pumpman, and log results.
4. Clean salt water strainers and log: sanitary/salt water service suction; cargo pump L.O. cooling water; evap feed pump suction; evap feed pump discharge (2); fire and general service pump suction (2); generator L.O. cooling water (2).
5. Change and clean L.O. strainer on generator, after shutdown, from load or standby.
6. Test L.O. purifier overflow alarm and log.
7. Test L.O. gravity tank low level alarm. Log.
8. List lamp locker requirements: lamps, fuses, indicator lamps, plugs, etc.
9. List galvanized pipe fitting requirements.
10. Inspect all lifeboat floodlights. Check all dogs, toggles and swivels. Ensure that light is capable of swinging in all directions. Free-up, lubricate and repair, as required.
11. Change over lube service pumps, when directed, testing automatic changeover, main turbine L.O. trip and L.O. failure alarm. (In port only.)
12. Change over auxiliaries when directed by the First Assistant Engineer.
13. Change and clean main L.O. strainers. (In port only.)
14. Clean refrigeration condensers, on galley, saloon and crew messroom refrigerators, all scuttlebutts and ice cube maker.

### V.3 Work Activities and Monitoring

Engine room personnel were observed and monitored at various times throughout the voyage. Several time-motion observations were conducted in conjunction with personal sampling for hydrocarbons, asbestos, and sound pressure levels. These observations indicated that the engine room operates on a work schedule which is much more stable than the Deck department's schedule. As a result, the number of samples collected during each shift was increased. The collection of a greater number of samples precluded the detailed documentation of activities which normally accompanies each sample. In the remainder of this section we have presented a summary of activities, a record of samples collected, and tabulated results of the analyses performed on each sample.

During loading, an OVA survey was conducted in the engine room (the results of this survey are reported in Section VII). Also during loading, an assistant engineer wore a personal sampler for determining total hydrocarbon level. This was Sample No. SB-96 as shown in Table V.7, which summarizes all engine room exposure samples. The assistant engineer supervised work which the oiler was performing in the machine shop. He also walked around the engine room inspecting all areas and filled out a log of work for the next shift to perform. The results of this sample are reported in Table V.8, which contains a summary of all personal sampling results for the engine room. Extended vapor exposure monitoring was not conducted during loading because the

- o ambient wind direction was not conducive to infiltration of cargo vapors into the engine room ventilation system and
- o OVA surveys indicated vapor concentrations were not substantially different from the ambient background.

While underway, SwRI collected time-motion data and personal samples on an oiler and a fireman. These observations also indicated that the engine room personnel followed fairly routine schedules. The fireman monitored the operation of the boilers. He was responsible for cleaning the burners and adjusting valve settings as required. The majority of his watch was spent in a very small area of the engine room. Likewise, the oiler had very specific duties. He made "rounds" every hour to check the entire engine room. This inspection normally required less than 10 minutes to complete. The assistant engineers generally remained close to the steam control valves while underway. They would periodically check the work being performed by the other engine room personnel. The wipers had the greatest variety in the location of their work. They might be assigned to clean or paint in a different area of the engine room during each shift. In this voyage, most of the work performed by the wipers occurred near the steam control panel.

Based on these observations, a sampling pattern was set up which required the assistant engineer, the oiler, and the fireman to wear two samplers simultaneously. The type of samples available were total hydrocarbon, asbestos, and sound pressure level. The combination was rotated at each shift. Table V.7 indicates the samples collected on each shift. Table V.8 summarizes the results of the engine room personal sampling for hydrocarbons and asbestos.

Area samples for total hydrocarbons, asbestos, and noise were also collected near the control panel for the boilers. The placement of these samples was chosen based upon a walk-through inspection of the engine room. Lagging on a pipe almost directly above the spot where the fireman stood was cracked and open. The sample was placed below the cracked lagging. The noise dosimeter was set up as a stationary monitor because the fireman appeared to spend most of his watch at one spot.

TABLE V.7. ENGINE ROOM PERSONAL SAMPLING

2

FT: 0800 to 1200

|                    | Noise | Hydrocarbons | Asbestos |
|--------------------|-------|--------------|----------|
| ler                |       |              |          |
| reman              |       |              |          |
| Assistant Engineer |       | SB-96        |          |

3

FT: 1822 to 2000; 2000 to 2200

|                    | Noise  | Hydrocarbons | Asbestos |
|--------------------|--------|--------------|----------|
| ler                | TX-10* | TX-108       | M-118    |
| reman              | TX-9*  | SB-32        | M-113    |
| Assistant Engineer |        |              |          |

\*Worn by SwRI Personnel

5

FT: 0800 to 1200

|                    | Noise  | Hydrocarbons | Asbestos |
|--------------------|--------|--------------|----------|
| ler                |        | CG2-025      | M-123    |
| reman              | TX-11A |              |          |
| Assistant Engineer | TX-13A | CG2-029      |          |

AD-A157 300

A CREW EXPOSURE STUDY PHASE II VOLUME 2 AT SEA PART B  
(U) SOUTHWEST RESEARCH INST SAN ANTONIO TX DIV OF  
ENGINEERING AND... W J ASTLEFORD ET AL. APR 85

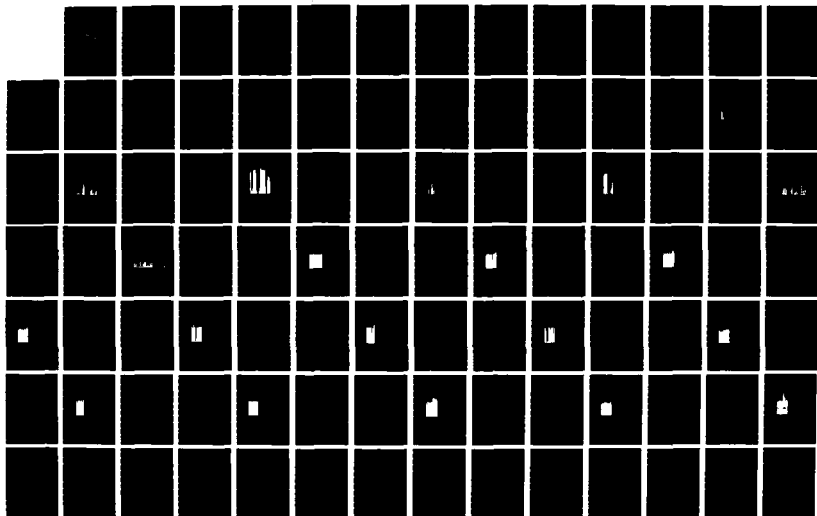
2/5

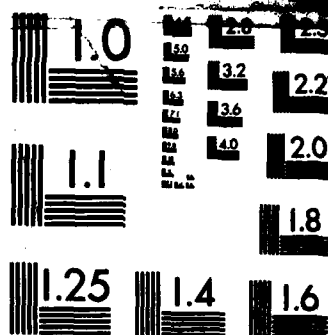
UNCLASSIFIED

USCG-D-12-85 DTCG23-80-C-20015

F/G 6/10

NL





MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A



TABLE V.7. ENGINE ROOM PERSONAL SAMPLING (Continued)

DAY: 5

SHIFT: 1200 to 1600

|                    | Noise  | Hydrocarbons | Asbestos |
|--------------------|--------|--------------|----------|
| Oiler              | TX-12A | CG2-022      |          |
| Fireman            |        | CG2-028      | M-154    |
| Assistant Engineer | TX-13B |              | M-150    |

DAY: 5

SHIFT: 1600 to 2000

|                    | Noise  | Hydrocarbons | Asbestos |
|--------------------|--------|--------------|----------|
| Oiler              | TX-12B |              | M-160    |
| Fireman            | TX-11B | CG2-023      |          |
| Assistant Engineer |        | 03-P11       | M-140    |

DAY: 6

SHIFT: 0800 to 1200

|                    | Noise  | Hydrocarbons | Asbestos |
|--------------------|--------|--------------|----------|
| Oiler              | TX-14A |              | M-132    |
| Fireman            | TX-15A | CG2-026      |          |
| Assistant Engineer |        | CG2-024      | M-124    |

TABLE V.7. ENGINE ROOM PERSONAL SAMPLING (Concluded)

DAY: 6

SHIFT: 1200 to 1600

|                    | Noise  | Hydrocarbons | Asbestos |
|--------------------|--------|--------------|----------|
| Oiler              | TX-14B | CG2-021      |          |
| Fireman            |        | CG2-030      | M-162    |
| Assistant Engineer | TX-15B |              | M-153    |

DAY: 8

SHIFT: 0800 to 1200

|                    | Oil Mist |
|--------------------|----------|
| Oiler              | M-141    |
| Fireman            | M-158    |
| Assistant Engineer |          |

TABLE V.8. RESULTS OF SAMPLE ANALYSES FOR PERSONAL SAMPLING

| Day | Operation    | Sample ID | THC<br>ppm | Asbestos<br>Fibers/cc >5 $\mu$ | Sample<br>Duration<br>min. |
|-----|--------------|-----------|------------|--------------------------------|----------------------------|
| 2   | Loading      | SB-96     | 0.749      | --                             | 155                        |
| 3   | Laden Voyage | M-118     | --         | 0.0046                         | 213                        |
|     |              | SB-32     | <0.324     | --                             | 217                        |
|     |              | M-113     | --         | 0.0063                         | 213                        |
| 5   |              | CG2-025   | 0.75       | --                             | 232                        |
|     |              | M-123     | --         | 0.0051                         | 230                        |
|     |              | M-134     | --         | 0.0038                         | 225                        |
|     |              | CG2-029   | 1.17       | --                             | 232                        |
|     |              | CG2-022   | 1.38       | --                             | 177                        |
|     |              | CG2-028   | 1.97       | --                             | 184                        |
|     |              | M-154     | --         | 0.0093                         | 183                        |
|     |              | M-150     | --         | 0.0270                         | 176                        |
|     |              | M-160     | --         | 0.037                          | 220                        |
|     |              | CG2-023   | 1.34       | --                             | 211                        |
|     |              | 03-P11    | 1.08       | --                             | 216                        |
|     |              | M-140     | --         | 0.0044                         | 216                        |
| 6   |              | M-132     | --         | <0.0035                        | 212                        |
|     |              | CG2-026   | 1.82       | --                             | 221                        |
|     |              | CG2-024   | 0.92       | --                             | *                          |
|     |              | M-124     | --         | <0.0043                        | 211                        |
|     |              | CG2-021   | 3.25       | --                             | *                          |
|     |              | CG2-030   | 1.95       | --                             | 223                        |
|     |              | M-162     | --         | 0.0063                         | 222                        |
|     |              | M-153     | --         | 0.0071                         | 222                        |
| 8   |              | M-141**   | --         | --                             | 191                        |
|     |              | M-158**   | --         | --                             | 168                        |

\* The duration was not recorded. The pump count was used to calculate the THC concentration.

\*\* Samples M-141 and M-158 were analyzed for oil mist. M-141 showed 89  $\mu$ g as mineral oil and M-158 showed 110  $\mu$ g as mineral oil. The resultant oil mist concentrations were 0.28 and 0.46 mg/m<sup>3</sup>, respectively.

A summary of area samples collected in the engine room is given in Table V.9. The table indicates where the sample was taken, the ship's operating condition, and the detected level. For asbestos, the samples were analyzed using NIOSH P & CAM 239 to obtain a fiber count. The hydrocarbon samples are reported in ppm for THC. Finally, the oil mist sample was analyzed using an infrared spectrophotometry method to determine the weight as micrograms of mineral oil.

TABLE V.9. ENGINE ROOM AREA SAMPLES

| Sample No. | Description of Location                     | Operation    | Concentration* |      |      | Sample Duration min. |
|------------|---------------------------------------------|--------------|----------------|------|------|----------------------|
|            |                                             |              | A              | THC  | OM   |                      |
| M-144      | Engine room control console                 | loading      | .0027          |      |      | 244                  |
| SB-17      | Breathing zone level above bulge            | loading      |                | 1.59 |      | 243                  |
| M-139      | Forward side of boiler in fire control room | loading      | 0.010          |      |      | 204                  |
| M-111      | Fireman's work station                      | laden voyage |                |      | 0.26 | 249                  |
| SB-6       | Fireman's work station                      | laden voyage |                | 2.36 |      | 246                  |

\*A = Asbestos (fibers/cc); THC = Total Hydrocarbon (ppm);  
OM = Oil Mist ( $\mu\text{g/L}$  or  $\text{mg/m}^3$ )

The sound pressure levels (SPL's) measured in the engine room are reported in Appendix B-1 of this second voyage report. The appendix also contains a description of the procedure used to evaluate and present SPL data.

## VI. Pump Room

### VI.1 Configuration and Ventilation

The pump room had three levels separating the top and bottom levels. However, the pumpmen rarely spent any time on these intermediate levels. The uppermost level contained a control panel which permitted the pumpman to monitor and adjust the pumps from the top. The bottom level contained five cargo pumps and five stripper pumps.

At the bottom of the pump room five suction pickups were provided to draw air out of the pump room. There was no forced positive pressure ventilation in the pump room. Supply air was ingested passively from the deck level control panel area. As a result, flow velocities were very low. The placement of the pickups is shown in Figure VI.1. The location of the pump room exhausts is shown in Figure VI.2. Figure VI.3 shows the geometry of the pump room exhaust ducts. This figure also indicates the flow velocity and total hydrocarbon concentrations measured at the two discharge vents.

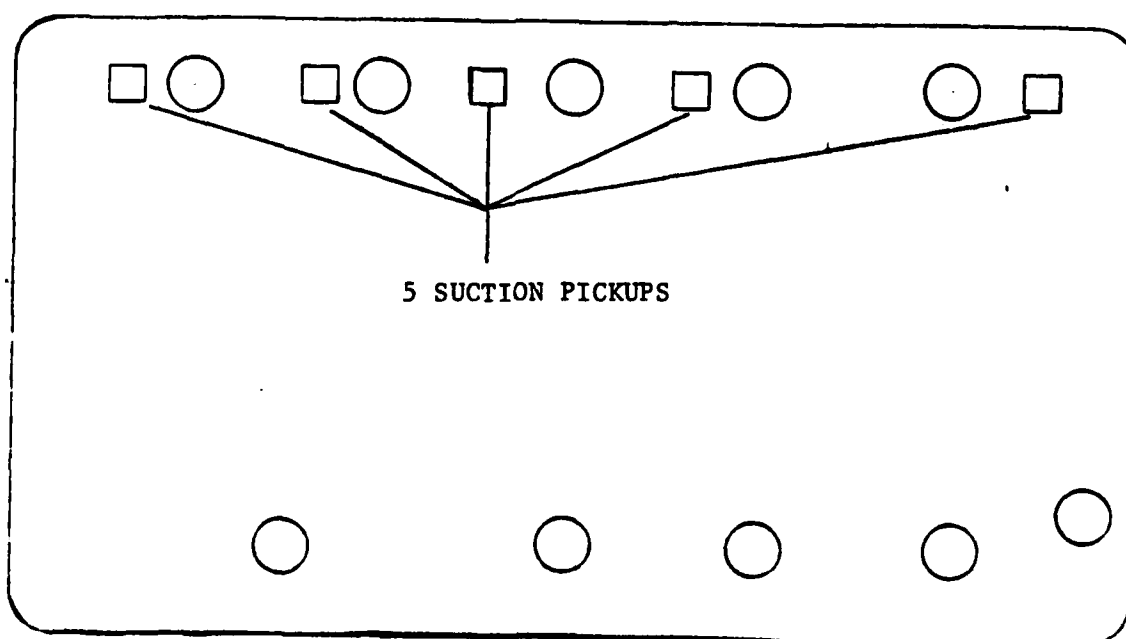


FIGURE VI.1. PUMPROOM VENTILATION PICKUPS

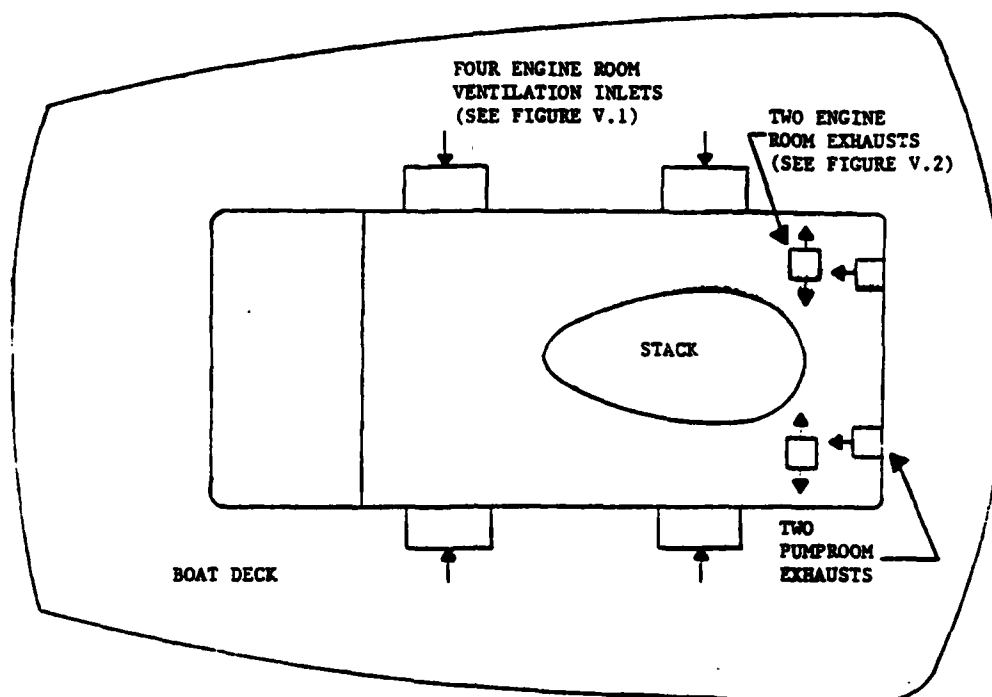


FIGURE VI.2. PUMP ROOM EXHAUST

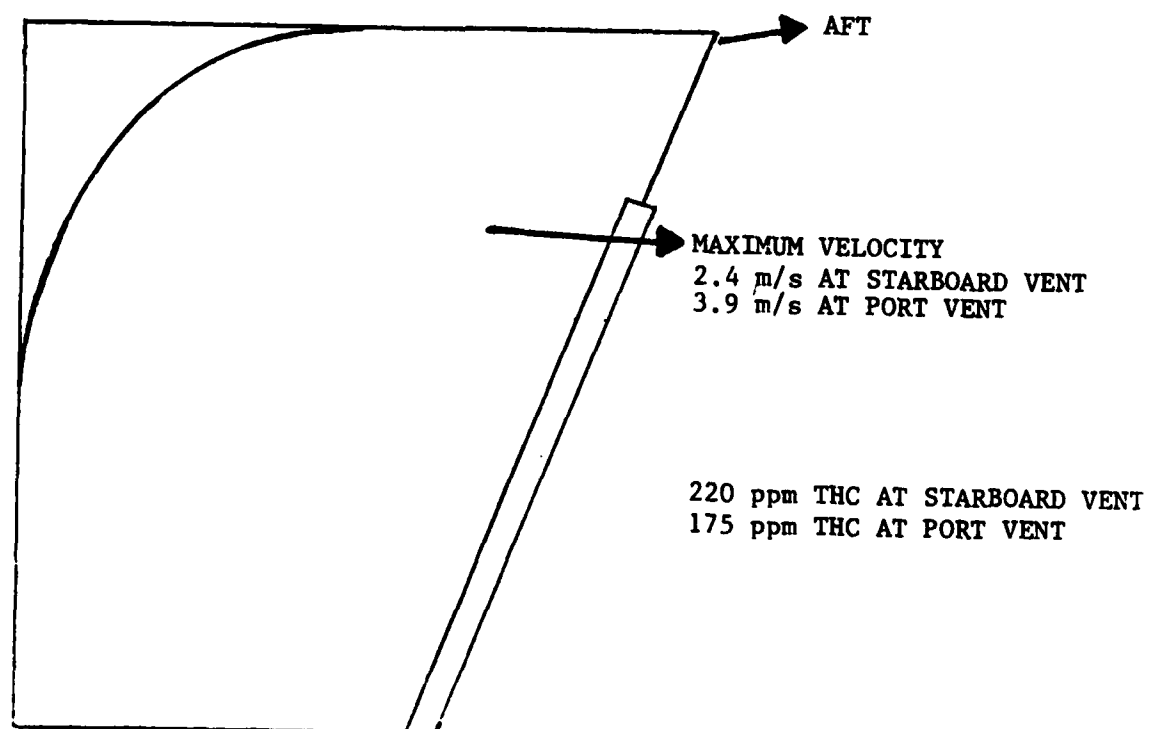


FIGURE VI.3. CROSS-SECTION OF PUMP ROOM EXHAUST

## VI.2 Watch Composition

During loading and discharge the pumpmen work shifts of 8-on and 8-off. The shifts change at 0800, 1600, and 2400 hours. The chief pumpman decides who will start the initial shift. For example, the ship may dock at 0400. The chief pumpman may elect to work from 0400 to 0800 or he may wait and work from 0800 to 1600. On the laden voyage both pumpmen worked the day shift.

## VI.3 Work Activities and Monitoring

The pumpmen were monitored several times during the voyage. In each case, a time-motion record was obtained for correlation with the dosimetry records. Table VI.1 shows summaries of entries into the pump room by the pumpmen. These tables also indicate the corresponding personal sample. The sample results are tabulated in Table VI.2. Area samples were also obtained in the pump room. These samples quantify the vapor concentration levels irrespective of the duration of entry into the pumproom. The results obtained from these samples are presented in Table VI.3.

TABLE VI.1. SUMMARY OF ENTRIES INTO PUMPROOM

DAY: 1

PUMPMAN: 2nd

PUMPROOM (1345 to 1845)

| Entry No. | Duration | Purpose                               | Level  | Personal Sample |
|-----------|----------|---------------------------------------|--------|-----------------|
| 1         | 5 min    | Discuss valve leak with C.M.          | Bottom | --              |
| 2         | >15 min  | Monitor and adjust main valve control | Top    | --              |
| 3         | 96 min   | Monitor and adjust main valve control | Top    | --              |
| 4         | Unknown  | Set up stripper pump                  | Bottom | --              |
| 5         | 9 min    | Check bilge                           | Bottom | SB-28           |
| 6         | 3 min    | Start bilge pump                      | Top    | SB-28           |
| 7         | 4 min    | Check bilge                           | Bottom | SB-28           |

DAY: 2

PUMPMAN: 2nd

PUMPROOM (0800 to 1535)

| Entry No. | Duration | Purpose                             | Level  | Personal Sample |
|-----------|----------|-------------------------------------|--------|-----------------|
| 1         | 12 min   | Visual inspection, start steam pump | Top    | TX-100          |
| 2         | 4 min    | Check pump 1 and block valve 1      | Bottom | TX-100          |
| 3         | 10 min   | Check gaskets for pump              | Top    | TX-100          |
| 4         | 30 min   | Supervise changing of gasket        | Bottom | TX-100          |
| 5         | 3 min    | Check crew working on pump          | Bottom | TX-105          |
| 6         | 32 min   | Operating air-driven winch          | Top    | TX-105          |



TABLE VI.1. SUMMARY OF ENTRIES INTO PUMPROOM (Continued)

DAY: 7

PUMPMAN: 1st

PUMPROOM (0800 to 0930)

| Entry No. | Duration | Purpose                              | Level  | Personal Sample |
|-----------|----------|--------------------------------------|--------|-----------------|
| 1         | 5 min    | Turn on blowers                      | Top    | --              |
| 2         | 70 min   | Check and lubricate pumps, strippers | Bottom | --              |

DAY: 8

PUMPMAN: 1st & 2nd

PUMPROOM (0800 to 0845)

| Entry No. | Duration | Purpose                                                           | Level  | Personal Sample |
|-----------|----------|-------------------------------------------------------------------|--------|-----------------|
| 1         | 45 min   | Check for leaks and lubricate pumps. (lubricant samples obtained) | Bottom | --              |

TABLE VI.1. SUMMARY OF ENTRIES INTO PUMPROOM (Continued)

DAY: 9

PUMPMAN: 1st

PUMPROOM (0700 to 1543)

| Entry No. | Duration | Purpose                  | Level  | Personal Sample |
|-----------|----------|--------------------------|--------|-----------------|
| 1         | 5 min    | Open valves              | Bottom | --              |
| 2         | 11 min   | Open valves; start pumps | Top    | TX-113          |
| 3         | 3 min    | Check pumps              | Bottom | TX-113          |
| 4         | 3 min    | Check pumps              | Bottom | TX-113          |
| 5         | 1 min    | Monitor gauges           | Top    | TX-113          |
| 6         | 3 min    | Check pumps              | Bottom | TX-113          |
| 7         | 11 min   | Monitor gauges           | Top    | TX-113          |
| 8         | 2 min    | Start small pump         | Top    | TX-113          |
| 9         | 3 min    | Stop small pump          | Top    | TX-113          |
| 10        | 5 min    | Check pumps              | Bottom | TX-119          |
| 11        | 12 min   | Adjust pumps             | Top    | TX-119          |
| 12a*      | 11 min   | Monitoring gauges        | Top    | TX-119          |
| 12b       | 19 min   | Monitoring gauges        | Top    | TX-127          |
| 13        | 4 min    | Monitoring gauges        | Top    | TX-127          |
| 14        | 5 min    | Check pumps              | Bottom | TX-127          |
| 15        | 1 min    | Monitor gauges           | Top    | TX-127          |
| 16        | 4 min    | Monitor gauges           | Top    | TX-127          |
| 17        | 11 min   | Drain sea line           | Bottom | TX-127          |
| 18        | 2 min    | Monitor gauges           | Top    | TX-127          |
| 19        | 1 min    | Monitor gauges           | Top    | TX-127          |
| 20        | 4 min    | Check pumps              | Bottom | TX-127          |
| 21        | 2 min    | Monitor gauges           | Top    | TX-127          |
| 22        | 3 min    | Monitor gauges           | Top    | TX-127          |
| 23        | <4 min   | Check pumps              | Bottom | SB-27           |
| 24        | 5 min    | Set up pump              | Bottom | SB-27           |
| 25        | 5 min    | Check pumps              | Bottom | SB-27           |
| 26        | 3 min    | Monitoring gauges        | Top    | SB-27           |
| 27        | 4 min    | Monitoring gauges        | Top    | SB-27           |

\*12a and 12b are the same entry. Sample was changed inside pumphroom

TABLE VI.1. SUMMARY OF ENTRIES INTO PUMPROOM (Concluded)

DAY: 10

PUMPMAN: 1st

PUMPROOM (0046 to 0640)

| Entry No. | Duration | Purpose                                                                            | Level  | Personal Sample |
|-----------|----------|------------------------------------------------------------------------------------|--------|-----------------|
| 1         | 57 min   | Monitor gauges; tighten leaky pump (gasoline from leak covered 5 ft <sup>2</sup> ) | Top    | TX-115          |
| 2         | 15 min   | Monitor gauges                                                                     | Top    | TX-115          |
| 3         | 2 min    | Monitor gauges                                                                     | Top    | TX-115          |
| 4         | 6 min    | Check pumps                                                                        | Bottom | TX-115          |
| 5         | 30 min   | Monitor gauges                                                                     | Top    | TX-115          |
| 6         | 2 min    | Check pumps                                                                        | Bottom | SB-34           |
| 7         | 2 min    | Monitor gauges                                                                     | Top    | SB-34           |
| 8         | 15 min   | Monitor gauges                                                                     | Top    | SB-34           |
| 9         | 8 min    | Monitor gauges                                                                     | Top    | SB-34           |
| 10        | 4 min    | Monitor gauges                                                                     | Top    | SB-34           |
| 11        | 2 min    | Monitor gauges; shut down 4                                                        | Top    | SB-34           |
| 12        | 4 min    | Line up valves for 4 stripper                                                      | Bottom | SB-34           |
| 13        | 3 min    | Check source of "thud"                                                             | Top    | SB-34           |
| 14        | 18 min   | Monitoring gauges                                                                  | Top    | SB-34           |
| 15        | 4 min    | Check pumps                                                                        | Bottom | SB-34           |
| 16        | 11 min   | Monitoring gauges                                                                  | Top    | TX-107          |

TABLE VI.2. ANALYSIS RESULTS FOR PUMPROOM SAMPLES

| Day | Operation   | Sample ID | THC<br>ppm   | BNZ<br>ppm  | Sample<br>Duration<br>min. |
|-----|-------------|-----------|--------------|-------------|----------------------------|
| 1   | Loading     | SB-28     | 36.1         | 2.1         | 17                         |
| 2   | Loading     | TX-100    | <b>25.05</b> | <b>1.14</b> | <b>159</b>                 |
| 9   | Lightering  | TX-105    | 39.07        | 1.4         | 138                        |
|     |             | TX-113    | 8.6          | <0.12       | 131                        |
|     |             | TX-119    | 3.7          | <0.18       | 92                         |
|     |             | TX-127    | 9.5          | <0.14       | 116                        |
|     |             | SB-27     | 6.3          | <0.15       | 111                        |
| 10  | Discharging | TX-115    | 4.2          | <0.14       | 117                        |
|     |             | SB-34     | 9.2          | .23         | 120                        |
|     |             | TX-107    | 4.9          | <0.15       | 108                        |

TABLE VI.3. PUMP ROOM AREA SAMPLES

| Day | Area No. | THC<br>ppm | BNZ<br>ppm | Sample<br>Duration<br>min. | Personal<br>Samples* |
|-----|----------|------------|------------|----------------------------|----------------------|
| 1   | CG2-027  | 60.4       | 2.2        | 162                        | SB-28                |
| 9   | H-37     | 12.2       | <0.4       | 43                         | TX-113<br>TX-119     |
| 9   | H-34     | 29.4       | 1.2        | 172                        | TX-127               |
| 9   | H-36     | 22.5       | 1.5        | 195                        | SB-27                |
| 8   | SB-1     | 58.2       | 2.2        | 237                        | --                   |
| 10  | SB-7     | 136.2      | 3.8        | 240                        | --                   |
| 10  | H-40     | 75.5       | 0.9        | 234                        | --                   |
| 10  | H-29     | 157.1      | 4.0        | 223                        | --                   |

\*Personal samples listed in this column were collected concurrently with the area samples. The concentrations recorded for the personal samples are shown in Table VI.2.

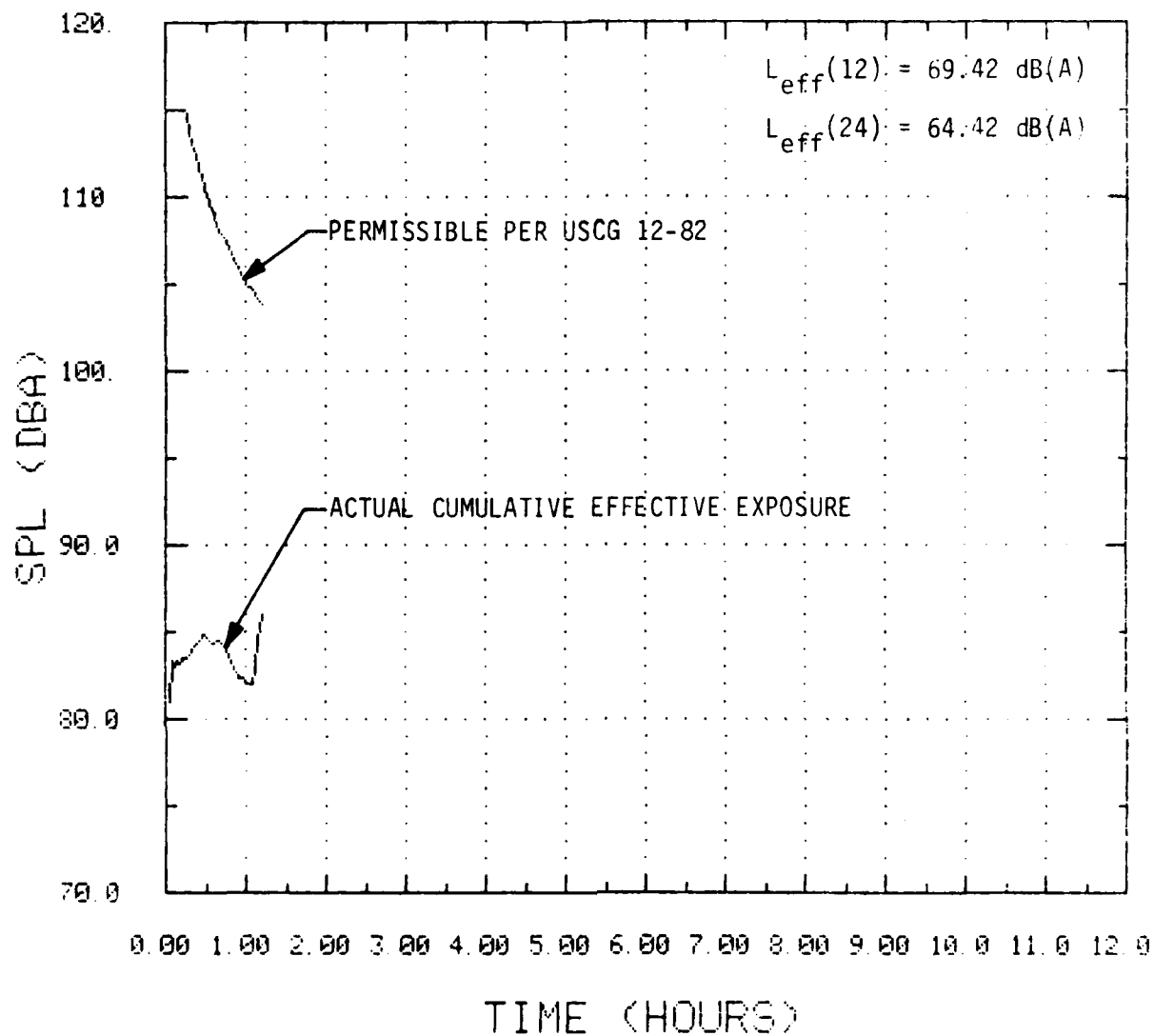


FIGURE B-2. CUMULATIVE EFFECTIVE EXPOSURE ON SWRI PERSONNEL  
Sample No. TX-1

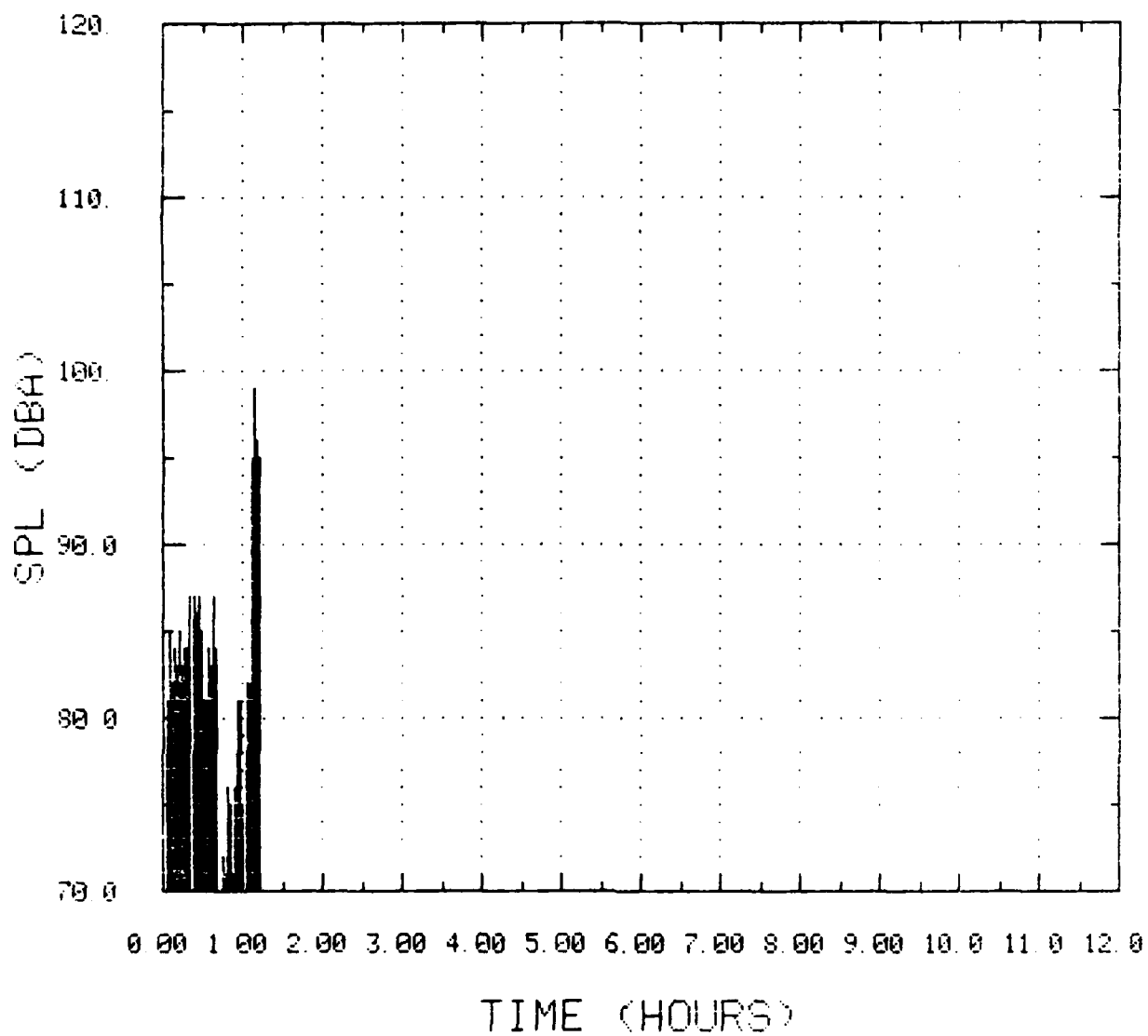


FIGURE B-1. NOISE DOSIMETRY ON SwRI PERSONNEL  
(Taken in pump room during loading)  
Sample No. TX-1

$$SPL_{PER}(i) = 5 \frac{\log(8/T)}{\log 2} + 90$$

where

T = exposure time calculated from

$$T = \sum_{i=1}^m \Delta t_i$$

A maximum  $SPL_{PER}$  of 115 dB(A) was applied based on USCG NYC 12-82. Assuming no hearing protection, the permissible exposure was exceeded if the two curves cross. The 12-hour and 24-hour effective exposures were calculated and are included in each figure. The permissible  $L_{eff}(12)$  is 87 dB(A), and the permissible  $L_{eff}(24)$  is 82 dB(A).

Finally, the data was presented as a cumulative dose versus SPL. By definition, the permissible dose equals 100% as indicated on each figure. The plots indicate the percentage of the permissible dose due to exposures to SPL's less than or equal to the indicated SPL.

In many cases, the dosimetry records are approximately 4 hours long. This corresponds to one-half of the normal workday for 4-on, 8-off shifts. In areas where the sound pressure level is relatively constant, it is reasonable to assume that the exposure recorded during one shift would be repeated on the next shift. This permits a rough assessment of the overall noise exposure. The noise dosimetry records presented in Figures B-29, B-31, B-34, B-37, B-40, B-43, B-46, B-49, B-52, B-55, and B-58 fall into this category.

Noise dosimetry data collected at-sea is discussed in this appendix. The data was collected using Metrosonic dB-301 Dosimeters programmed for an 80 dB(A) cutoff and a 5 dB exchange rate. During sampling, the microphones from these units were attached to the worker's collar, as close to the ear as possible. The data obtained is presented in three formats to facilitate analysis. The formats include histograms, cumulative effective exposures and cumulative dose.

The histograms presented illustrate the variation of exposures encountered during a particular workday. In conjunction with time-motion studies, exposures can be correlated to specific work activities throughout the day. For engine room personnel, the exposures remained relatively constant throughout a shift. Therefore, time-motion data was not collected with each sample.

Cumulative effective exposures,  $L_{eff}$ , were calculated and plotted as a function of time. This calculation is based on a permissible 8-hour exposure of 90 dB(A), a 5 dB exchange rate, and an 80 dB(A) cutoff using the following relationship.

$$L_{eff}(i) = 16.61 \text{ LOG } \frac{1}{\sum_{i=1}^m \Delta t_i} \sum_{i=1}^m 10^{L_{A_i}/16.61} \Delta t_i$$

where

- $L_{A_i}$  = SPL measured during the  $i$ -th sample interval
- $\Delta t_i$  = exposure duration during  $i$ -th interval
- $i$  = time period of interest

A plot of the permissible exposure as a function of time was superimposed on the cumulative effective exposure graphs. The permissible exposure function is described by



APPENDIX B-1  
NOISE DOSIMETRY

On the laden voyage, Deck Department employees were monitored for exposure to noise from needle guns that were being used for paint chipping. Two of the employees were directly involved in paint chipping. The third employee was painting in the area where chipping was being conducted. In addition, the Radio Officer was monitored during tank entry to replace a fathometer transponder. The remainder of this section presents the results of these sampling activities.

The safety equipment used by the seamen involved in deck day work varied considerably. Some wore ear muffs, others wore no protective equipment. Table VII.5 indicates the activity, safety equipment, and sample numbers. The noise dosimetry results are presented in Appendix B-1.

TABLE VII.5. SAMPLING DURING DECK DAY WORK

| Activity          | Noise Dosimetry | Hearing Protectors |
|-------------------|-----------------|--------------------|
| Painting          | TX-4            | None               |
| Chipping          | TX-3            | Ear muffs*         |
| Chipping/Painting | TX-5            | Ear plugs          |

\*Ear muffs manufactured by Fibre-Metal Products, Inc., Noisegard Model 2011; tested in accordance with ANSI S3.19-1974.

While following the Radio Officer during tank entry (forepeak ballast tank), an SwRI employee wore charcoal tube sample TX-106. Subsequent analysis of TX-106 showed 18 ppm THC as hexane and 0.4 ppm benzene. During the tank entry, the oxygen level was 20.8%. The total hydrocarbon concentration in the tank was measured as 30 ppm Methane using an OVA. In addition, a colorimetric tube for measuring the concentration of CO did not show any measurable stain length. At the time of these measurements the temperature in the tank was 89°F dry bulb and 80°F wet bulb.

TABLE VII.3. OVA SURVEY RESULTS - BOTTOM OF PUMP ROOM (Day 3)

| Location ID | Concentration (ppm) |
|-------------|---------------------|
| A           | 25                  |
| B           | 25                  |
| C           | 25                  |
| D           | 25                  |
| E           | 25                  |
| F           | 30                  |
| G           | 30                  |
| H           | 25                  |
| I           | 26                  |
| J           | 25                  |
| K           | 26                  |
| L           | 24                  |
| M           | 26                  |
| N           | 24                  |
| O           | 25                  |
| P           | 30                  |

TABLE VII.4. OVA SURVEY RESULTS - BOTTOM OF PUMP ROOM (Day 9)

| Location ID | Concentration (ppm) |
|-------------|---------------------|
| A           | 26                  |
| B           | 25                  |
| C           | 20-25               |
| D           | 34                  |
| E           | 35                  |
| F           | 100                 |
| G           | 20                  |
| H           | 20                  |
| I           | 20                  |

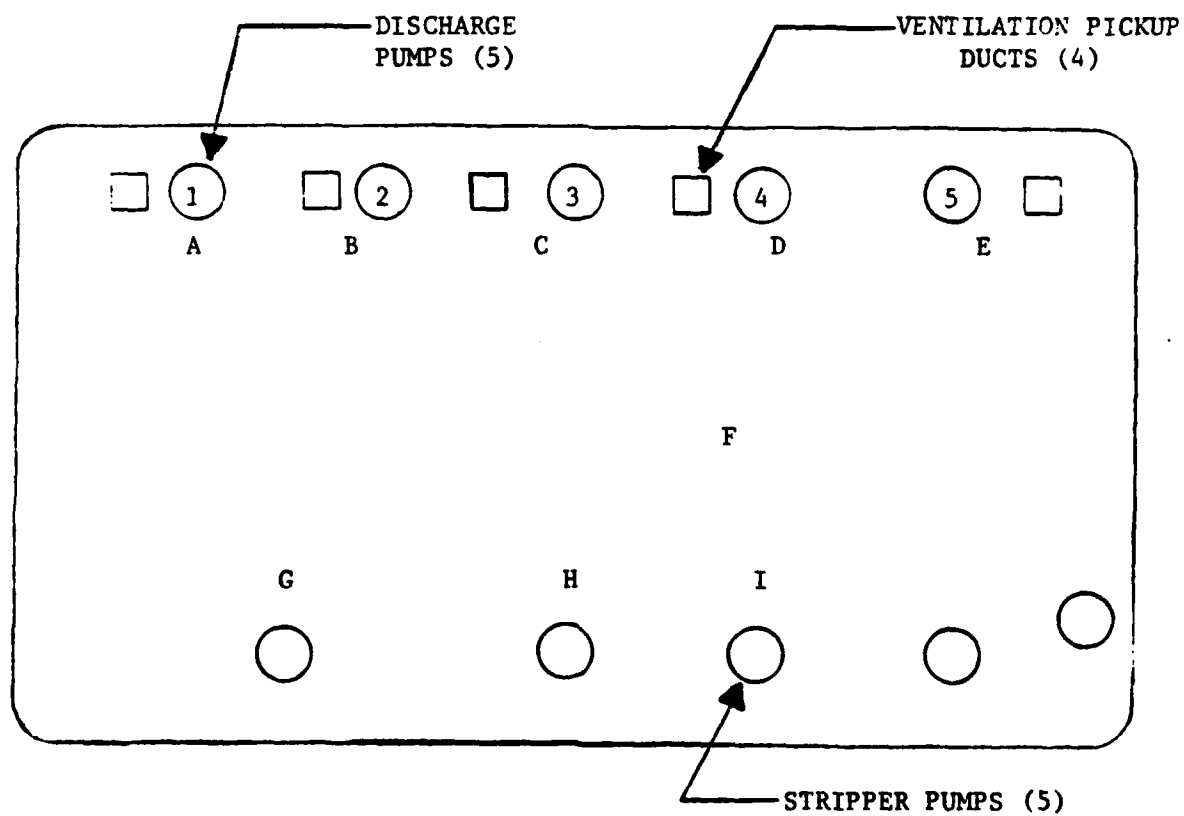


FIG. VII.4. OVA SURVEY POINTS - BOTTOM OF PUMP ROOM (Day 9)

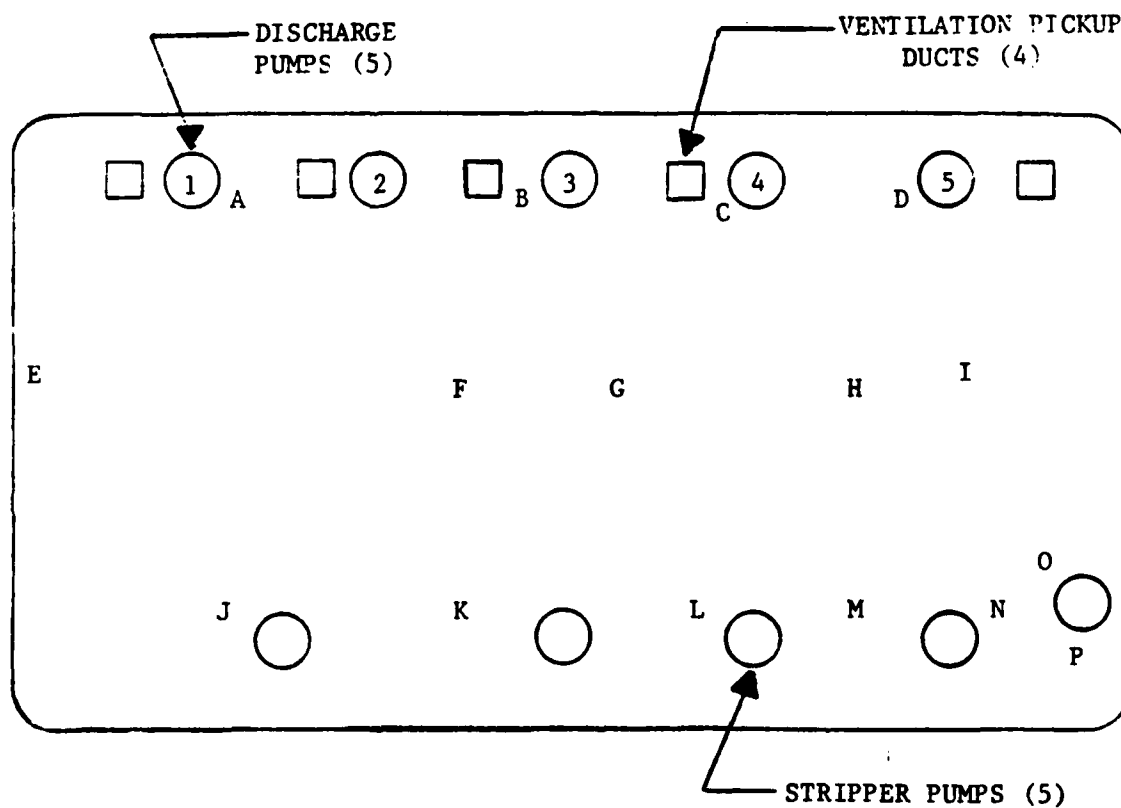


FIGURE VII.3. OVA SURVEY POINTS - BOTTOM OF PUMP ROOM (Day 3)

TABLE VII.2. OVA SURVEY RESULTS - SHAFT LEVEL OF ENGINE ROOM

| Location ID | Concentration* (ppm) |           |
|-------------|----------------------|-----------|
|             | Survey I             | Survey II |
| A           | 19                   | 14        |
| B           | 19                   | 14        |
| C           | 19                   | 15        |
| D           | 19                   | 14        |
| E           | 20                   | 14        |
| F           | 19                   | 14        |
| G           | 17                   | 14        |
| H           | 18                   | 14        |
| I           | 18                   | 14        |
| J           | 17                   | 14        |
| K           | 17                   | 14        |
| L           | 17                   | 15        |
| M           | 18                   | 14        |
| N           | 17                   | 15        |
| O           | 18                   | 15        |
| P           | 17                   | 16        |
| Q           | 18                   | 15        |
| R           | 18                   | 16        |

\*I. Survey conducted at loading terminal.

II. Survey conducted while underway.

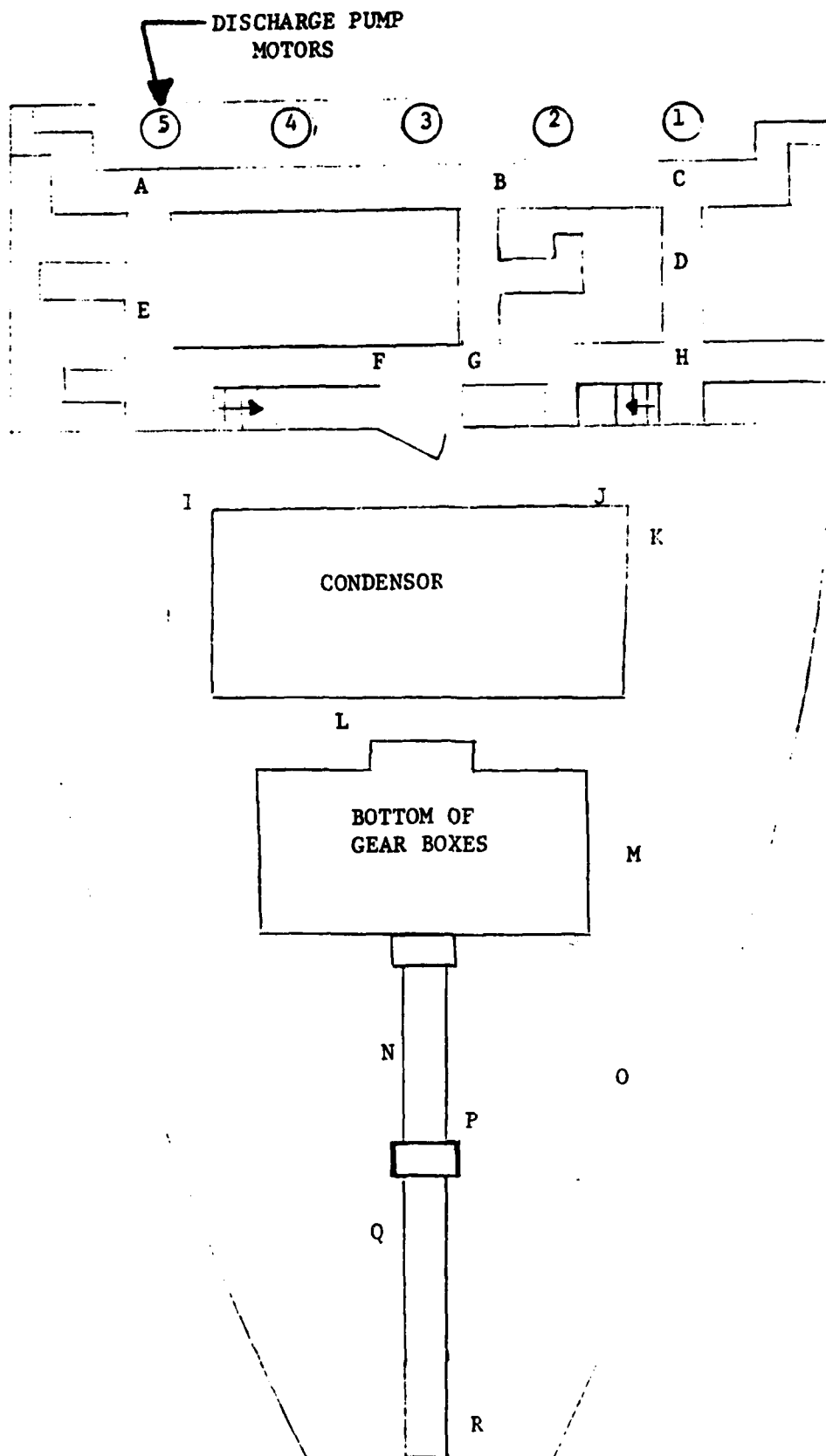


FIGURE VII.2. OVA SURVEY POINTS - SHAFT LEVEL OF ENGINE ROOM

TABLE VII.1. OVA SURVEY RESULTS - CONTROL ROOM AND FIRE ROOM

| Location ID | Concentration* (ppm) |           |
|-------------|----------------------|-----------|
|             | Survey I             | Survey II |
| A           | 15                   | 14        |
| B           | 15                   | --        |
| C           | 15                   | 14        |
| D           | 16                   | 14        |
| E           | 15                   | 15        |
| F           | 15                   | 12        |
| G           | 15                   | 15        |
| H           | 15                   | 12        |
| I           | 34                   | 44        |
| J           | 12                   | 12        |
| K           | 12                   | 11        |
| L           | 12                   | 11        |
| M           | 14                   | 12        |
| N           | 11                   | --        |
| O           | 15                   | 12        |
| P           | 15                   | 13        |
| Q           | 15                   | 13        |
| R           | 13                   | 14        |
| S           | 15                   | 14        |
| T           | 13                   | 13        |

\*I. Survey conducted at loading terminal.

II. Survey conducted while underway.



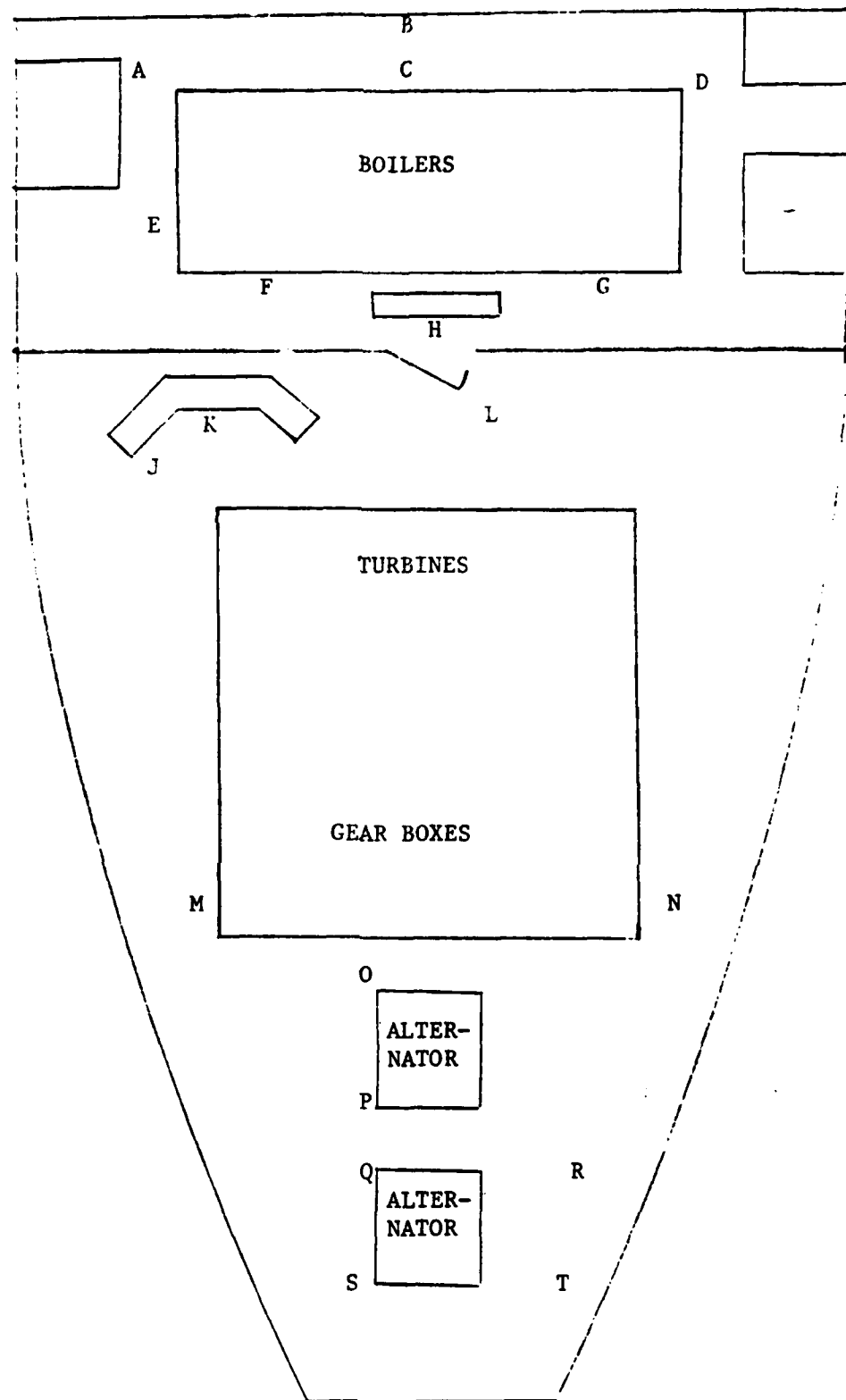


FIGURE VII.1. OVA SURVEY POINTS - CONTROL ROOM AND FIRE ROOM

## VII. Miscellaneous

This section presents the results of OVA surveys and sampling during deck activities such as chipping and painting. Figure VII.1 shows the OVA survey points in the Engine Control Room and Fire Room. The levels measured at these points during loading and at-sea are presented in Table VII.1. Location I in Figure VII.1 corresponds to the fireman's work station where burner tips are quenched in a bath of fuel oil treatment. Figure VII.2 and Table VII.2 provide the same information for measurements taken in the shaft level of the Engine Room.

Similarly, two surveys were conducted in the Pump Room. One was conducted during loading and the other was conducted during discharge. At the time of the first survey, the following readings were obtained:

- o 17 ppm on the top level
- o 18 ppm one level down
- o 19 ppm two levels down
- o 20 ppm three levels down

The points surveyed at the bottom of the Pump Room are indicated in Figure VII.3. The results are shown in Table VII.3. At the bottom of the pump room, wet bulb and dry bulb temperatures were 82°F and 97°F, respectively.

At the time of the second survey, the following readings were obtained:

- o 25 ppm at the top
- o 27 ppm one level down
- o 27 ppm two levels down
- o 28 ppm three levels down

Figure VII.4 shows the location of measurements taken on the bottom level of the pump room. Table VII.4 indicates the concentrations recorded at these points.

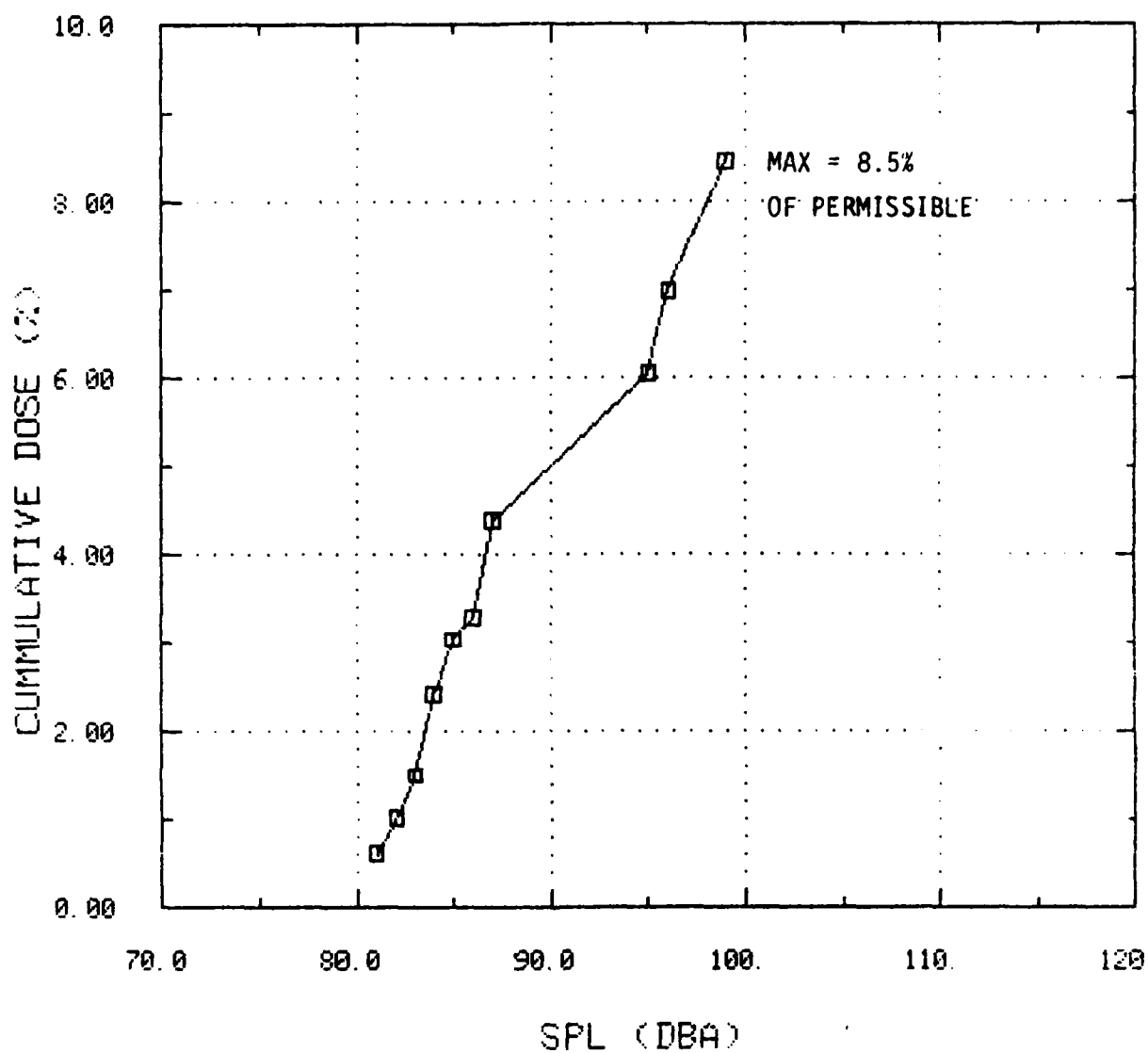


FIGURE B-3. CUMULATIVE DOSE RECORDED ON SWRI PERSONNEL  
Sample No. TX-1

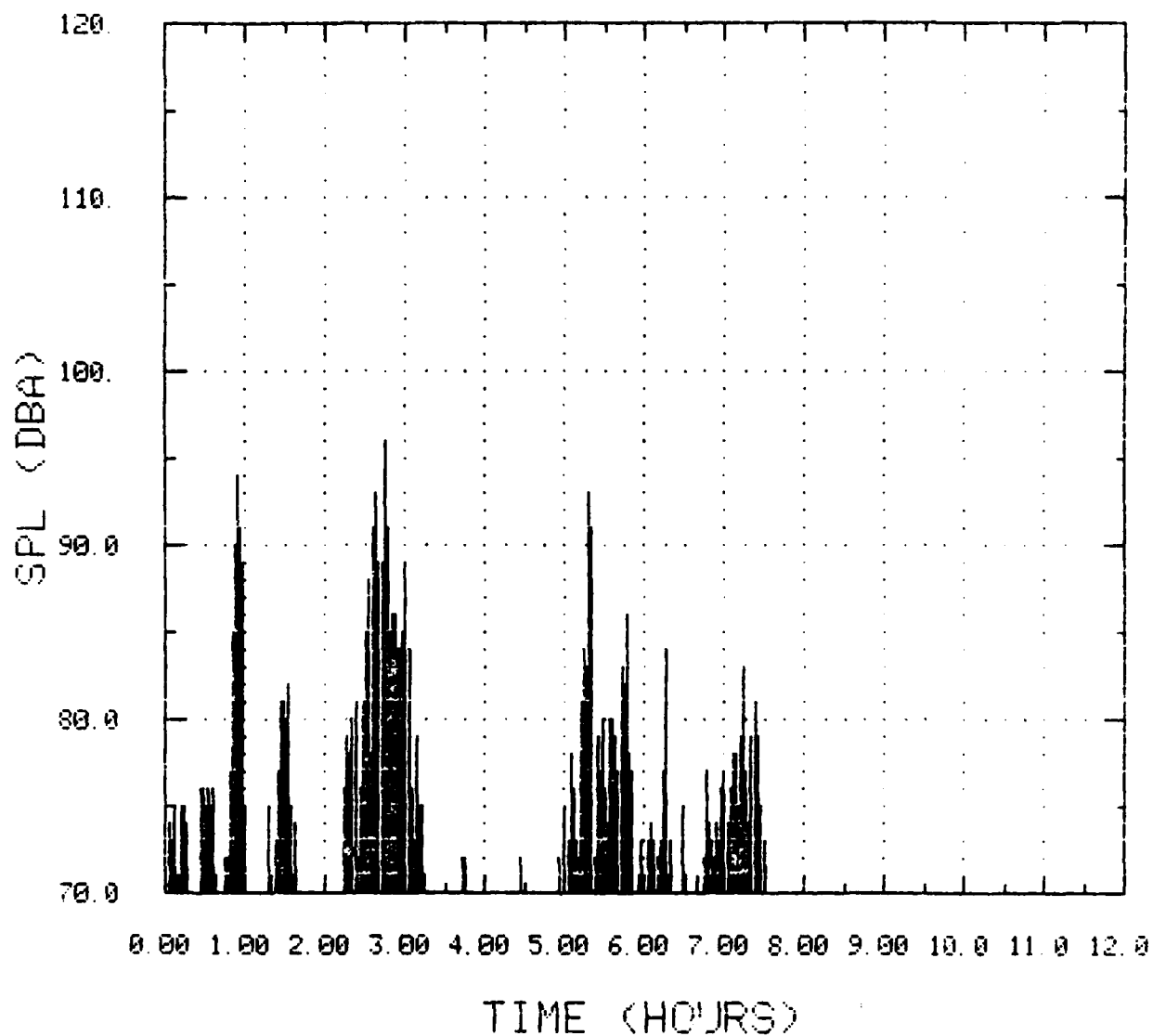


FIGURE B-4. NOISE DOSIMETRY ON SWRI PERSONNEL  
(Taken during loading while  
accompanying pumpman)  
Sample No. TX-2

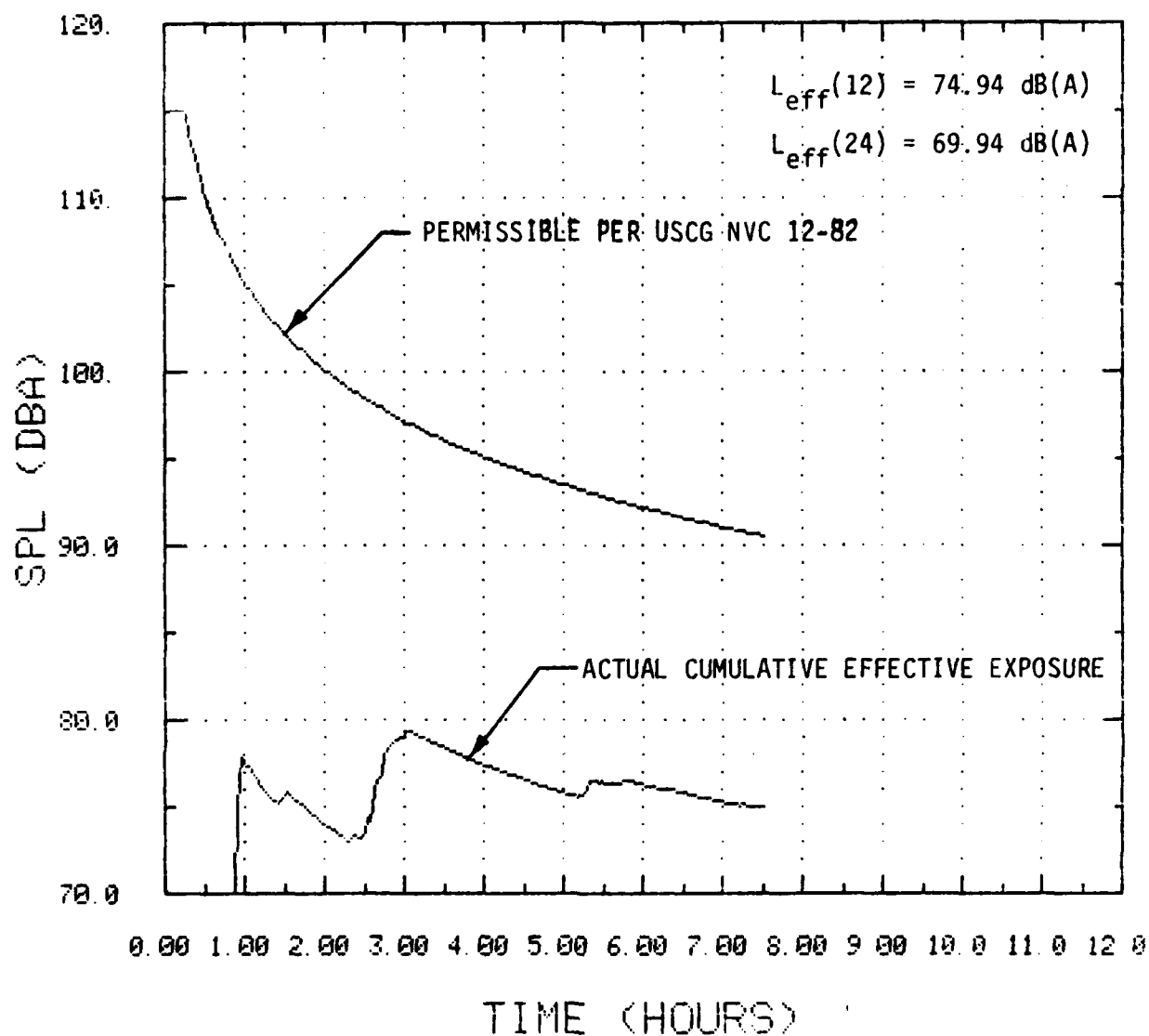


FIGURE B-5. CUMULATIVE EFFECTIVE EXPOSURE ON SWRI PERSONNEL  
Sample No. TX-2

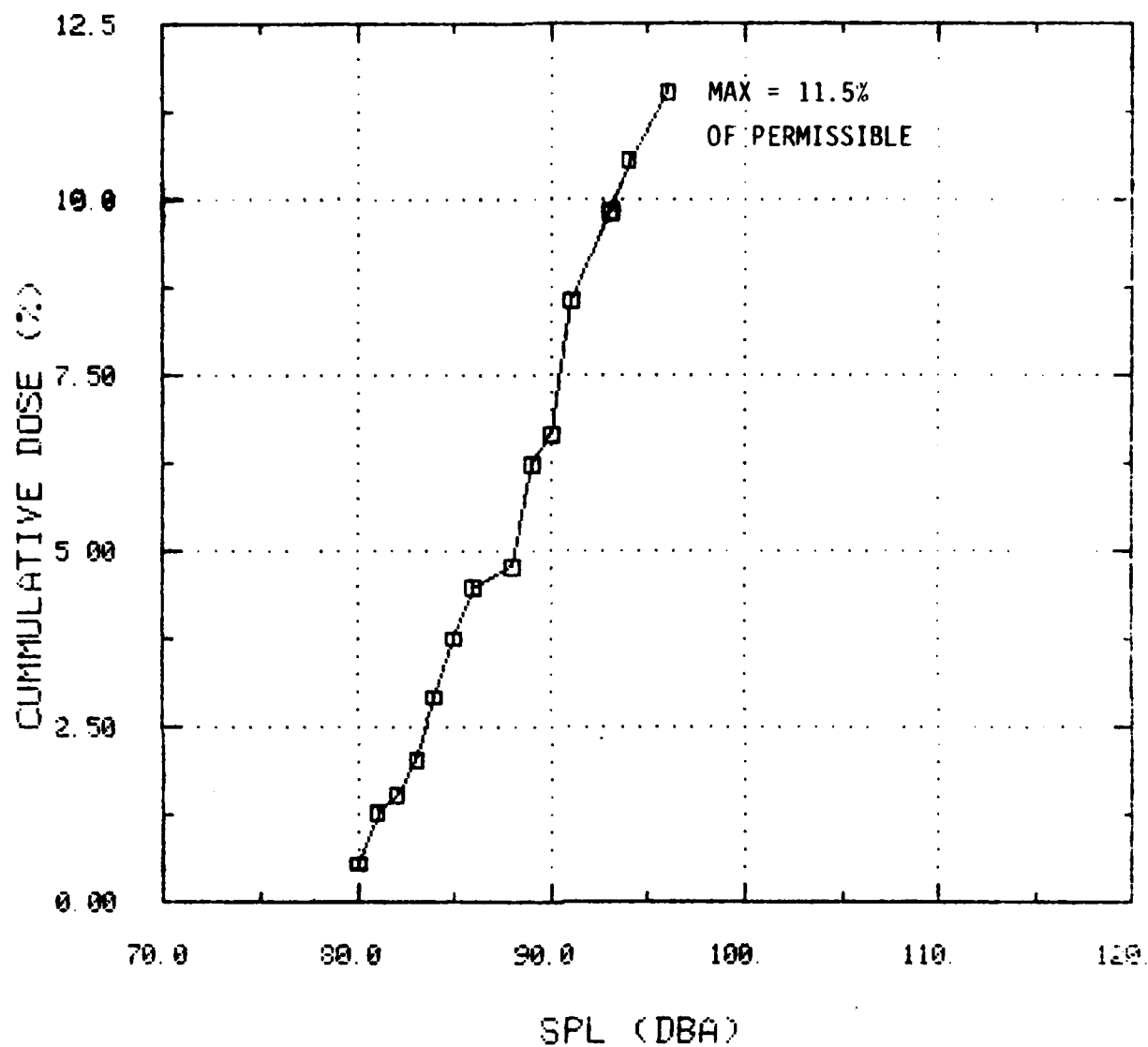


FIGURE B-6. CUMULATIVE DOSE RECORDED ON SwRI personnel  
Sample No. TX-2

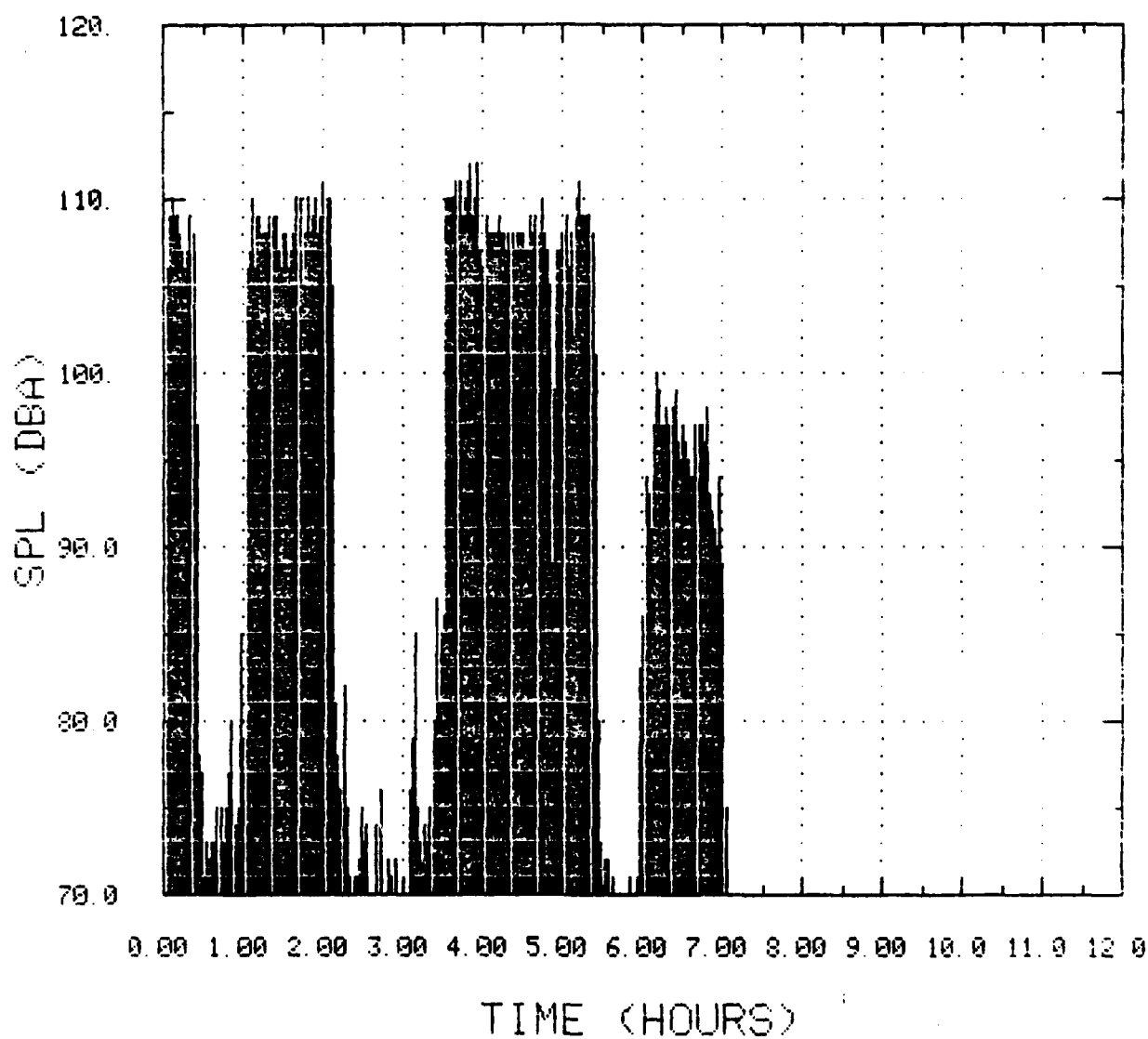


FIGURE B-7. NOISE DOSIMETRY ON SEAMAN  
(Taken during laden voyage  
while chipping paint)  
Sample No. TX-3

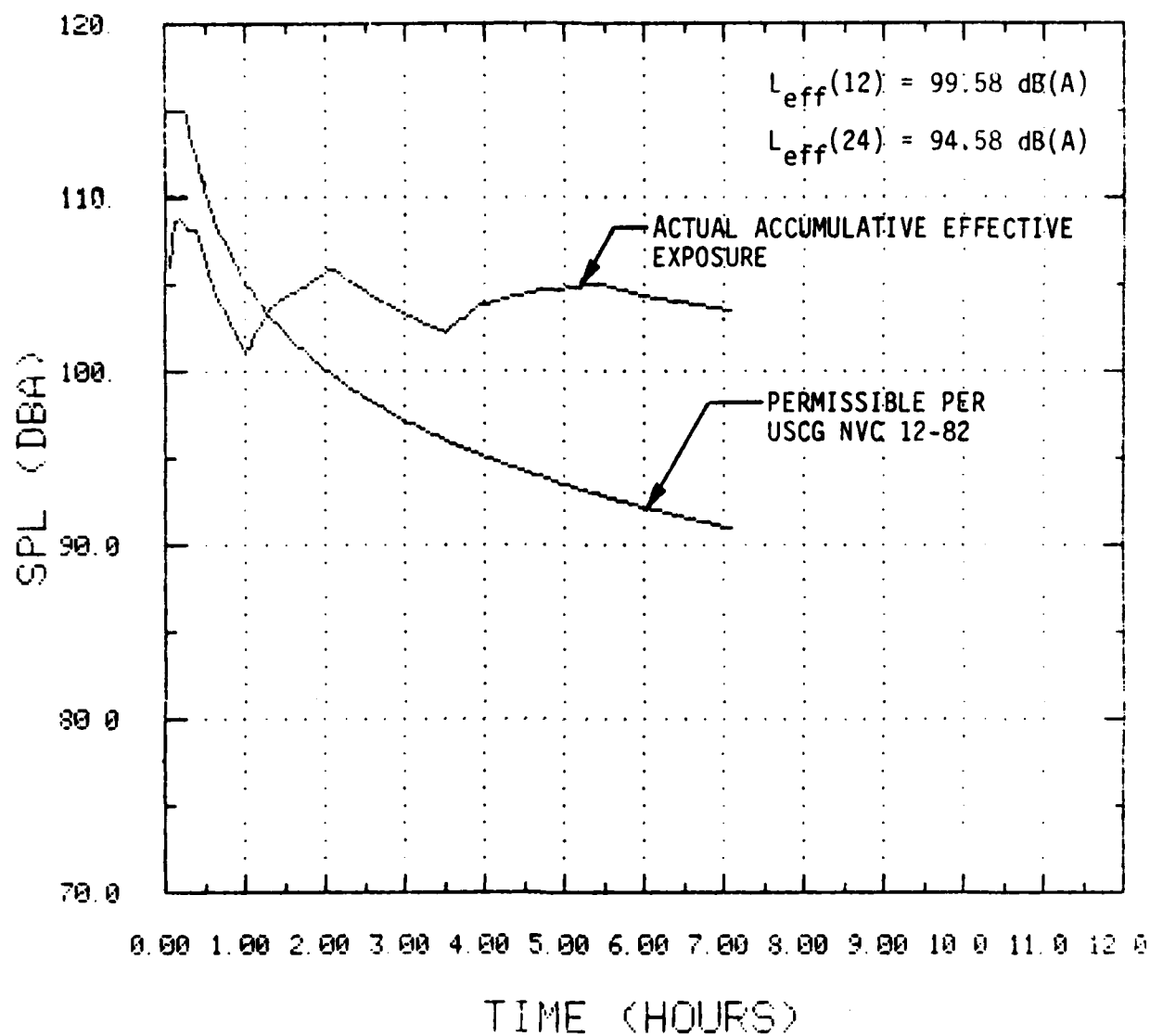


FIGURE B-8. CUMULATIVE EFFECTIVE EXPOSURE ON SEAMAN  
Sample No. TX-3



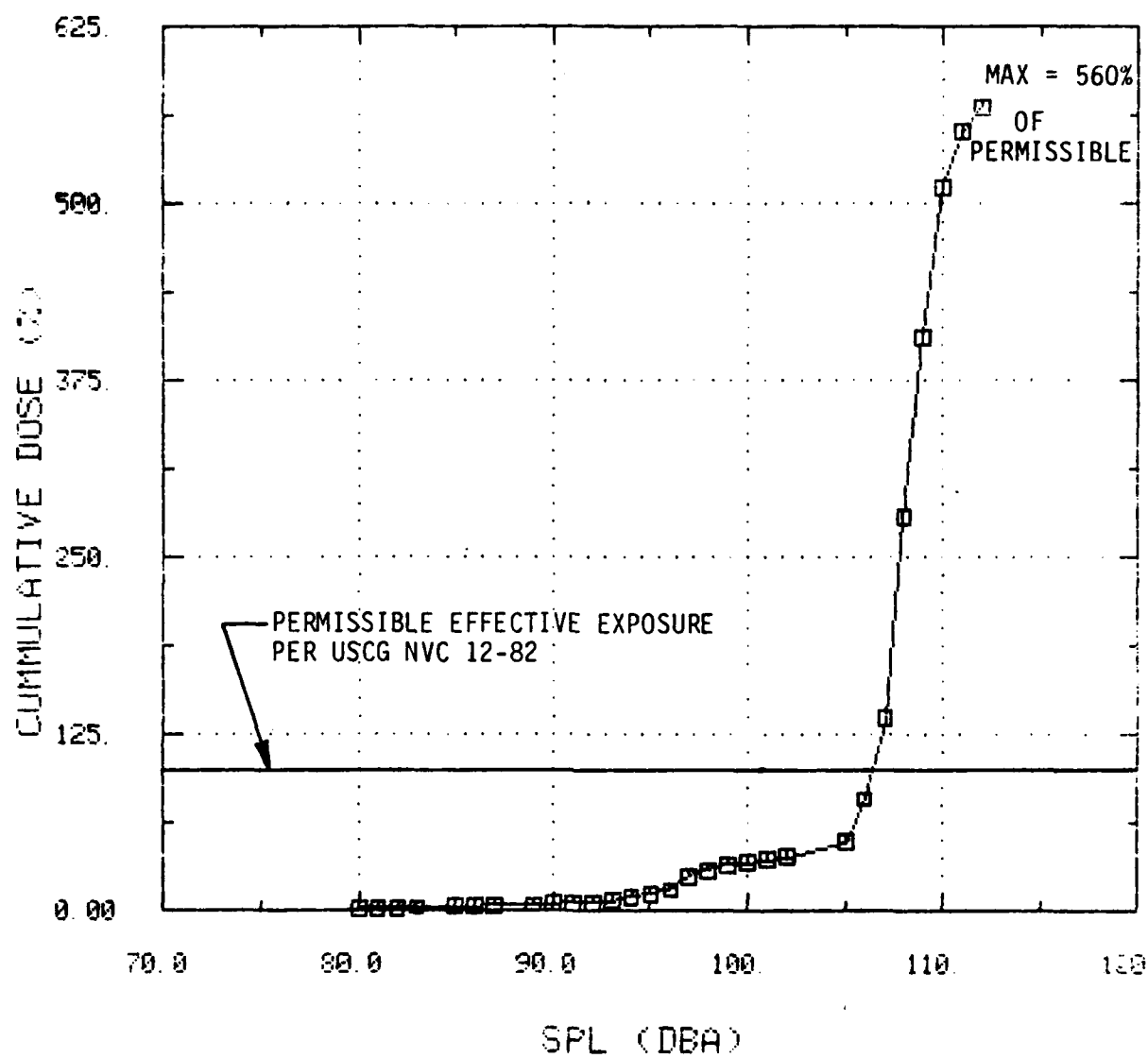


FIGURE B-9. CUMULATIVE DOSE RECORDED ON SEAMAN  
Sample No. TX-3

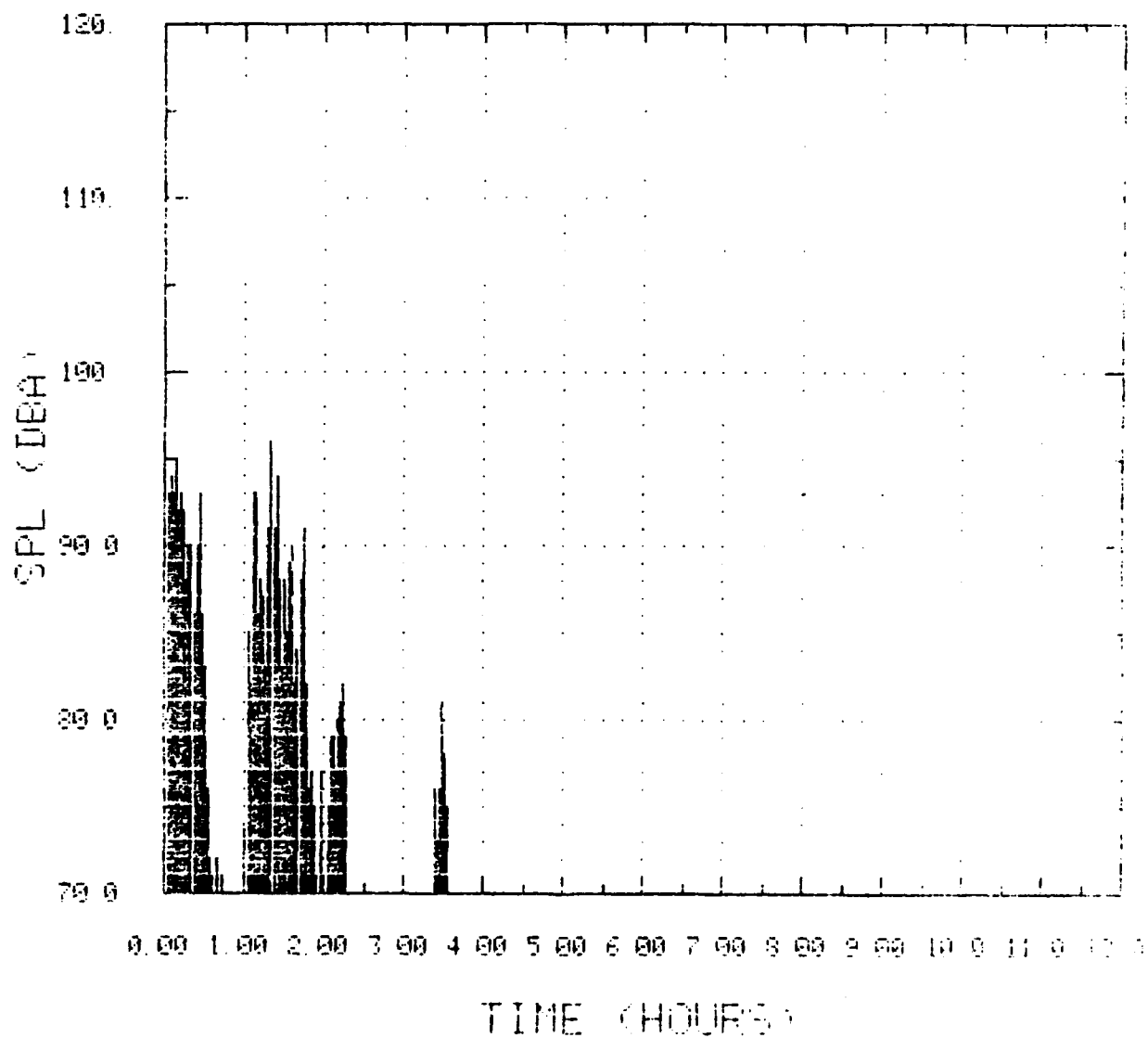


FIGURE B-10. NOISE DOSIMETRY ON SEAMAN  
(Taken during laden voyage  
while chipping paint)  
Sample No. TX-4

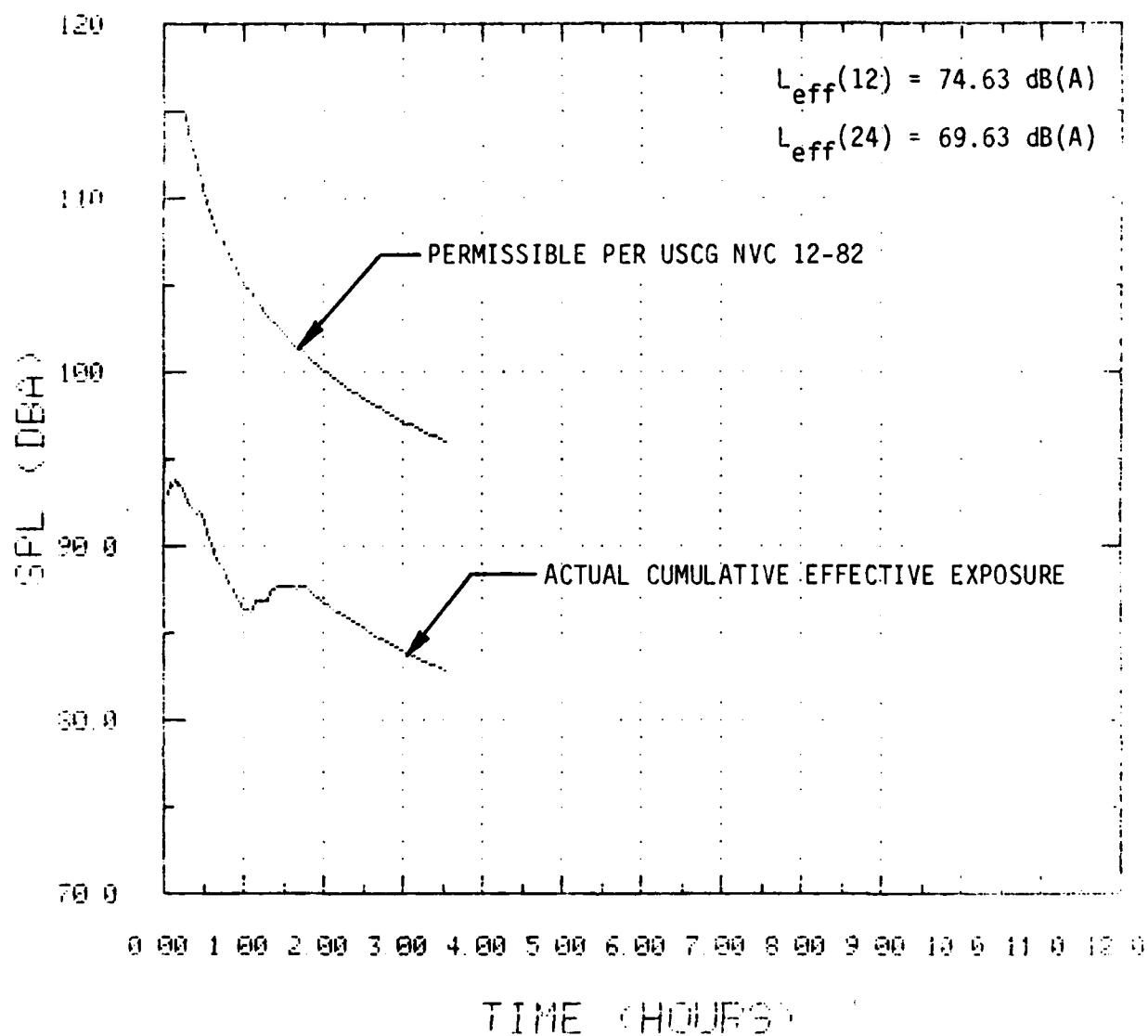


FIGURE B-11. CUMULATIVE EFFECTIVE EXPOSURE ON SEAMAN  
Sample No. TX-4

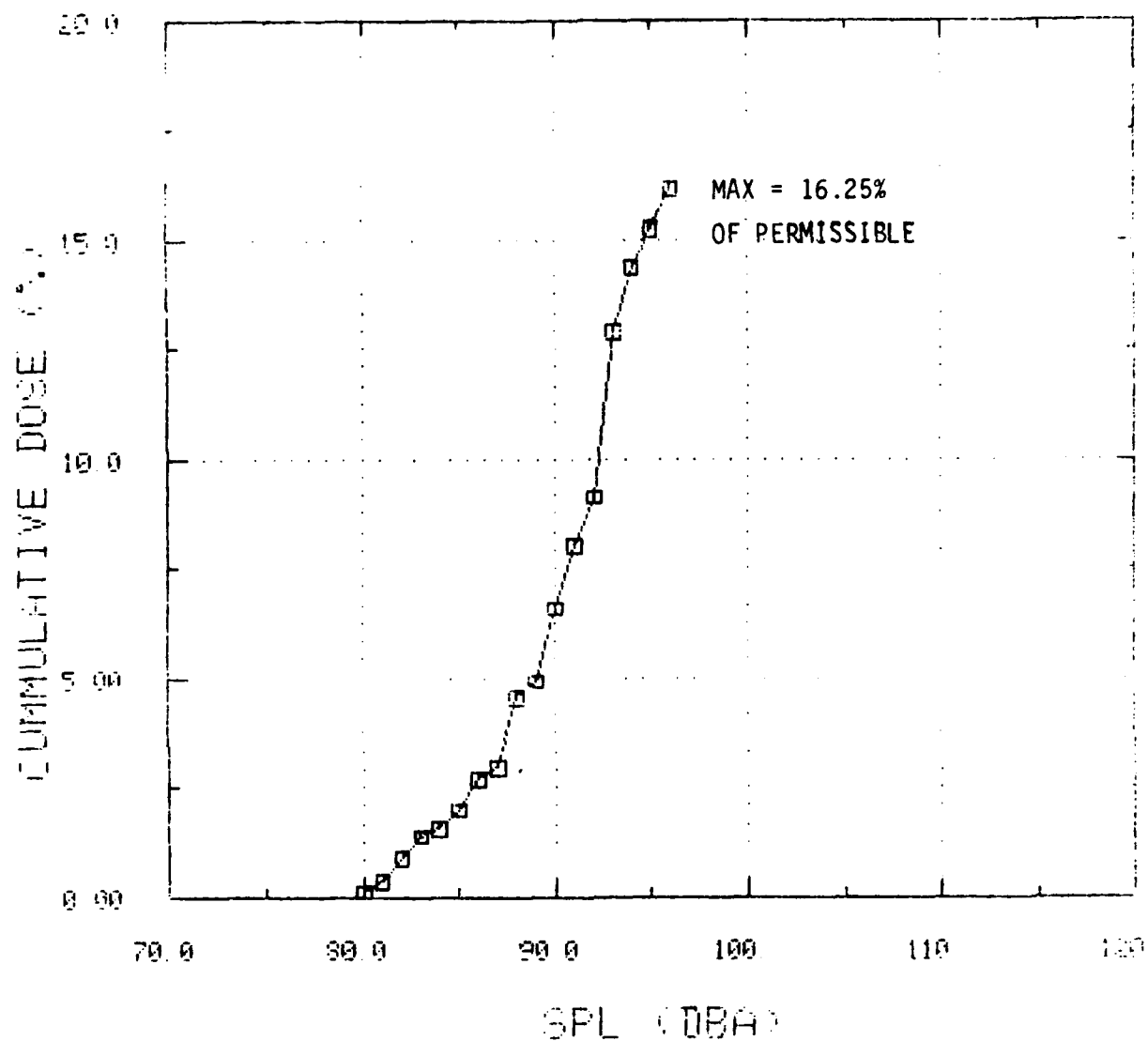


FIGURE B-12. CUMULATIVE DOSE RECORDED ON SEAMAN  
Sample No. TX-4

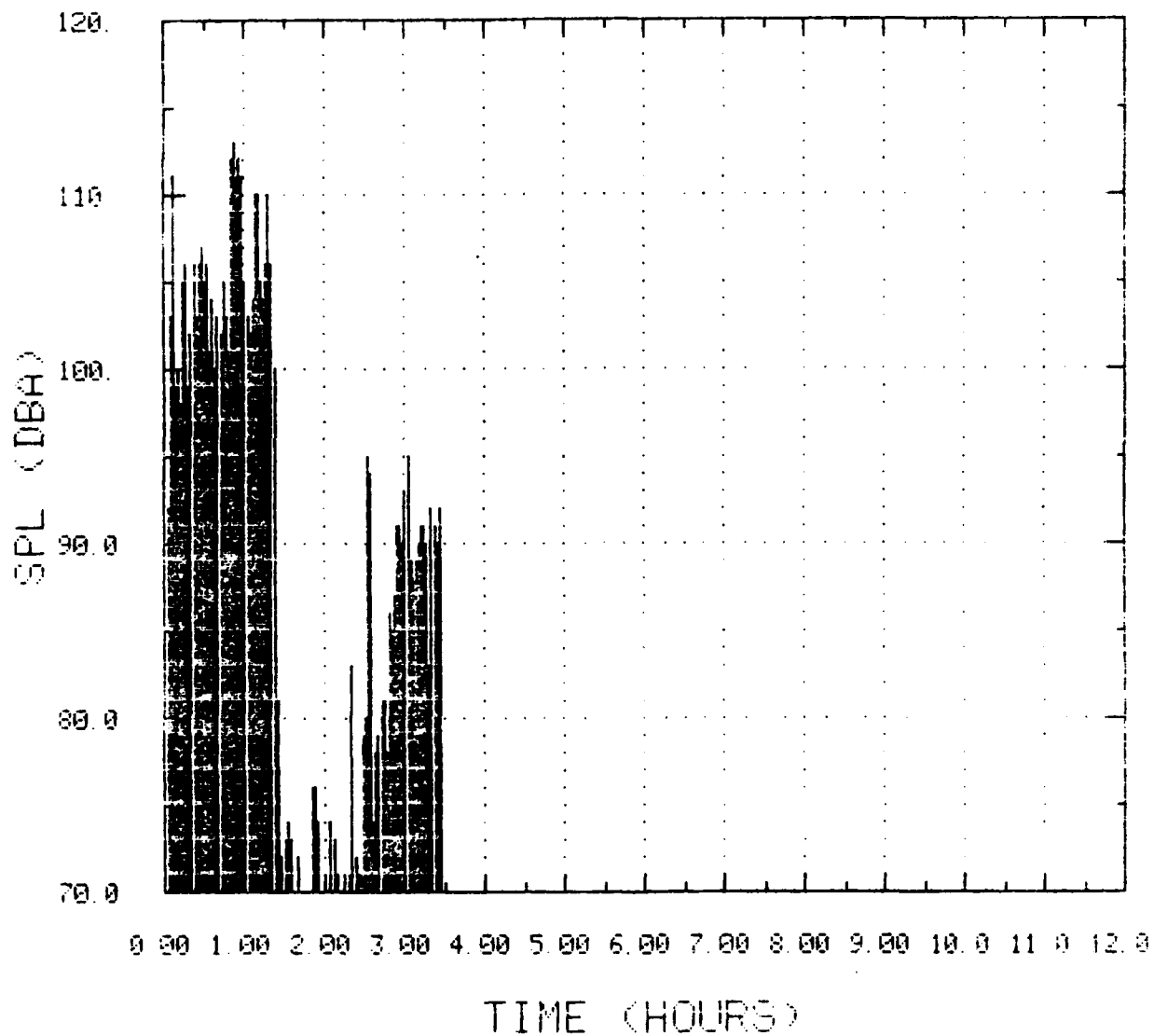


FIGURE B-13. NOISE DOSIMETRY AND SEAMAN  
(Taken during laden voyage  
while chipping paint)  
Sample No. TX-5

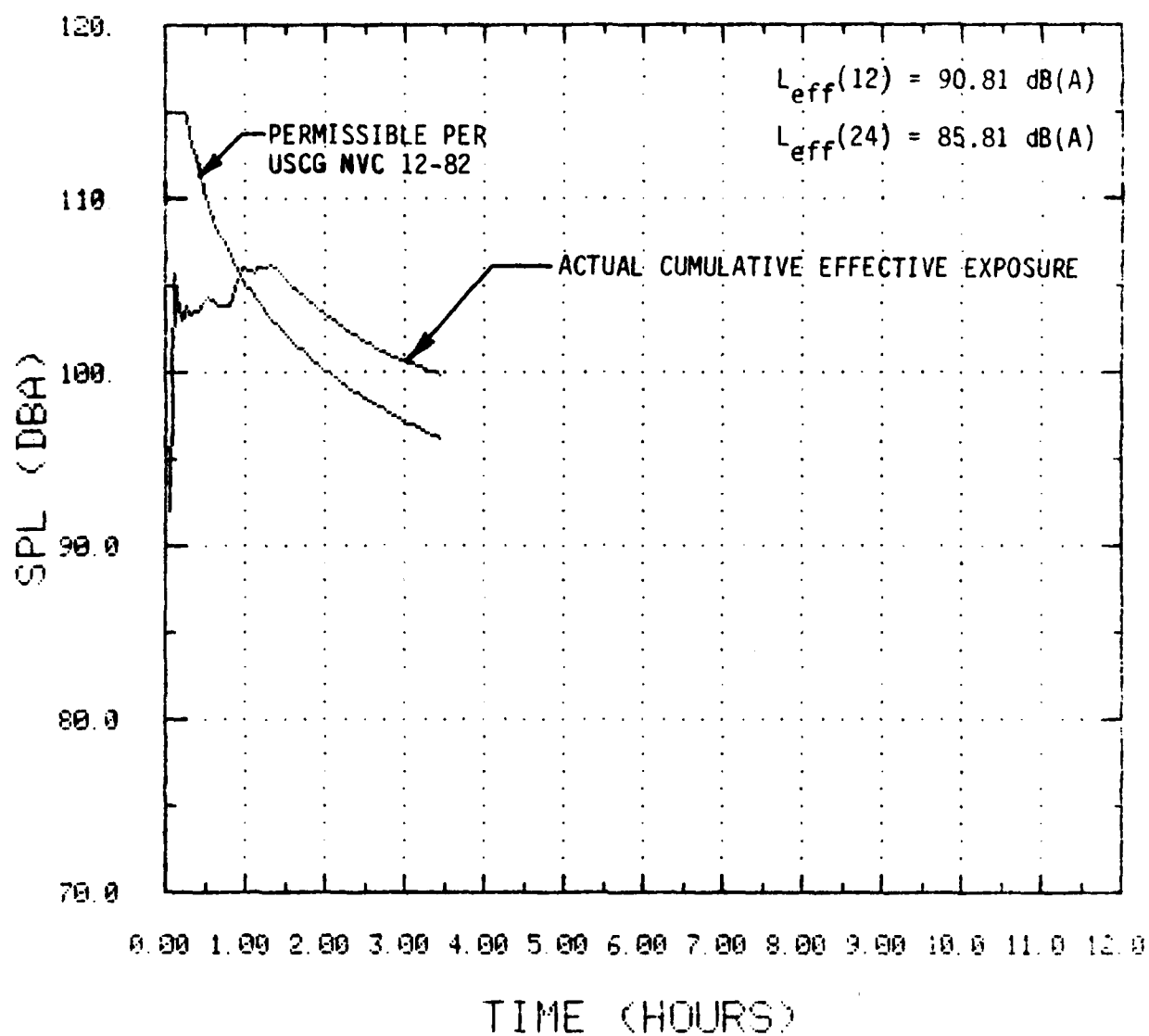


FIGURE B-14. CUMULATIVE EFFECTIVE EXPOSURE ON SEAMAN  
Sample No. TX-5

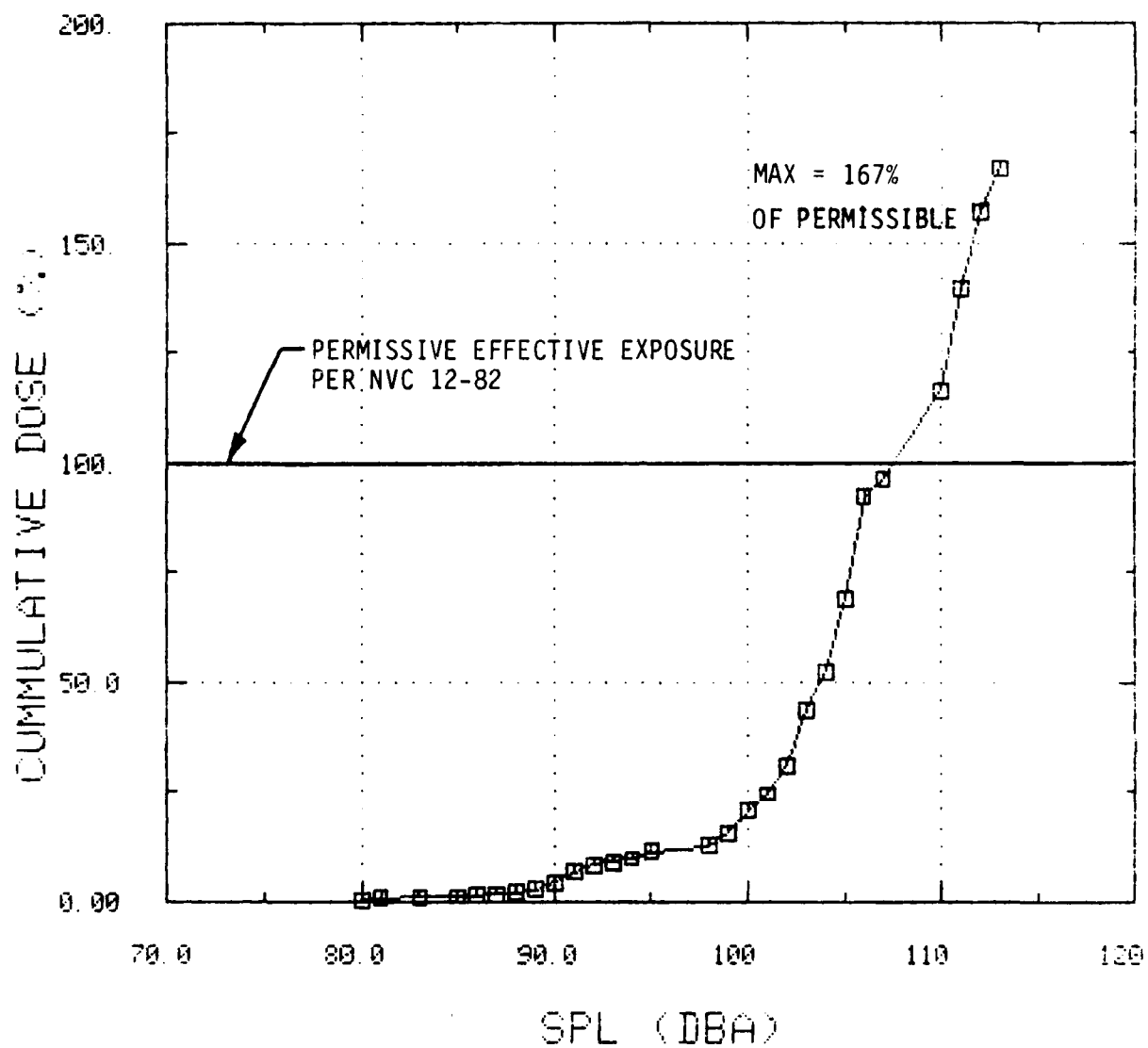


FIGURE B-15. CUMULATIVE DOSE RECORDED ON SEAMAN  
Sample No. TX-5

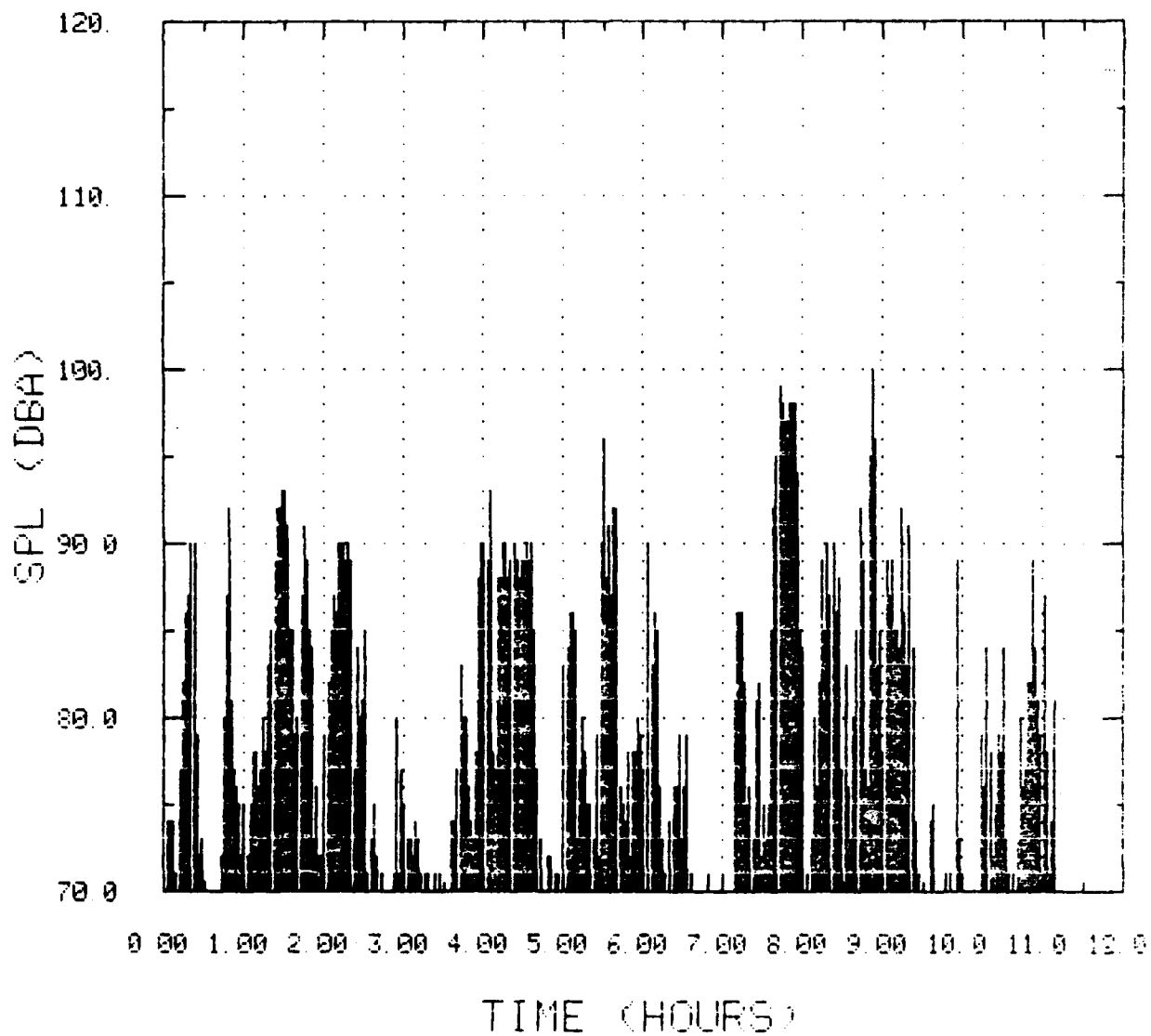


FIGURE B-16. NOISE DOSIMETRY ON SWRI PERSONNEL  
(Taken during discharge while  
accompanying pumpman)  
Sample No. TX-6



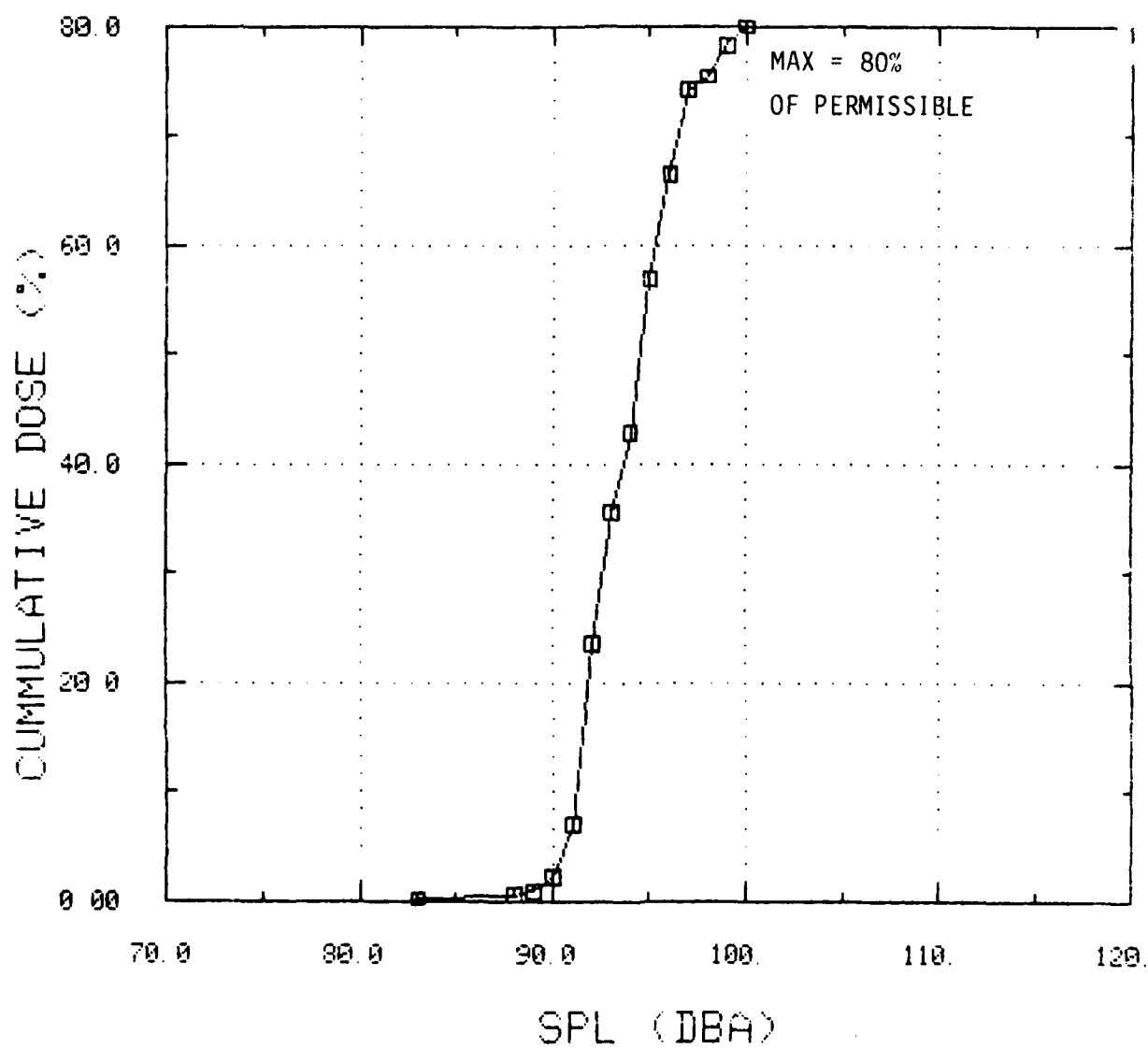


FIGURE B-30. CUMULATIVE DOSE RECORDED ON SWRI PERSONNEL  
Sample No. TX-10

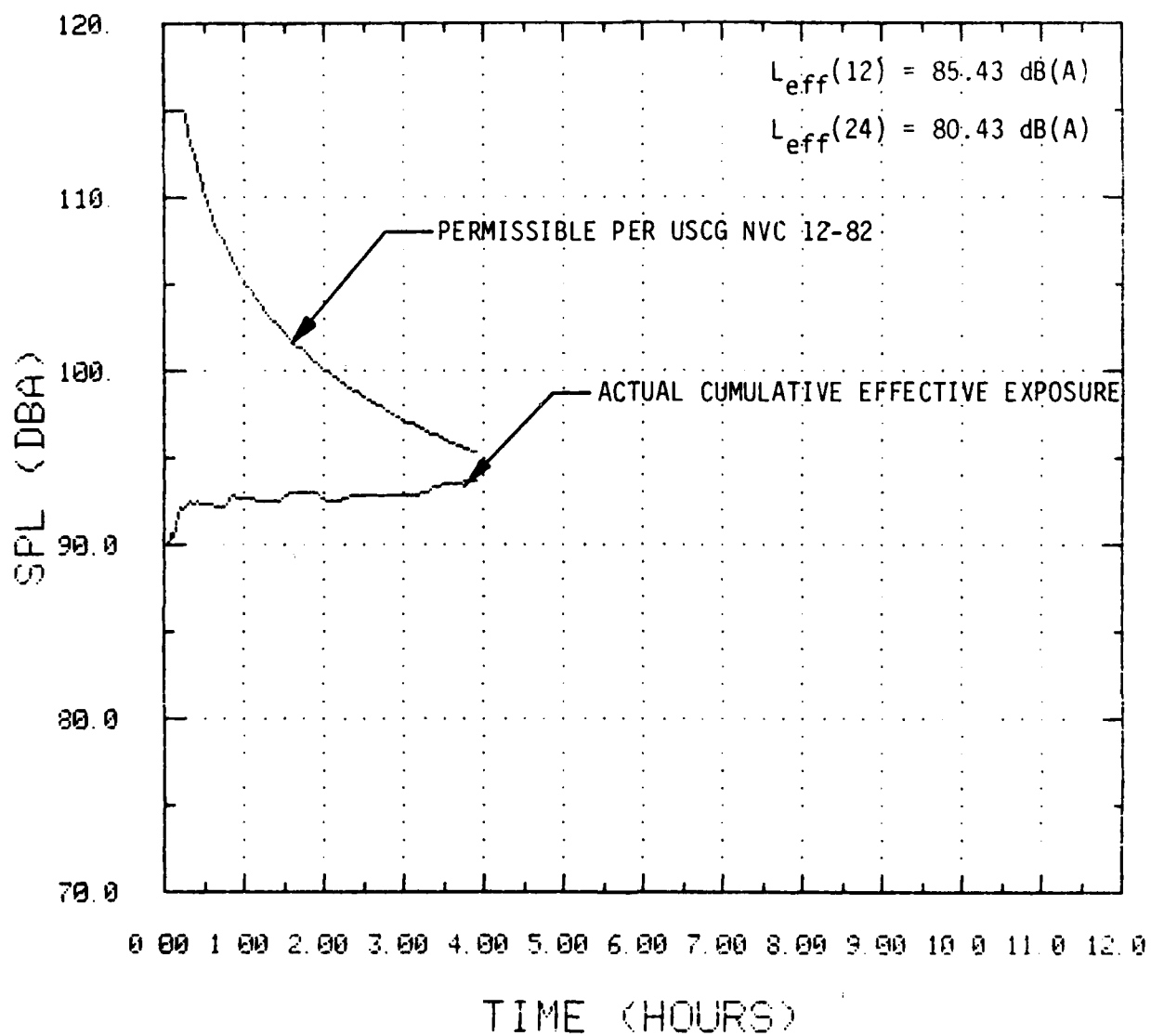


FIGURE B-29. CUMULATIVE EFFECTIVE EXPOSURE ON SWRI PERSONNEL  
Sample No. TX-10

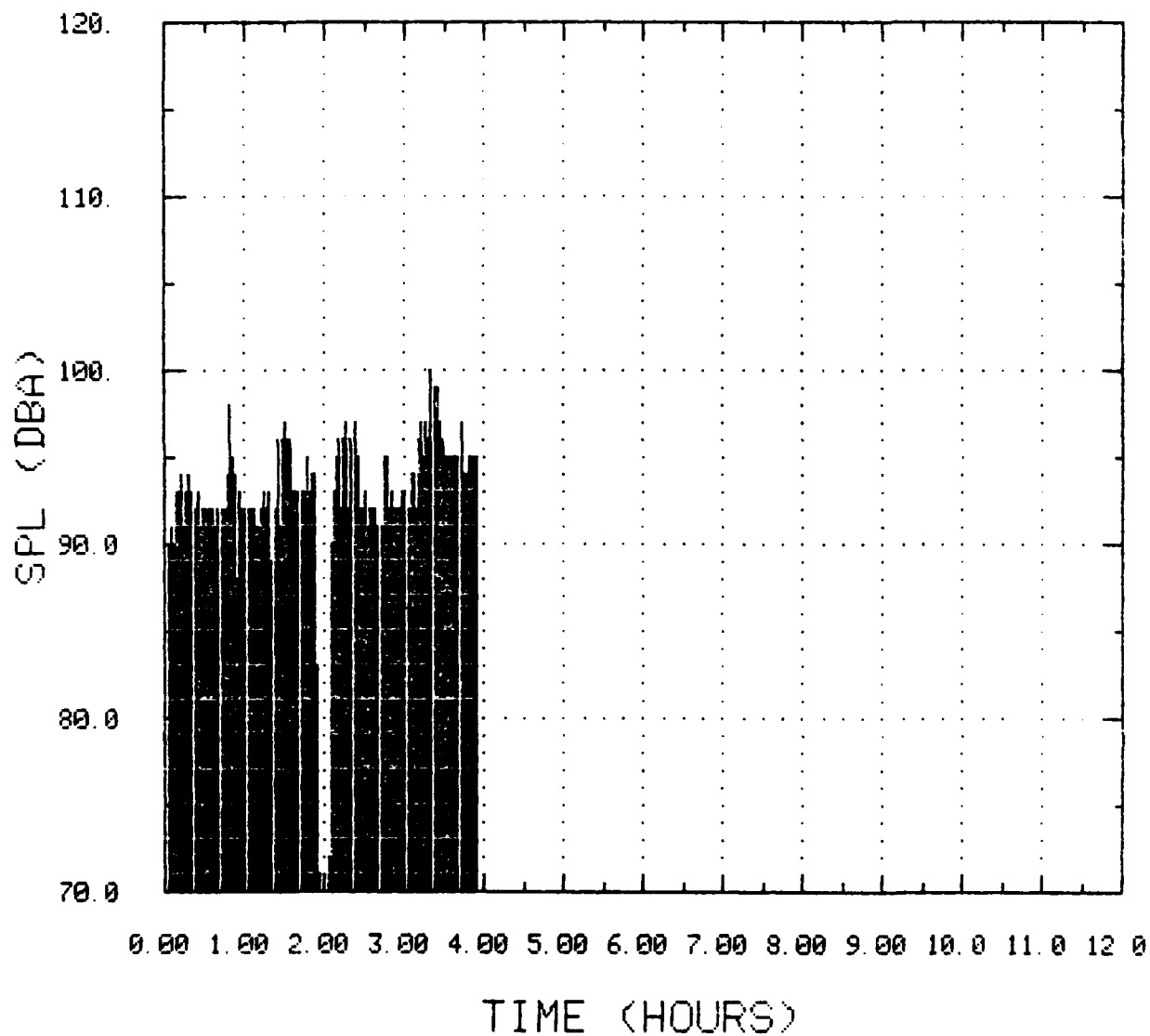


FIGURE B-28. NOISE DOSIMETRY ON SWRI PERSONNEL  
(Taken during laden voyage while  
accompanying officer)  
Sample No. TX-10

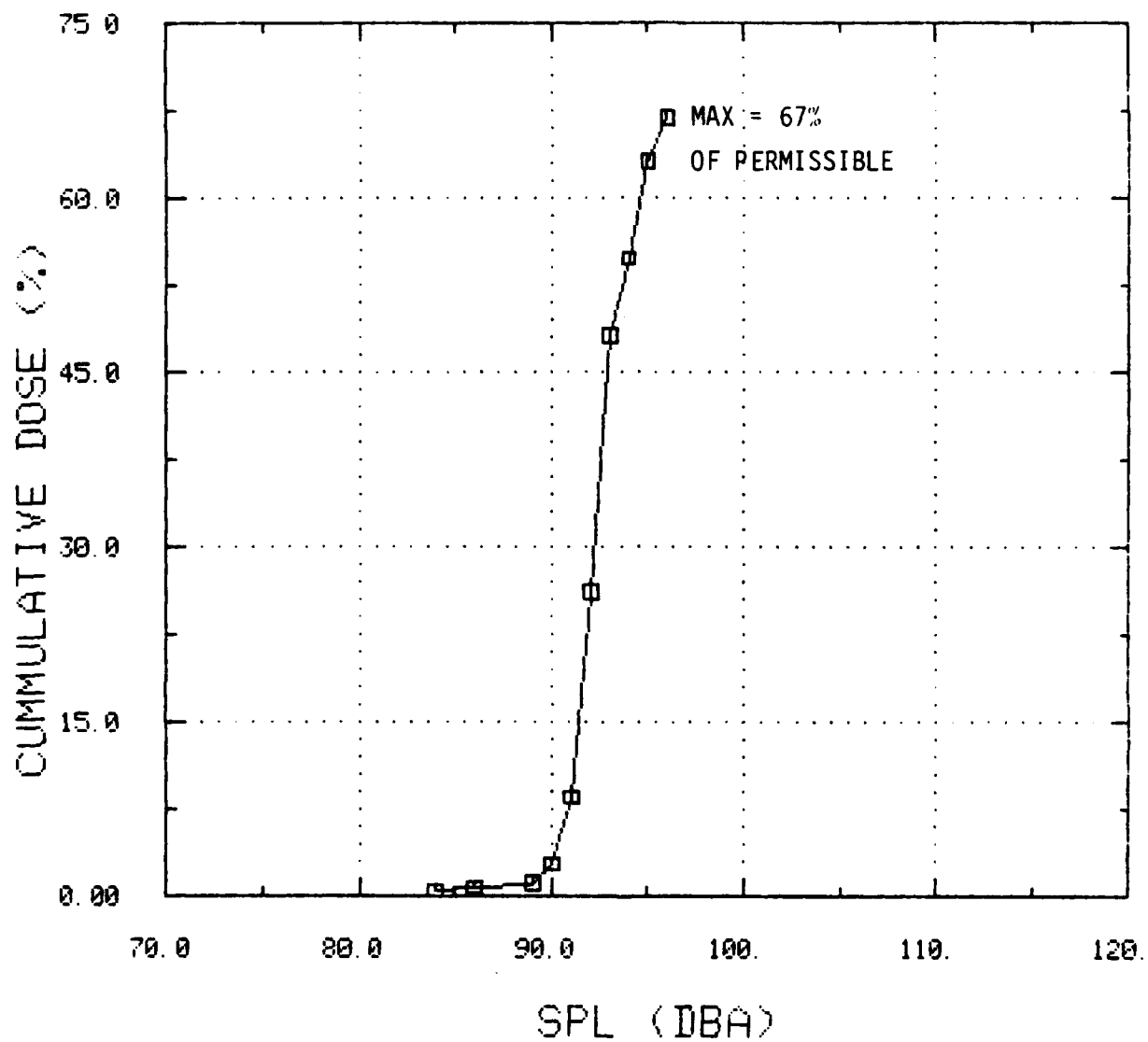


FIGURE B-27. CUMULATIVE DOSE RECORDED ON SwRI PERSONNEL  
Sample No. TX-9

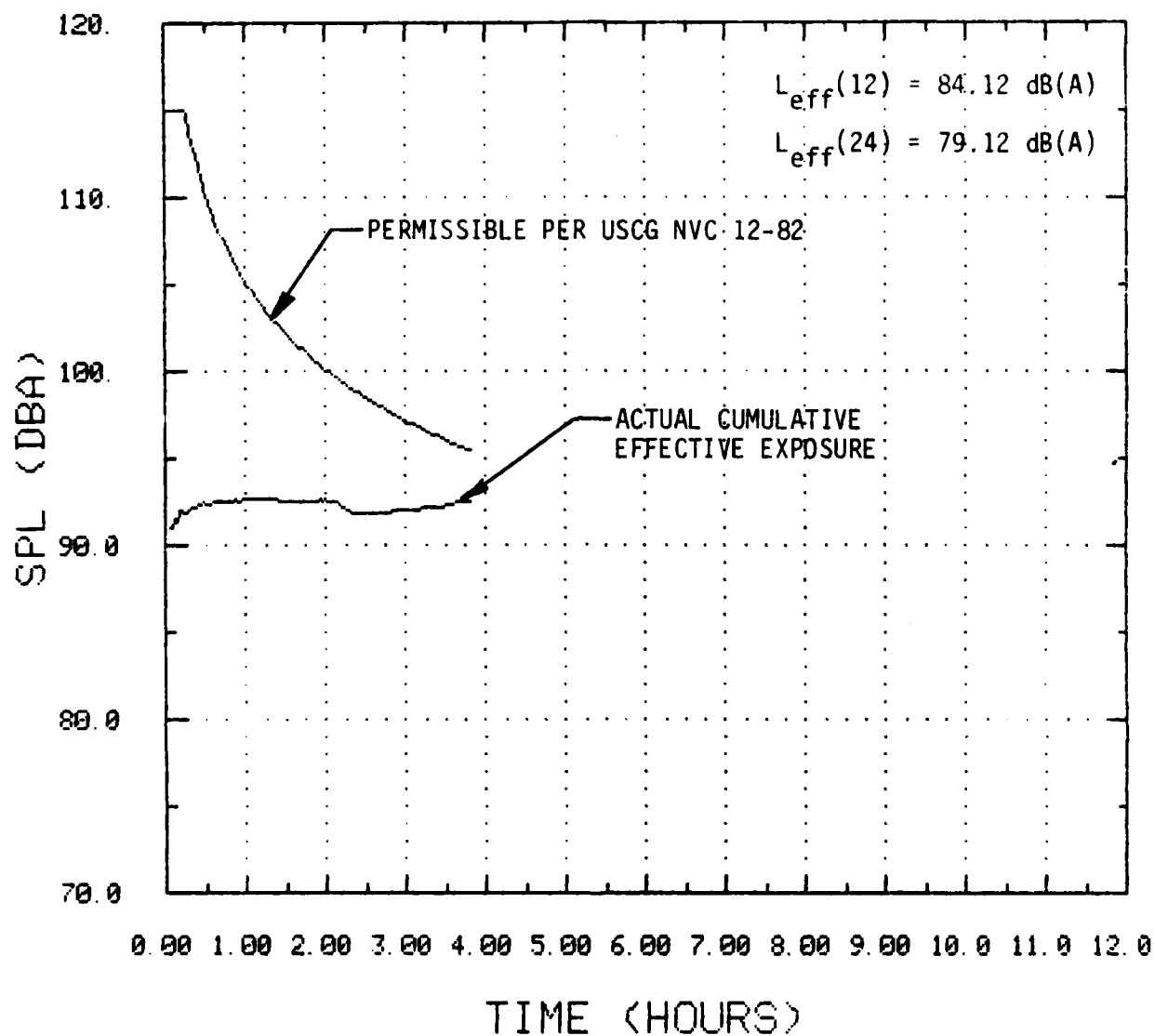


FIGURE B-26. CUMULATIVE EFFECTIVE EXPOSURE ON SWRI PERSONNEL  
Sample No. TX-9

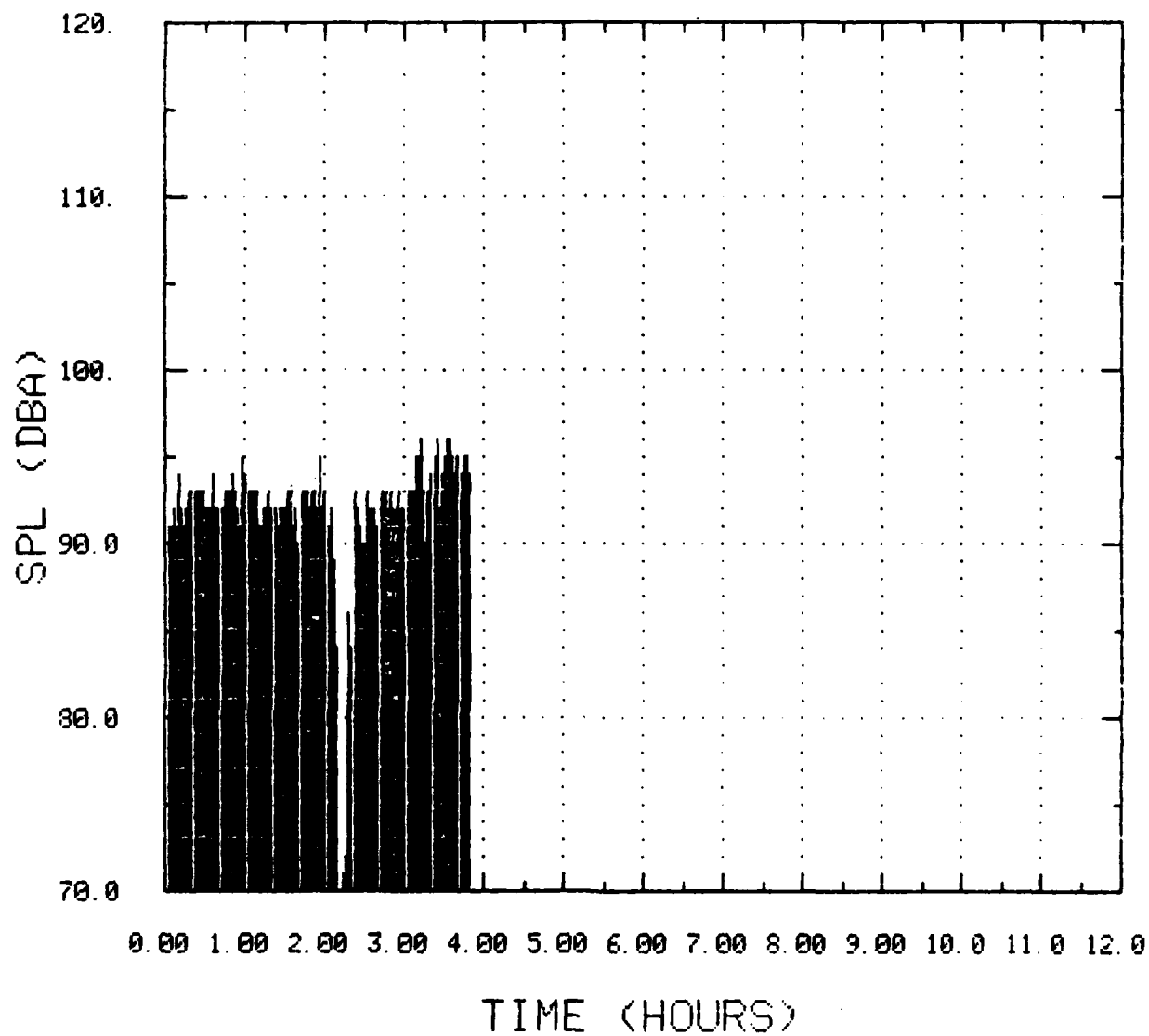


FIGURE B-25. NOISE DOSIMETRY ON SWRI PERSONNEL  
(Taken during laden voyage while  
accompanying fireman)  
Sample No. TX-9

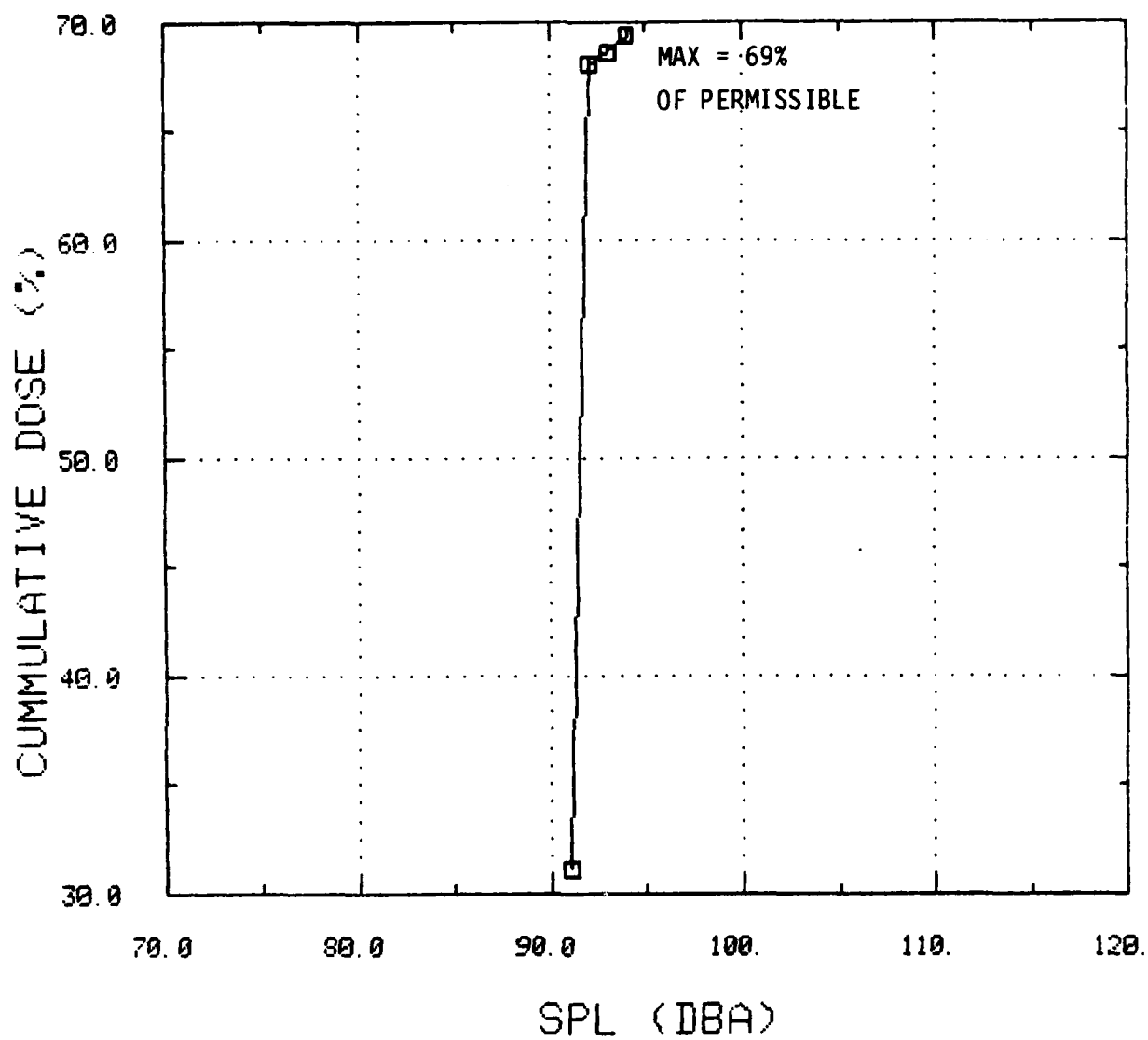


FIGURE B-24. CUMULATIVE DOSE RECORDED  
Sample No. TX-8

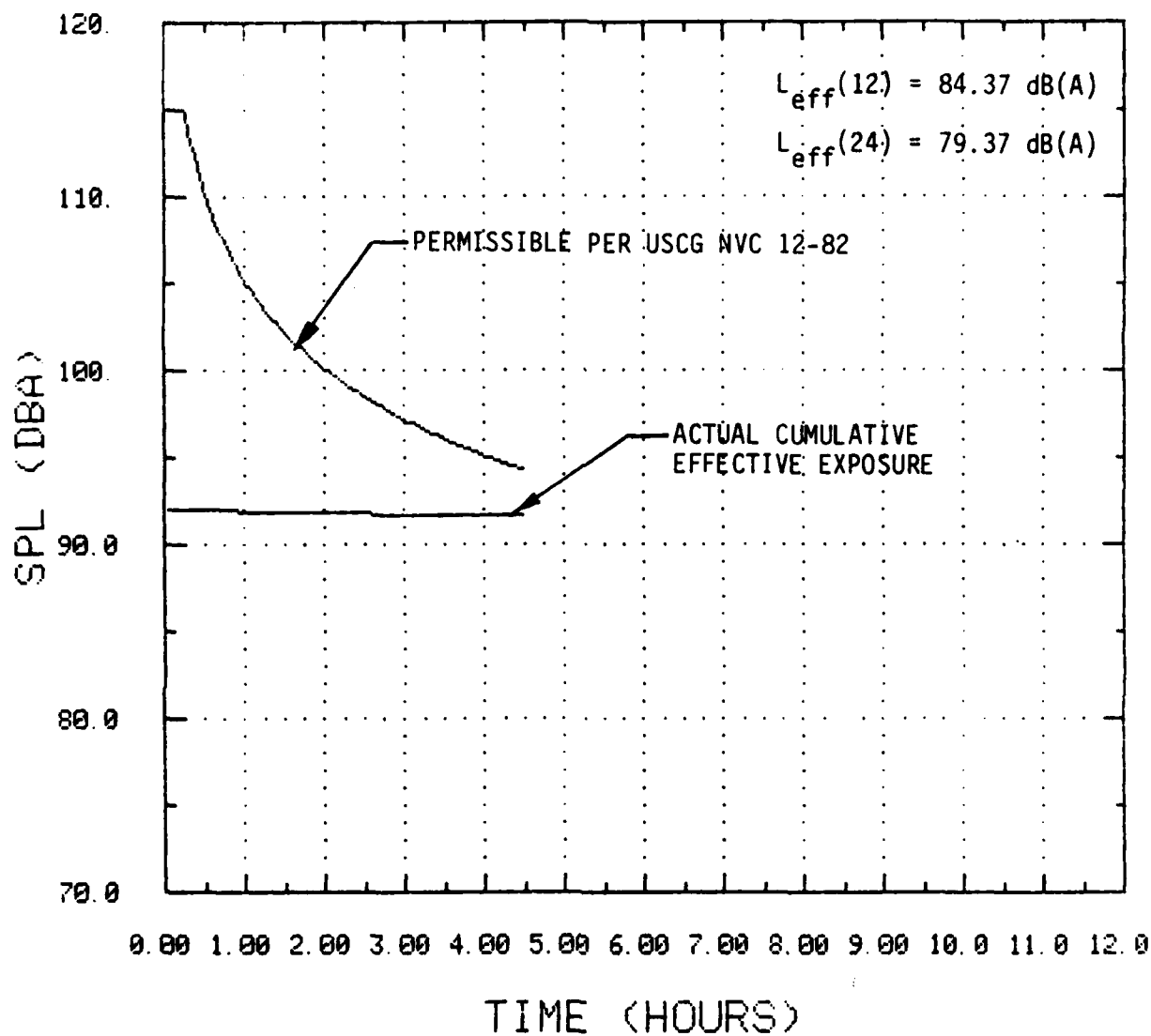


FIGURE B-23. CUMULATIVE EFFECTIVE EXPOSURE  
Sample No. TX-8



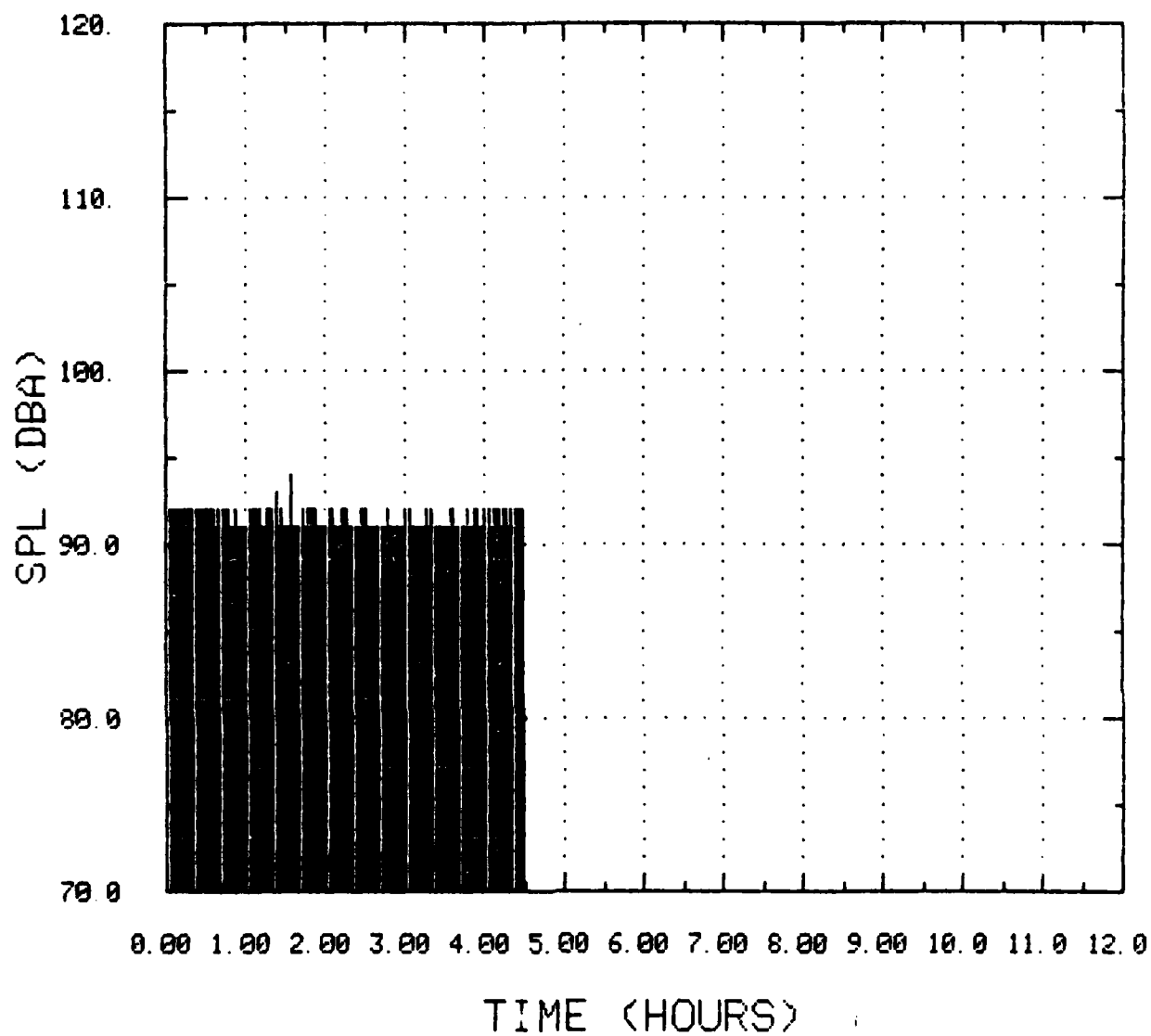


FIGURE B-22. NOISE DOSIMETRY NEAR FIREMAN'S CONTROL CONSOLE  
Sample No. TX-8

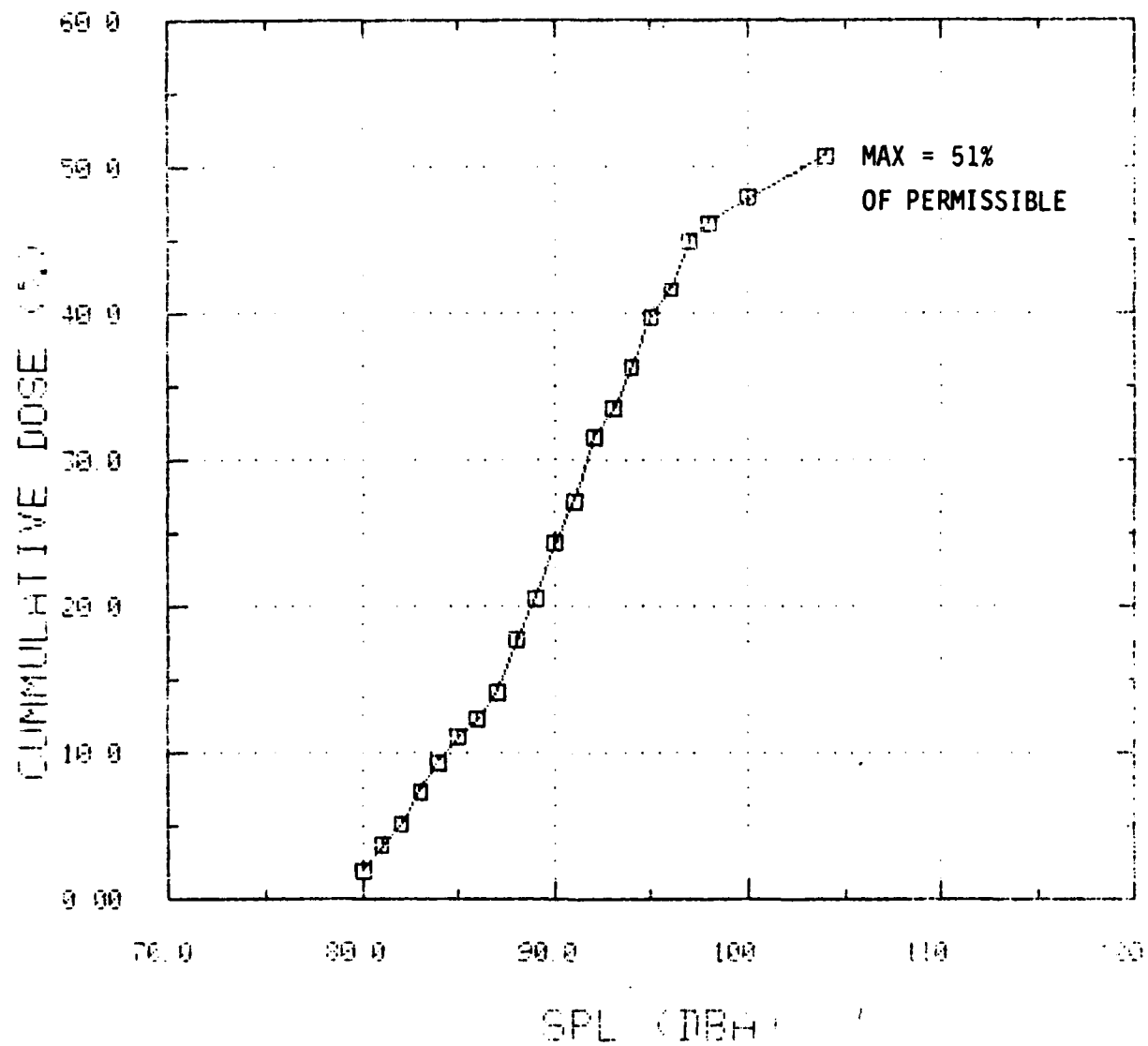


FIGURE B-21. CUMULATIVE DOSE RECORDED ON COMPANY REPRESENTATIVE  
Sample No. TX-7

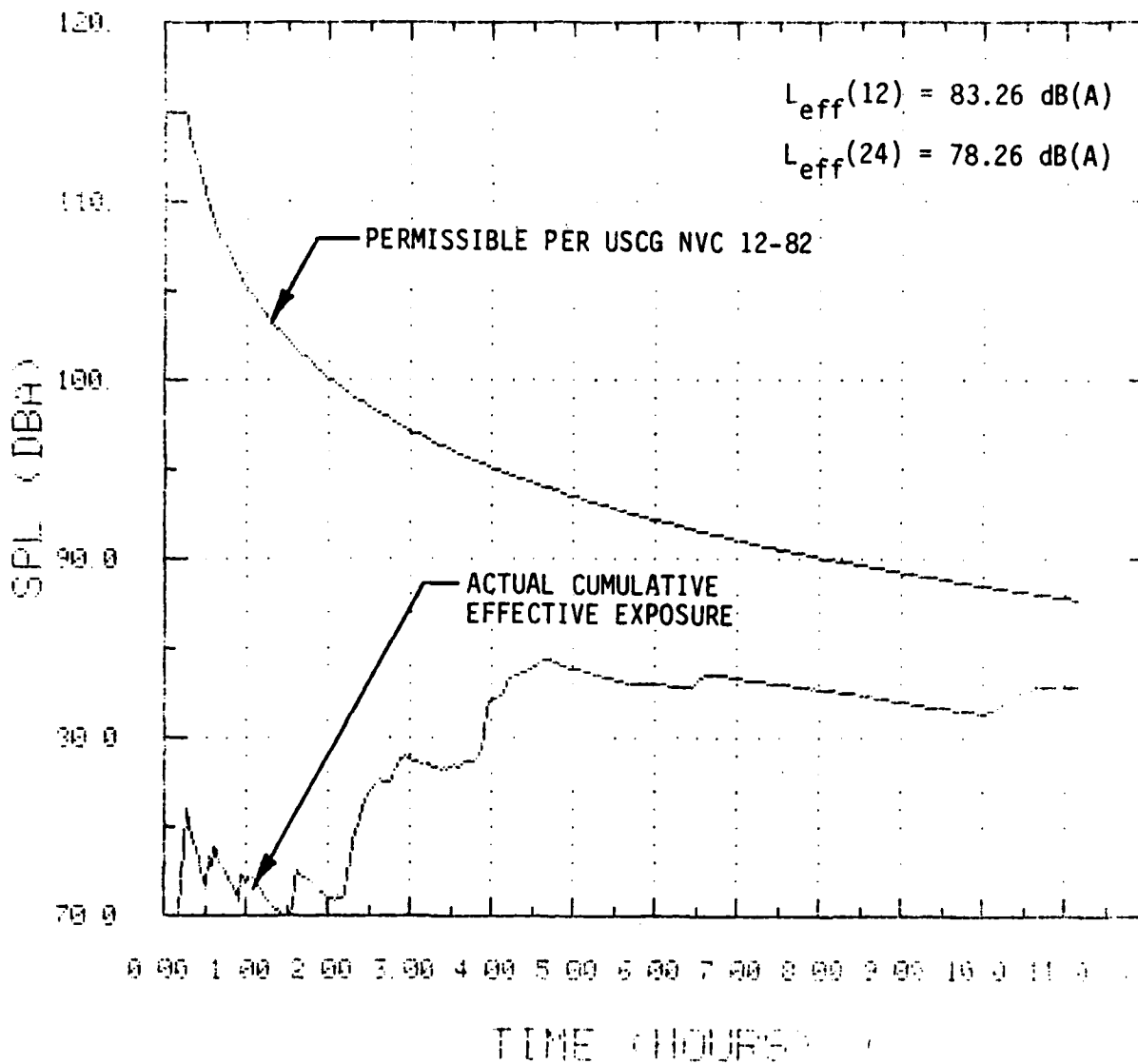


FIGURE B-20. CUMULATIVE EFFECTIVE EXPOSURE ON COMPANY REPRESENTATIVE  
Sample No. TX-7

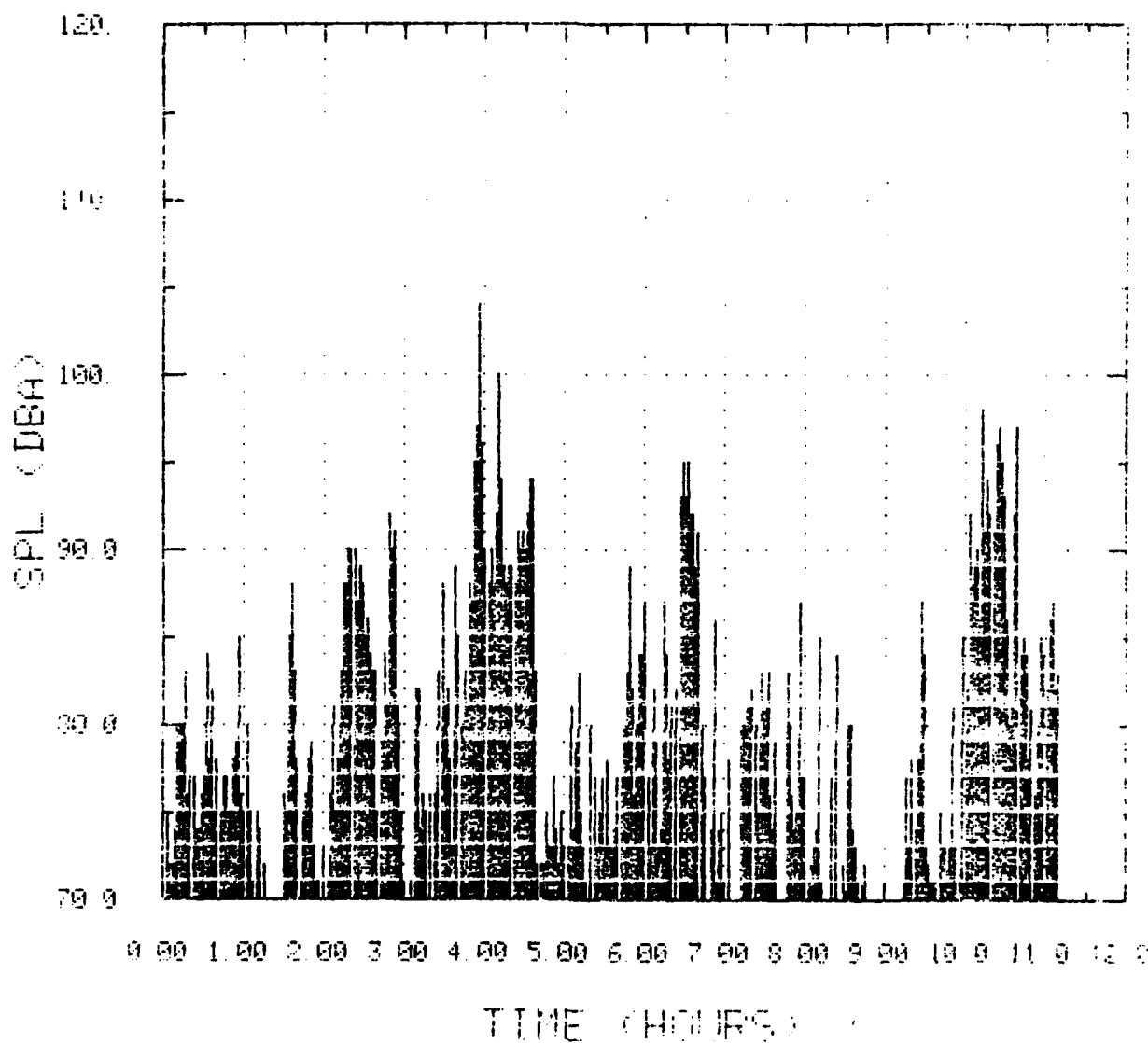


FIGURE B-19. NOISE DOSIMETRY ON COMPANY REPRESENTATIVE  
 (Taken During Discharge While Working on  
 Deck and Forward Mast)  
 Sample No. TX-7

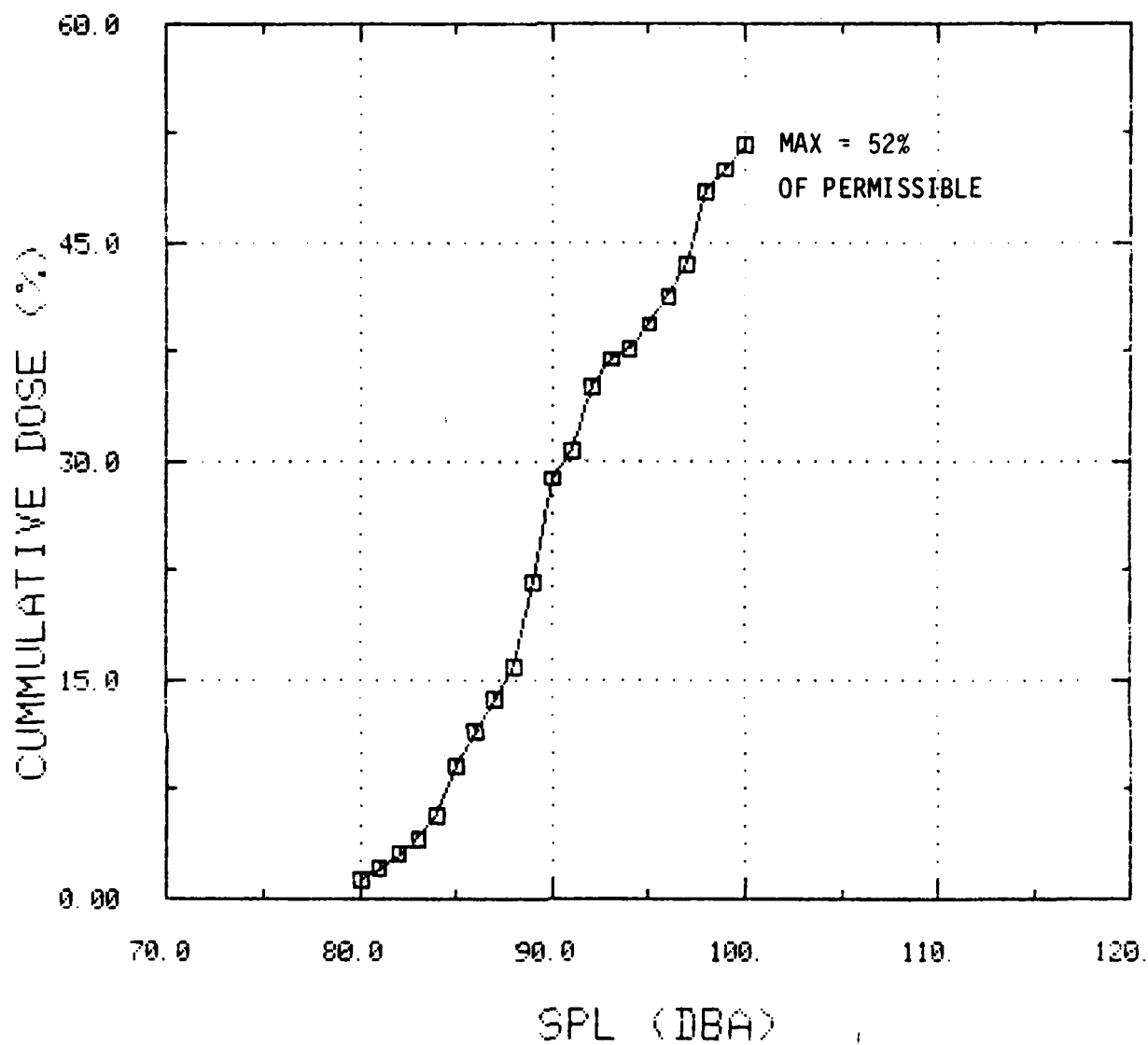


FIGURE B-18. CUMULATIVE DOSE RECORDED ON SwRI PERSONNEL  
Sample No. TX-6

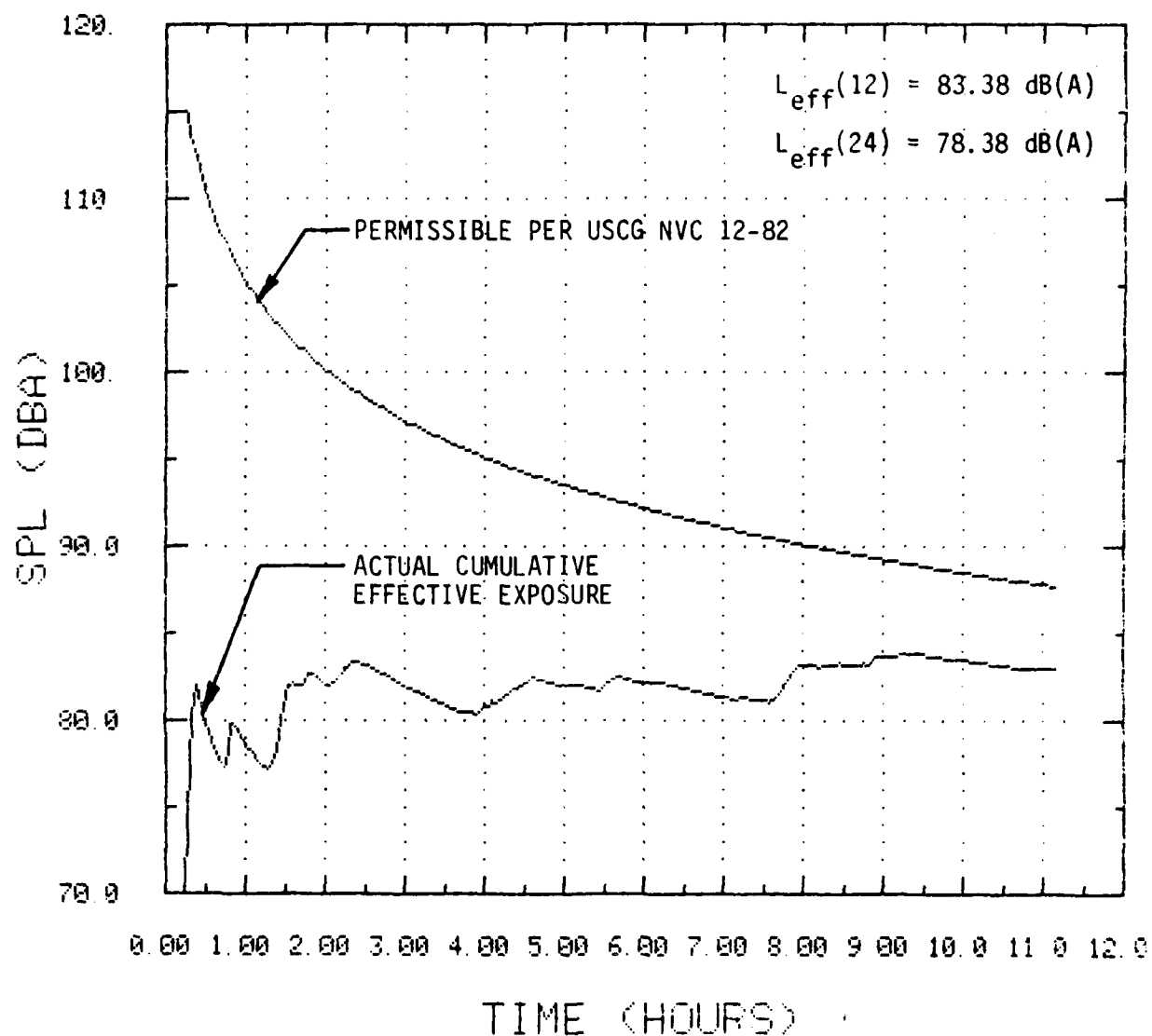


FIGURE B-17. CUMULATIVE EFFECTIVE EXPOSURE ON SWRI PERSONNEL  
Sample No. TX-6

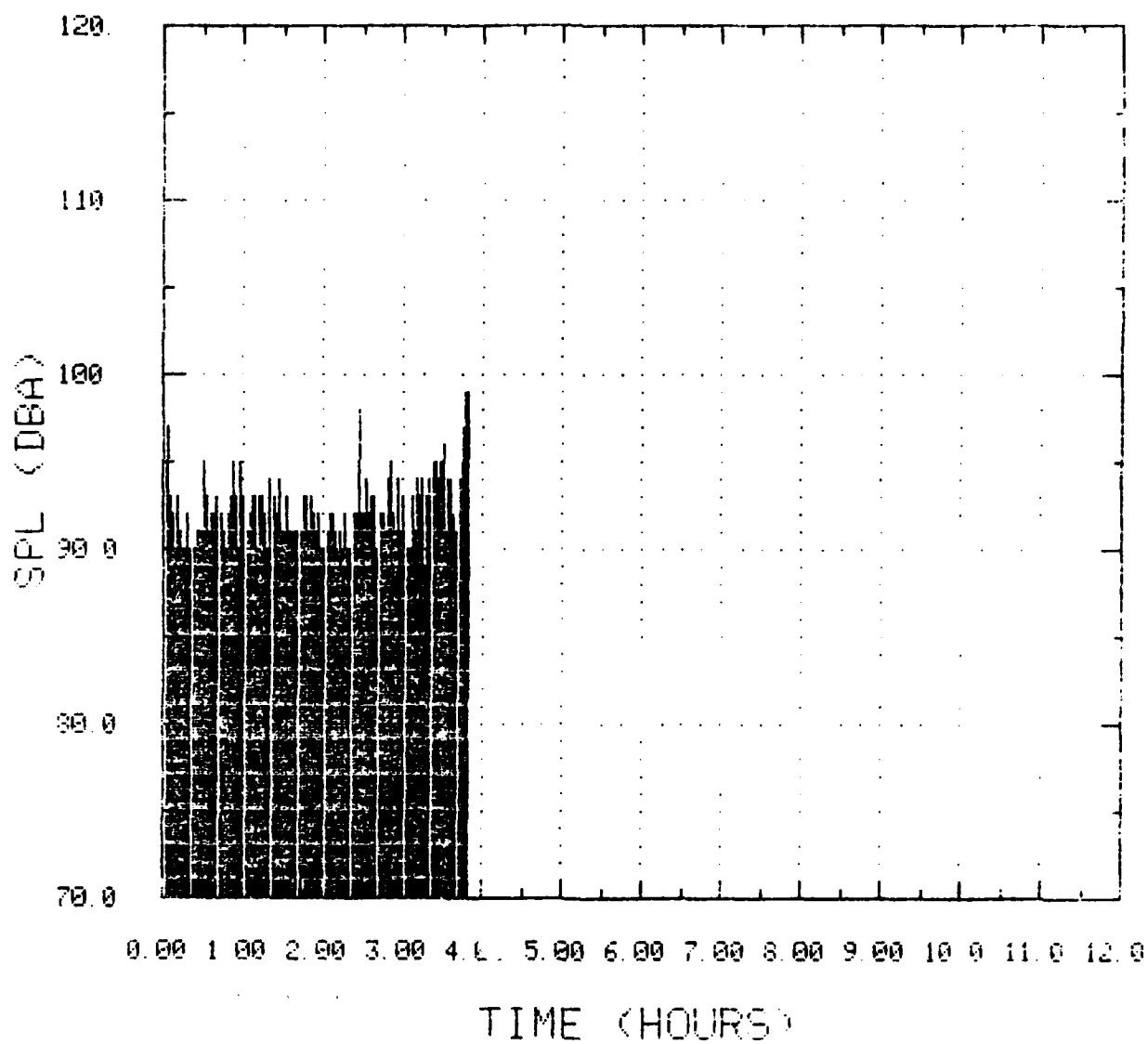


FIGURE B-31. NOISE DOSIMETRY ON FIREMAN  
(Taken during laden voyage)  
Sample No. TX-11A

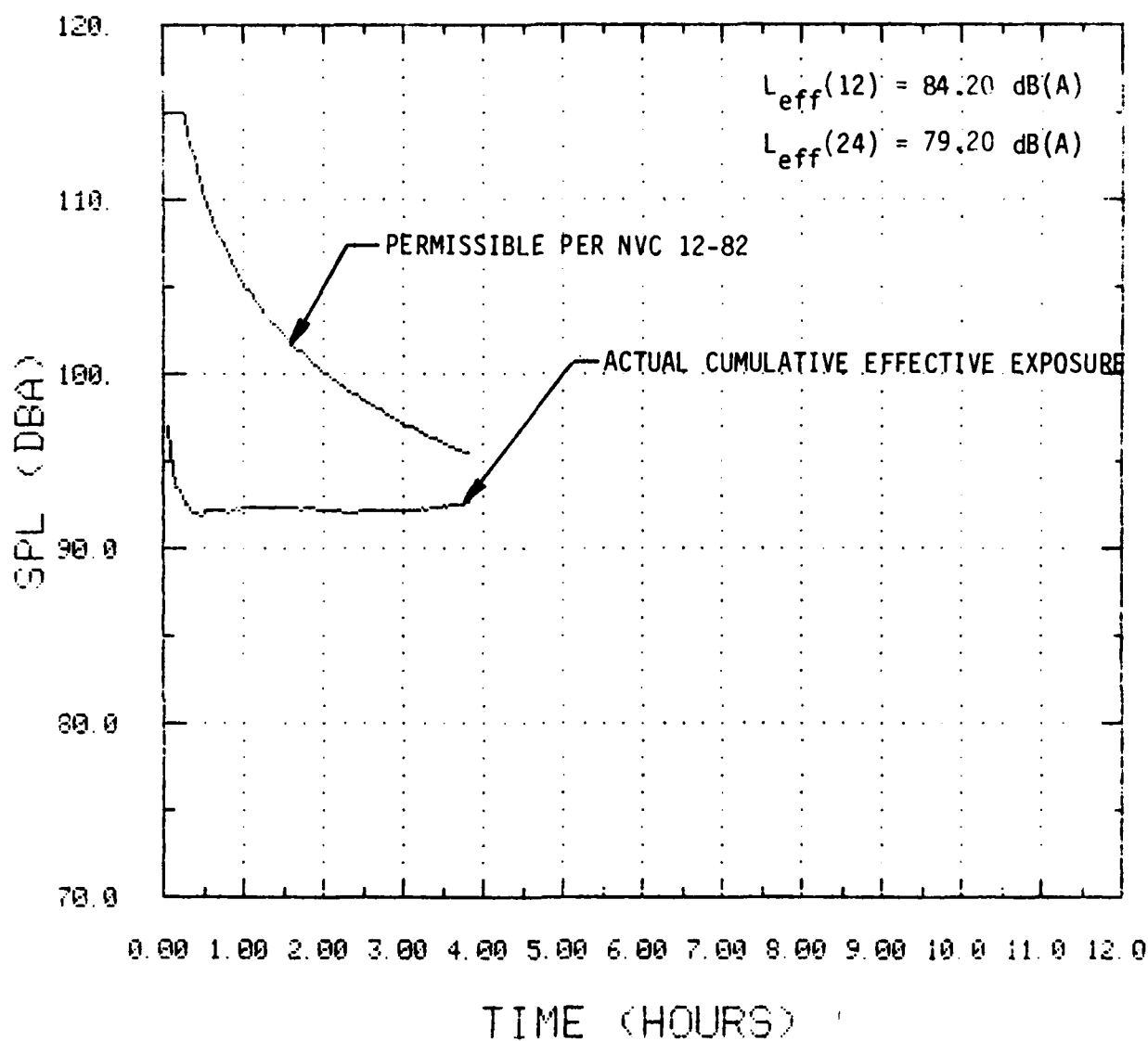


FIGURE B-32. CUMULATIVE EFFECTIVE EXPOSURE ON FIREMAN  
Sample No. TX-11A



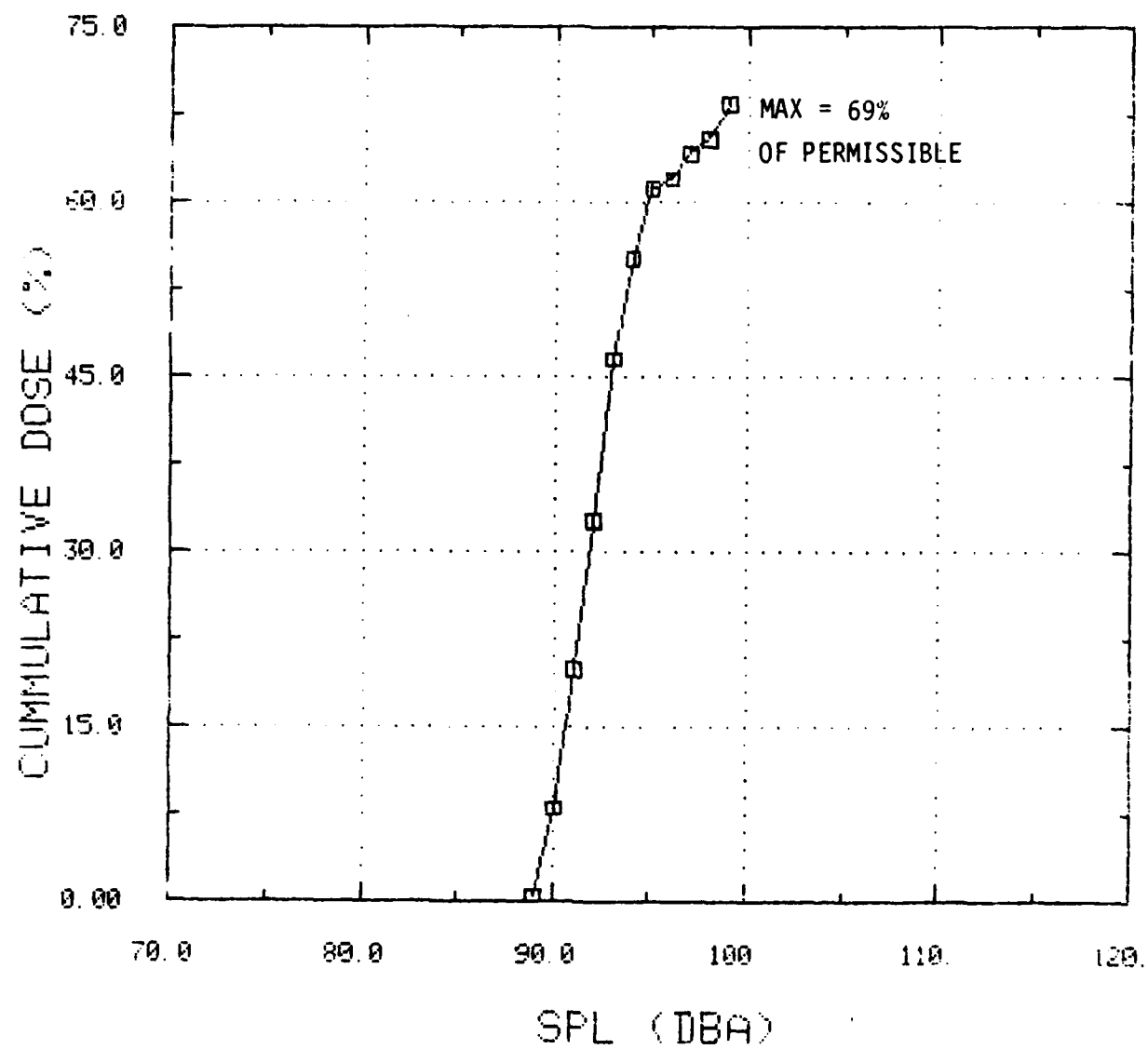


FIGURE B-33. CUMULATIVE DOSE RECORDED ON FIREMAN  
Sample No. TX-11A

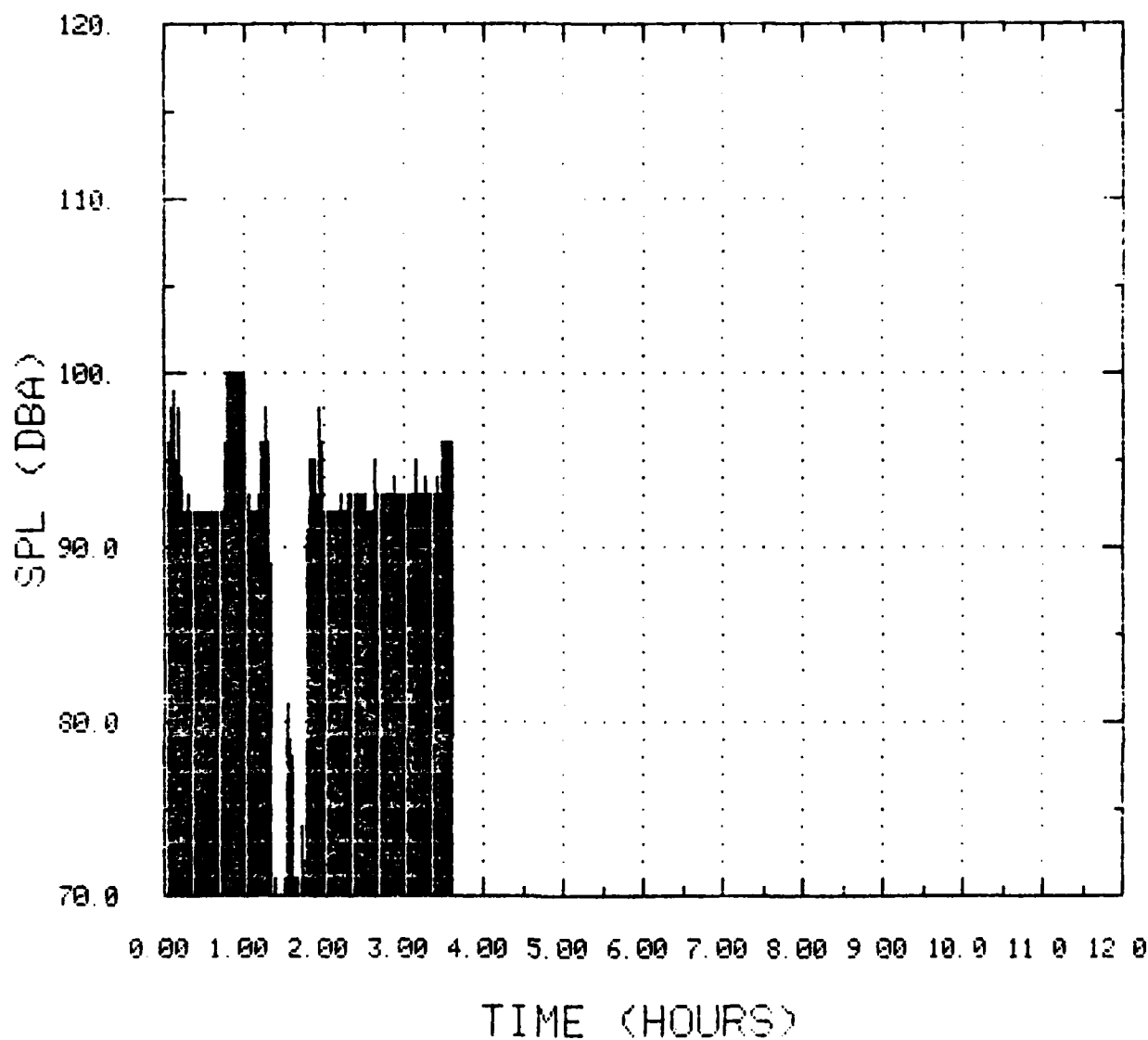


FIGURE B-34. NOISE DOSIMETRY ON FIREMAN  
(Taken during laden voyage)  
Sample No. TX-11B

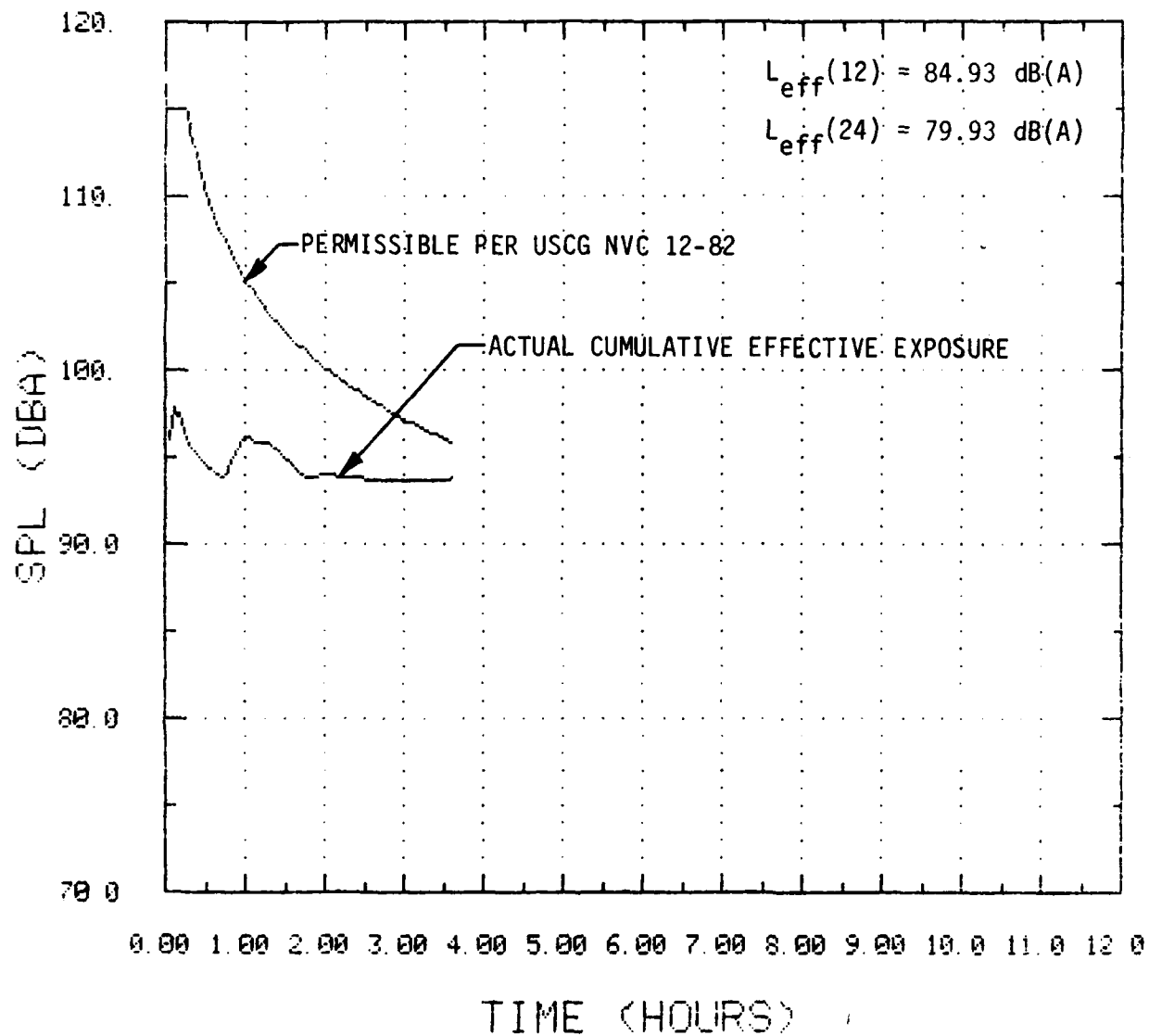


FIGURE B-35. CUMULATIVE EFFECTIVE EXPOSURE ON FIREMAN  
Sample No. TX-11B

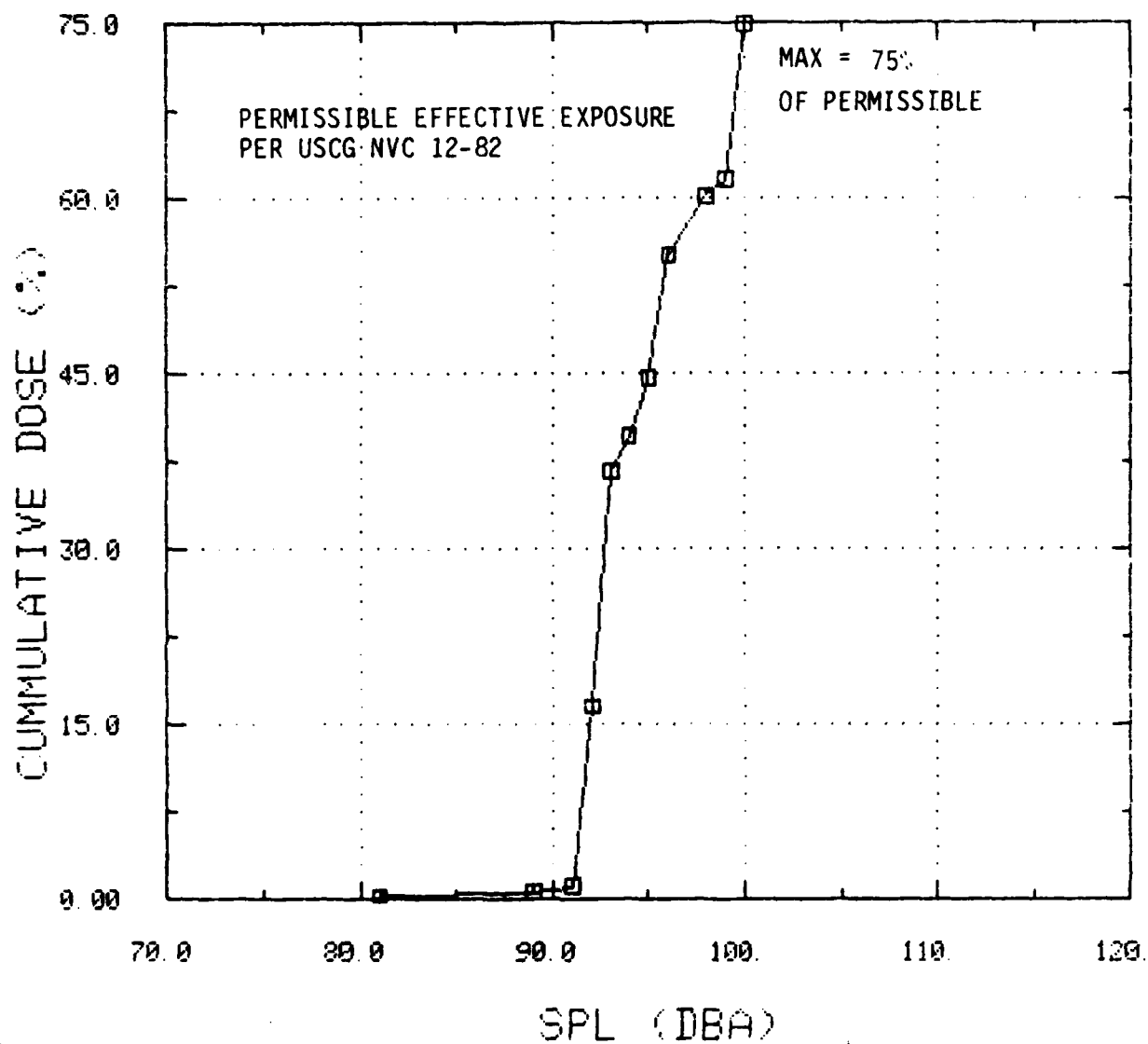


FIGURE B-36. CUMULATIVE DOSE RECORDED ON FIREMAN  
Sample No. TX-11B

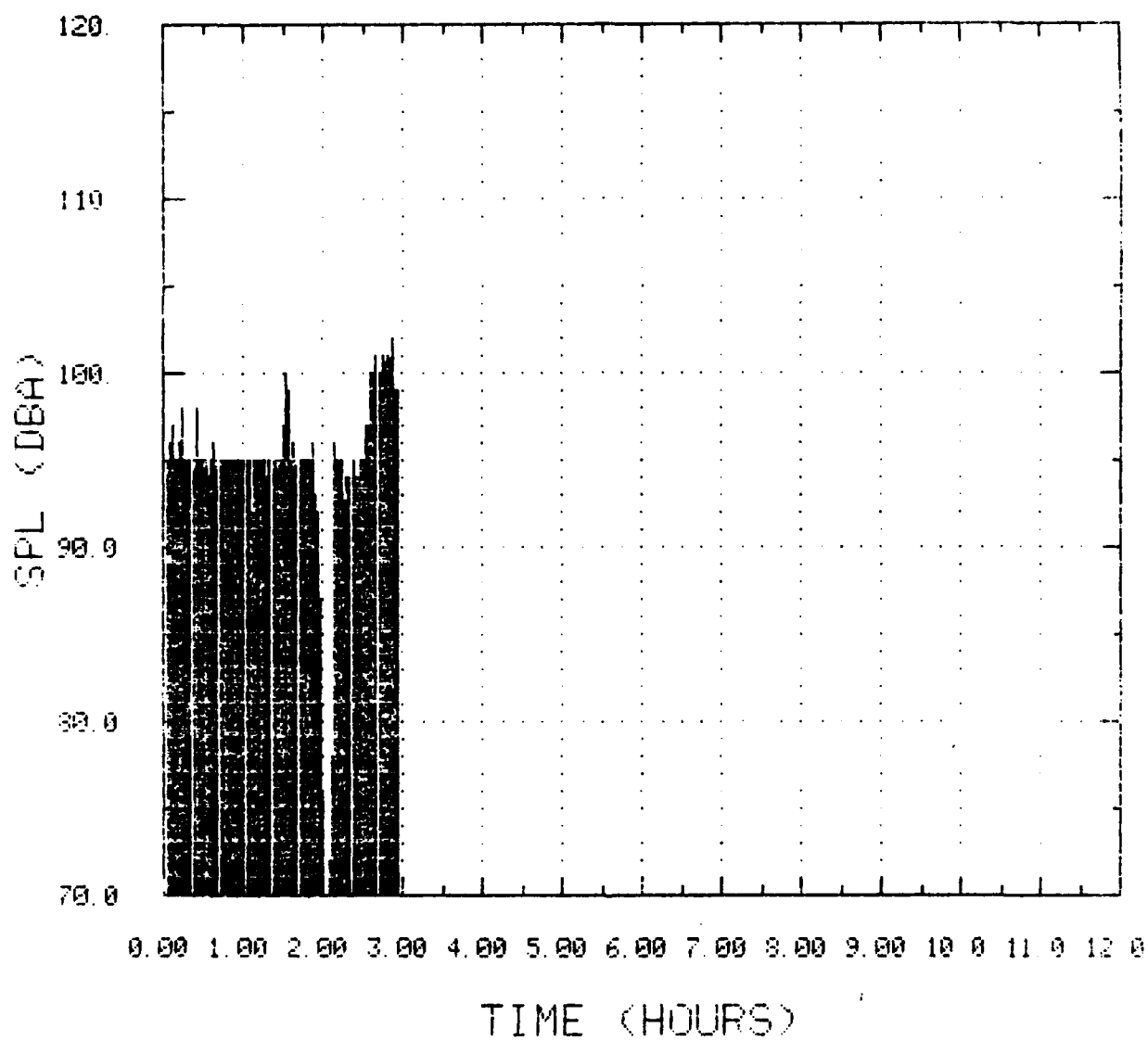


FIGURE B-37. NOISE DOSIMETRY ON OILER  
(Taken during laden voyage)  
Sample No. TX-12A

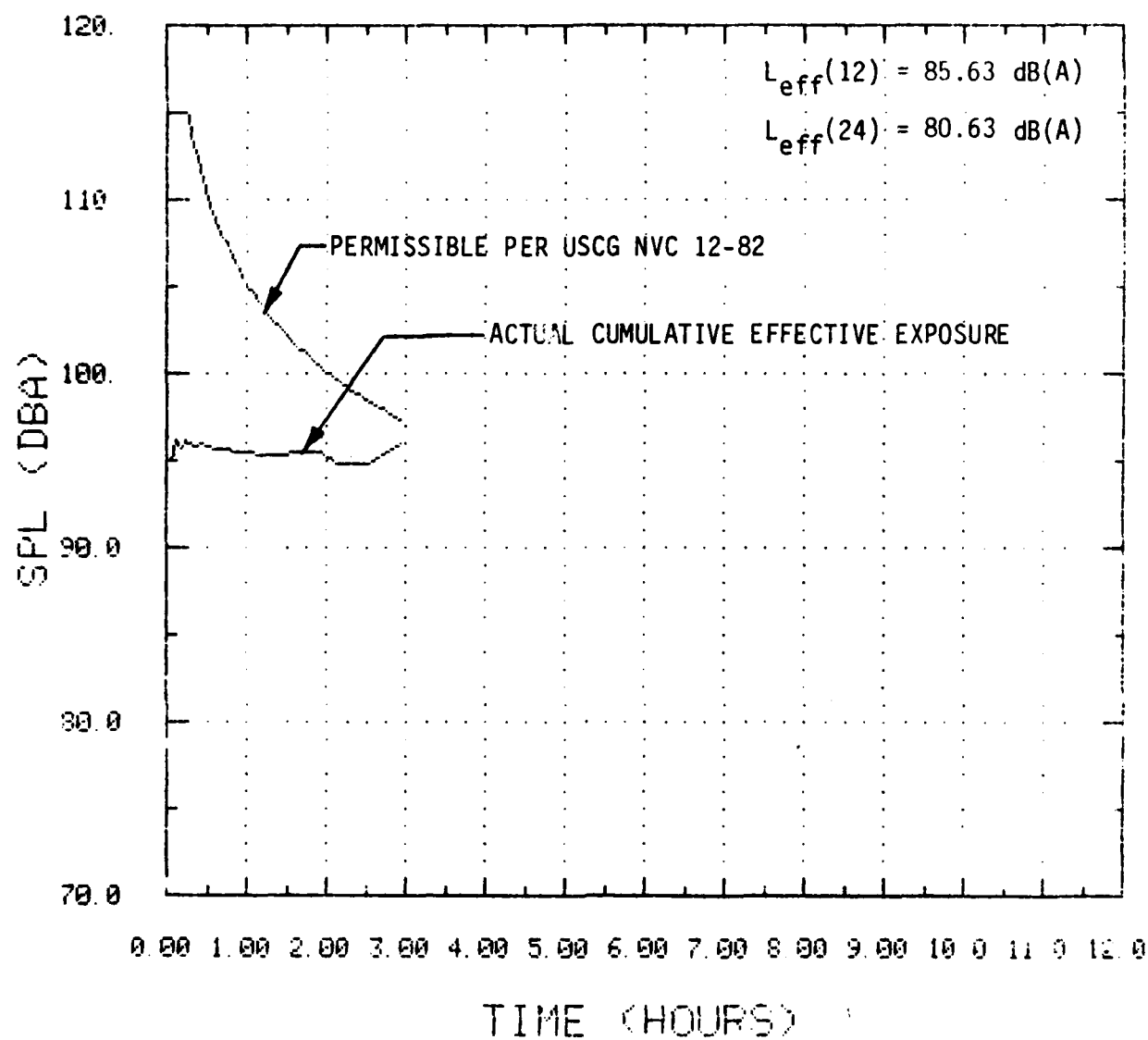


FIGURE B-38. CUMULATIVE EFFECTIVE EXPOSURE ON OILER  
Sample No. TX-12A

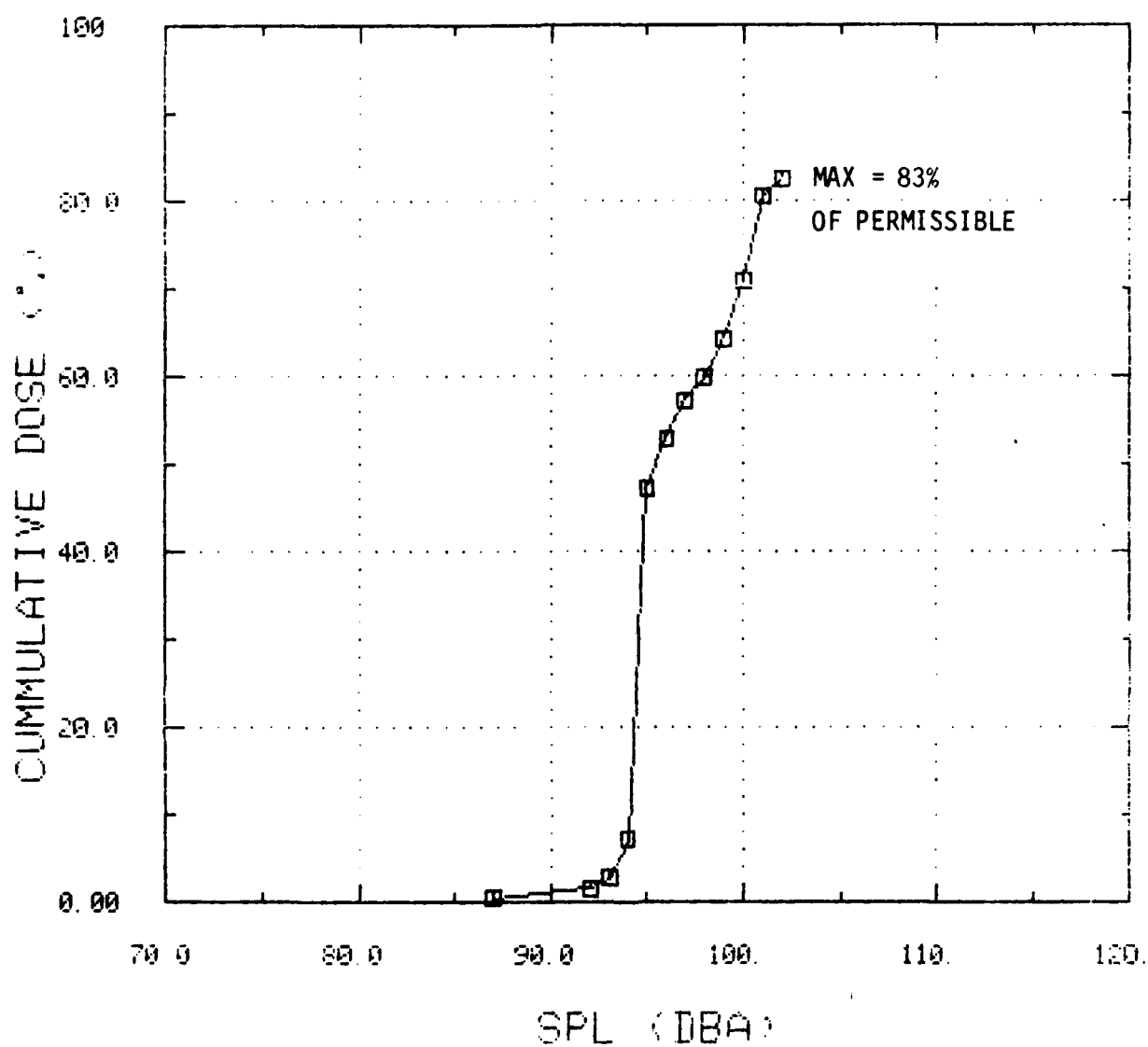


FIGURE B-39. CUMULATIVE DOSE RECORDED ON OILER  
Sample No. TX-12A

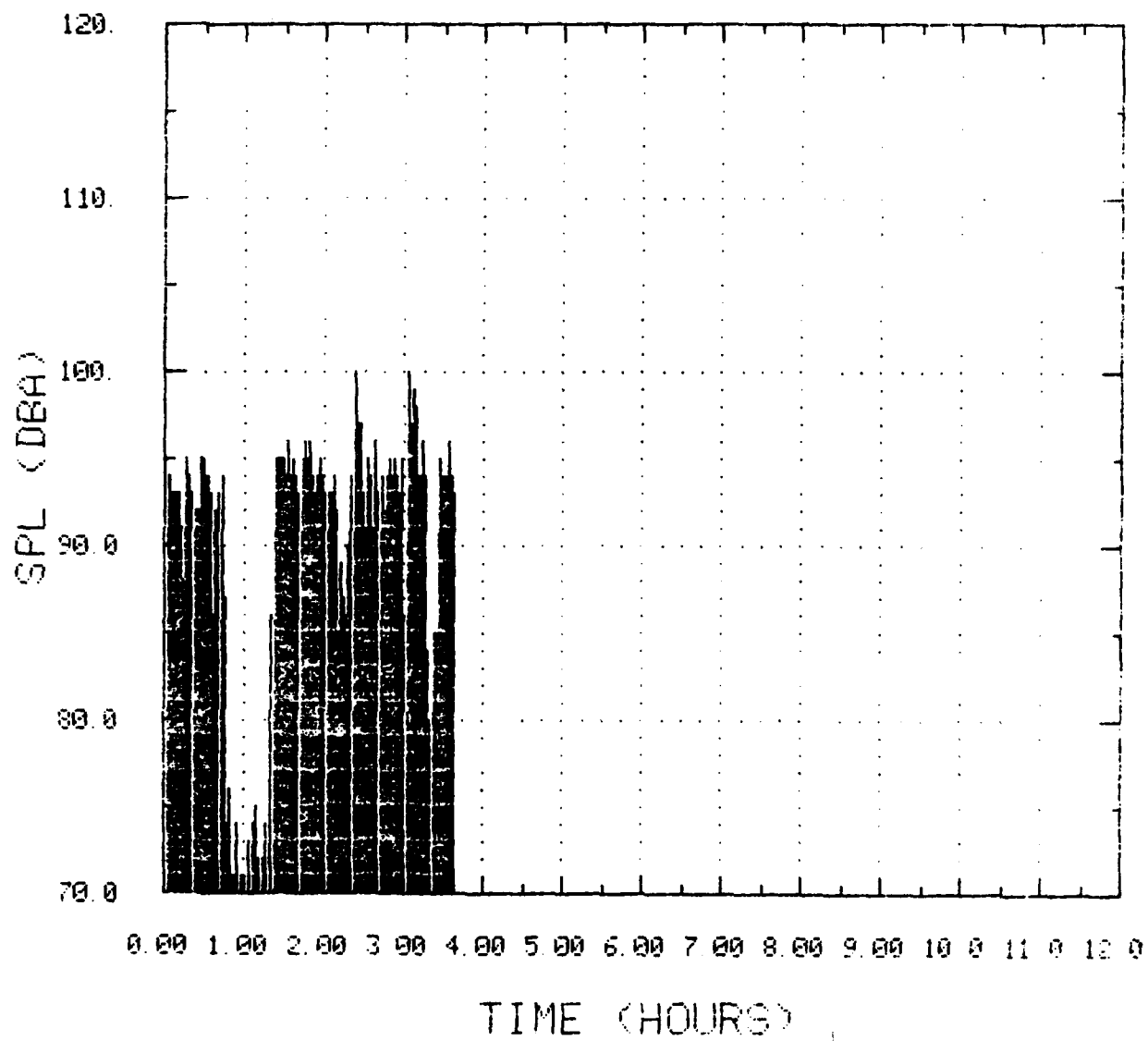


FIGURE B-40. NOISE DOSIMETRY ON OILER  
(Taken during laden voyage)  
Sample No. TX-12B



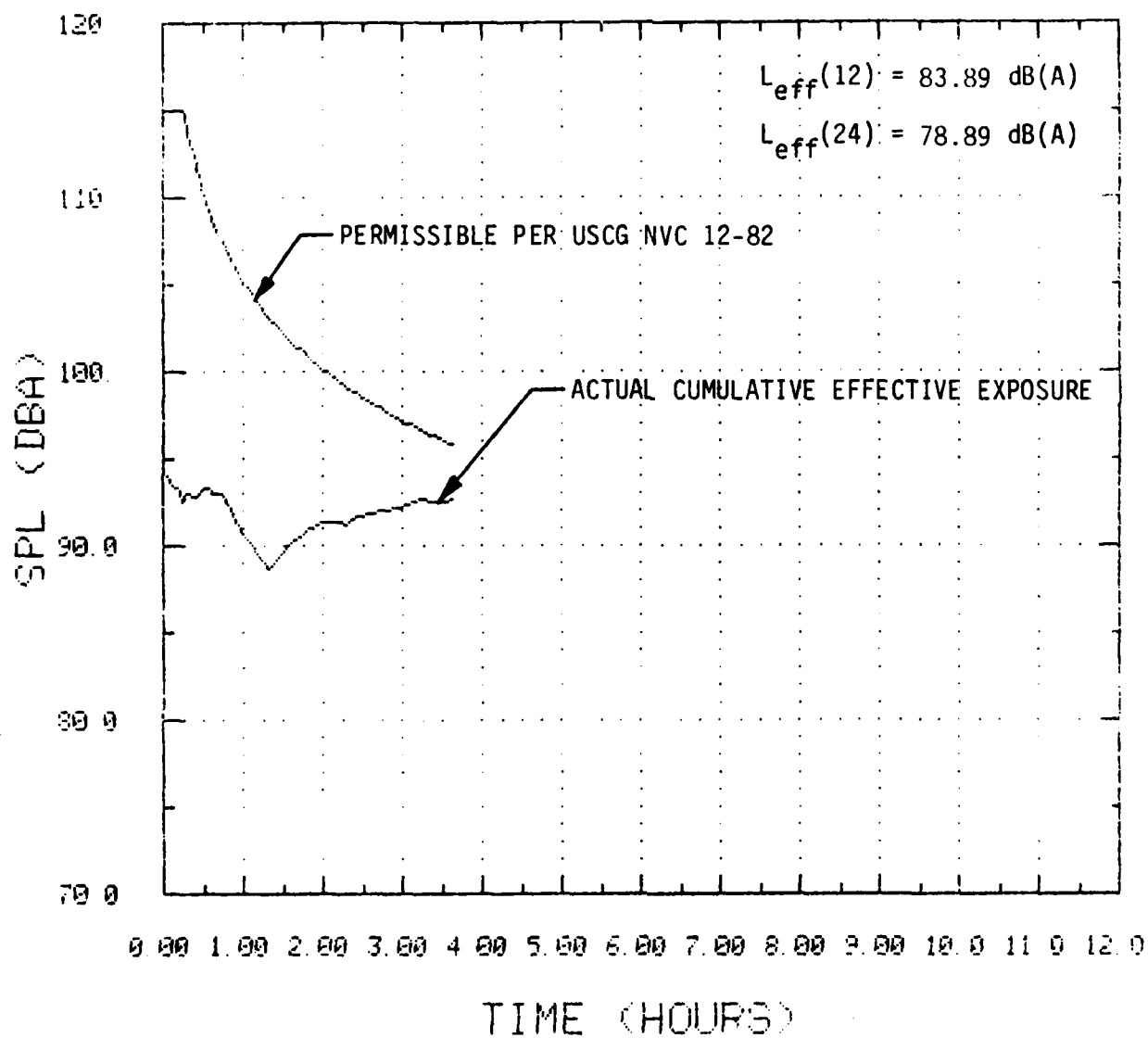


FIGURE B-41. CUMULATIVE EFFECTIVE EXPOSURE ON OILER  
Sample No. TX-12B

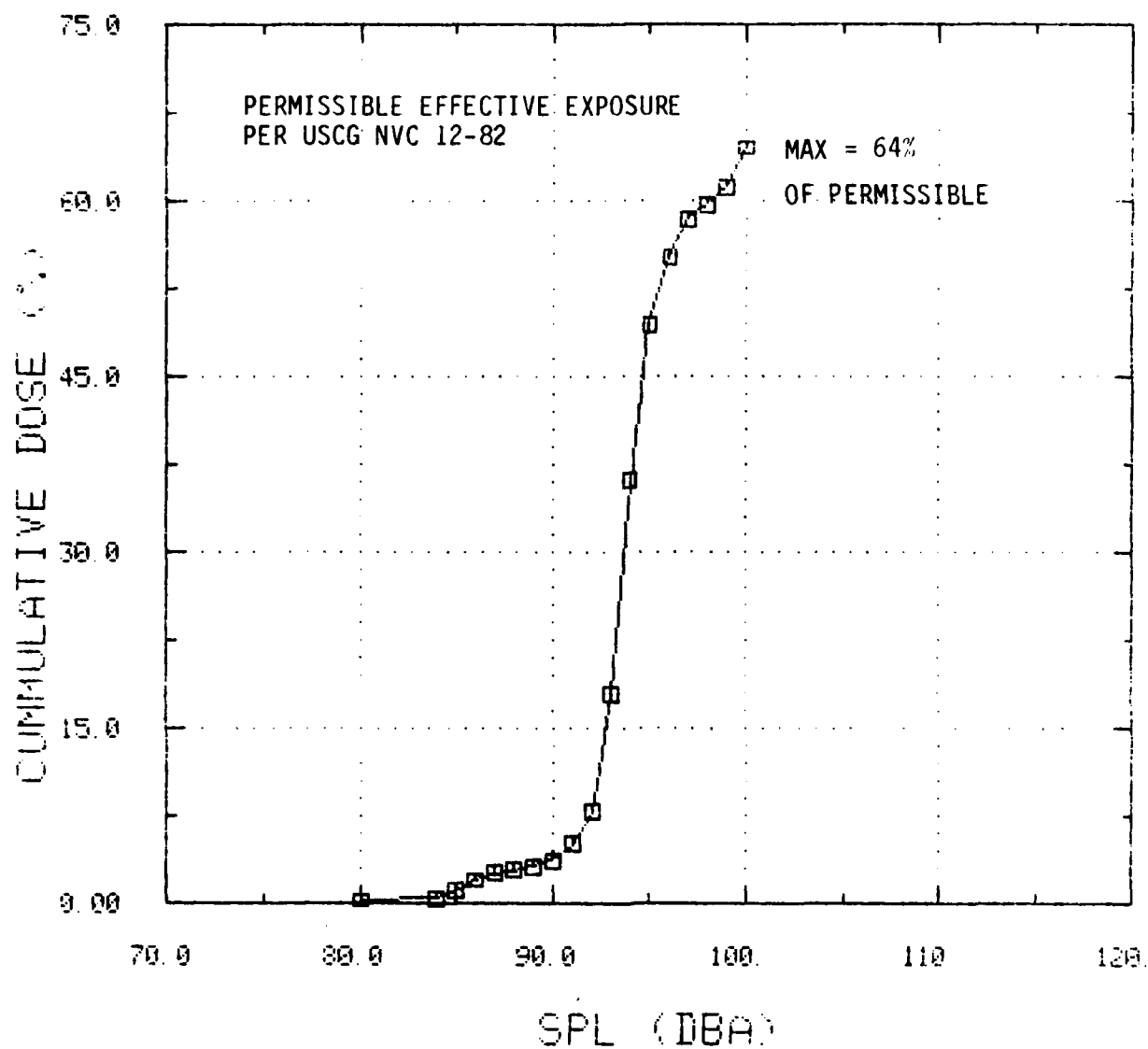


FIGURE B-42. CUMULATIVE DOSE RECORDED ON OILER  
Sample No. TX-12B

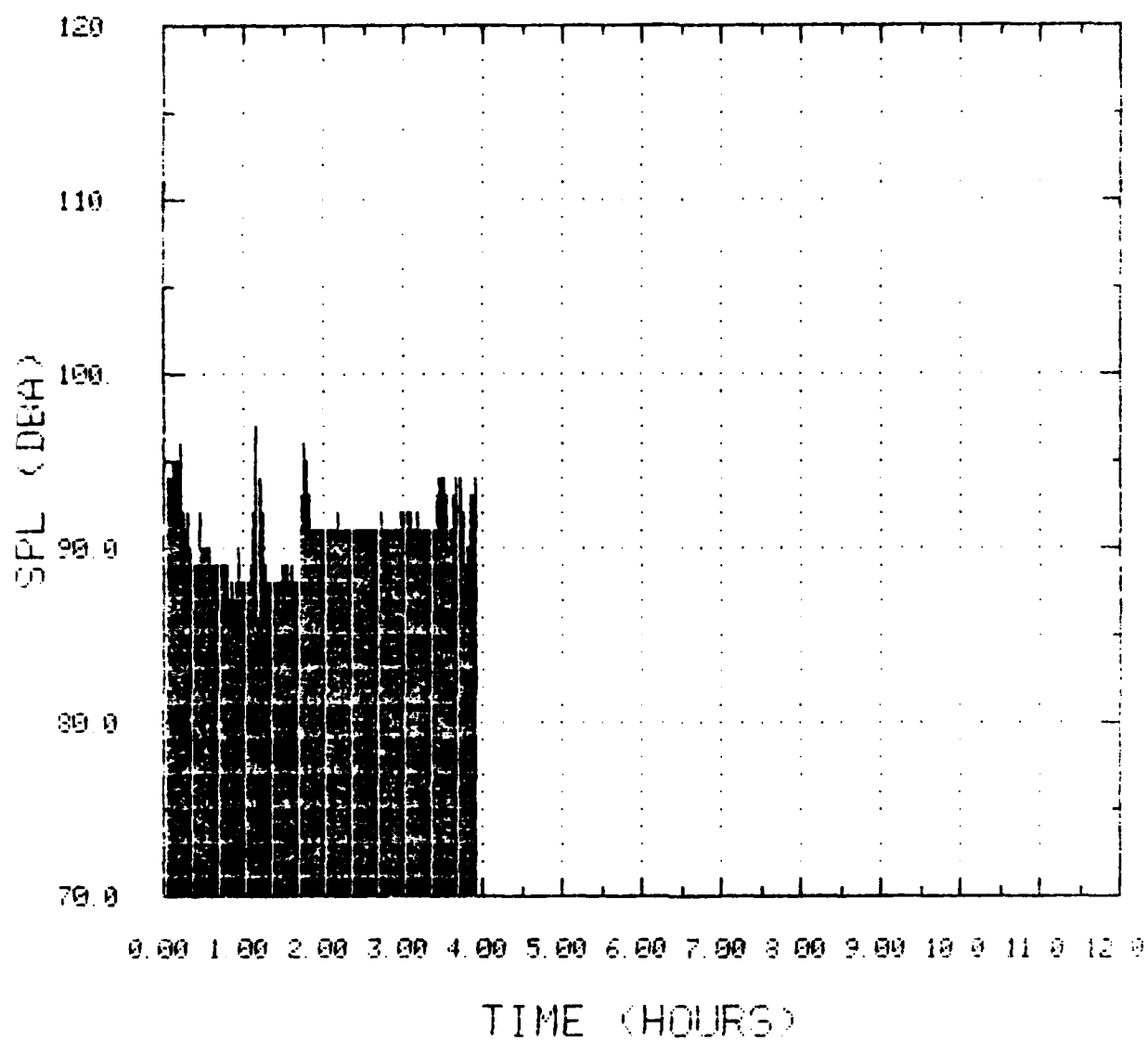


FIGURE B-43. NOISE DOSIMETRY ON ASSISTANT ENGINEER  
(Taken during laden voyage)  
Sample No. TX-13A

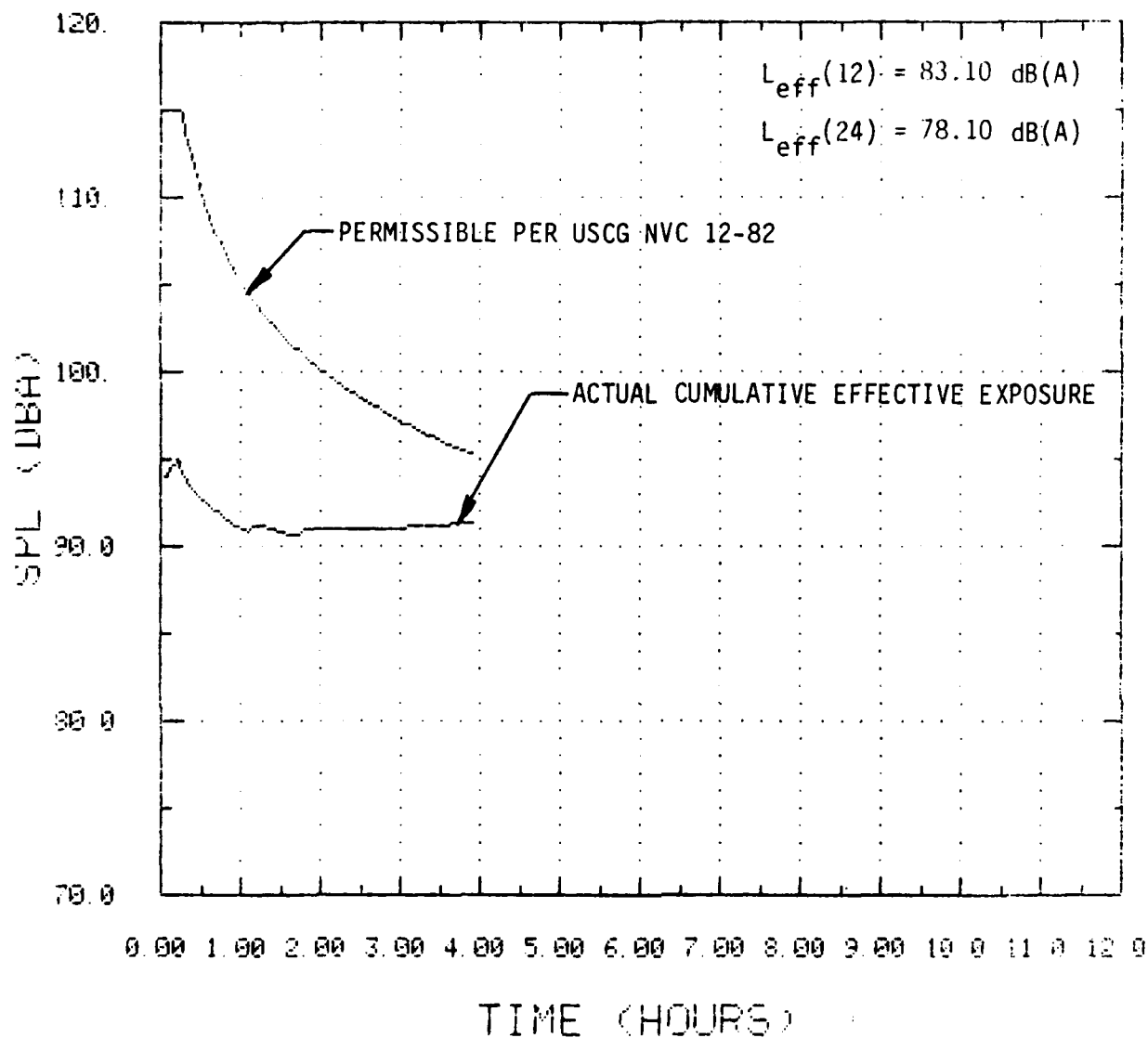


FIGURE B-44. CUMULATIVE EFFECTIVE EXPOSURE ON ASSISTANT ENGINEER  
Sample No. TX-13A

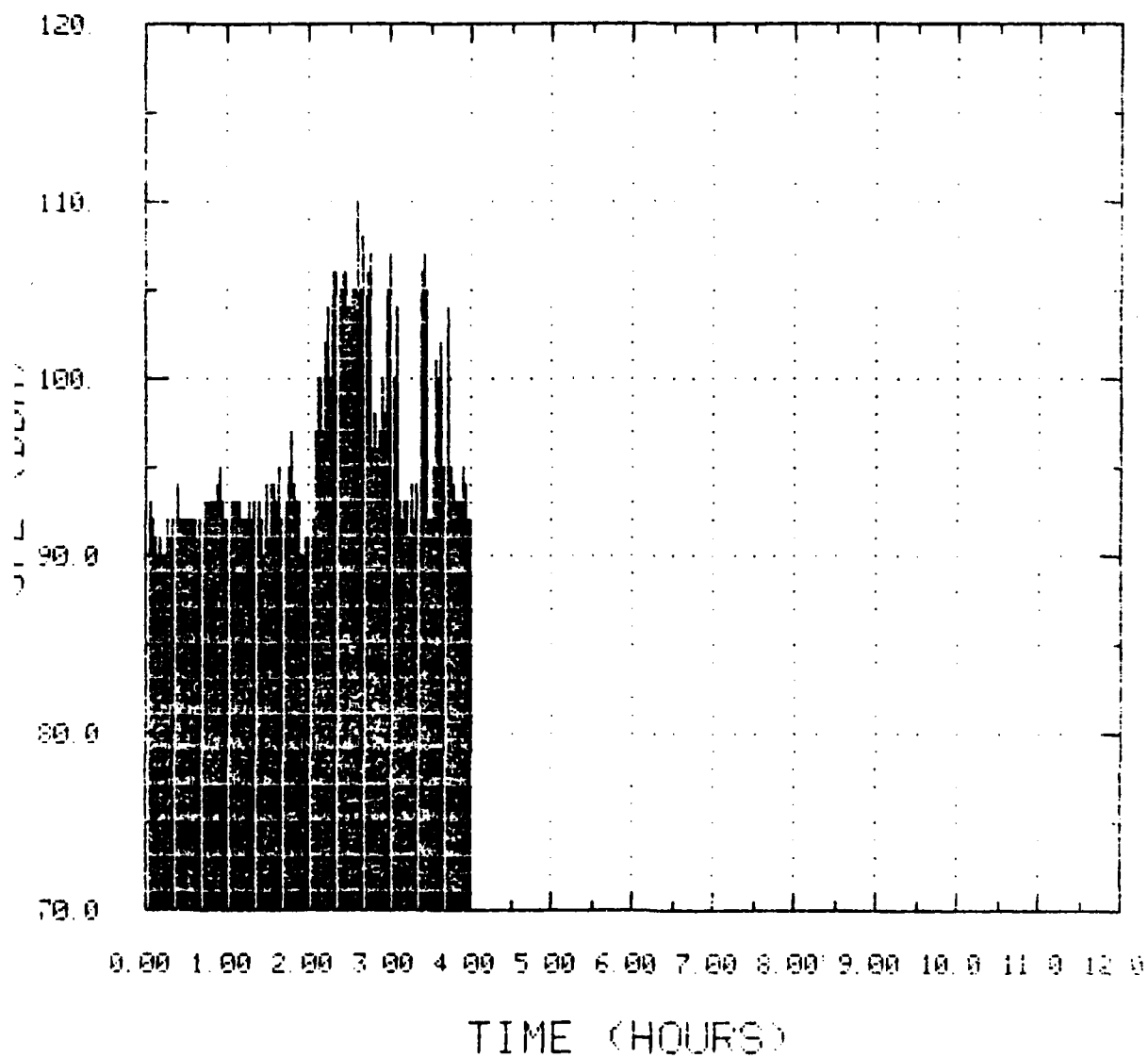


FIGURE B-58. NOISE DOSIMETRY ON ASSISTANT ENGINEER  
(Taken during laden voyage)  
Sample No. TX-15B

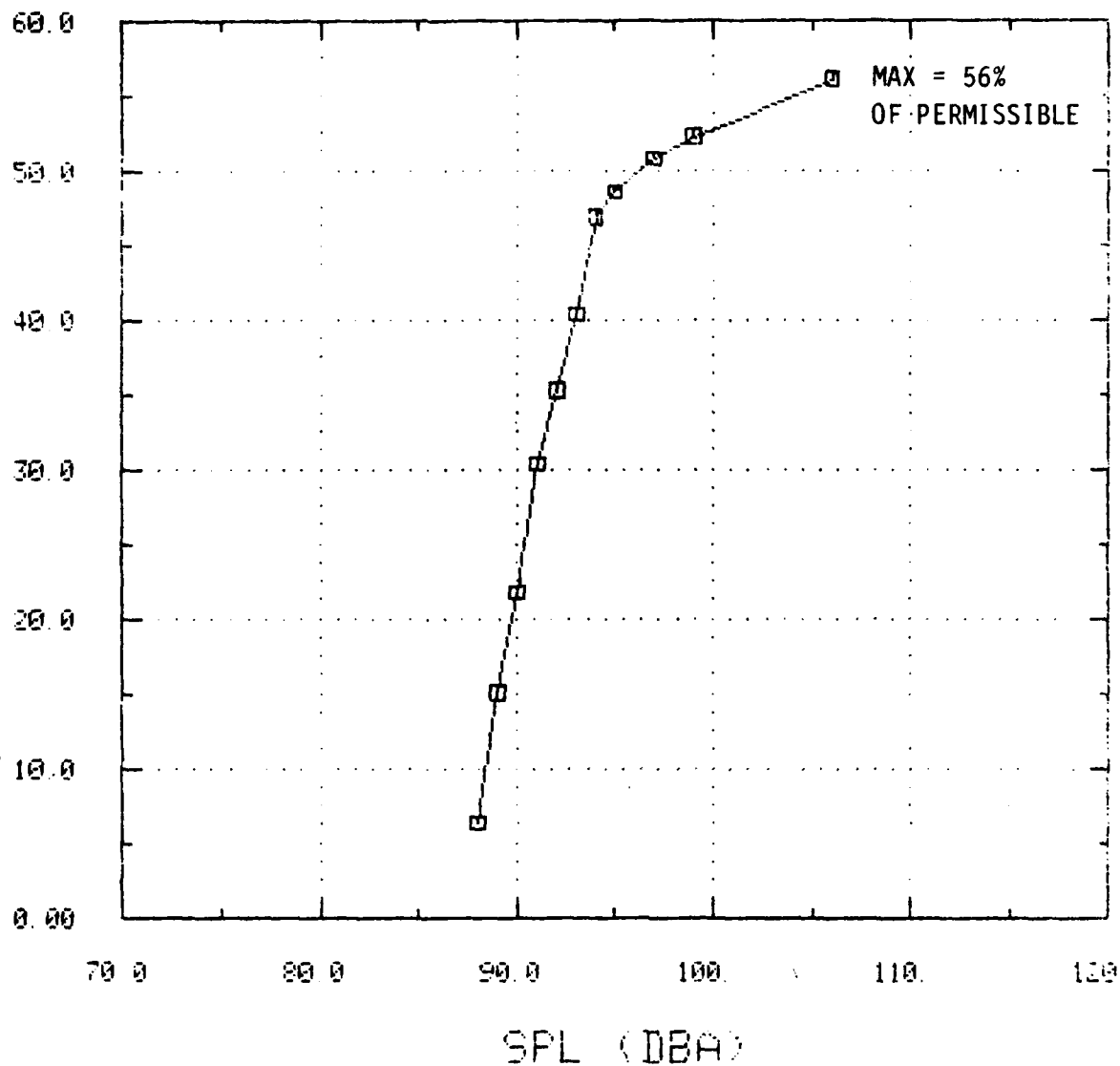


FIGURE B-57. CUMULATIVE DOSE RECORDED ON FIREMAN  
Sample No. TX-15A

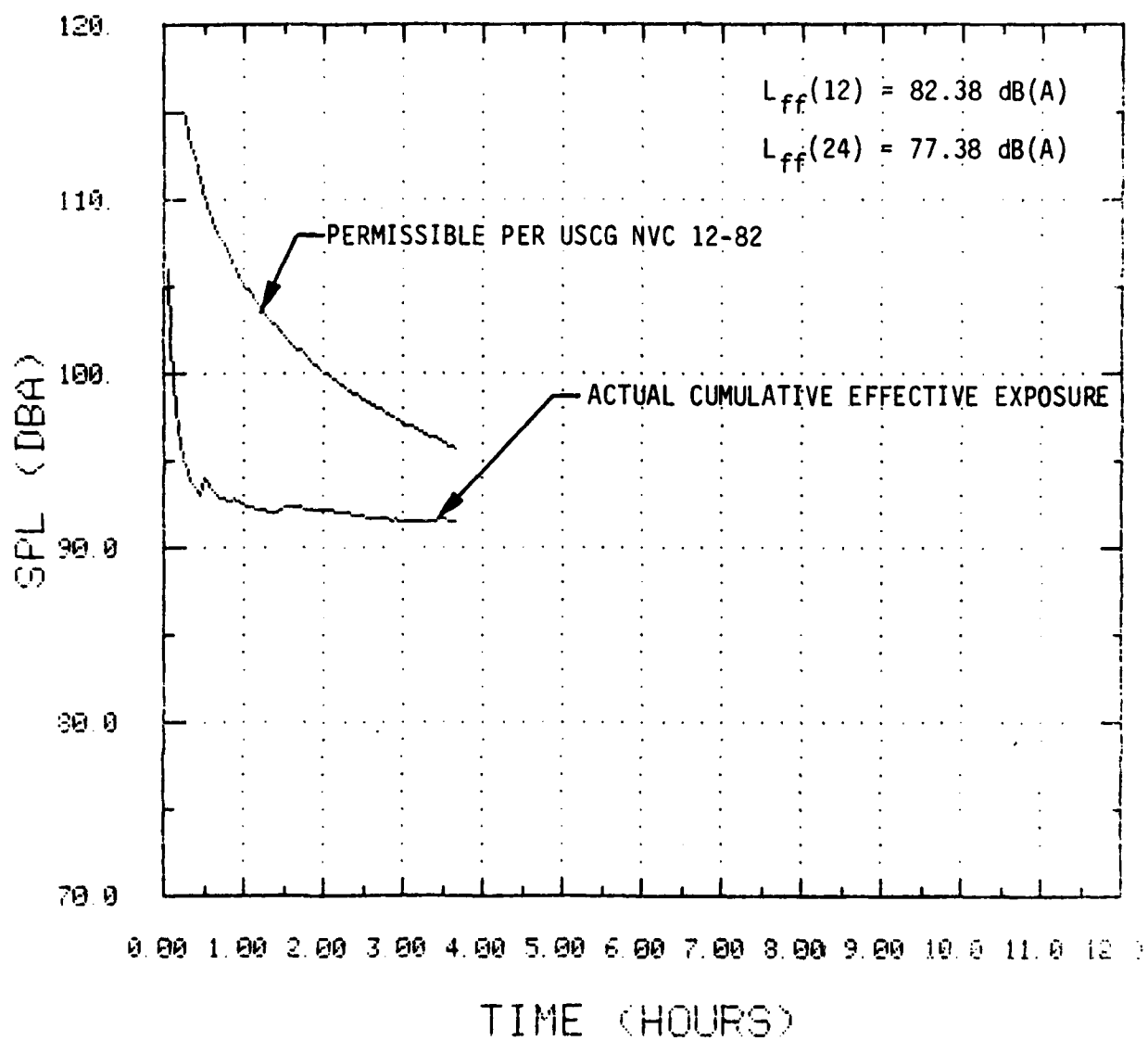


FIGURE B-56. CUMULATIVE EFFECTIVE EXPOSURE ON FIREMAN  
Sample No. TX-15A

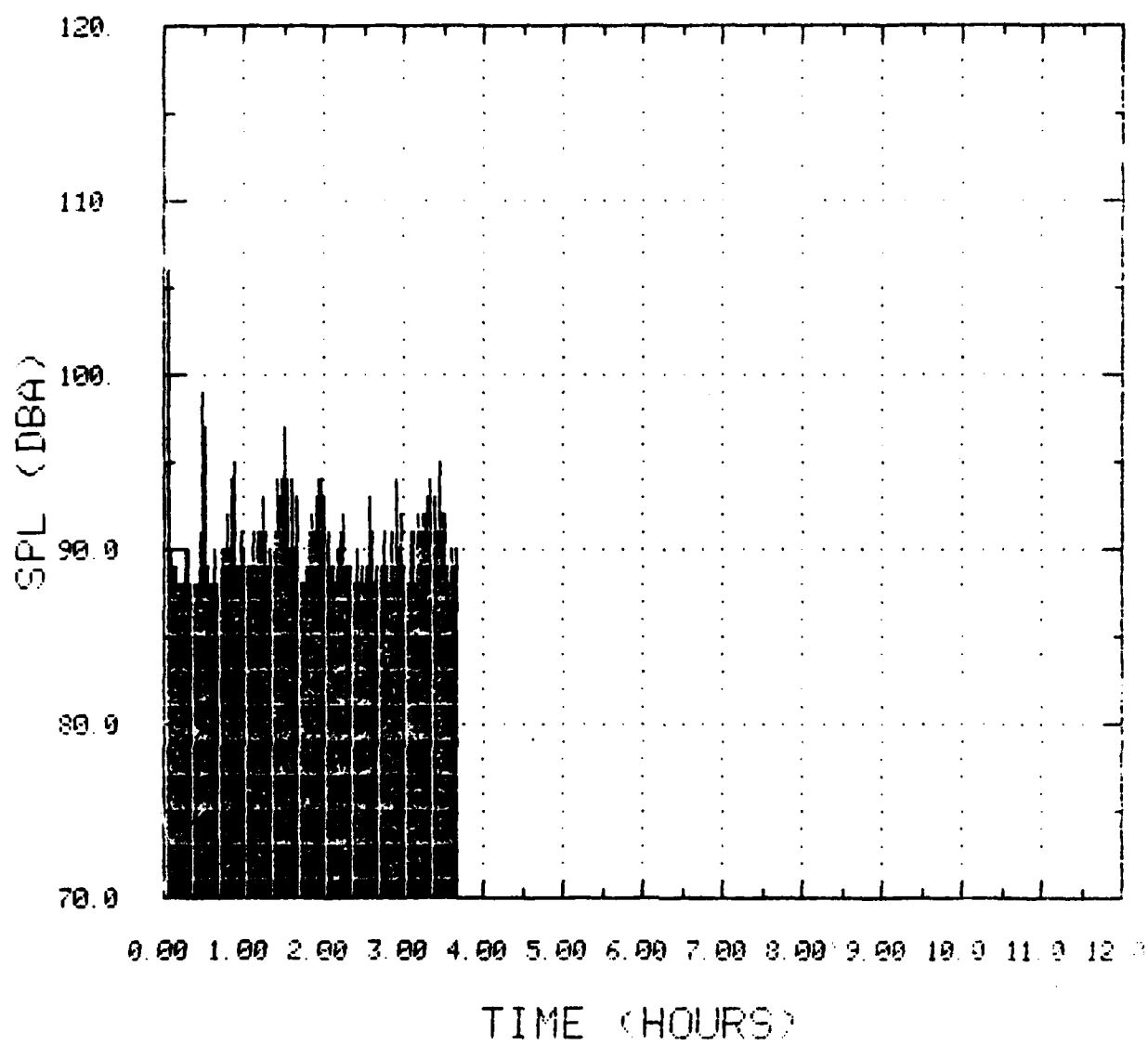


FIGURE B-55. NOISE DOSIMETRY ON FIREMAN  
(Taken during laden voyage)  
Sample No. TX-15A



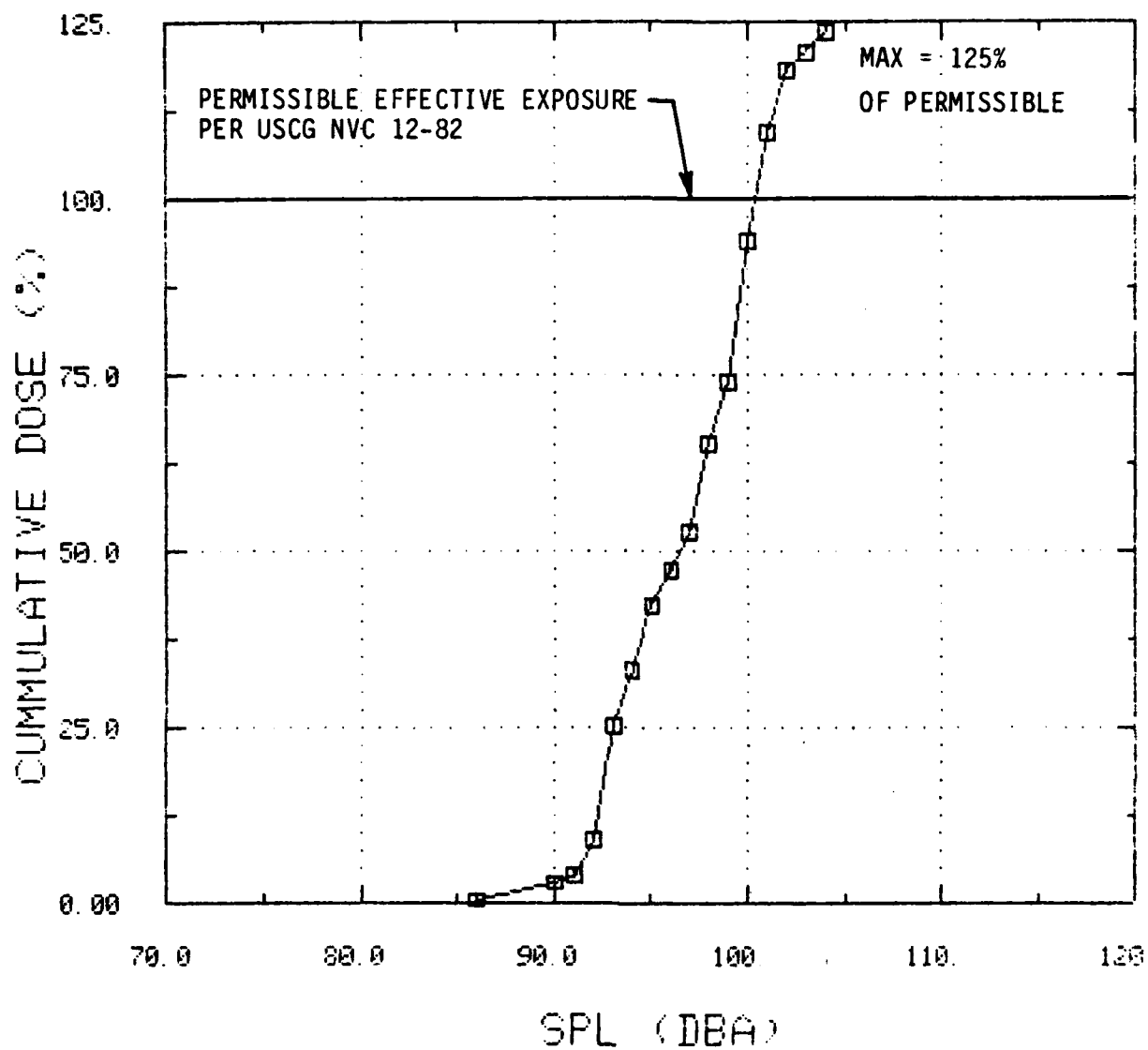


FIGURE B-54. CUMULATIVE DOSE RECORDED ON OILER  
Sample No. TX-148

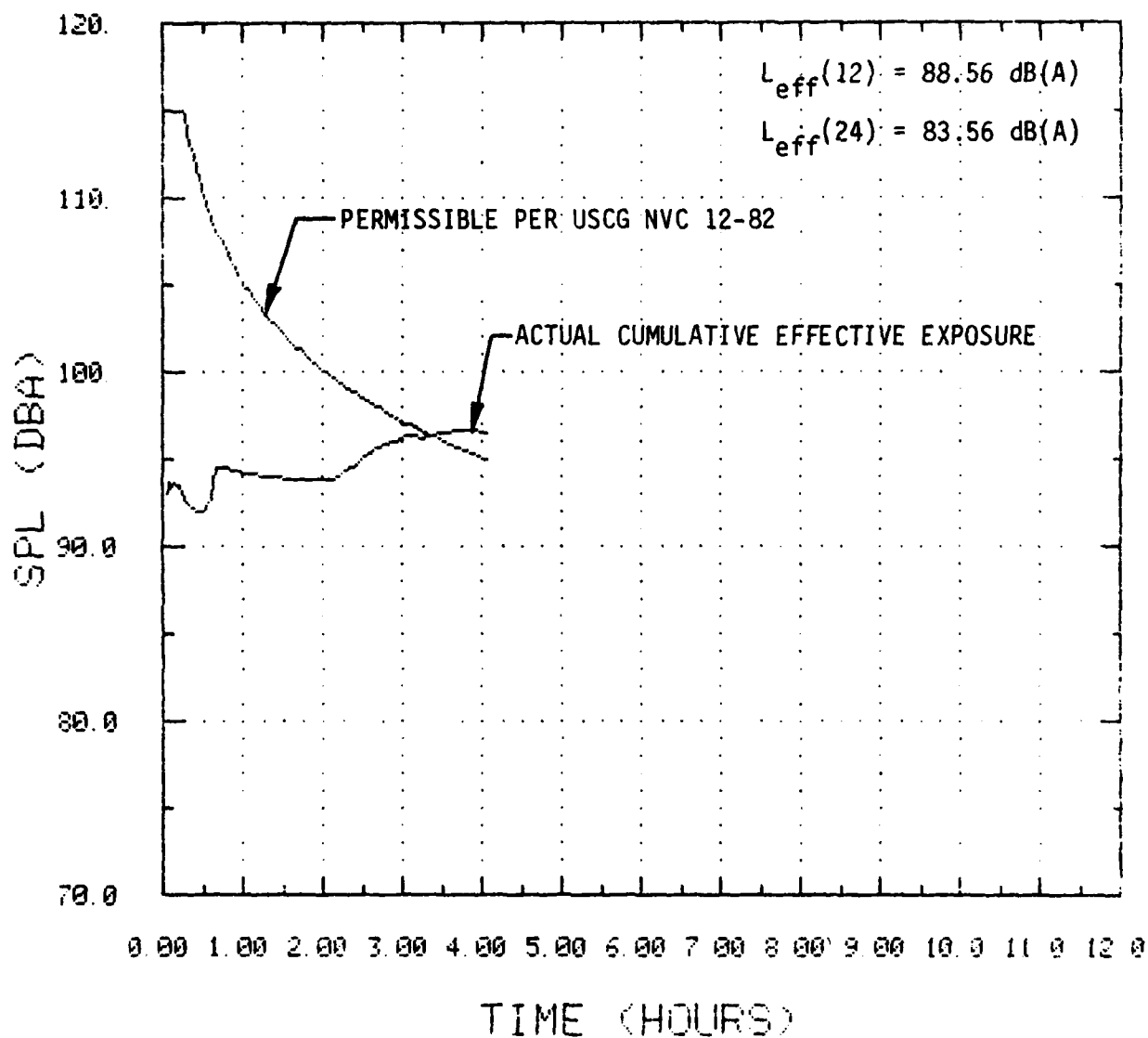


FIGURE B-53. CUMULATIVE EFFECTIVE EXPOSURE ON OILER  
Sample No. TX-14B

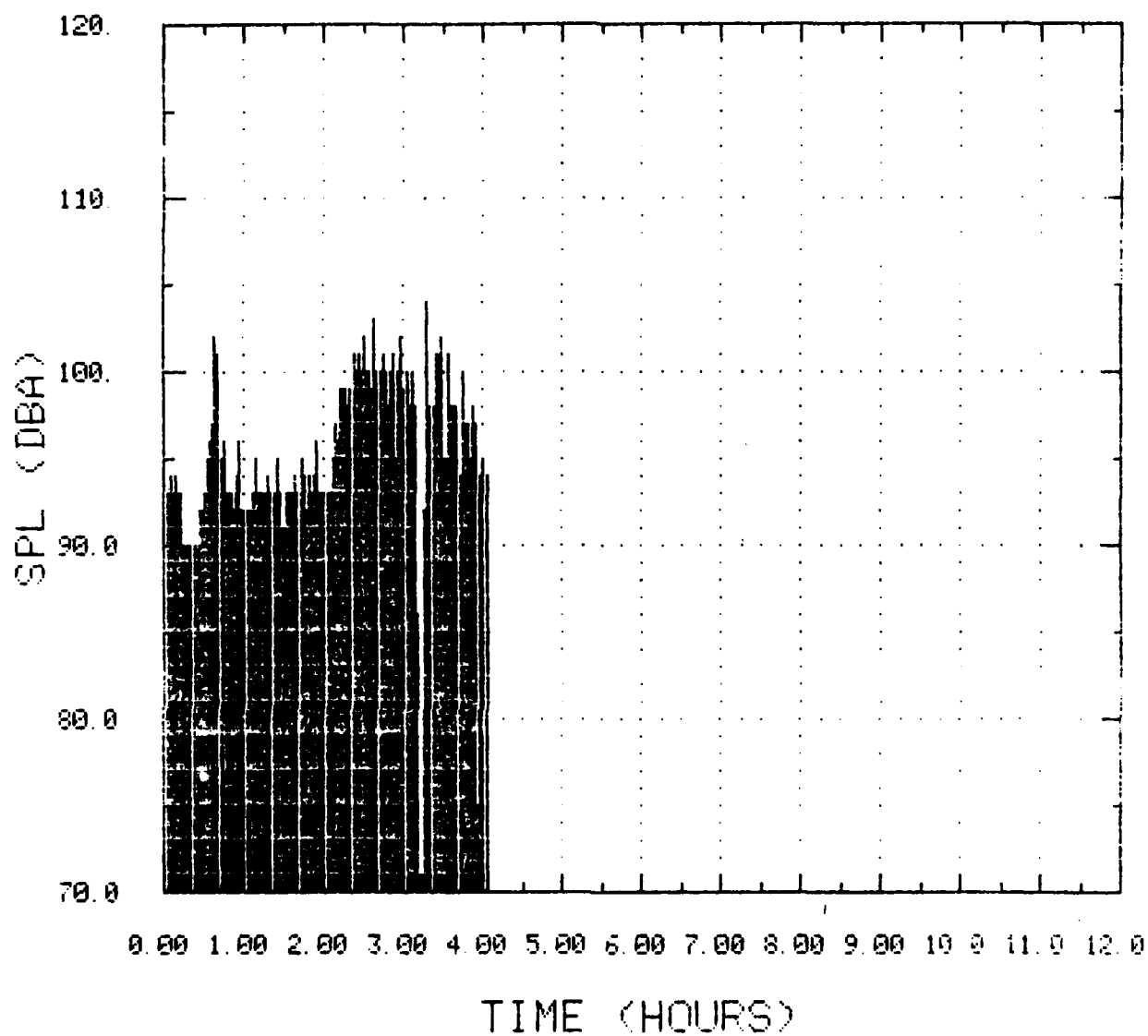


FIGURE B-52. NOISE DOSIMETRY ON OILER  
(Taken during laden voyage)  
Sample No. TX-14B

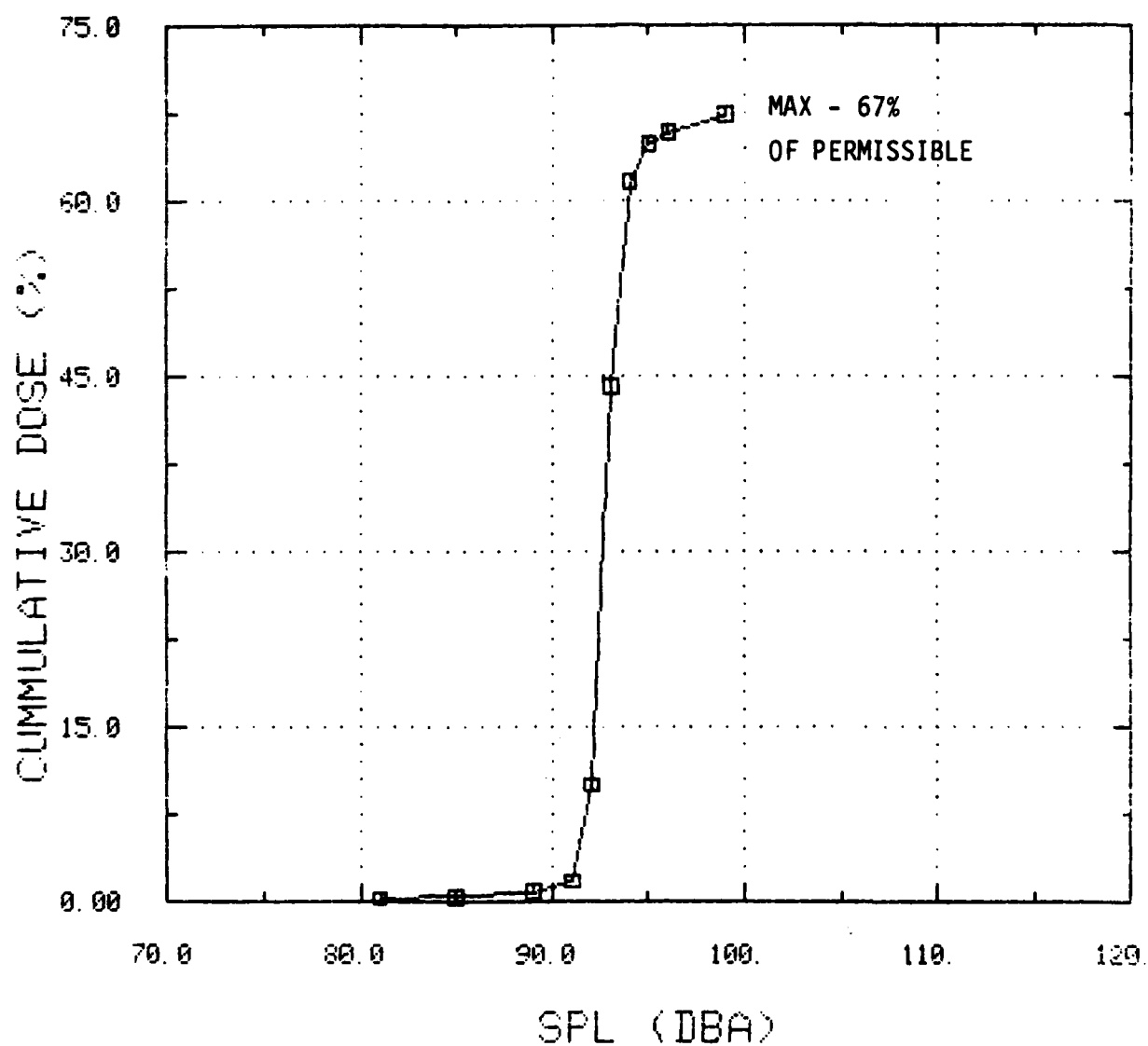


FIGURE B-51. CUMULATIVE DOSE RECORDED ON OILER  
Sample No. TX-14A

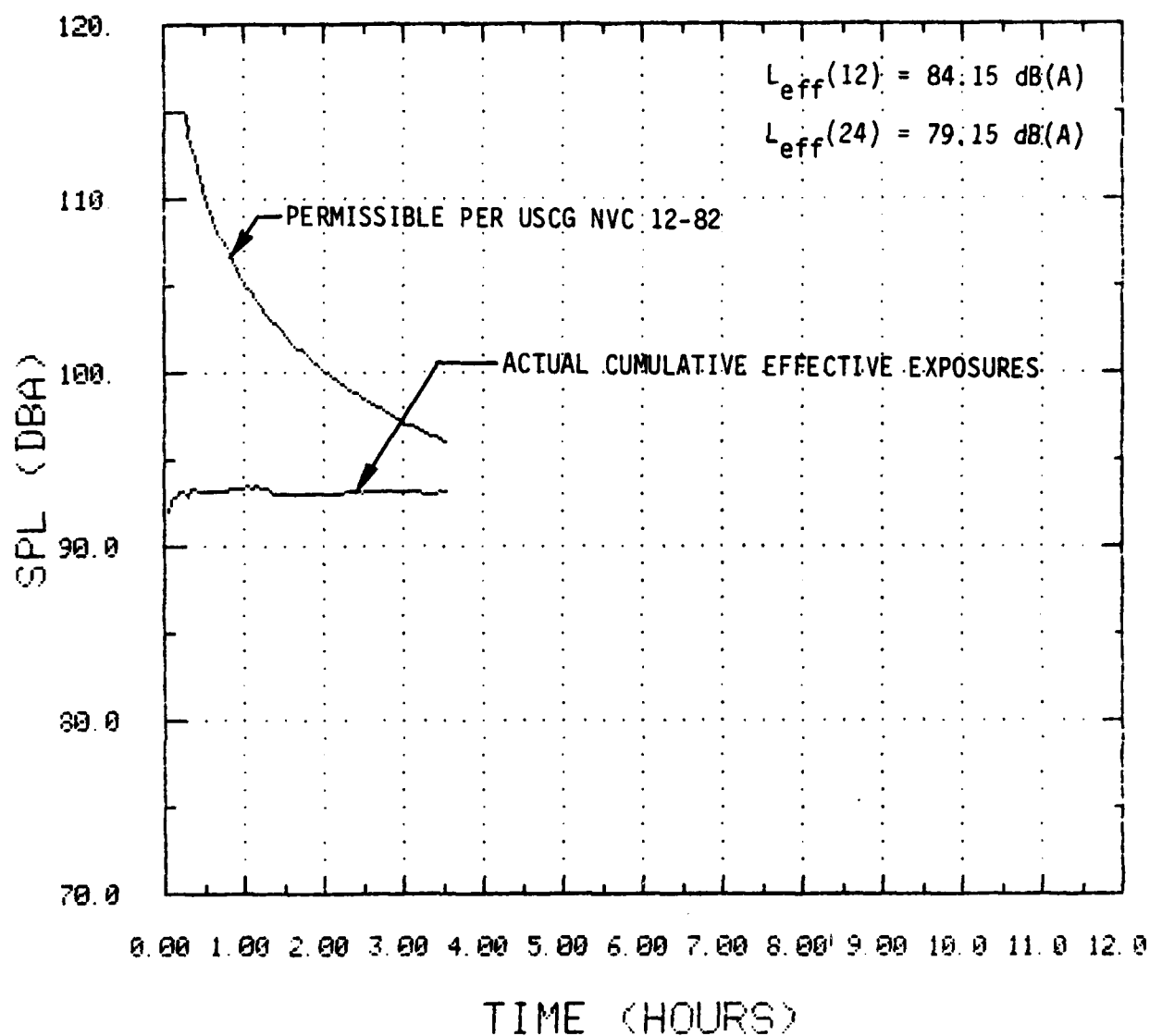


FIGURE B-50. CUMULATIVE EFFECTIVE EXPOSURE ON OILER  
Sample No. TX-14A

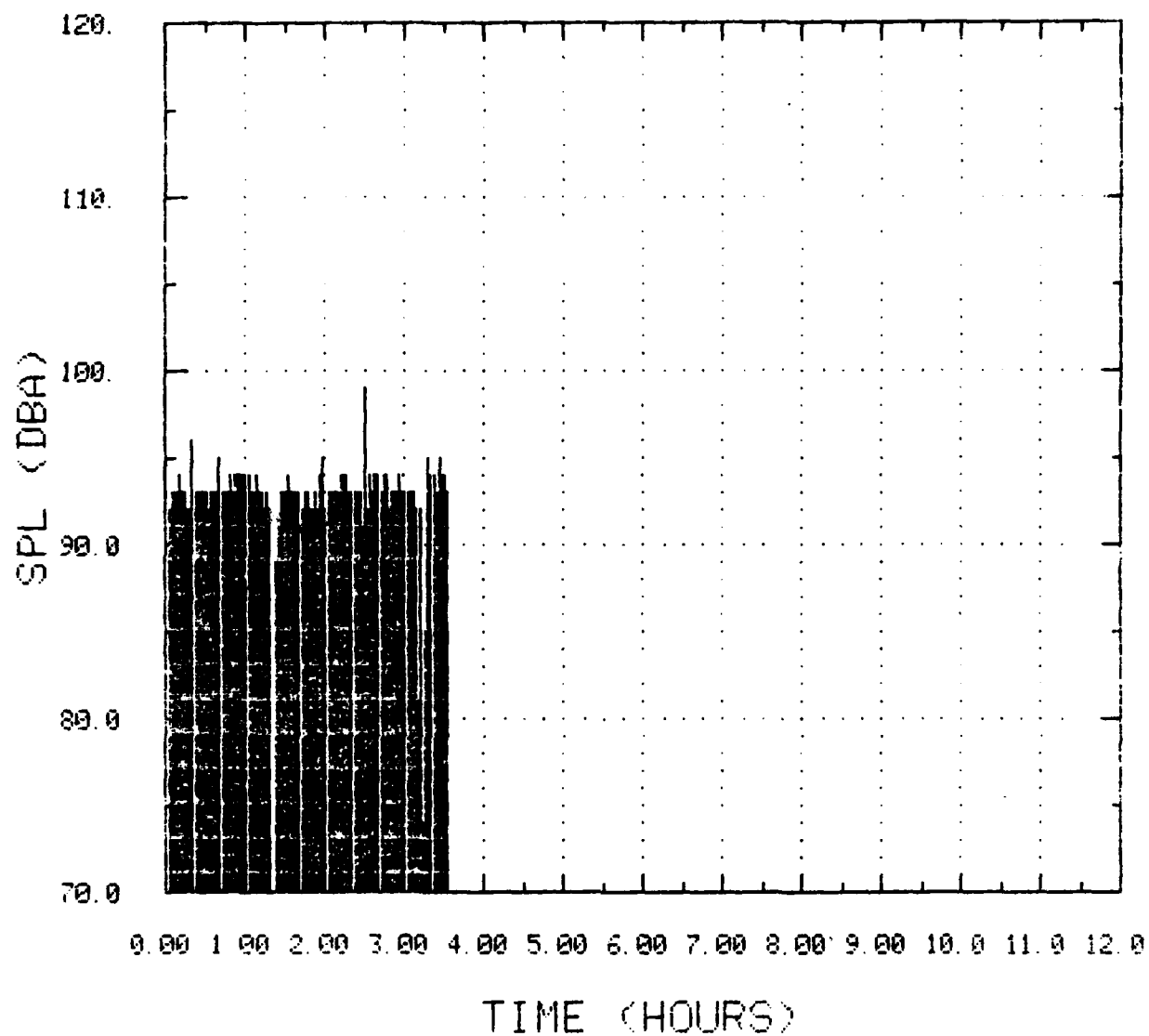


FIGURE B-49. NOISE DOSIMETRY ON OILER  
(Taken during laden voyage)  
Sample No. TX-14A

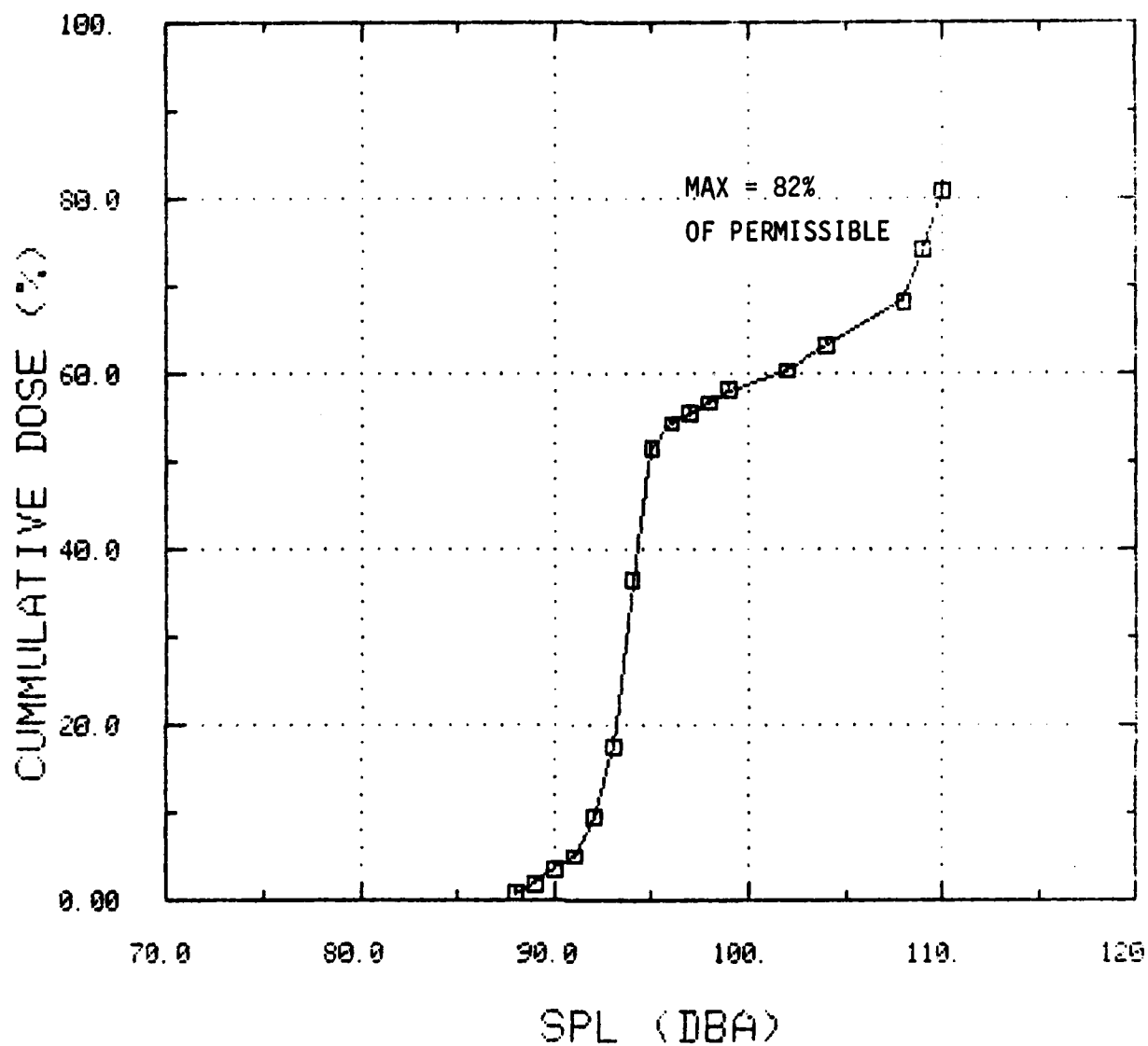


FIGURE B-48. CUMULATIVE DOSE RECORDED ON ASSISTANT ENGINEER  
Sample No. TX-13B

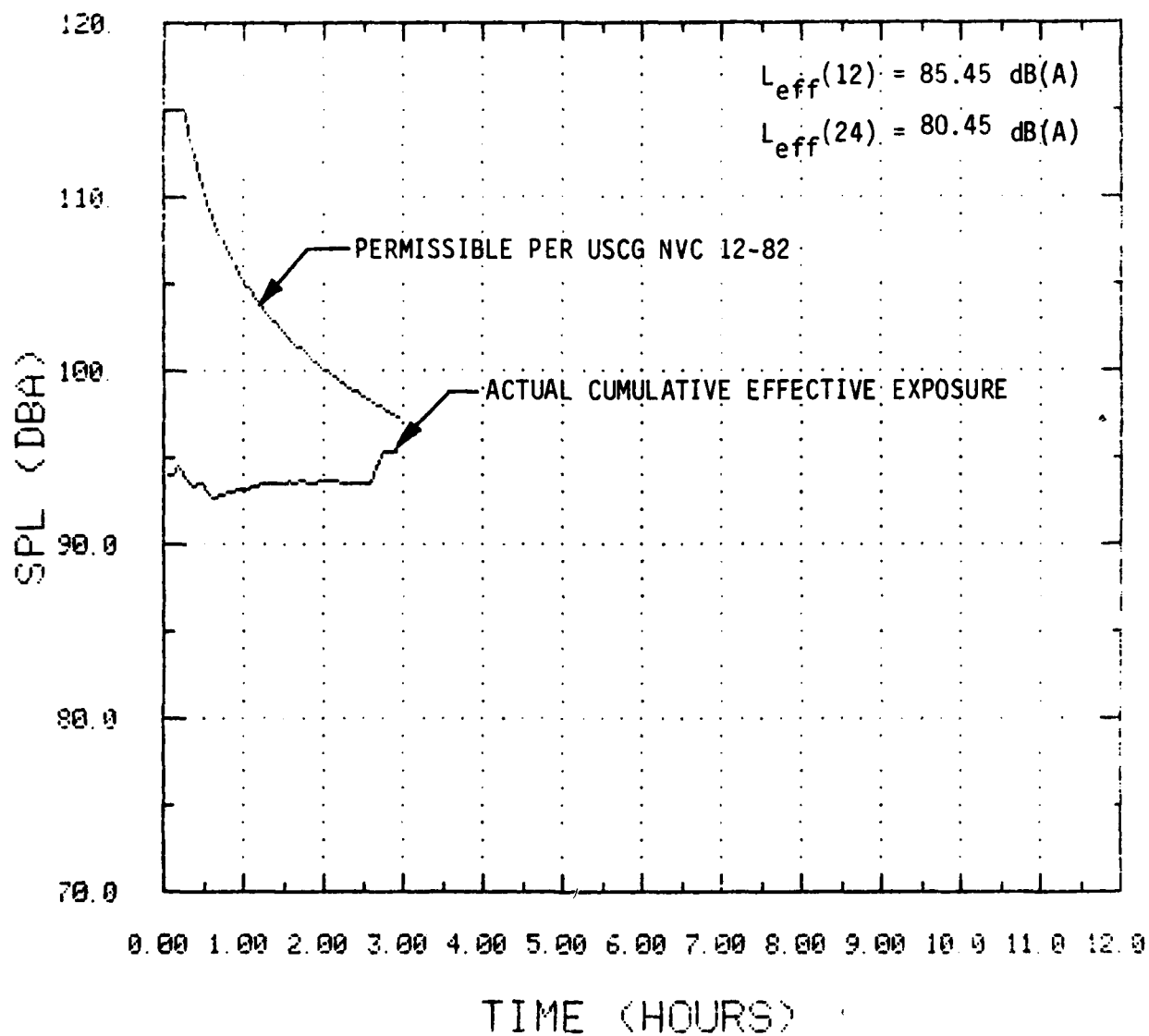


FIGURE B-47. CUMULATIVE EFFECTIVE EXPOSURE ON ASSISTANT ENGINEER  
Sample No. TX-13B



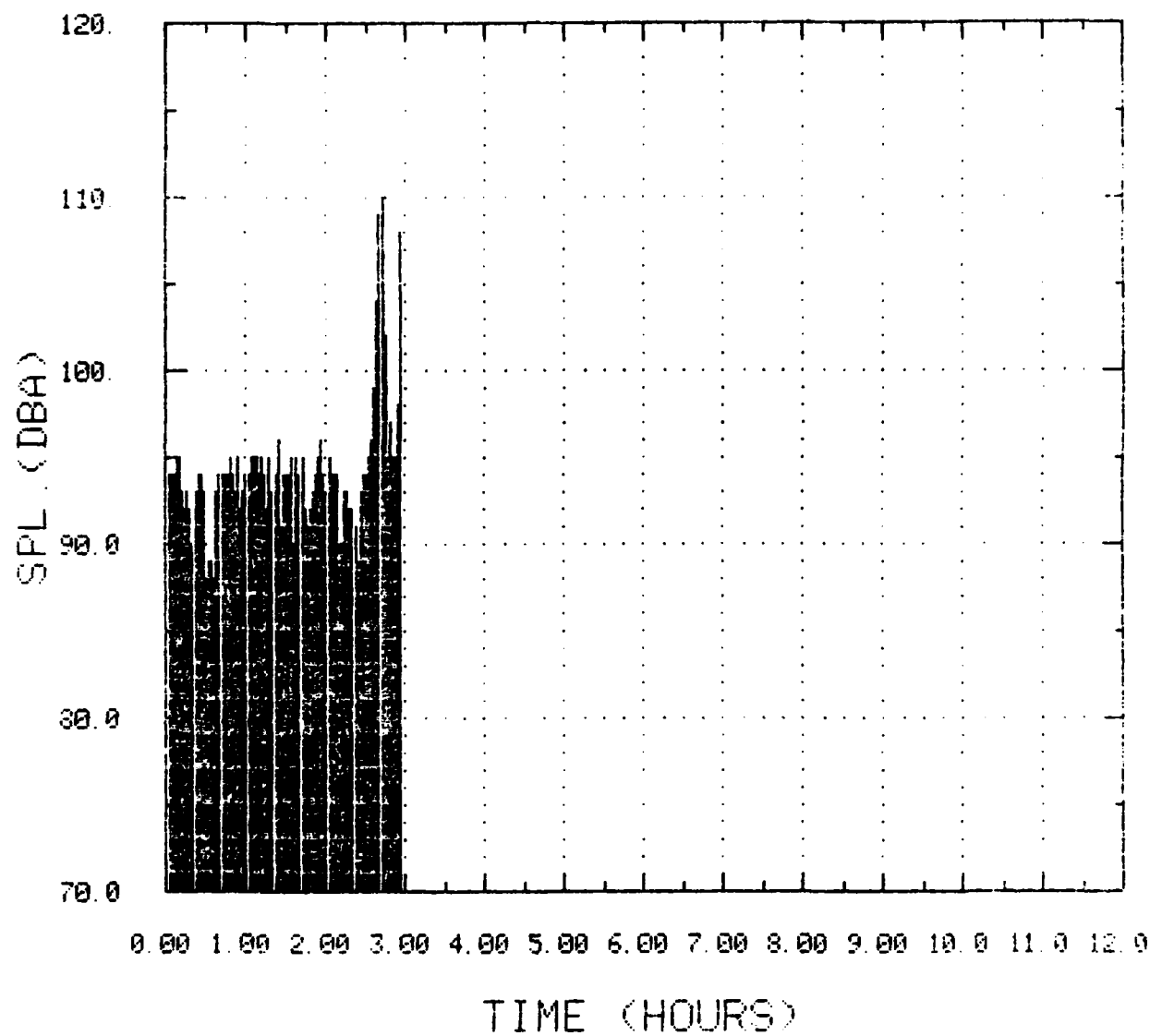


FIGURE B-46. NOISE DOSIMETRY ON ASSISTANT ENGINEER  
(Taken during laden voyage)  
Sample No. TX-13B

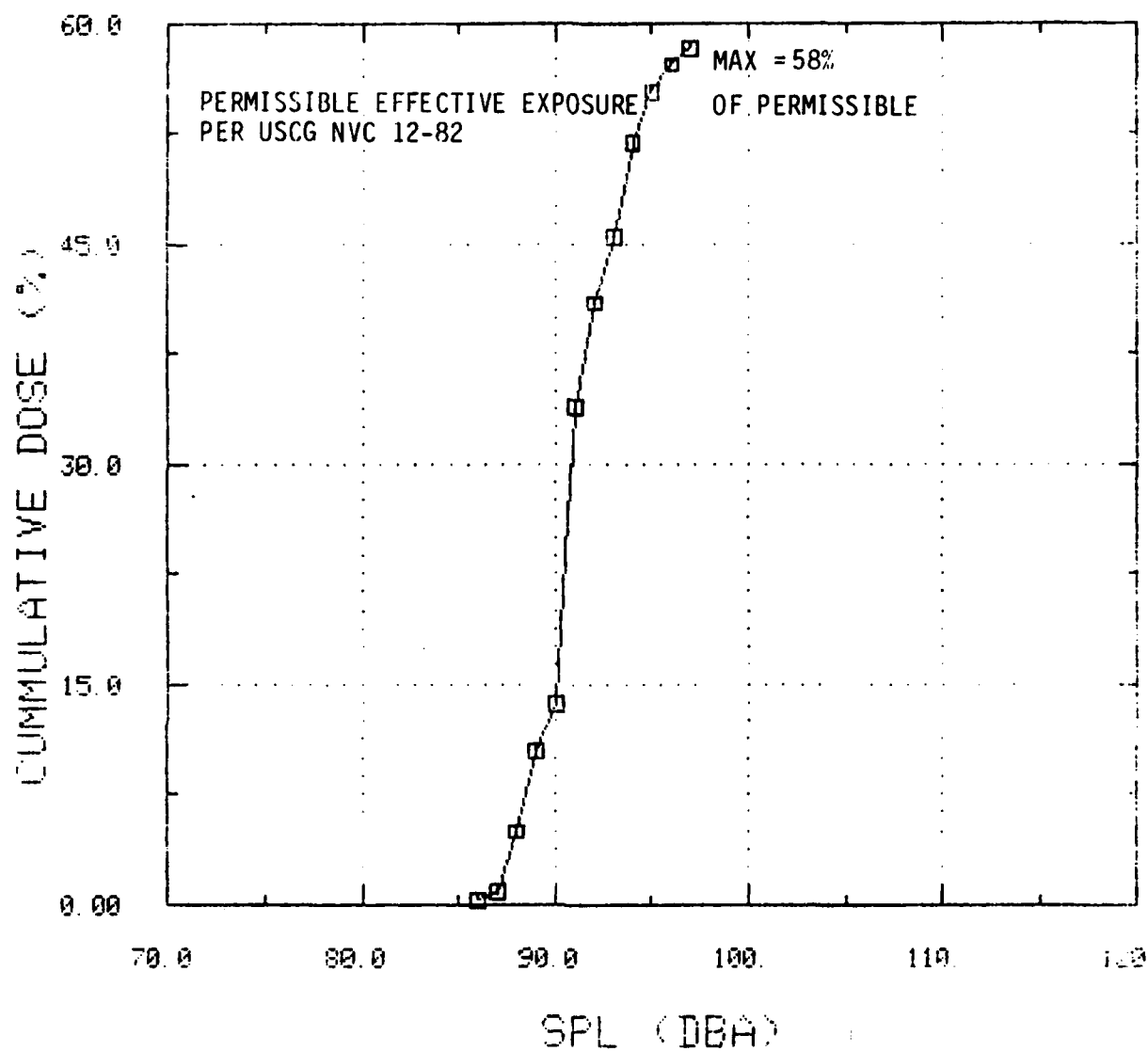


FIGURE B-45. CUMULATIVE DOSE RECORDED ON ASSISTANT ENGINEER  
Sample No. TX-13A

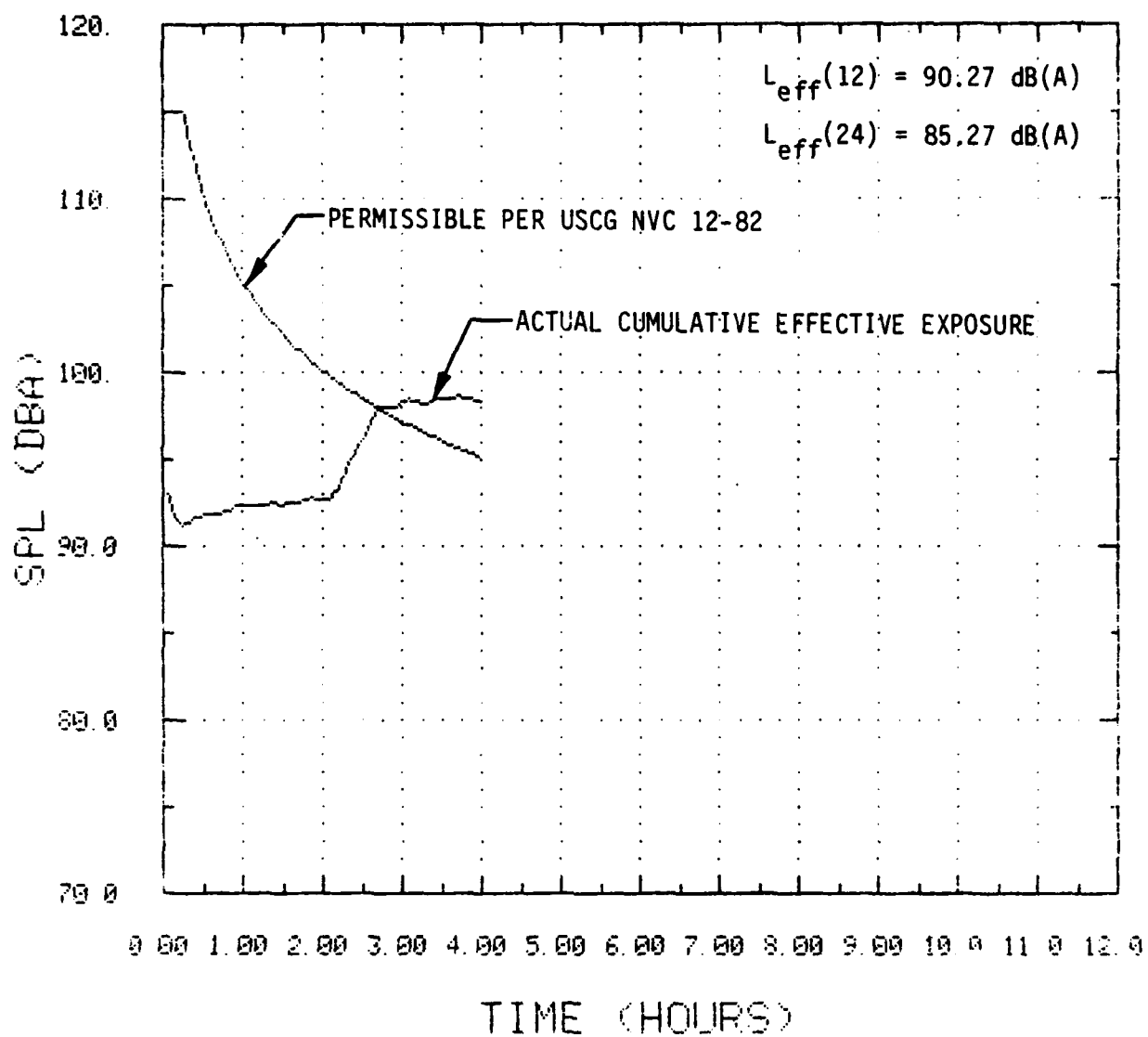


FIGURE B-59. CUMULATIVE EFFECTIVE EXPOSURE ON ASSISTANT ENGINEER  
Sample No. TX-15B

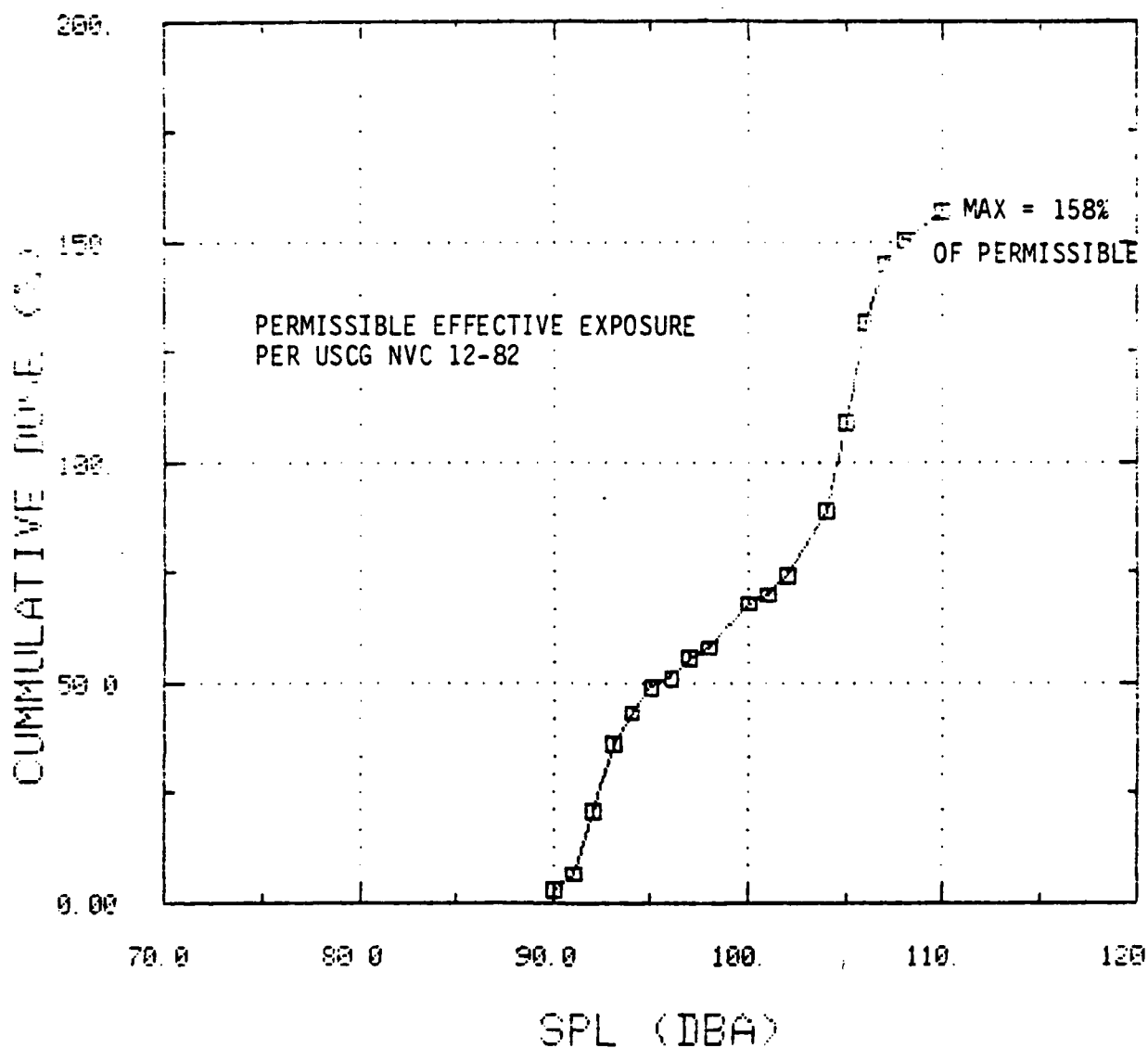


FIGURE B-60. CUMULATIVE DOSE RECORDED ON ASSISTANT ENGINEER  
Sample No. TX-15B

APPENDIX C  
VOYAGE REPORT - VOYAGE 3

## VOYAGE 3 REPORT OUTLINE

- I. Vessel Description
- II. Deck House Configuration and Ventilation
- III. Cargo Storage and Transfer
- IV. Deck Watch Composition and Work Schedule
- V. Trip Overview and Objectives
- VI. Sampling Strategy and Sample Analysis
- VII. Activities and Occupational Exposures of Various  
Deck Department Crewmen
  - VII.1 Product Loading
  - VII.2 Product Discharge
  - VII.3 Ballasting
  - VII.4 Tank Cleaning
  - VII.5 Tank Entry
- VIII. Miscellaneous Observations

## I. Vessel Description

### I.1 Dimensions

- o Length overall, 672'
- o Breadth molded, 89'

### I.2 Tonnage

- o Summer draft - 36,100 DWT

### I.3 Propulsion

- o Steam - 15000 hp

### I.4 Cargo Tanks

- o 30 Grade "A" cargo tanks
- o 4 Grade "A" or "B" cargo deck tanks
- o 6 Segregated ballast/Grade "B" cargo tanks  
(Tanks 2P/S, 4P/S and 5P/S)

### I.5 Cargo Pumps

- o Grade "A" Tanks - (30) Independent deep well pumps ranging from 250-1000 gpm
- o Deck Tanks - (4) Independent pumps each 200 gpm
- o Segregated Ballast/Grade "B" Tanks - (2) Deepwell pumps at 3300 gpm each, one for port tanks and one for starboard tanks

#### I.6 Cargo Loading

- o Open drop, short loading and full loading, both shore and ship-stop

#### I.7 Cargo Gauging Method

- o Restricted gauging on (30) Grade "A" tanks
- o Open gauging on (6) Ballast/Grade "B" cargo tanks and (4) deck tanks

#### I.8 Vapor Venting System

- o Grade "A" cargo tanks had dedicated vent piping that originated at the expansion trunk and terminate at one of five B/3 mast risers. Each vent line had a P/V valve. In practice, however, this sytem was not used. Instead, tank venting was accomplished through slightly raised tank hatches.
- o Ballast/Grade "B" tanks had only standard ullage ports atop the expansion trunk hatches for venting and no P/V valves.
- o Deck tanks had separate vent lines.
- o One of the cargos, styrene, was vented by vapor return back to shore.

#### I.9 Tank Cleaning Method

- o Hot and cold water washing with portable Butterworth machines.
- o Gas freeing accomplished by a portable air driven Coppus blowers, or central "Kathabar" blower (4500 CFM) that discharged into the tanks through the open drop of the cargo piping.



## II. Deckhouse Configuration and Ventilation

### II.1 Deckhouse Configuration

The deckhouse consisted of four levels:

- o Main Deck - Galley, crew and officer's mess, ship's office and unlicensed crewmen's quarters.
- o 2nd Level - Licensed crewmen, the Bosun and Pumpman, and contained the officer's lounge.
- o 3rd Level - Captain's and Radio Officer's quarters and office, and the ship's gyro room.
- o 4th Level - Navigation bridge.

Access to the deckhouse could be accomplished on all levels. On the main deck, two pairs of double doors were located in front of the deckhouse. These doors were not the standard marine type, water-tight doors. Three standard marine doors were located on the 2nd level. Two were on the sides and one in the rear of the deckhouse. Similar type access ways were located on the third and fourth level.

### II.2 Deckhouse Ventilation

Conditioned air was provided to all levels by a central heating and cooling unit located in the rear of the deckhouse on the 2nd level. Fresh air vents were located near the unit and were open to the ambient atmosphere during the entire voyage.

### III. Cargo Description and Transfer

A total of 16 different pure chemicals and solvents were handled on this voyage. They were contained in 33 of the 34 cargo tanks. One cargo tank, 1C, was empty for the entire voyage. Dirty ballast was being carried in the six ballast tanks upon arrival to the loading port. The ballast was "dirty" because the tanks had previously carried Naphtha and had not been cleaned prior to ballasting. The cargo and ballast storage plan is shown in Table I. For those chemicals having a CHRIS abbreviation, one is shown in the parentheses next to the chemical.

Also shown in Table I, is the type of cargo transfer that occurred at the loading port. Both loading and discharge of cargo were observed. When the ship arrived, 13 of the tanks were laden with product. Six of these tanks were off-loaded at the port. The other seven tanks were emptied at one of the discharge ports on the East Coast. All in all, a total of 21 tanks were loaded including the back loading of product into one of the six tanks that were discharged at the loading port. Most of the tanks were loaded to nearly full capacity except for seven which were short loaded between 33% to 72% of their capacity.

All products on board after leaving the loading port were subsequently discharged to three terminals and one barge on the East Coast.

### IV. Deck Watch Composition and Work Schedules

The Deck Department was made up of four licensed and eleven unlicensed crewmen. The licensed crewmen consisted of the Chief Mate (C/M), Second Mate (2/M) and two Third Mates (3/M). Six able-body seamen (A/B), three ordinary seamen (O/S), a Bosun and a Pumpman comprised the unlicensed crew.

TABLE I. CARGO STORAGE AND TRANSFER AT LOADING PORT

| Tank No. | Cargo                       | Transfer Code | Quantity (Gallons) | % Full |
|----------|-----------------------------|---------------|--------------------|--------|
| DKTK 1P  | EA-E100 (EAL)               | L             | 19141              | 97.2   |
| DKTK 1S  | Methanol (MAL)              | D             | 19064              | 96.4   |
| DKTK 2P  | Methanol (MAL)              | D             | 19180              | 61.8   |
| DKTK 2S  | EA-E100 (EAL)               | L             | 14705              | 99.0   |
| 1A       | 1,1,1-Trichloroethane (TCE) | L             | 92134              | 87.7   |
| 1B       | Ethylene Dichloride (EDC)   | L             | 85267              | 42.5   |
| 1C       | Empty                       | -             | -                  | -      |
| 1D       | Trichloroethylene (TCL)     | L             | 43564              | 72.4   |
| 2A       | Ethylene Glycol (EGL) (1)   | D/L           | 342546             | 98.3   |
| 2B       | Caustic (CSS)               | D             | 165668             | 96.9   |
| 2C       | Caustic (CSS)               | D             | 166563             | 97.5   |
| 2D       | Acetone (ACT)               | L             | 447168             | 98.2   |
| 2E       | Caustic (CSS)               | D*            | -                  | -      |
| 3A       | Perchloroethylene (TTE)     | L             | 291689             | 51.3   |
| 3B       | Caustic (CSS)               | D             | 107820             | 95.8   |
| 3C       | Ethylene Glycol (EGL)       | L             | 107820             | 95.8   |
| 3D       | Propylene Glycol (PPG)      | L             | 111562             | 97.7   |
| 3E       | Caustic (CSS)               | D*            | -                  | -      |
| 3F       | Caustic (CSS)               | L             | 217392             | 96.7   |
| 3P       | Styrene (STY)               | L             | 718205             | 97.6   |
| 3S       | Styrene (STY)               | L             | 715585             | 97.2   |
| 4A       | Voranol                     | L             | 125990             | 98.4   |
| 4B       | Caustic (CSS)               | D*            | -                  | -      |
| 4C       | Glycerine (GCR)             | L             | 125888             | 98.1   |
| 4D       | Lignin Liquor               | D*            | -                  | -      |
| 5A       | 1,1,1-Trichloroethane (TCE) | L             | 333919             | 98.2   |
| 5B       | 1,1,1-Trichloroethane (TCE) | L             | 331195             | 97.5   |
| 6A       | Lignin Liquor               | D*            | -                  | -      |
| 6B       | Lignin Liquor               | D*            | -                  | -      |
| 6P       | Versene 100                 | L             | 130790             | 33.0   |
| 6S       | Ethylene Glycol (EGL)       | L             | 219165             | 55.4   |
| 7C       | Lignin Liquor               | D*            | -                  | -      |
| 7P       | Methylene Chloride (DCM)    | L             | 150281             | 58.5   |
| 7S       | Methylene Chloride (DCM)    | L             | 133918             | 52.0   |
| 2P,2S    | Dirty Ballast               | D/L           | -                  | -      |
| 4P,4S    | Dirty Ballast               | D/-           | -                  | -      |
| 5P,5S    | Dirty Ballast               | D/-           | -                  | -      |

(1) - Diethylene glycol was discharged prior to loading of EGL

L - Tank was loaded

D - Product was on board upon arrival at loading port and subsequently discharged at the same port

D\* - Same as D except discharge was on the East Coast

All crewmen did the majority of their work in a 4-hour on, 8-hour off routine, with the exception of the C/M, the Bosun, and the Pumpman. These three individuals usually worked between 0800-1700 hours. Depending on whether the ship was in port or at sea, certain work activities required some of these individuals to work more than eight hours per 24-hour day.

The primary activity when the ship was in port was cargo transfer. The standard ship watch complement for this activity consisted of one mate (excluding the C/M), two A/Bs and one O/S. The cargo transfer watch was four hours. The unlicensed crewmen seldom exceeded their two 4-hour watches during a 24 hour day. The 3/Ms, however, did exceed 8-hour workdays by standing a day or barrel watch (0800-1700) in addition to their normal 4-hour watches. The day watch rotated to the other 3/M the next time the ship was in port. Although the 2/M is not included in this rotation, he worked for a period of time exceeding his two 4-hour watch periods.

Between the hours of 1600-0800, the four man watch team was assisted by two shore based mates called Port Relief Officers (PRO), who each stand an 8-hour watch. These same PROs are available during the next 16-hour night period provided the ship is still in port.

The C/M was also involved in the cargo transfer operation. Because he had overall responsibility for cargo transfer, the C/M was usually on call during the entire time while the ship was in port. At the loading port, he acted in a supervisory capacity, periodically canvassing the Mates' tank ullage readings to assure that the ship maintained the proper list and trim. Occasionally, he did perform tank gauging. At the discharge port, however, he became more involved in the cargo transfer by stripping a number of the tanks.

Other activities observed while the ship was in port were transfer and gauging of ballast and the loading of stores. These activities usually are handled by the Pumpman and the Bosun, respectively. In most cases, the A/Bs and O/Ss on cargo transfer watch will assist the Bosun in securing the stores to the deckhouse. In addition to gauging ballast tanks, the Pumpman was involved in cargo tank gauging during the product discharge. He was also responsible for the startup and periodic checking of the ship's discharge pumps while the ship was at the discharge port.

When the ship was at sea, the four man cargo watch team stands navigation watch. During navigation watch, the Mate was assisted by one of the A/Bs (quartermaster), who steered the ship at the direction of the Mate. The other unlicensed crewmen were on standby to relieve the quartermaster when he took his break. During the night hours, the two reliefs also stand a bow watch. During daylight hours and when not on watch, the unlicensed crew members worked overtime performing various deck work tasks at the direction of the C/M. The 2/M and two 3/Ms, however, spent their entire work periods in the ship's wheelhouse.

During this voyage, the deck work activities primarily involved gas freeing the ship in preparation for drydock for repairs and biennial inspection. These activities commenced soon after the ship left the loading terminal with the cleaning of the dirty ballast tanks. After the bulk of the products were off-loaded at the next to last discharge port, tank cleaning resumed until all tanks and enclosed spaces were ventilated.

The Bosun, C/M, and majority of the ship's A/Bs and O/Ss were involved in tank cleaning. The Bosun and C/M supervised the operation. Some of the tanks were washed prior to gas freeing while others required only ventilation. Tanks were entered for testing and manual cleaning.

## V. Objective and Trip Overview

At the onset of this test, it was apparent that the selection of only two individual Deck Department crewmen for documentation and exposure monitoring would result in missing many other pertinent work activities involving other crewmen. Consequently, rather than concentrating on certain individuals for the entire voyage, the objective was expanded to observe and monitor as many work activities as possible that involved potential exposures to the chemical cargos of interest.

The work activities performed on this voyage were generally similar to those carried out on other voyages of this ship with one exception. Because the ship was scheduled to go into dry dock for its biennial inspection, more extensive tank cleaning was performed. This included tank entry. A summary of the major activities observed and monitored on this voyage are shown in Table II.

TABLE II. MAJOR DECK WORK ACTIVITIES

Period Cargo Tank Gauging - Restricted, Loading  
Tank Top-off Gauging - Restricted, Loading  
Period Ballast Tank Gauging - Open, Ballasting  
Hose Hookup and Disconnect  
Periodic Cargo Tank Gauging - Restricted, Discharge  
Tank Stripping  
Tank Washing and Ventilation  
Tank Entry for Inspection  
Tank Entry for Mucking

The entire voyage observation lasted 15 days. The sequence of voyage segments is shown in Figure 1.

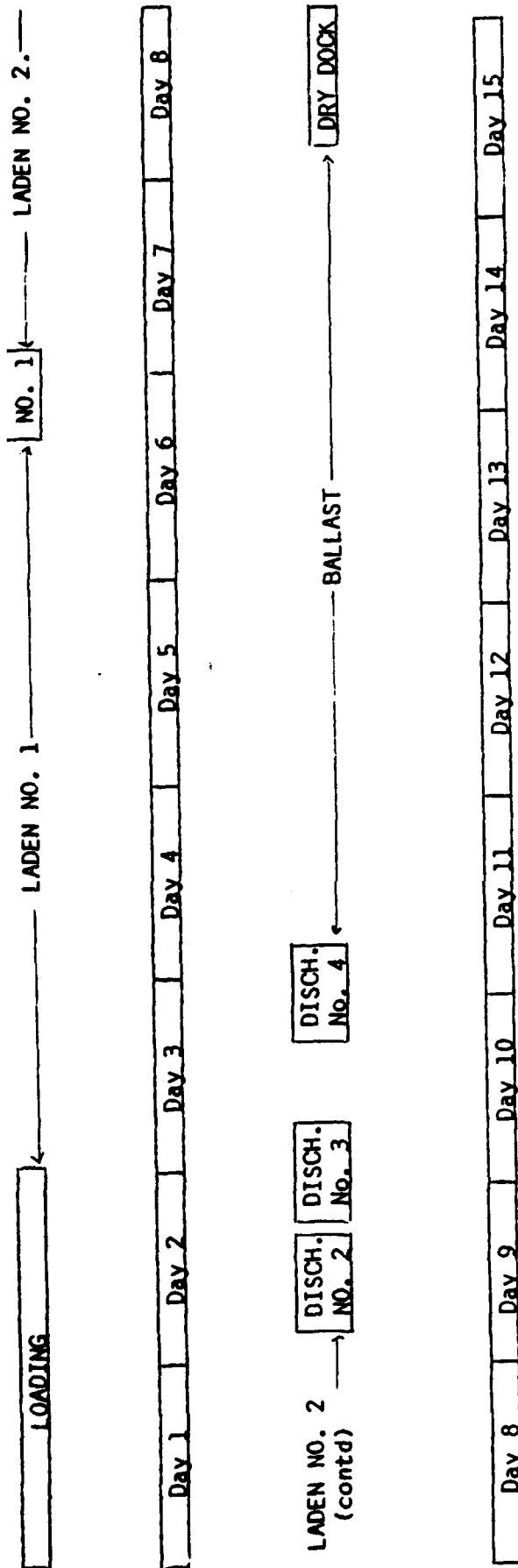


FIGURE 1. SEQUENCE AND DURATION OF MAJOR VOYAGE SEGMENTS

### Sampling Strategy and Sample Analysis

Nine of the chemicals transported on the ship were chosen for occupational exposure monitoring. These chemicals were chosen because they had NIOSH sampling and analysis procedures and published exposure limits. Listing of these chemicals is shown in Table III.

TABLE III. RECOMMENDED NIOSH SAMPLING METHODS AND TLV LIMITS OF THE SELECTED CHEMICALS

| Chemical                    | NIOSH Sampling Method No. | TLV-TWA(1) (ppm) | TLV-STEL (1) |
|-----------------------------|---------------------------|------------------|--------------|
| Acetone (ACT)               | S1                        | 750              | 1000         |
| 1,1,1-Trichloroethane (TCE) | S328                      | 350              | 450          |
| Methylene Chloride (DCM)    | S329                      | 100              | 500          |
| Trichloroethylene (TCL)     | S336                      | 50               | 150          |
| Perchloroethylene (TTE)     | S335                      | 50               | -            |
| Ethylene Dichloride (EDC)   | S122                      | 10               | 15           |
| Styrene (STY)               | S30                       | 50               | 100          |
| 1,4-PHTHA (STODDARD) (NSS)  | S382                      | 100              | 200          |
| Ethylene Glycol (EGL)       | S338                      | 50(vapor)        | -            |

Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment, American Conference of Governmental Industrial Hygienist, 1983.

The main reason for not monitoring the remainder of the chemicals /or solvents was due primarily to the absence of sampling and analysis procedures for these compounds. This was the case for EA-E100, Propylene col, Lignin Liquor, Versene 100 and Voranol. Some of the chemicals, however, did have published procedures but due to circumstances were not followed. These are summarized below:

- o Methanol - Small quantities of methanol were carried in the deck tanks. After discharge, the tanks were washed, but not ventilated or entered. As such, the potential for exposure to methanol vapors was judged to be minimal.



AD-A157 308

A CREW EXPOSURE STUDY PHASE II VOLUME 2 AT SEA PART B  
(U) SOUTHWEST RESEARCH INST SAN ANTONIO TX DIV OF  
ENGINEERING AND... W J ASTLEFORD ET AL. APR 85

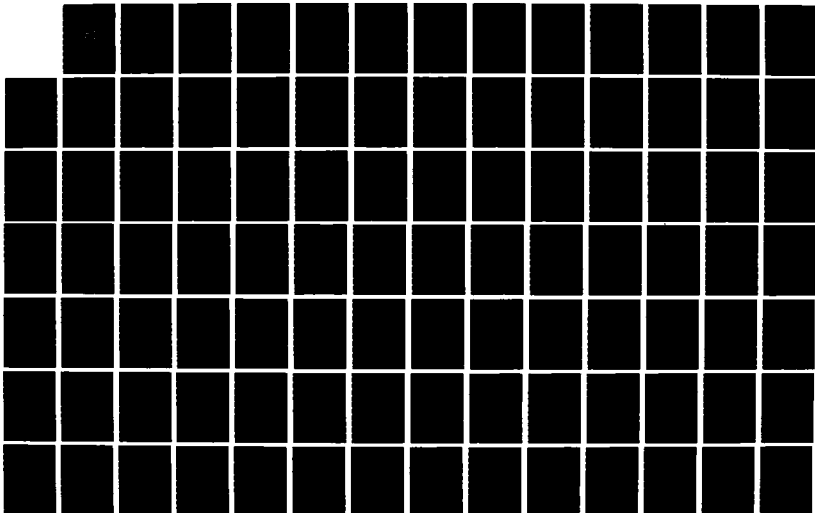
3/5

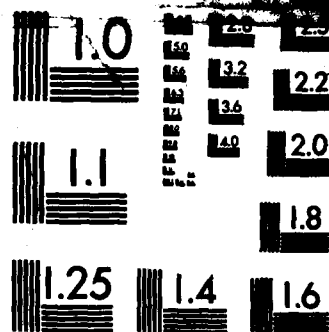
UNCLASSIFIED

USCG-D-12-85 DTCG23-80-C-20015

F/G 6/10

NL





MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

- o Caustic Soda - Primary occupational exposure route is through dermal contact with bulk liquid.
- o Glycerine - Neither vapor nor mist are likely to be encountered during standard ship transfer procedures.

Both active and passive dosimeters were used. The active dosimeters included large and small charcoal tubes. The passive dosimeters were Dupont G-AA and G-BB badges. The adsorbent used for monitoring of EGL vapors was silica gel. All tube and badge samples were analyzed by an AIHA accredited laboratory.

The results of the sampling effort are summarized in Tables IV through VI. Table IV contains the flow rate, time, and ambient temperature conditions for each sample. A total of 107 tubes and badge samples were collected including 24 passive badges (samples whose sample number begins with 6) and 83 tubes. Three of the sample tubes contained silica gel to monitor exposure to EGL vapors. The remaining 80 tubes comprised the charcoal tube samples (75 small and 5 large). All active samples were collected at a nominal flow rate of 0.2 Liter/min.

Table V illustrates the chemical desorption efficiencies (DE) for the charcoal tubes and badges. Manufacturer's DEs were used for the passive badges whereas the DEs for the tubes were determined by the AIHA laboratory that analyzed the unknown samples. Because EGL was not detected in the unknown samples, its' desorption efficiency was not determined.

The information from Table IV and V along with the weight analysis of the samples was inserted into one of the following expressions used to calculate ambient exposure concentration.

TABLE IV. OCCUPATIONAL AND AREA SAMPLING CONDITIONS

| Sample No. | Pump No. | Flow Rate<br>(L/min) | Average<br>Temperature<br>(°F) | Sample<br>Duration<br>(min.) |
|------------|----------|----------------------|--------------------------------|------------------------------|
| H-8        | M12      | 0.199                | 84.                            | 97.                          |
| MC-17      | M5       | 0.204                | 79.                            | 227.                         |
| 03-P18     | M12      | 0.199                | 79.                            | 149.                         |
| MC-19      | M5       | 0.204                | 78.                            | 36.                          |
| 01-P18     | 9A       | 0.191                | 76.5                           | 266.                         |
| TX-104     | M12      | 0.199                | 76.5                           | 132.                         |
| SB-36      | M3       | 0.201                | 75.                            | 21.                          |
| SB-16      | M10      | 0.203                | 75.                            | 221.                         |
| H-9        | M11      | 0.202                | 75.                            | 32.                          |
| 62799      | -        | -                    | 75.                            | 24.                          |
| 03-P19     | M3       | 0.201                | 75.                            | 28.                          |
| SB-38      | M3       | 0.201                | 75.                            | 14.                          |
| SB-98      | M11      | 0.202                | 85.                            | 49.                          |
| H-11       | M3       | 0.201                | 81.5                           | 129.                         |
| MC-13      | M10      | 0.203                | 83.                            | 44.                          |
| MC-37      | 9A       | 0.191                | 80.                            | 296.                         |
| 01-P14     | P5       | 0.196                | 77.                            | 170.                         |
| MC-11      | M5       | 0.204                | 77.                            | 134.                         |
| MC-18      | M10      | 0.203                | 77.                            | 130.                         |
| MC-12      | M3       | 0.201                | 80.                            | 95.                          |
| CG-2018    | 2A       | 0.194                | 80.                            | 77.                          |
| MC-20      | M3       | 0.201                | 80.                            | 64.                          |
| SB-18      | 2A       | 0.194                | 80.                            | 50.                          |
| CG-2019    | M12      | 0.199                | 85.                            | 149.                         |
| X-1        | M3       | 0.201                | 85.                            | 132.                         |
| 02-P20     | 2A       | 0.194                | 85.                            | 57.                          |
| 02-P17     | M11      | 0.202                | 88.                            | 74.                          |
| X-10       | M5       | 0.204                | 88.                            | 90.                          |
| CG-2017    | 2A       | 0.194                | 88.                            | 50.                          |
| X-4        | M10      | 0.203                | 77.                            | 34.                          |
| 02-P12     | M11      | 0.202                | 77.                            | 17.                          |
| 63778      | -        | -                    | 77.                            | 15.                          |
| CG-2015    | M11      | 0.202                | 77.                            | 11.                          |
| SB-25      | M11      | 0.202                | 74.5                           | 181.                         |
| X-7        | M10      | 0.203                | 74.5                           | 55.                          |
| CG-2020    | P1       | 0.198                | 72.                            | 4.                           |
| X-3        | 2A       | 0.194                | 74.5                           | 10.                          |
| 62745      | -        | -                    | 72.                            | 9.                           |
| DM-7       | P1       | 0.190                | 68.5                           | 183.                         |
| 62743      | -        | -                    | 68.5                           | 162.                         |
| DM-3       | M11      | 0.202                | 65.                            | 19.                          |
| DM-4       | P1       | 0.198                | 62.                            | 16.                          |
| DM-8       | M-11     | 0.202                | 62.                            | 11.                          |
| X-2        | P1       | 0.198                | 65.                            | 92.                          |

TABLE IV. OCCUPATIONAL AND AREA SAMPLING CONDITIONS (cont'd)

| Sample No. | Pump No. | Flow Rate<br>(L/min) | Average<br>Temperature<br>(°F) | Sample<br>Duration<br>(min.) |
|------------|----------|----------------------|--------------------------------|------------------------------|
| DM-6       | M-11     | 0.202                | 72.                            | 82.                          |
| DM-2       | P6       | 0.200                | 72.                            | 82.                          |
| X-6        | 2A       | 0.194                | 72.                            | 40.                          |
| X-9        | 2A       | 0.194                | 75.                            | 119.                         |
| DM-9       | 4A       | 0.198                | 75.                            | 116.                         |
| DM-5       | 4A       | 0.198                | 66.5                           | 123.                         |
| X-5        | P7       | 0.208                | 65.                            | 203.                         |
| DM-1       | P2       | 0.204                | 66.5                           | 130.                         |
| 62746      | -        | -                    | 66.5                           | 116.                         |
| 62040      | -        | -                    | 65.                            | 119.                         |
| DM-17      | 4A       | 0.198                | 65.                            | 112.                         |
| 64426      | -        | -                    | 65.                            | 77.                          |
| DM-13      | P2       | 0.204                | 68.                            | 84.                          |
| X-19       | P7       | 0.208                | 58.                            | 215.                         |
| X-14       | M9       | 0.199                | 58.                            | 225.                         |
| 64421      | -        | -                    | 58.                            | 59.                          |
| 64422      | -        | -                    | 58.                            | 21.                          |
| 64424      | -        | -                    | 58.                            | 1.                           |
| X-100      | P3       | 0.150                | 58.                            | 65.                          |
| X-13       | P7       | 0.208                | 58.                            | 177.                         |
| MC-14      | M7       | 0.205                | 65.                            | 154.                         |
| 62039      | -        | -                    | 65.                            | 154.                         |
| X-12       | M9       | 0.199                | 65.                            | 65.                          |
| 62038      | -        | -                    | 65.                            | 57.                          |
| DM-15      | P2       | 0.204                | 65.                            | 66.                          |
| DM-16      | 4A       | 0.198                | 65.                            | 66.                          |
| 08-P8      | M2       | 0.196                | 65.                            | 445.                         |
| SB-2       | P4       | 0.207                | 65.                            | 115.                         |
| 64423      | -        | -                    | 65.                            | 107.                         |
| 62037      | -        | -                    | 65.                            | 128.                         |
| DM-19      | 4A       | 0.198                | 65.                            | 84.                          |
| DM-11      | P2       | 0.204                | 65.                            | 85.                          |
| X-15       | M9       | 0.199                | 65.                            | 43.                          |
| L-7        | P4       | 0.207                | 65.                            | 40.                          |
| DM-14      | M1       | 0.201                | 65.                            | 18.                          |
| 64425      | -        | -                    | 65.                            | 34.                          |
| X-16       | M7       | 0.205                | 65.                            | 2.                           |
| DM-20      | M1       | 0.201                | 67.                            | 6.                           |
| 68996      | -        | -                    | 67.                            | 12.                          |
| X-23       | M7       | 0.205                | 67.                            | 2.                           |

TABLE IV. OCCUPATIONAL AND AREA SAMPLING CONDITIONS (concluded)

| Sample No. | Pump No. | Flow Rate<br>(L/min) | Average<br>Temperature<br>(°F) | Sample<br>Duration<br>(min.) |
|------------|----------|----------------------|--------------------------------|------------------------------|
| DM-12      | M1       | 0.201                | 67.                            | 2.                           |
| X-27       | M7       | 0.205                | 67.                            | 16.                          |
| 62035      | -        | -                    | 67.                            | 9.                           |
| DM-30      | M-8      | 0.199                | 67.                            | 15.                          |
| SB-8       | C        | 0.202                | 75.                            | 434.                         |
| DM-26      | M4       | 0.198                | 75.                            | 16.                          |
| 62034      | -        | -                    | 75.                            | 18.                          |
| X-26       | M7       | 0.205                | 75.                            | 15.                          |
| 62033      | -        | -                    | 75.                            | 15.                          |
| X-18       | M9       | 0.199                | 75.                            | 43.                          |
| X-25       | M7       | 0.205                | 75.                            | 16.                          |
| X-35       | M7       | 0.205                | 68.                            | 14.                          |
| 62032      | -        | -                    | 68.                            | 14.                          |
| X-21       | M9       | 0.199                | 68.                            | 26.                          |
| X-8        | M9       | 0.198                | 68.                            | 11.                          |
| 63839      | -        | -                    | 68.                            | 11.                          |
| X-40       | M6       | 0.197                | 68.                            | 10.4                         |
| 63837      | -        | -                    | 68.                            | 10.4                         |
| DM-41      | M4       | 0.198                | 68.                            | 44.                          |
| 62790      | -        | -                    | 68.                            | 44.                          |
| DM-47      | M8       | 0.199                | 68.                            | 45.                          |
| 62797      | -        | -                    | 68.                            | 45.                          |
| DM-40      | M4       | 0.198                | 68.                            | 48.                          |

TABLE V. DESORPTION EFFICIENCY OF SAMPLING MEDIA

Passive Charcoal Dosimeters

| <u>Compound</u>             | <u><math>\eta</math>, Desorption Efficiency(1)</u> | <u>Sampling Rate (cm<sup>3</sup>/min)(1)(2)</u> |
|-----------------------------|----------------------------------------------------|-------------------------------------------------|
| Acetone (ACT)               | 0.67                                               | 38.2                                            |
| 1,1,1-Trichloroethane (TCE) | 1.01                                               | 30.2                                            |
| Methylene Chloride (DCM)    | 0.93                                               | 34.6                                            |
| Trichloroethylene (TCL)     | 0.98                                               | 32.6                                            |
| Perchloroethylene (TTE)     | 0.98                                               | 25.5                                            |
| Ethylene Dichloride (EDC)   | 0.94                                               | 28.9                                            |
| Styrene (STY)               | 0.89                                               | 29.6                                            |
| Naphtha (NSS)               | 1.00                                               | 26.5                                            |

Charcoal Sampling Tubes (3)

| <u>Compound</u>             | <u>Small Tubes</u> |              | <u>Large Tubes</u> |              |
|-----------------------------|--------------------|--------------|--------------------|--------------|
|                             | <u>0.5 TWA</u>     | <u>2 TWA</u> | <u>0.5 TWA</u>     | <u>2 TWA</u> |
| Acetone (ACT)               | 81.6               | 92.6         | 69.8               | 83.2         |
| 1,1,1-Trichloroethane (TCE) | 97.4               | 89.6         | 113.7              | 99.8         |
| Methylene Chloride (DCM)    | 93.2               | --           | 113.2              | --           |
| Trichloroethylene (TCL)     | 96.8               | 98.0         | 111.6              | 103.3        |
| Perchloroethylene (TTE)     | 96.2               | 90.4         | 112.7              | 103.7        |
| Ethylene Dichloride (EDC)   | 93.4               | 72.9         | 104.4              | 97.6         |
| Styrene (STY)               | 89.0               | 94.0         | 89.0               | 84.4         |
| Naphtha (NSS)               | 105.0              | 104.0        | 107.0              | 106.0        |

(1) Manufacturer's data

(2) Sampling rate is for DuPont GBB Badge or GAA Badge with one cover off

(3) Experimentally determined data at the two concentration levels noted

o Adsorbent Tubes

$$C \text{ (ppm)} = \frac{W_c}{nQt} \frac{24.45}{MW} \left( \frac{T + 273}{298} \right) \frac{760}{P}$$

where

$W_c$  = cumulative weight of analyte on the tube corrected for blank,  $\mu\text{g}$

$n$  = desorption efficiency as a decimal

$Q$  = sampling flow rate, LPM

$t$  = sample duration, min

$MW$  = analyte molecular weight

$T$  = sampling temperature,  $^{\circ}\text{C}$

$P$  = sampling barometric pressure, mm Hg

o Passive Dosimeters

$$C \text{ (ppm)} = \left( \frac{W_{CF} + 2.2 W_{CB}}{n(SR) T} \right) \frac{24.45}{MW} \left( \frac{T + 273}{298} \right) \frac{760}{P}$$

where

$W_{CF}$  = weight of analyte on exposed front strip corrected for blank, ng

$W_{CB}$  = weight of analyte on backup strip corrected for blank, ng

$SR$  = passive sampling rate,  $\text{cm}^3/\text{min}$ .

Other quantities are as defined for the adsorbent tubes. The pressure correction was not applied as all samples were collected at sea level conditions.



Table VI summarizes the calculated occupational exposure and area concentrations monitored during this voyage. These concentrations are listed by sample number, personnel upon whom the sample was taken and the general activity that was performed during monitoring. Area sample locations are also included. Concentrations with a greater than (>) sign next to them signify that the actual concentration value may be more than indicated since the back section of the sampling media contained in excess of 10% of the amount collected on the front section for that sample.

## VII. Activities and Occupational Exposures of Various Deck Department Crewmen

### VII.1 Product Loading

Following hose hookup, the sequence of events during loading was as follows.

- o Approximately one foot of cargo ("heel") was pumped into the tank, then the flow was stopped.
- o A deck employee retrieved a dropline sample of the "heel" through the tank expansion trunk and took it to shore for lab analysis.
- o If the sample met specification, pumping was resumed at the approval of the mate on watch.
- o Cargo continued to be loaded until the required quantity was onboard. The loading of some cargoes was stopped prior to the finish of loading and then resumed until finished.
- o Termination of loading was accomplished by a "shore" stop on some chemicals and "ship" stop on others.

TABLE VI. CALCULATED AMBIENT VAPOR EXPOSURE CONCENTRATION, PPM

| Voyage Day | Sample No. | Worker  | Activity                                                | ACT   | TCE    | DCM | TCI | ITE | EDC | STY | NSS   | EGL |
|------------|------------|---------|---------------------------------------------------------|-------|--------|-----|-----|-----|-----|-----|-------|-----|
| 1          | H-8        | 2/M     | Restricted Gauging (Loading)                            | --    | --     | 0.2 | --  | --  | --  | ND  | --    | --  |
| 1          | MC-17      | 3/M-1   | Restricted Gauging (Loading)                            | ND    | ND     | ND  | --  | ND  | ND  | ND  | --    | --  |
| 1          | 03-P18     | 2/M     | Restricted Gauging (Loading)                            | 7.7   | ND     | --  | --  | --  | --  | ND  | --    | --  |
| 1          | MC-19      | 3/M-1   | Tank Top-Off of 2D (ACT)                                | 176.6 | --     | --  | --  | ND  | --  | ND  | --    | --  |
| 1          | 01-P18     | AREA    | Near 3C (EGL) Standpipe                                 | --    | --     | --  | --  | --  | --  | --  | --    | ND  |
| 1          | TX-104     | PRO-1   | Restricted Gauging (Loading)                            | --    | --     | --  | --  | --  | --  | ND  | --    | --  |
| 2          | SB-36      | PRO-1   | Tank Top-Off of 5A (TCE)                                | --    | 58.4   | --  | --  | --  | --  | --  | --    | --  |
| 2          | SB-16      | 3/M-2   | Restricted Gauging (Loading)                            | --    | --     | 0.3 | --  | 0.1 | ND  | ND  | --    | --  |
| 2          | H-9        | AREA +  | Near Styrene Tank Standpipe                             | --    | --     | --  | --  | --  | --  | ND  | --    | --  |
| 2          | 62799      | AREA +  | Near Styrene Tank Standpipe                             | --    | --     | --  | --  | --  | --  | ND  | --    | --  |
| 2          | 03-P19     | PRO-2   | Tank Top-Off of 3S (STY)                                | --    | --     | --  | --  | --  | --  | 15  | --    | --  |
| 2          | SB-38      | PRO-2   | Tank Top-Off of 3P (STY)                                | --    | --     | --  | --  | --  | --  | 7.5 | --    | --  |
| 2          | SB-98      | Pumpman | Open Gauging (Ballasting)                               | --    | --     | --  | --  | --  | --  | 6.6 | --    | --  |
| 2          | H-11       | AREA    | Near 5B (TCE) - 10' DW of Expansion Trunk               | --    | >154.5 | --  | --  | --  | --  | --  | 111.8 | --  |
| 2          | MC-13      | PRO-1   | Restricted Gauging (Loading) & Tank Top-Off of 5B (TCE) | --    | 56.9   | --  | --  | --  | --  | --  | --    | --  |
| 2          | MC-37      | AREA    | Near 2A (EGL) Standpipe                                 | --    | --     | --  | --  | --  | --  | --  | --    | ND  |
| 2          | 01-P14     | AREA    | Near 2A (EGL) Standpipe                                 | --    | --     | --  | --  | --  | --  | --  | --    | ND  |
| 2          | MC-11      | PRO-1   | Tank Top-Off of 1A (TCE)                                | --    | 28.8   | --  | --  | --  | --  | --  | --    | --  |
| 2          | MC-18      | AREA    | Near 1A (TCE) Standpipe & Expansion Trunk               | --    | >123.0 | --  | --  | --  | --  | --  | --    | --  |
| 3          | MC-12      | C/M     | Tank Cleaning (Washing)                                 | --    | --     | --  | --  | --  | --  | --  | 49.9  | --  |
| 3          | CG2-018    | Bosun   | Tank Cleaning (Washing)                                 | --    | --     | --  | --  | --  | --  | --  | 36.9  | --  |
| 3          | MC-20      | C/M     | Tank Cleaning (Washing)                                 | --    | --     | --  | --  | --  | --  | --  | 38.5  | --  |
| 3          | SB-18      | Bosun   | Tank Cleaning (Washing)                                 | --    | --     | --  | --  | --  | --  | --  | 35.8  | --  |
| 4          | CG2-019    | Bosun   | Tank Cleaning (Ventilation)                             | --    | --     | --  | --  | --  | --  | --  | >89.8 | --  |
| 4          | X-1        | O/S-1   | Tank Cleaning (Washing)                                 | --    | --     | --  | --  | --  | --  | --  | 23.0  | --  |
| 4          | 02-P20     | O/S-2   | Tank Washing (Ventilation)                              | --    | --     | --  | --  | --  | --  | --  | 18.0  | --  |
| 4          | 02-P17     | SwRI-1  | Tank Washing (Ventilation)                              | --    | --     | --  | --  | --  | --  | --  | 3.7   | --  |

ND = Not Detected

+ = Parallel active and passive sample

TABLE VI. CALCULATED AMBIENT VAPOR EXPOSURE CONCENTRATION, PPP (CONT'D)

| Voyage Day | Sample No. | Worker    | Activity                       | ACT | ICE | DCM  | ICL | TTE | EDC | STY  | NSS  | EGL |
|------------|------------|-----------|--------------------------------|-----|-----|------|-----|-----|-----|------|------|-----|
| 4          | X-10       | O/S-1     | Tank Cleaning (Wash & Vent)    | --  | --  | --   | --  | --  | --  | --   | 7.8  | --  |
| 4          | CG2-017    | O/S-3     | Tank Washing (Ventilation)     | --  | --  | --   | --  | --  | --  | --   | 14.0 | --  |
| 9          | X-4        | A/B-1     | Hose Connect                   | --  | --  | --   | --  | --  | --  | ND   | --   | --  |
| 9          | 02-P12     | A/B-2     | Hose Connect                   | --  | --  | --   | --  | --  | --  | ND   | --   | --  |
| 9          | 63778      | AREA      | Loading Manifold               | --  | --  | --   | --  | --  | --  | 4.5  | --   | --  |
| 9          | CG2-015    | A/B-2     | Hose Connect                   | --  | --  | --   | --  | --  | --  | ND   | --   | --  |
| 9          | SB-25      | 2/M       | Restricted Gauging (Discharge) | --  | --  | --   | --  | --  | --  | ND   | --   | --  |
| 9          | X-7        | Pumpman   | Restricted Gauging (Discharge) | --  | --  | --   | --  | --  | --  | ND   | --   | --  |
| 9          | X-3        | A/B-4     | Restricted Gauging (Discharge) | --  | --  | --   | --  | --  | --  | ND   | --   | --  |
| 9          | CG2-020    | A/B-3     | Hose Disconnect                | --  | --  | --   | --  | --  | --  | ND   | --   | --  |
| 9          | 62745      | AREA      | Restricted Gauging (Discharge) | --  | --  | --   | --  | --  | --  | 9.8  | --   | --  |
| 9          | DM-7       | 3/M-1     | Near Loading Manifold          | --  | --  | --   | --  | --  | --  | ND   | --   | --  |
| 9          | 62743      | PRO-2     | Restricted Gauging (Discharge) | --  | --  | --   | --  | --  | --  | 0.9  | --   | --  |
| 10         | DM-4       | C/M       | Tank Stripping                 | --  | --  | --   | --  | --  | --  | 5.8  | --   | --  |
| 10         | DM-3       | C/M+3/M-2 | Tank Stripping                 | --  | --  | --   | --  | --  | --  | ND   | --   | --  |
| 10         | DM-8       | A/B-1     | Hose Disconnect                | --  | --  | --   | --  | --  | --  | 12.9 | --   | --  |
| 10         | X-2        | 2/M       | Tank Sampling                  | ND  | 0.3 | --   | 0.3 | 0.2 | 0.1 | ND   | --   | --  |
| 10         | DM-6       | A/B-1     | Hose Connect                   | ND  | 9.9 | 2.8  | ND  | 0.2 | 0.2 | ND   | --   | --  |
| 10         | DM-2       | A/B-2     | Hose Connect                   | ND  | ND  | ND   | ND  | ND  | ND  | ND   | --   | --  |
| 10         | X-6        | A/B-3     | Hose Connect                   | --  | 0.4 | 1.7  | --  | --  | ND  | --   | --   | --  |
| 10         | X-9        | A/B-4     | Hose Connect                   | --  | --  | --   | ND  | --  | 0.1 | --   | --   | --  |
| 10         | DM-9       | 3/M-2     | Restricted Gauging (Discharge) | ND  | 0.1 | 26.1 | ND  | ND  | 0.2 | ND   | --   | --  |
| 10         | DM-5       | 3/M-1     | Restricted Gauging (Discharge) | ND  | 0.2 | --   | 0.4 | 0.1 | 1.9 | 5.8  | --   | --  |
| 10         | X-5        | 3/M-2     | Restricted Gauging (Discharge) | --  | --  | ND   | --  | --  | --  | 2.4  | --   | --  |
| 10         | DM-1       | C/M       | Restricted Gauging (Discharge) | ND  | ND  | 26.1 | --  | --  | --  | 2.4  | --   | --  |
| 10         | 62746      | PRO-3     | Near 3S (STY) Tank Ventilation | ND  | --  | --   | --  | --  | --  | 8.1  | --   | --  |
| 10         | 62040      | AREA      | Restricted Gauging (Discharge) | ND  | --  | --   | --  | --  | --  | 50.1 | --   | --  |
| 10         | DM-17      | 3/M-1     | Restricted Gauging (Discharge) | ND  | --  | --   | --  | --  | --  | 3.1  | --   | --  |
| 10         | 64426      | PRO-3     | Restricted Gauging (Discharge) | ND  | --  | --   | --  | --  | --  | 0.7  | --   | --  |
| 10         | DM-13      | C/M       | Restricted Gauging (Discharge) | ND  | 0.4 | 0.4  | --  | --  | --  | ND   | --   | --  |
| 11         | X-19       | 3/M-2     | Restricted Gauging (Discharge) | ND  | --  | --   | --  | 0.2 | --  | ND   | --   | --  |
| 11         | X-14       | A/B-3     | Hose Disconnect                | ND  | 0.4 | 1.4  | --  | 0.3 | --  | ND   | --   | --  |
| 11         | 64421      | AREA      | Near 2D (ACT)                  | ND  | --  | --   | --  | --  | --  | 15.6 | --   | --  |

ND = Not Detected

TABLE VI. CALCULATED AMBIENT VAPOR EXPOSURE CONCENTRATION, PPM (CONT'D)

| Voyage Day | Sample No. | Worker  | Activity                                          | ACT | ICE   | DCM    | TCL | TTE | EDC | STY  | NSS | EGL |
|------------|------------|---------|---------------------------------------------------|-----|-------|--------|-----|-----|-----|------|-----|-----|
| 11         | X-100      | C/M     | Stripping 2D (ACT), 3A (TTE)                      | ND  | --    | --     | --  | ND  | --  | 7.1  | --  | --  |
| 11         | 64422      | C/M     | Stripping 2D Only (ACT)                           | ND  | --    | --     | --  | --  | --  | 15.8 | --  | --  |
| 11         | X-13       | O/S-1   | Hose Disconnect                                   | ND  | 0.4   | 0.1    | --  | 0.1 | --  | ND   | --  | --  |
| 11         | MC-14      | C/M     | Tank Cleaning (Wash & Vent)                       | --  | 34.0  | 29.2   | --  | --  | --  | --   | --  | --  |
| 11         | 62039      | C/M     | Tank Cleaning (Wash & Vent)                       | --  | 36.0  | 29.8   | --  | --  | --  | --   | --  | --  |
| 11         | X-12       | A/B-5   | Tank Cleaning (Wash & Vent)                       | --  | 191.2 | ND     | --  | --  | --  | --   | --  | --  |
| 11         | 62038      | A/B-5   | Tank Cleaning (Wash & Vent)                       | --  | 133.0 | 6.9    | --  | --  | --  | --   | --  | --  |
| 11         | DM-15      | Bosun   | Tank Cleaning (Wash & Vent)                       | --  | 49.8  | 0.3    | ND  | --  | --  | ND   | --  | --  |
| 11         | DM-16      | O/S-2   | Tank Cleaning (Wash & Vent)                       | --  | 113.8 | ND     | ND  | --  | --  | ND   | --  | --  |
| 11         | 08-P8      | AREA    | SwRI Personnel Room (During Tank Cleaning)        | --  | 4.5   | 9.9    | ND  | --  | --  | ND   | --  | --  |
| 11         | SB-2       | Pumpman | Tank Cleaning (Wash & Vent)                       | --  | 181.7 | 14.7   | ND  | --  | --  | ND   | --  | --  |
| 11         | 64423      | SwRI-1  | Tank Cleaning (Wash & Vent)                       | --  | 104.3 | ND     | ND  | --  | --  | ND   | --  | --  |
| 11         | 62037      | SwRI-2  | Tank Cleaning (Ventilation)                       | --  | 79.3  | 13.4   | --  | --  | --  | --   | --  | --  |
| 11         | DM-19      | O/S-2   | Tank Cleaning (Wash & Vent)                       | --  | 69.0  | ND     | 0.7 | --  | --  | ND   | --  | --  |
| 11         | DM-11      | Bosun   | Tank Cleaning (Wash & Vent)                       | --  | 138.3 | 68.5   | ND  | --  | --  | ND   | --  | --  |
| 11         | X-15       | A/B-5   | Tank Cleaning (Ventilation)                       | --  | --    | --     | ND  | 4.5 | --  | --   | --  | --  |
| 11         | L-7        | Pumpman | Open Gauging (Ballast (NCT)) (During Ventilation) | ND  | 21.0  | 18.2   | ND  | 0.5 | --  | ND   | --  | --  |
| 11         | DM-14      | O/S-2   | Tank Cleaning (Wash & Vent)                       | --  | 10.2  | ND     | ND  | --  | --  | ND   | --  | --  |
| 11         | 64425      | SwRI-1  | Tank Cleaning (Wash & Vent)                       | ND  | --    | --     | --  | ND  | --  | --   | --  | --  |
| 12         | X-16       | Bosun   | Tank Entry 7P                                     | --  | --    | 1479   | --  | --  | --  | --   | --  | --  |
| 12         | DM-20      | Bosun   | Tank Entry 5A                                     | --  | 65.5  | --     | --  | --  | --  | --   | --  | --  |
| 12         | 68996      | SwRI-1  | Tank Entry 5A                                     | --  | 58.0  | --     | --  | --  | --  | --   | --  | --  |
| 12         | X-23       | Bosun   | Tank Entry 5B                                     | --  | 890.5 | --     | --  | --  | --  | --   | --  | --  |
| 12         | DM-12      | Bosun   | Tank Entry 7S                                     | --  | --    | >11890 | --  | --  | --  | --   | --  | --  |
| 13         | X-27       | C/M     | Tank Entry 3P,3S,5A,7P,7S                         | --  | 172.8 | 615.9  | --  | --  | --  | 81.0 | --  | --  |
| 13         | 62035      | C/M     | Tank Entry 3P,3S,5A,7P,7S                         | --  | 115.8 | 669.5  | --  | --  | --  | 95.0 | --  | --  |
| 13         | DM-30      | SwRI-1  | Tank Entry 7P                                     | --  | --    | 839.7  | --  | --  | --  | --   | --  | --  |
| 13         | SB-8       | AREA    | SwRI Personnel Room                               | ND  | ND    | 0.2    | ND  | ND  | --  | ND   | --  | --  |

ND = Not Detected

+ = Parallel active and passive sample

| Voyage Day | Sample No. | Worker         | Activity                                      | ACT | ICE   | DCM | ICL   | TIE   | EDC   | STY | NSS | EGL |
|------------|------------|----------------|-----------------------------------------------|-----|-------|-----|-------|-------|-------|-----|-----|-----|
| 13         | DM-26 } +  | A/B-2          | Tank Entry 1A                                 | --  | 1718  | --  | --    | --    | --    | --  | --  | --  |
| 13         | 62034 }    | A/B-2          | Tank Entry 1A                                 | --  | 1893  | --  | ND    | --    | --    | --  | --  | --  |
| 13         | X-26 } +   | A/B-3          | Tank Entry 1D                                 | --  | --    | --  | 752.2 | --    | --    | --  | --  | --  |
| 13         | 62033 }    | A/B-3          | Tank Entry 1D                                 | --  | --    | --  | 908.4 | --    | --    | --  | --  | --  |
| 13         | X-18       | A/B-5          | Tank Cleaning (Washing 1B)                    | --  | 0.2   | --  | ND    | --    | 10.1  | --  | --  | --  |
| 13         | X-25       | AREA           | SwRI Personnel Room                           | ND  | --    | --  | --    | 0.3   | --    | --  | ND  | --  |
| 14         | X-35 } +   | C/M            | Tank Entry 1B, 2D, 3A, 5B                     | ND  | 48.5  | --  | --    | 146.8 | 301.6 | --  | --  | --  |
| 14         | 62032 }    | C/M            | Tank Entry 1B, 2D, 3A, 5B                     | ND  | 201.4 | --  | --    | 221.8 | 539.6 | --  | --  | --  |
| 14         | X-21       | SwRI-2         | Tank Entry 1B, 2D, 3A, 5B                     | ND  | 39.1  | --  | --    | 138.2 | 300.2 | --  | --  | --  |
| 14         | X-8 } +    | C/M            | Tank Entry 1B, 3A                             | --  | --    | --  | --    | 194.3 | 83.4  | --  | --  | --  |
| 14         | 63839 }    | C/M            | Tank Entry 1B, 3A                             | --  | --    | --  | --    | 236.7 | 75.2  | --  | --  | --  |
| 14         | X-40 } +   | SwRI-2         | Tank Entry 1B, 3A                             | --  | --    | --  | --    | 63.3  | 65.4  | --  | --  | --  |
| 14         | 63837 }    | SwRI-2         | Tank Entry 1B, 3A                             | --  | --    | --  | --    | 242.4 | 83.9  | --  | --  | --  |
| 14         | DM-41 }    | A/B-3          | Tank Entry 1D                                 | --  | --    | --  | --    | 267.4 | 144.2 | --  | --  | --  |
| 14         | 62790 }    | A/B-3          | Tank Entry 1D                                 | --  | --    | --  | --    | 425.7 | 183.1 | --  | --  | --  |
| 14         | DM-47 }    | A/B-2          | Tank Entry 1A                                 | --  | --    | --  | --    | 256.0 | 140.2 | --  | --  | --  |
| 14         | 62797 }    | A/B-2          | Tank Entry 1A                                 | --  | --    | --  | --    | 288.4 | 149.0 | --  | --  | --  |
| 15         | DM-40      | Marine Chemist | Tank Entry 1A, 1B, 1D, 2D, 3A, 3P, 3S, 5A, 5D | ND  | 9.1   | --  | 5.7   | 5.3   | 9.2   | 0.7 | --  | --  |

ND = Not Detected

+ = Parallel active and passive sample

The loading of the nine chemicals identified in the sampling plan was accomplished in the above manner. These nine chemicals were loaded into fourteen tanks. A retabulation of the distribution of these chemicals from a previous table is shown in Table VII. Also included is additional information regarding the quantity of cargo loaded per tank and the loading termination method.

TABLE VII. TANK LOADING INFORMATION FOR SELECTED CHEMICALS

| <u>Tank</u> | <u>Chemical</u> | <u>% of Tank<br/>Loaded</u> | <u>Shore Stop<br/>Tanks</u> |
|-------------|-----------------|-----------------------------|-----------------------------|
| 1A          | TCE             | 87.7                        | -                           |
| 1B          | EDC             | 42.5                        | x                           |
| 1D          | TCL             | 72.4                        | x                           |
| 2A          | EGL             | 98.3                        | -                           |
| 2D          | ACT             | 98.2                        | -                           |
| 3A          | TTE             | 51.3                        | -                           |
| 3C          | EGL             | 95.8                        | x                           |
| 3P          | STY             | 97.6                        | -                           |
| 3S          | STY             | 97.2                        | -                           |
| 5A          | TCE             | 98.2                        | -                           |
| 5B          | TCE             | 97.5                        | -                           |
| 6S          | EGL             | 55.4                        | x                           |
| 7P          | DCM             | 58.5                        | x                           |
| 7S          | DCM             | 52.5                        | x                           |

The activities of five different crew members were documented at various times, and their exposures were monitored during the loading sequence. Area samples were also collected. Three of the individuals were from the ship's crew which included the 2/M, 3/M-1, and 3/M-2. The other two were PRO's (PRO-1 and PRO-2). Restricted periodic gauging and restricted tank top-off were the major activities observed. A total of six tank top-offs were documented, five of which were conducted by the PRO's. Most of the periodic gauging was performed by the ship's officers. Discussion of these activities and the corresponding occupational exposures follows.

The last observation period (0000-0400 hours), before the discharge of all tanks was finished, consisted of more tank stripping and one periodic gauging round. The personnel involved in these activities were again the C/M and 3/M-2. The C/M did not appear out on the deck until the tanks were ready to be stripped. The 3/M, though, was out most of this last 4-hour period. The 3/M was made only one gauging round during this time. The tanks that he gauged were 2D, 2E, 3A, 3D and 4A. During the remaining time he was either in the deck house or on deck supervising the A/Bs who were disconnecting the hoses on the tanks that had

During the last hour of this period, the C/M stripped three more cargo tanks. These were 2D, 2E and 3A. This time the 3/M did not assist the C/M. Instead, the C/M performed the activity by himself. In the stripping of 2D and 2E, he viewed the liquid level of these tanks through the open tank hatch. He also observed the discharge pressure gauge. As before, he would continually go through a sequence of valve closings until all the product was discharged. In the stripping of 3A, he monitored the last stages of discharge through the tank gauging standpipe. He did not open the 3A expansion trunk.

Both the C/M and 3/M-2 were monitored for occupational exposure to chemical vapors during these activities. An area sample was also taken in the vicinity of the 2D cargo pump which had leaked a small amount of acetone during the stripping operation. The measured concentrations are shown below.

| <u>Sample No.</u> | <u>Time Period</u> | <u>Personnel</u> | <u>ACT</u> | <u>TTE</u> | <u>STY</u> |
|-------------------|--------------------|------------------|------------|------------|------------|
| X-19              | 0020-0355          | 3/M-2            | ND         | 0.2        | ND         |
| X-100             | 0250-0355          | C/M              | ND         | ND         | 7.1        |
| 64422*}+          | 0304-0325          | C/M              | ND         | --         | 15.8       |
| 64421             | 0258-0347          | AREA             | ND         | --         | 15.6       |

+ Parallel samples

\* Passive sample worn during tank stripping of 2D tank only.

tanks. The PRO-3, who came on duty at 1600 hours, was assigned to 4A and 4B. 3/M-2 assisted the C/M with the aft tanks. All tanks were gauged twice over the 2 hours.

During the middle of this 4-hour period, three cargo tanks were also stripped. These were 5A, 5B and 7P. The personnel involved in this task were the C/M and 3/M-2. In order to strip 7P, the C/M had to view into the tank through the open expansion trunk. As the cargo level dropped, the C/M signaled to 3/M-2 to close down on the cargo valve. They continued this procedure until most of the product was off-loaded. The stripping of 5A and 5B did not require opening of their expansion trunks. Instead, the C/M used the drop in the pump discharge pressure gauge as the indicator for throttling the cargo valve. Again, the 3/M-2 handled the closing of the tanks cargo valves. The duration of tank stripping lasted for approximately 15 minutes for each tank.

Between 2200 and 2400 hours, 6P, 6S and 7S were stripped. The same procedure used by the C/M to strip 7P was also utilized on these tanks.

Along with the occupational exposures measured on the above four individuals during the 4-hour period, one area sample was also collected to evaluate the contribution of styrene vapors from the ventilation of 3P and 3S. Its' location was about 20 feet forward of the 3S deckplate and downwind of it. The concentrations measured on these samples are shown below.

| Sample No. | Time Period | Personnel | Concentrations, ppm |     |      |     |     |     |      |
|------------|-------------|-----------|---------------------|-----|------|-----|-----|-----|------|
|            |             |           | ACT                 | ICE | DCM  | ICL | TTE | EDC | STY  |
| DM-5       | 1958-2200   | 3/M-1     | ND                  | 0.2 | --   | 0.4 | 0.1 | 1.9 | 5.8  |
| DM-17      | 2205-2351   | 3/M-1     | ND                  | --  | --   | --  | --  | --  | 3.1  |
| X-5        | 2045-2400   | 3/M-2     | --                  | --  | ND   | --  | --  | --  | 2.4  |
| DM-1       | 2016-2226   | C/M       | ND                  | ND  | 26.1 | --  | --  | --  | 2.4  |
| DM-13      | 2234-2358   | C/M       | ND                  | 0.4 | 0.4  | --  | --  | --  | ND   |
| 62746      | 2025-2221   | PRO-3     | ND                  | --  | --   | --  | --  | --  | 8.1  |
| 64426      | 2224-2341   | PRO-3     | ND                  | --  | --   | --  | --  | --  | 0.7  |
| 62040      | 2154-2353   | AREA      | ND                  | --  | --   | --  | --  | --  | 50.1 |



| <u>Sample<br/>No</u> | <u>Time<br/>Period</u> | <u>Concentration, ppm</u> |            |            |            |            |            |            |
|----------------------|------------------------|---------------------------|------------|------------|------------|------------|------------|------------|
|                      |                        | <u>ACT</u>                | <u>ICE</u> | <u>DCM</u> | <u>ICL</u> | <u>ITE</u> | <u>EDC</u> | <u>STY</u> |
| DM-6                 | 1028-1150              | ND                        | 9.9        | 2.8        | ND         | 0.2        | 0.2        | ND         |
| DM-2                 | 1028-1150              | ND                        | ND         | ND         | ND         | ND         | ND         | ND         |
| X-6                  | 1030-1110              | --                        | 0.4        | 1.7        | --         | --         | ND         | --         |
| X-9                  | 1130-1329              | --                        | --         | --         | ND         | --         | 0.1        | --         |

During product discharge, both periodic gauging and tank stripping were monitored. Both 3/Ms, the C/M and one PRO were involved in periodic gauging. The task of tank stripping, however, was again handled primarily by the C/M with assistance from 3/M-2. Documentation on these activities occurred between 1500 hours of voyage Day 10 and 0400 hours of Day 11.

The initial observation was conducted on 3/M-2 between 1500-1629 hours. The only tank he gauged during this time was 4A. He spent most of his time near the loading manifold handling the initiation of discharge. He also tightened bolts on some of the valve flange connections which had developed leaks. The EDC flange (1B) and the flange connection on the runaround that was used to transport styrene washing slops to one of the deck tanks had developed leaks. 3/M-2's exposure was monitored on sample DM-9.

| <u>Sample<br/>No</u> | <u>Time<br/>Period</u> | <u>Concentration, ppm</u> |            |            |            |            |            |            |
|----------------------|------------------------|---------------------------|------------|------------|------------|------------|------------|------------|
|                      |                        | <u>ACT</u>                | <u>ICE</u> | <u>DCM</u> | <u>ICL</u> | <u>ITE</u> | <u>EDC</u> | <u>STY</u> |
| DM-9                 | 1500-1629              | ND                        | 0.1        | 26.1       | ND         | ND         | 0.2        | ND         |

The next observations were conducted from 2000-2400 hours. The start of this time period coincided with the commencement of tank ventilation of 3P and 3S. Between 2000-2200, periodic gauging duties were divided up between 3/M-1 and the C/M. 3/M-1 took care of the tanks forward of the Number 3 tanks while the C/M handled the tanks aft of the Number 3

- o The ship's winch was connected to the hose by a strap.
- o The hose flange was maneuvered to the ship's flange and was bolted in place.
- o The bolts were tightened and the strap removed.

A/B-1 and A/B-2 hooked up the hoses on the bottom level of the manifold while A/B-4 worked on the upper level hose connections. Hose connect times ranged from 2-5 minutes with an average of 4 minutes. There was no noticeable spillage of liquid during the entire activity.

The exposures for the above individual were monitored during the hose connect activity. Shown below are the individuals, the hoses they connected or the flanges they removed, and their exposure sample numbers.

| <u>Sample No.</u> | <u>Personnel</u> | <u>Hoses Connected</u>          | <u>Ship's Flanges Removed</u>     |
|-------------------|------------------|---------------------------------|-----------------------------------|
| DM-6              | A/B-1            | 2A, 2D, 3A<br>5A, 5B, 6P,<br>7P | --                                |
| DM-2              | A/B-2            | 2A, 2D, 3A<br>5A, 5B, 6P,<br>7P | --                                |
| X-6               | A/B-3            | --                              | 1A, 1B, 2A, 3F,<br>4A, 4C, 5B, 7P |
| X-9               | A/B-4            | 1B, 1D, 3C,<br>3D, 4A, 4C       | --                                |

The sample times and concentration of chemical vapors collected on these samples are shown below.

### Discharge to Terminal No. 3

The bulk of the ship's cargo was off-loaded at this terminal. In addition, the two styrene tanks, 3P and 3S, were washed and ventilated while the ship was docked at Terminal 3.

Prior to hose connect, the 2/M took initial ullage and temperature readings on the remaining tanks. The 2/M was accompanied by two dock employees who also made similar measurements. The readings were taken through the gauging standpipes. Although all tanks were gauged, the 2/M's exposure to chemical vapors were monitored only for the chemicals contained in the No. 1 through the No. 3 tanks. When he reached the first No. 4 tank he requested that the sampler be removed. The chemical concentrations measured on the sample are shown below.

| <u>Sample<br/>No.</u> | <u>Time<br/>Period</u> | <u>Concentration, ppm</u> |            |            |            |            |            |
|-----------------------|------------------------|---------------------------|------------|------------|------------|------------|------------|
|                       |                        | <u>ACT</u>                | <u>ICE</u> | <u>ICL</u> | <u>ITE</u> | <u>EDC</u> | <u>STY</u> |
| X-2                   | 0839-0900<br>1010-1121 | ND                        | 0.3        | 0.3        | 0.2        | 0.1        | ND         |

Hose hook-up was a more complex activity at this terminal than at the previous terminals. A total of four crewman were involved. Prior to connecting the hoses to the ship's valves, the valve flanges were unloosened and removed. This task was performed by A/B-3. He removed eight flanges spending approximately two minutes per flange. The other three crewmen connected the dock hoses to the ship's valves. Their procedure was as follows:

- o The hose was moved to the vicinity of the ship's manifold by a dock winch.
- o The crewmen proceeded to remove the blind flange from the hose.

Tank 3P was stripped of cargo in much the same fashion as 3S. However, the duration and frequency of sighting into 3P were slightly different. The C/M viewed 3P only seven times through the Butterworth opening for the following duration: 6, 7, 12, 15, 43, 58 and 60 seconds. The vapor exposures during stripping are summarized below.

| <u>Sample<br/>No.</u> | <u>Time<br/>Period</u> | <u>Personnel</u> | <u>STY<br/>(ppm)</u> |
|-----------------------|------------------------|------------------|----------------------|
| DM-4                  | 0746-0802              | C/M              | 5.7                  |
| DM-3                  | 0814-0833              | C/M              | ND                   |

Disconnect of the 3S and 3P loading hoses followed after discharge was completed. Only one crewman, A/B-1, performed the disconnect on these hoses. His attire consisted of shorts, an open short sleeve shirt and rubber gloves. These were the same clothes he wore when he was involved in hook up of hoses prior to barge loading. His lack of clothing was much more noticeable during this hose disconnect activity because when he loosened the bolts to each hose about two gallons of styrene splashed down into the drip pan and partially onto his legs. Once all bolts were removed, the dock crane lifted the hose from the last bolt. At this time more liquid styrene spilled out into the drip pan. Finally, A/B-1 bolted the blind to the hose and motioned the dock crew to remove the hose. The total time for the activity was 11 minutes. A/B-1 was monitored for exposure to styrene vapor during this activity. The measured concentration is shown below on Sample DM-8.

| <u>Sample<br/>No.</u> | <u>Time<br/>Period</u> | <u>STY<br/>(ppm)</u> |
|-----------------------|------------------------|----------------------|
| DM-8                  | 0841-0852              | 12.9                 |

| <u>Sample<br/>No.</u> | <u>Time<br/>Period</u> | <u>Personnel</u> | <u>STY<br/>(ppm)</u> |
|-----------------------|------------------------|------------------|----------------------|
| X-3                   | 1553-1603              | A/B-4            | ND                   |
| CG2-020               | 1600-1604              | A/B-3            | ND                   |
| 62745                 | 1556-1605              | AREA             | 9.8                  |

#### Discharge to Terminal No. 2

As a result of rainy weather conditions, documentation and occupational exposure monitoring of the hose hook up activity was not conducted at Terminal 2. Exposure monitoring was performed on crewmen involved in periodic discharge gauging after the weather cleared. Documentation and monitoring of the 3P and 3S tank stripping activity and hose disconnect was also accomplished.

Occupational exposure samples were collected during a portion of the periodic tank gauging activities. The personnel monitored for periodic tank gauging were 3/M-1 and PRO-3. Shown below are the exposure concentrations measured on these samples.

| <u>Sample<br/>No.</u> | <u>Time<br/>Period</u> | <u>Personnel</u> | <u>STY<br/>(ppm)</u> |
|-----------------------|------------------------|------------------|----------------------|
| DM-7                  | 2042-2345              | 3/M-1            | ND                   |
| 62743                 | 2104-2304              | PRO-3            | 0.9                  |

The first tank to be stripped was 3S. Toward the end of discharge of 3S, the C/M instructed one of the A/Bs on watch to remove the Butterworth (BW) plate. During the next 15 minutes, the C/M peered into the 3S tank through the BW opening to make sure that the maximum amount of liquid was pumped out of the tank. During this time, he made 14 consecutive sightings through the opening ranging from 4-17 seconds each. His breathing zone was roughly four to five feet above the opening. Each time he would look into the tank, he motioned to one of the A/Bs to close down slightly on the product valve.

| <u>Sample<br/>No.</u> | <u>Time<br/>Period</u> | <u>Personnel</u> | <u>STY<br/>(ppm)</u> |
|-----------------------|------------------------|------------------|----------------------|
| X-4                   | 1049-1123              | A/B-1            | ND                   |
| 02-P12                | 1050-1107              | A/B-2            | ND                   |
| CG2-015               | 1112-1123              | A/B-2            | ND                   |
| 63778                 | 1049-1104              | AREA             | 4.5                  |

During the off-loading of styrene to the barge, the 2/M and Pumpman performed periodic tank gauging on 3P and 3S. Although the Pumpman was out on deck a similar amount of time as the 2/M, he did not become involved in tank gauging until the end of discharge. The Second Mate made ullage readings over a 3-hour period. He gauged tank 3P five times and 3S three times for durations ranging from 15 to 30 seconds. During the last hour, the Pumpman gauged the tanks. He made two rounds on each tank spending less than 31 seconds during each visit. He finally stationed himself near 3S until discharge was completed. Both crewman usually stood with their breathing zone approximately 2-3 feet above the standpipe. Both crew members were monitored for styrene exposure during these activities. However, no styrene was detected on the samples taken, as shown below.

| <u>Sample<br/>No.</u> | <u>Time<br/>Period</u> | <u>Personnel</u> | <u>STY<br/>(ppm)</u> |
|-----------------------|------------------------|------------------|----------------------|
| SB-25                 | 1310-1611              | 2/M              | ND                   |
| X-7                   | 1504-1559              | Pumpman          | ND                   |

After discharge had stopped, the hoses were removed by two other crewmen, A/B-3 and A/B-4. A/B-3 unbolted the cargo hose flanges. When the first bolt was loosened, a cupful of product drained from the connection. During this time, A/B-4 was stationed above the manifold and eventually operated the winch to transfer the hoses back to the barge. The total time for this activity was 3-4 minutes. In addition to monitoring both individuals, an area sample was also collected near the 3P and 3S manifold valves. The measured concentrations are shown below.

## VII.2 Product Discharge

Cargo was off loaded from the ship at four terminals and one barge. Detailed observation of the discharge to the first and last terminal was not performed because the off-loaded cargo (Lignin Liquor) was not one of the chemicals selected for the sampling program. Documentation of the activities of the crew was accomplished at the other three locations. The first of these three was the discharge of half of the styrene cargo to a barge. The final half of this cargo was off-loaded at the second terminal. Finally, the bulk of the ship's cargo was discharged at the third terminal.

The activities of ten different crewmen and PRO were documented and monitored during these cargo discharge operations. The ten crewmen consisted of four A/Bs, one O/S, the C/M, the 2/M, both 3/Ms and the Pumpman. The predominant activities performed by the unlicensed crew were cargo hose hookup and disconnect. Periodic tank gauging was handled by the Mates and Pumpman. Tank stripping was conducted primarily by the C/M. The observations and monitored exposures are summarized below.

### Discharge to a Barge

As the barge came alongside the ship, A/B-1 and A/B-2 removed the bolts from the flanges of the 3P and 3S manifold valves. Liquid spillage was not observed when the flanges were unloosened. Following this, A/B-2 moved forward to help secure the barge to the ship. Upon his return, he and AB 1 proceeded to secure the barge loading hose to the 3P and 3S manifold valve flanges. Flange removal and hose hookup took two and four minutes, respectively.

Exposures were measured on both of the A/Bs during hose hookup. A/B-1 was monitored with one continuous sample while two sequential samples were collected on A/B-2: one for flange removal and one for hook up of the barge hose. In addition to the personal samples, one area sample was taken with a passive badge in between the 3P and 3S valve flanges during flange removal. These concentrations are shown below.

The PRO's position relative to the gauging standpipe for the top-off of 3S and 3P was similar to 5A. During these gaugings though he constantly kept his head above the standpipe viewing the gauging tape repeatedly. He observed the tape continuously for 4-1/2 minutes on 5A followed by a 2-minute reading on 3S. The total time spent near the 3S gauging standpipe was 13 minutes. He spent about a fourth of this time actually topping off 3P. The actual gauging on 3P lasted for 3-minutes during which time, he left the tape in the gauge pipe and looked at it continuously.

After the loading of 3P and 3S, nitrogen was blown through the cargo piping from shore to drain the lines into the ship tanks. When 3P was purged, styrene spilled out of the gauging standpipe. After noticing the leak, the PRO secured the ullage cap, and the leak stopped. The period of time he spent in the vicinity of the styrene vapors from this spill was about 2 minutes.

Three separate occupational exposure samples were collected on the PRO-2, one for each top-off. In addition, a parallel (passive and active) area sample was taken during top-off of 3S. Its' location was 2 feet above and 6 inches to the stern of the 3S standpipe. The concentrations on these samples are shown below.

| <u>Sample No.</u> | <u>Tank No.</u> | <u>Type of Sample</u> | <u>Concentration (ppm)</u> |            |
|-------------------|-----------------|-----------------------|----------------------------|------------|
|                   |                 |                       | <u>ICE</u>                 | <u>STY</u> |
| SB-36             | 5A              | P                     | 58.4                       | ---        |
| 03-P19            | 3S              | P                     | --                         | 7.5        |
| H-9               | 3S              | A                     | --                         | ND         |
| 62799 } +         | 3S              | A                     | --                         | 15         |
| SB-38             | 3P              | P                     | --                         | 6.6        |

+ Parallel Sample



During the first hour of the last observation period, PRO 1 made three soundings of tank 1A each about 20 minutes apart. In the last hour, he stationed himself about 20-30 feet away from the tank hatch. During this hour, he also gauged the tank three times. About 10 minutes before loading had stopped, his position was next to the standpipe where he continually checked the product level until loading of 1A was finished.

Occupational exposures were monitored during each of the periods. Area samples were also obtained during the top-off of tanks 5B and 1A. The following concentrations were measured.

| <u>Sample No.</u> | <u>Tank No.</u> | <u>Type of Sample</u> | <u>Concentration (ppm)</u> |            |
|-------------------|-----------------|-----------------------|----------------------------|------------|
|                   |                 |                       | <u>ICE</u>                 | <u>STY</u> |
| TX-104            | 3P & 3S         | P                     | ---                        | ND         |
| MC-13             | 5B              | P                     | 56.9                       | ---        |
| H-11              | 5B              | A                     | >154.5                     | ---        |
| MC-11             | 1A              | P                     | 28.8                       | ---        |
| MC-18             | 1A              | A                     | >123.0                     | ---        |

Activities of PRO-2 (0016-0037), (0215-0243), (0245-0259) Day 2

This PRO stood the 0000-0800 watch. During his watch, he topped off three tanks, 5A, 3S and 3P. The periods shown above correspond to the times during which he was being monitored for each tank top-off, respectively.

The overall time PRO-2 spent topping-off the 5A tank was approximately 8 minutes. He made six ullage readings during this time; five of these readings took from 6-23 seconds, and one reading took 2-minutes. He was located downwind of the standpipe with his breathing zone approximately 1-2 ft above it for each gauging. The standpipe was approximately 20 feet downwind from the expansion trunk where the tank was being vented.

Later in his watch, his area of responsibility shifted to three aft tanks and one forward tank (1B). Two of the aft tanks, 7S and 7P, were gauged twice each within one hour. The other aft tank, 5B, was gauged once as it had resumed loading during this time. He made one ullage reading at 1B. Not long after this reading was made, loading was stopped on 1B. The method and duration of these tank gaugings were the same as noted previously.

The 3/M's exposure during the entire observation period was monitored on the sample shown below:

| <u>Sample</u> | <u>DCM</u> | <u>TTE</u> | <u>EDC</u> | <u>STY</u> |
|---------------|------------|------------|------------|------------|
| SB-16         | 0.3        | 0.13       | ND         | ND         |

Activities of PRO 1 (2116-2328) Day 1, (1757-1841) and (2152-0006) Day 2

The PRO performed periodic gauging of 3P and 3S, top-off of 5B, and periodic gauging and top-off of 1A during time period 1, 2 and 3, respectively.

Exact observation of PRO 1 during periodic gauging of 3S and 3P was not possible because the activities of other ship personnel were being documented. However, based on discussions with the PRO he gauged these tanks once every 20 minutes between 2116-2328 hours.

During the second time PRO-1 topped off tank 5B. The total time spent near 5B was approximately 15 minutes. During this time, he gauged the tank nine times. When not actually taking an ullage reading, he sat about two feet downwind of the standpipe on cargo piping. This location was also downwind of the vapors venting from the 5B tank hatch.

tanks 3A, 5A, 3C and 1B. He made three soundings at 3A and 1B and one sounding at 5A and 3C. He also gauged other tanks that were already being loaded. These were 5B, 2D, 4C, 7P and 7S. He made one sounding at each of these except for 4C and 2D, of which he gauged twice.

The top-off of 2D was performed over a 22-minute period. During this time he gauged the tank 11 times. The gauging durations ranged from 15-30 seconds each. The odor of acetone vapors was very evident around the gauging standpipe. These vapors were from the 2D tank hatch which was upwind of the standpipe. The acetone tank was one of the chemical tanks that was not short loaded.

One occupational exposure sample was collected during each of these periods. The concentration of the chemicals monitored are shown below.

| <u>Sample<br/>No.</u> | <u>Time<br/>Period</u> | <u>Day</u> | <u>Concentration, ppm</u> |            |            |            |            |            |
|-----------------------|------------------------|------------|---------------------------|------------|------------|------------|------------|------------|
|                       |                        |            | <u>ACI</u>                | <u>ICE</u> | <u>DCM</u> | <u>TTE</u> | <u>EDC</u> | <u>STY</u> |
| MC-17                 | 1727-2114              | 1          | ND                        | ND         | ND         | ND         | ND         | ND         |
| MC-19                 | 2118-2154              | 1          | 176.7                     | ---        | ---        | ND         | ---        | ND         |

Activities of 3M-2 (0005-0346) Day 2

3/M-2 performed periodic tank gauging during this watch period. He made two gauging rounds to four of the tanks located on the forward half of the ship within the first 30 minutes of the period. These tanks were 3P, 3S, 3A and 1B. With the exception of one 9-minute gauging period at 3A, 3/M-2 spent between 10-50 seconds making the actual ullage reading on the other tanks during these two rounds. His breathing zone was upwind and normally 1-2 feet above the standpipe.

Activities of 2/M (1524-1701) and (1840-2109) Day 1

The second mate performed restricted periodic tank gauging during both observation periods. During most of the first period, styrene (3P & 3S) was the only chemical being loaded. Toward the end of this period, loading of 2D (ACT), 7P (DCM), and 7S (DCM) had commenced. The 2/M gauged each of these tanks once during this period. Although more tanks were being loaded during the second period, the 2/M gauged only two tanks. One of the tanks was 5B (TCE). A heel was being loaded into 5B. The 2/M stayed near the 5B standpipe continuously for 11 minutes gauging the tank every 30 seconds. The other tank that he gauged was 2D, which now had resumed loading. He gauged 2D three times for a period of 2 minutes each and one time for 30 seconds.

With the exception of 7P & 7S, all gauging standpipes were downwind of their respective tank hatches. In addition, styrene was being vented by vapor return.

One occupational exposure sample was collected on the 2/M during each of these observation periods. The concentration of the chemicals monitored are shown below.

| <u>Sample No.</u> | <u>Time Period</u> | <u>Day</u> | <u>Concentration, ppm</u> |            |            |            |
|-------------------|--------------------|------------|---------------------------|------------|------------|------------|
|                   |                    |            | <u>ACT</u>                | <u>ICE</u> | <u>DCM</u> | <u>STY</u> |
| H-8               | 1524-1701          | 1          | ---                       | ---        | 0.2        | ND         |
| 03-P18            | 1840-2109          | 1          | 7.7                       | ND         | ---        | ND         |

Activities of 3/M-1 (1727-2114) and (2118-2154) Day 1

This 3/M was involved in periodic tank gauging during the first period and tank top-off of 2D during the second period. Between 1727-2114 hours, 3/M-1 made initial gaugings of the heel loading of four different

The final activity observed at Terminal 3 was the disconnect of loading hoses by two unlicensed crewmen, A/B-3 and O/S-1. The entire activity lasted for approximately three hours. Basically, A/B-3 performed most of the hose disconnects. O/S-1 assisted the A/B for the first hour; however, most of O/S-1's time was spent bringing equipment from the dock to the ship. A/B-3 disconnected the hoses in the reverse order described earlier for hose connect. When the flanges were unbolted some residual liquid would spill out. The amount was usually small because after loading each cargo line was back purged with N<sub>2</sub> from the shore. The hoses that A/B-3 disconnected were 3C, 3D, 7P, 3A, 5B, and 6P. The other cargo lines had been removed earlier the day before. The occupational exposures of these two individuals were monitored while they performed the above activities. The concentrations measured are shown below.

| <u>Sample No.</u> | <u>Time Period</u> | <u>Personnel</u> | <u>ACT</u> | <u>ICE</u> | <u>DCM</u> | <u>ITE</u> | <u>STY</u> |
|-------------------|--------------------|------------------|------------|------------|------------|------------|------------|
| X-13              | 0444-0741          | O/S-1            | ND         | 0.4        | 0.1        | 0.1        | ND         |
| X-14              | 0453-0745          | A/B-3            | ND         | 0.4        | 1.4        | 0.3        | ND         |

### VII.3 Ballasting

Periodic gauging of the ship's ballast tanks by the Pumpman was documented twice, once at the end of loading while the ship was in port and again during tank cleaning on the ballast leg of the voyage. The condition of the ballast tanks were different on each occasion. The first time the tanks were ballasted they were "dirty" because they contained residual naptha product which had been previously carried, off-loaded, and once ballasted prior to reaching the loading port. Consequently, there existed a potential for exposure to naptha vapors for the Pumpman. Prior to the second ballasting operation, the ballast tanks were cleaned and ventilated. As a result, exposure to naptha vapors was anticipated to be low as compared to the first ballasting operation.

The method used to periodically gauge the ballast tanks was the open gauging method. As noted in Section I, the ballast tanks contained no other means of venting except through the ullage ports atop the tank hatches. Restricted gauging standpipes were not available on these tanks. Consequently, ullage readings had to be taken through the open ullage port, which also served as the vent.

Documentation of the Pumpman's work practices during gauging, as well as monitoring his exposure, was performed during the first ballasting activity. However, because tank cleaning was the major activity when the second ballasting operation was performed, only exposure monitoring was accomplished at that time. The tanks that were ballasted at the loading port were the 2P and 2S tanks. The Pumpman made six visits to 2S and four visits to 2P. Except for two ullage readings, that lasted 1-2 minutes, all gauging durations lasted for less than 60 seconds. Initially, he would visually sight through the ullage port, to make sure his gauging tape float was touching the liquid surface. Since it was during the day, he used a mirror to reflect light into the tank so that he could see inside. After the fourth gauging, he changed his technique to viewing the gauging tape on the edge of the ullage port from an upwind position. He could not view directly into the tank because the naptha vapors were too strong.

One occupational exposure sample was collected for each ballasting operation. During the second ballasting other chemicals venting from tanks being cleaned were also noted. The exposure concentrations that were obtained on these samples are shown below. The samples are listed in the order that they were taken.

| <u>Sample<br/>No.</u> | <u>Chemical Concentration, ppm</u> |            |            |
|-----------------------|------------------------------------|------------|------------|
|                       | <u>ACT</u>                         | <u>TTE</u> | <u>NSS</u> |
| SB-98                 | --                                 | --         | 111.8      |
| X-25                  | ND                                 | 0.3        | ND         |

#### VII.4 Tank Cleaning

Extensive tank cleaning was performed on both the laden and ballast portions of the voyage. The purpose for cleaning the tanks was to gasfree the ship because it was going into dry dock at the end of the voyage. During the laden voyage the ship's six ballast tanks were washed and ventilated over a two day period. On the ballast leg, the cargo tanks were cleaned. Some of the cargo tanks required both washing and ventilation while others were just ventilated. As many as nine different crew members were monitored for occupational exposure during both cleaning operations. In some cases, as many as six individuals were being monitored at one time. Consequently, a general description of these activities will be given along with the monitored exposures.

##### Cleaning of Ballast Tanks

During the first day of the laden voyage, all six of ballast tanks were water washed. Washing was not initiated until the ship was far enough away from shore (50 miles) to discharge the dirty wash water overboard. The two individuals who supervised this activity were the C/M and the Bosun. Although they were being assisted by A/Bs and O/Ss, only the activities of the C/M and Bosun were monitored and documented during washing. While the exact timing and sequence of the washing procedure varied from tank to tank, in general, the following method was used.

- o The hatch on the tank to be washed was opened for visual determination of wash water level.
- o Wash water was pumped in using a portable Butterworth machine.
- o The ballast pump was started and the discharge valve was adjusted to balance inflow to outflow.

- o To set the flow, periodic sighting was made into the tank hatch to observe the water level.
- o When the rate was balanced, the person washing the tank would station himself near the manifold railing where the slops were being discharged overboard.
- o Clearness of the wash water was the sign of a clean tank.
- o After all ballast tanks on one side of the ship were finished, the ballast deck piping was drained onto the deck.

The starboard ballast tanks were washed first. The Bosun handled 2S while the C/M took 4S. After finishing 4S, the C/M worked 5S. The Bosun assisted him for a short while, then directed the unlicensed crew to move the washing machines from 2S and 4S over to the port tanks. Once the starboard ballast lines were drained the C/M and Bosun, commenced working of the port ballast tanks in the same manner. While on the port side, the C/M spent most of his time just forward of the 4P expansion trunk controlling the washing rate. The Bosun accompanied the C/M. The Bosun also directed the A/Bs and O/Ss to set stripping lines into the starboard tanks to strip out the residual wash water in these tanks.

During the tank washing activity, the C/M and Bosun were monitored for occupational exposure to naphtha vapors. Two consecutive samples were obtained on each of these individuals. The first set monitored their exposure while washing the starboard ballast tank. The second set was worn while these individuals worked with the port tanks. Listed below are the measured concentrations.

| <u>Sample No.</u> | <u>Personnel</u> | <u>Time Period</u> | <u>Naphtha (ppm)</u> |
|-------------------|------------------|--------------------|----------------------|
| MC-12             | C/M              | 1237-1412          | 49.9                 |
| CG2-018           | Bosun            | 1209-1426          | 36.9                 |
| MC-20             | C/M              | 1420-1524          | 38.5                 |
| SB-18             | Bosun            | 1429-1519          | 35.8                 |



On the next day, all six ballast tanks were ventilated using the ship's central Kathabar blower. Air supplied by this unit is sent to the ship's manifold where it can be transferred to any tank on the ship by means of a flexible hose connection. At this time the hoses were connected to the port and starboard ballast tank manifold valves. The air was then discharged into the tank through the cargo drop at the tank bottom. The tank vapors were discharged to the atmosphere through the tanks' ullage ports and their Butterworth openings.

The activities of three of the crewmen were documented during the morning while the ballast tanks were being ventilated. These were the Bosun, O/S-1 and O/S-2. The two O/Ss moved Butterworth hoses near the 6A and 6B tanks so that these tanks could be washed immediately after their cargo was off-loaded at the first discharge terminal. The Bosun directed these two individuals to make ready other equipment and to secure items that were not going to be used. Periodically, the Bosun viewed into some of the ballast tanks to see how dry they were. Similar activities such as securing equipment on deck, were performed after lunch. The workers this time were O/S-1 and O/S-3.

In addition to monitoring the exposures of these individuals during their morning and afternoon work activities, one of the SwRI personnel also wore a passive dosimeter during the afternoon activities. These exposures are noted below.

| <u>Sample<br/>No.</u> | <u>Personnel</u> | <u>Time<br/>Period</u> | <u>Naphtha<br/>(ppm)</u> |
|-----------------------|------------------|------------------------|--------------------------|
| X-1                   | O/S-1            | 0930-1142              | 23                       |
| CG2-019               | Bosun            | 0849-1112              | >89.8                    |
| 02-P20                | O/S-2            | 1035-1132              | 18.0                     |
| X-10                  | O/S-1            | 1326-1456              | 7.8                      |
| 02-P17                | SwRI-1           | 1336-1450              | 3.7                      |
| CG2-017               | O/S-3            | 1323-1413              | 14                       |

### Cleaning of the Cargo Tanks

The cleaning of the ship's cargo tanks commenced the day the ship left Terminal No. 3. At this time, only one tank contained cargo, and it was subsequently off loaded at the fourth and last terminal. The majority of the cargo tanks were washed with water and gas freed. Eight of the tanks, however, were only ventilated. These eight tanks contained one of the chemicals selected for exposure monitoring. These were 1A, 1D, 5A, 5B, 2D, 3A, 7P, and 7S. Tank 1B was the only selected chemical tank that was washed prior to being ventilated. Both Coppus blowers and the Katharbar system were used to ventilate the tanks.

Five different crewman were documented and monitored during the tank cleaning operation. These included the C/M, Bosun, Pumpman, A/B-5, and O/S-2. These individuals performed a variety of tasks. The C/M performed the actual washing of tank 1B. He was assisted by the Bosun, who washed 6P and 6S. The Bosun also supervised the unlicensed crewmen in preparing and moving equipment to the various tanks being washed. After a tank washing was finished, the Bosun removed the drain plugs to drain the cargo deck piping. The Pumpman also removed drain plugs on cargo lines while he was on deck. In addition, the Pumpman transferred ballast between the forward ballast tanks to adjust the ship's list and facilitate maximum removal of wash water. During washing O/S-2 and A/B-5 moved the Butterworth machines from tank to tank and removed blind flanges on all vent lines at the B/3 mast risers.

All of these tasks were performed while most of the tanks of interest were being ventilated. The odor of chemical vapors was prevalent over the entire ship's deck. The vapors of TCE and DCM were most predominant because of the cargos high volatility and because these products had been carried in more than one tank.

Occupational exposure to the chemical vapors was monitored on each of the five ship's crewmen involved in the tank cleaning activities. Parallel passive and active samples were obtained on the C/M and A/B-5. SwRI personnel also wore passive badges while they were on deck documenting the activities of the crew. The measured exposures on these samples are shown in the following table.

| Sample No. | Personnel | Time Period | Concentration, ppm |       |      |     |     |     |     |
|------------|-----------|-------------|--------------------|-------|------|-----|-----|-----|-----|
|            |           |             | ACT                | ICE   | DCM  | ICL | TTE | STY | NSS |
| MC-14 }+   | C/M       | 1226-1500   | --                 | 34.0  | 29.2 | --  | --  | --  | --  |
| 62039 }    | C/M       | 1226-1500   | --                 | 36.0  | 29.8 | --  | --  | --  | --  |
| X-12 }+    | A/B-5     | 1245-1350   | --                 | 191.2 | ND   | --  | --  | --  | --  |
| 62038 }    | A/B-5     | 1245-1350   | --                 | 133.0 | 6.9  | --  | --  | --  | --  |
| X-15       | A/B-5     | 1412-1455   | --                 | --    | --   | ND  | 4.5 | --  | --  |
| DM-15      | Bosun     | 1217-1323   | --                 | 49.8  | 0.3  | ND  | --  | ND  | --  |
| DM-11      | Bosun     | 1327-1452   | --                 | 138.3 | 68.5 | ND  | --  | ND  | --  |
| SB-2       | Pumpman   | 1258-1453   | --                 | 181.7 | 14.7 | ND  | --  | ND  | --  |
| L-7        | Pumpman   | 1545-1625   | ND                 | 21.0  | 18.2 | ND  | 0.5 | ND  | ND  |
| DM-16      | O/S-2     | 1229-1335   | --                 | 113.8 | ND   | ND  | --  | ND  | --  |
| DM-19      | O/S-2     | 1335-1502   | --                 | 69.0  | ND   | 0.7 | --  | ND  | --  |
| DM-14      | O/S-2     | 1535-1553   | --                 | 10.2  | ND   | ND  | --  | ND  | --  |
| 64423      | SwRI-1    | 1240-1427   | --                 | 104.3 | ND   | ND  | --  | ND  | --  |
| 64425      | SwRI-1    | 1551-1625   | ND                 | --    | --   | --  | ND  | --  | --  |
| 62037      | SwRI-2    | 1302-1510   | --                 | 79.3  | 13.4 | --  | --  | --  | --  |

+ Parallel samples

The only tank of interest that was washed and gas freed, was 1B. This tank was washed by A/B-5. The washing was performed the day after the ship left the last discharge terminal. A/B-5 did not monitor the wash water level through the tank hatch. The hatch was kept closed. Instead, he stationed himself near the 1B tank pump and balanced wash water rates by opening and closing the pump discharge valves. This procedure was similar to that used to strip tanks of cargo. To determine if the tank was clean, he would open the cargo line drain valve, collect a sample of the wash water with his hands, and smell and taste the liquid for the presence of EDC. On the third test he could not detect EDC; therefore, he ceased washing of 1B.

A/B-5's exposure to EDC and to other chemical vapors being vented from nearby tanks was monitored in the following sample.

| <u>Sample<br/>No.</u> | <u>Time<br/>Period</u> | <u>ICE</u> | <u>ICL</u> | <u>EDC</u> |
|-----------------------|------------------------|------------|------------|------------|
| X-18                  | 1411-1434              | 0.2        | ND         | 10.1       |

#### Tank Entry

All enclosed spaces, especially cargo tanks, had to be gas-freed for the ship to enter dry dock. It is very seldom that gas-freeing can be accomplished without tank entry by some of the ship's personnel. The tanks were entered to test the tanks to see if they were, in fact, gasfreed. Only after the tank concentration was measured could the C/M determine if more cleaning or ventilation was necessary. If tank conditions indicated that continued ventilation would not be sufficient to produce a gas free state, then tanks were entered to do manual hand mucking. Tanks were also entered to alleviate improper equipment malfunction or ship design that would have prolonged the gas-freeing time of certain tanks.

All in all, tanks were entered on 11 different occasions. The individuals that entered tanks included the Bosun, the C/M and three A/Bs (A/B-1, A/B-2, and A/B-3). The activities performed by these individuals were documented and their exposures were monitored. To compliment the exposure measurements, grab samples were collected in glass syringes and later analyzed on a gas chromatograph. The grab samples were collected by SwRI personnel who accompanied the crewmen into the tank when possible. On certain occasions the SwRI personnel also wore personal sampling equipment.

The first series of tank entries involved the Bosun, exclusively. He entered four tanks (7P, 7S, 5A, and 5B) for the purpose of eliminating conditions that would have extended the ventilation time for these tanks.

Two of these tanks, 7P and 7S, contained pump priming cans that were used for priming of the tank's cargo pump. After cargo was off-loaded, approximately 55 gallons of residual cargo remained in the reservoirs. Because the liquid surface was small and the priming cans were located in areas shielded from the ventilation air flow, removal by evaporation was slow. To accelerate the evaporation the Bosun entered these tanks to open the drain valves on the priming cans. This allowed the residual cargo to spread out over the tank bottom and evaporate more rapidly.

Accumulation of residual cargo in hard to ventilate areas of the tank was also the reason tanks 5A and 5B had to be entered. The areas in question were the pump sumps. Fixed stripping lines from the deck to the bottom of the sump had become clogged by previous cargo that had polymerized in these tubes. Consequently, to remove the liquid from the sump, stripper hoses had to be physically placed inside the sump at the tank bottom. The Bosun performed this activity in both 5A and 5B.

Precautionary procedures were minimal in all four entries. Before entering, oxygen, combustible gas and toxicity measurements were not taken. The Bosun utilized his sense of smell to tell him how strong the chemical vapors were inside the tank. Even though the vapor concentrations were high in some of these tanks, the rationale that he was only going to be down in the tanks for a short time was used to justify his entry. With the exception of 5A, the duration of the tank entries was approximately two minutes. His tank entry time on 5A was six minutes. An organic vapor cartridge respirator was worn only when tanks 5B and 7S were entered. A ship's crewman was on standby on deck during each of the Bosun's entries except for 5B.

Shown in Table VIII are the occupational exposure concentrations measured on the sample tubes the Bosun wore during each tank entry. Grab samples were also collected during each entry except for tank 7P. A parallel exposure sample was collected on an SwRI employee who entered tank 5A with the Bosun.

At some point in the ventilation process, tanks were entered by the C/M to determine if they were gas-freed or if more cleaning or ventilation was required. The C/M was the only individual that performed the tank testing activity. In a two-day period, he made three series of multiple tank entries. During each series, the following items were documented. While the C/M was in the tank, he did not have anyone standing by on deck.

TABLE VIII. TANK ENTRY EXPOSURE CONCENTRATIONS ON THE BOSUN

| Tank No. | Type of Sample | Sample No. | Duration (min) | TCE (ppm) | DCM (ppm) |
|----------|----------------|------------|----------------|-----------|-----------|
| 5A       | Personnel      | DM-20      | 6              | 65.5      | --        |
|          | Personnel*     | 68996      | 12             | 58.0      | --        |
|          | Grab           |            |                |           |           |
| 5B       | Personnel      | X-23       | 2              | 890.5     | --        |
|          | Grab           | --         | --             | 2000      | --        |
| 7P       | Personnel      | X-16       | 2              | --        | 1479      |
| 7S       | Personnel      | DM-12      | 2              | --        | >11890    |
|          | Grab           |            |                |           | 5500      |

\* SwRI Personnel No. 1

He did not wear any protective equipment during the entries. Prior to an entry, in-tank drop line measurements were not made. Instead, the C/M utilized an oxygen meter and a combustible gas meter to test the tank atmosphere as he descended into the tank. Once he was in the tank, toxicity level measurements were made with a Draeger tube system. The time spent in each tank was predicated on the time required to complete all three measurements. In some tanks, additional time was taken to visually inspect tank surfaces. The entry durations ranged between 2.5 to 8 minutes.

The first series of tank entries by the C/M were made into 1A, 1D, 3S, 3P, 5A, 7S and 7P. Based on Draeger tube measurements and visual tank inspection, 1A and 1D required manual hand mucking to facilitate gas-freeing. For the other tanks, only continued ventilation was necessary. On the morning of the second day the second series of tank entries were made into 1B, 2D, 3A, and 5B. Two of the four tanks (1B and 3A) contained a significant amount of rust, debris, and residual chemical in wash water. Ventilation was continued on these tanks as well as the other two. Later in the afternoon 1B and 3A were re-entered and tested again. Because only a small reduction in vapor concentration had been achieved, it was decided that hand mucking of 1B and 3A would also be required.

The C/M's exposure during tank entry for vapor testing was monitored on three sets of parallel passive and active dosimeters. Each set corresponded to each series of entries. The exposures are shown in Table IX, along with the entry duration (in brackets [ ]). Also shown in the table are exposures that were monitored on the SwRI personnel. SwRI personnel accompanied the C/M into 7S and 7P on the first series and every tank entry on the second and third series. In addition, the grab samples collected by the C/M with the Draeger tube, as well as the GC analysis of the syringe grab samples, are also shown in Table IX.

The entry durations for tank mucking were longer than the durations for the entries made by the C/M and the Bosun. These activities lasted between 15-22 minutes. The tasks performed during tank mucking required equipment such as a broom, dust pan, bucket, and a supply of dry rags. The individuals involved in this activity swept the tank floor clean of loose rust debris. Any moisture or puddles of liquid were sponged up with the dry rags and wrung out into the same buckets holding the solid debris. The predominant location where liquid had accumulated was in the pump sump. Once the bucket was filled it was pulled to the top by a crewman on deck and replaced with an empty one. The deck crewman emptied the buckets by

TABLE IX. OCCUPATIONAL EXPOSURES OF C/M DURING TANK ENTRY

| Entry Round | Type of Sample | Sample Number | Exposure Concentration, ppm/[Entry Time, Minutes] |             |     |     |             |               |             |                |             |     |      |
|-------------|----------------|---------------|---------------------------------------------------|-------------|-----|-----|-------------|---------------|-------------|----------------|-------------|-----|------|
|             |                |               | TCE                                               | EDC         | TCL | ACT | ITE         | STY           | STV         | TCE            | TCE         | DCM | DCM  |
|             |                |               | 1A                                                | 1B          | 1D  | 2D  | 3A          | 3S            | 3P          | 5A             | 5B          | 7S  | 7P   |
| 1           | Personnel      | X-27          | ②                                                 | --          | ②   | --  | --          | 81.0<br>[4.2] | ②<br>[6.03] | 172.8<br>[3.1] | --          | --  | --   |
|             | Personnel      | 62035         | ②                                                 | --          | ②   | --  | --          | --            | 95          | 115.8<br>[3.1] | --          | --  | --   |
|             | Personnel ①    | DM-30         | --                                                | --          | --  | --  | --          | --            | --          | --             | --          | --  | --   |
|             | Area (Draeger) | --            | 100                                               | --          | 200 | --  | --          | 60            | 70          | 90             | --          | 100 | 750  |
| 2           | Area (Grab) ③  | --            | 140                                               | --          | 657 | --  | --          | 115           | 35-52       | 172            | --          | 47  | 1327 |
|             | Personnel      | X-35          | --                                                | 301.6[4.35] | --  | ND  | 146.8[2.72] | --            | --          | --             | 48.5[3.33]  | --  | --   |
|             | Personnel      | 62032         | +                                                 | 539.6[4.35] | --  | ND  | 221.8[2.72] | --            | --          | --             | 201.4[3.33] | --  | --   |
|             | Personnel ①    | X-21          | --                                                | 300.2[3.5]  | --  | ND  | 136.2[2.87] | --            | --          | --             | 39.1[3.37]  | --  | --   |
| 3           | Area (Draeger) | --            | --                                                | 5           | --  | 0   | 100         | --            | --          | --             | 0           | --  | --   |
|             | Area (Grab) ③  | --            | --                                                | 500         | --  | ND  | 150         | --            | --          | --             | 60          | --  | --   |
|             | Personnel      | X-8           | --                                                | 83.4[7.67]  | --  | --  | 194.3[4.18] | --            | --          | --             | --          | --  | --   |
|             | Personnel      | 63839         | +                                                 | 75.2[7.67]  | --  | --  | 236.7[4.18] | --            | --          | --             | --          | --  | --   |
| 3           | Personnel ①    | X-40          | --                                                | 65.4[6.18]  | --  | --  | 63.3[4.2]   | --            | --          | --             | --          | --  | --   |
|             | Personnel ①    | 63837         | +                                                 | 83.9[6.18]  | --  | --  | 242.4[4.2]  | --            | --          | --             | --          | --  | --   |
|             | Area (Draeger) | --            | --                                                | 20-30       | --  | --  | 150         | --            | --          | --             | --          | --  | --   |
|             | Area (Grab) ③  | --            | --                                                | 170         | --  | --  | 214         | --            | --          | --             | --          | --  | --   |

+ Parallel active and passive samples

1 SwRI personnel

2 Samplers were not worn when C/M entered these tanks

3 Syringe vapor sample analyzed by gas chromatography on board ship



dumping their contents overboard. This procedure was repeated until all loose rust and liquid residue were removed from the tank. As previously mentioned, a total of four tanks were entered for tank mucking: 1A, 1B, 1D, and 3A. Tank 1A and 1D required only one individual each to clean these tanks because they were fairly small. Tank 3A and 1B, on the other hand, utilized a work compliment that included the two A/Bs that entered 1A and 1D as well as one other A/B and the Bosun.

The tank testing performed by the C/M was the only tank monitoring accomplished prior to man entry for tank mucking. Because the crew entered 3A and 1B within a half an hour after the C/M's entry to test these tanks, it was reasonable to expect these tanks still had the about same vapor concentration. On the other hand, entry into 1A and 1D was performed approximately four hours after these tanks were tested.

Protective equipment usage varied during these tank entries. Gloves were the only protective clothing worn for entry into 1A and 1D. The A/B who entered 1A wore cotton material gloves and the A/B who entered 1D wore rubber gloves. When these two crewmen entered 1B and 3A, they also wore an organic vapor cartridge type respirator. One of the two other crewmen comprising the four-man cleanup team of 1B and 3A also wore similar protective equipment. The fourth one, however, did not wear a respirator. The only consistent safety procedure during all these tank entries was the presence of on-deck personnel while people were in the tank. This situation was more of a necessity because someone was required on deck to empty the bucket of debris being generated. Tanks were not ventilated during entry.

Occupational exposures were monitored on the two A/Bs (A/B-2 and A/B-3) who were involved in all four tank entries. On every entry, each A/B wore a passive and active dosimeter. Both single and multiple grab samples were also collected during these tank entries by SwRI personnel in the vicinity where the A/Bs were working. The exposure concentrations and entry duration for these two individuals are shown in Table X.

TABLE X. OCCUPATIONAL EXPOSURE OF A/B-2 AND A/B-3 DURING TANK MUCKING

| Tanks<br>Entered | Crewmen | Sample<br>No. | Exposure conc., ppm [entry time, min] |              |              |              |
|------------------|---------|---------------|---------------------------------------|--------------|--------------|--------------|
|                  |         |               | TCE                                   | TCL          | TTE          | EDC          |
| 1A               | A/B-2   | DM-26         | 1718[16]                              | --           | --           | --           |
|                  |         | 62034 } +     | 1893[16]                              | --           | --           | --           |
|                  |         | Grab          | 2150                                  | --           | --           | --           |
| 1D               | A/B-3   | X-26          | --                                    | 752.2[15.83] | --           | --           |
|                  |         | 62033 } +     | --                                    | 908.4[15.83] | --           | --           |
|                  |         | Grab          | --                                    | 750          | --           | --           |
| 1B & 3A          | A/B-2   | DM-47         | --                                    | --           | 256[22]      | 140.2[18.25] |
|                  |         | 62797 } +     | --                                    | --           | 288.4[22]    | 149.0[18.25] |
| 1B & 3A          | A/B-3   | DM-41         | --                                    | --           | 267.4[20.75] | 144.2[19]    |
|                  |         | 62790         | --                                    | --           | 425.7[20.75] | 183.1[19]    |
|                  |         | Grab          | --                                    | --           | 340          | 220          |
|                  |         | Grab          | --                                    | --           | 365          | 176          |
|                  |         | Grab          | --                                    | --           | 304          | --           |

+ Parallel passive and active samples

#### VIII. Miscellaneous Observations

Three other noteworthy observations were made during the voyage that did not fall within one of the categories of ship operations previously discussed. These included:

- o Ship tank inspection by certified Marine Chemist and his assistants,
- o area monitoring of the deckhouse environment and
- o cargo line rupture during cargo transfer.

TABLE IV. CHARCOAL TUBE ANALYSES

| Sample No. | T(°C)* | Duration (Min) | V(L)* | Compound* | W <sub>C</sub> (μg)* | C(ppm) |
|------------|--------|----------------|-------|-----------|----------------------|--------|
| TX-101     | 29.8   | 65             | 13.06 | THC       | 37                   | 0.82   |
|            |        |                |       | BNZ       | <1                   | <0.024 |
|            |        |                |       | TOL       | <1                   | <0.019 |
|            |        |                |       | HXA       | <5                   | <0.11  |
| TX-103     | 27.0   | 43             | 8.64  | THC       | <5                   | <0.16  |
|            |        |                |       | BNZ       | <1                   | <0.036 |
|            |        |                |       | TOL       | <1                   | <0.029 |
|            |        |                |       | HXA       | <5                   | <0.16  |
| TX-110     | 22.6   | 20             | 4.02  | THC       | 169                  | 11.8   |
|            |        |                |       | BNZ       | <1                   | <0.076 |
|            |        |                |       | TOL       | <1                   | <0.061 |
|            |        |                |       | HXA       | 11                   | 0.76   |
| TX-111     | 31.2   | 230            | 39.79 | THC       | 2120                 | 15.4   |
|            |        |                |       | BNZ       | 14                   | 0.11   |
|            |        |                |       | TOL       | 39                   | 0.25   |
|            |        |                |       | HXA       | 270                  | 2.0    |
| TX-118     | 31.7   | 145            | 28.71 | THC       | 2055                 | 20.8   |
|            |        |                |       | BNZ       | 13                   | 0.14   |
|            |        |                |       | TOL       | 23                   | 0.20   |
|            |        |                |       | HXA       | 243                  | 2.4    |
| TX-121     | 24.8   | 11             | 2.21  | THC       | 23                   | 3.0    |
|            |        |                |       | BNZ       | <1                   | <0.14  |
|            |        |                |       | TOL       | <1                   | <0.11  |
|            |        |                |       | HXA       | <5                   | <0.64  |
| TX-122     | 22.8   | 40             | 8.04  | THC       | 356                  | 12.5   |
|            |        |                |       | BNZ       | 1                    | 0.035  |
|            |        |                |       | TOL       | 1                    | 0.031  |
|            |        |                |       | HXA       | 22                   | 0.76   |
| TX-123     | 25.3   | 188            | 37.22 | THC       | 616                  | 4.7    |
|            |        |                |       | BNZ       | 2                    | 0.016  |
|            |        |                |       | TOL       | 7                    | 0.047  |
|            |        |                |       | HXA       | 55                   | 0.42   |
| TX-125     | 29.8   | 27             | 5.24  | THC       | 61                   | 3.4    |
|            |        |                |       | BNZ       | <1                   | <0.059 |
|            |        |                |       | TOL       | <1                   | <0.048 |
|            |        |                |       | HXA       | <5                   | <0.27  |
| TX-126     | 34.8   | 31             | 6.23  | THC       | 4120                 | 193.8  |
|            |        |                |       | BNZ       | 24                   | 1.2    |
|            |        |                |       | TOL       | 38                   | 1.6    |
|            |        |                |       | HXA       | 340                  | 15.9   |
|            |        |                | HXA   | 43        | 2.0                  |        |

\*See notes at end of table

The analytical chemistry results for the H<sub>2</sub>S passive dosimeters and charcoal tubes are shown in Tables III and IV, respectively. The charcoal tube data reflect sampling temperature; pressure corrections were considered to be negligible. Where the analytical results did not exceed the detection limit, concentration was quantified at that limit.

TABLE III. ANALYSIS RESULTS FOR HYDROGEN SULFIDE PASSIVE DOSIMETERS

| Sample No. | A <sub>net</sub> * | Duration (hr) | C(ppm) | Sample No. | A <sub>net</sub> * | Duration (hr) | C(ppm) |
|------------|--------------------|---------------|--------|------------|--------------------|---------------|--------|
| 96302      | 0.019              | 4.43          | 0.33   | 96366      | 0.014              | 0.23          | 4.72   |
| 96303      | 0.011              | 1.25          | 0.68   | 96367      | 0.008              | 0.23          | 2.70   |
| 96304      | 0.007              | 0.53          | 1.02   | 96368      | 0.161              | 1.25          | 9.98   |
| 96305      | 0.006              | 0.48          | 0.97   | 96369      | 0.047              | 0.45          | 8.10   |
| 96306      | 0.009              | 0.78          | 0.89   | 96370      | 0.025              | 1.32          | 1.47   |
| 96307      | 0.008              | 0.72          | 0.86   | 96373      | 0.014              | 8.25          | 0.13   |
| 96308      | 0.030              | 3.83          | 0.61   | 96374      | 0.012              | 8.25          | 0.11   |
| 96309      | 0.024              | 2.40          | 0.78   | 96375      | 0.009              | 8.50          | 0.08   |
| 96310      | 0.021              | 1.42          | 1.15   | 96376      | 0.010              | 6.83          | 0.11   |
| 96311      | 0.009              | 0.18          | 3.88   | 96377      | 0.014              | 6.80          | 0.16   |
| 96312      | 0.011              | 0.18          | 4.74   | 96378      | 0.010              | 6.80          | 0.11   |
| 96313      | 0.015              | 0.18          | 6.46   | 96379      | 0.045              | 3.63          | 0.96   |
| 96314      | 0.009              | 0.22          | 3.17   | 96380      | 0.011              | 3.18          | 0.27   |
| 96361      | 0.025              | 0.33          | 5.87   | 96381      | 0.013              | 3.20          | 0.31   |
| 96362      | 0.231              | 1.38          | 12.98  | 96382      | 0.015              | 3.08          | 0.38   |
| 96363      | 0.054              | 1.13          | 3.70   | 96383      | 0.009              | 0.23          | 3.03   |
| 96364      | 0.024              | 1.13          | 1.65   | 96384      | 0.057              | 0.73          | 6.05   |
| 96365      | 0.009              | 0.23          | 3.03   |            |                    |               |        |

\*A<sub>net</sub> = net absorbance corrected for blank

$$C = \frac{A_{net}}{(DURATION)(CAL FACTOR)}$$

CAL FACTOR = 0.0129

downward correction to measured levels was applied on a selective basis with due regard for the proximity of the measurement point to the gas source (ullage port). The farther the measurement point is from source, the higher is the probability that interefent gases will be diluted to levels that have no affect on the indicated H<sub>2</sub>S concentration. Prior to each use, the monitor was calibrated against a known span gas concentration.

An Organic Vapor Analyzer (OVA) was used to measure instantaneous vapor concentrations. This instrument is sensitive to all hydrocarbon vapors from crude oil including the lights end down to methane. The instrument was calibrated against a known concentration of methane prior to each use period. Following the test, the instrument was cross-calibrated against hexane so that instrument readings as methane could be converted to their hexane equivalent. This procedure facilitates comparison of total Hydrocarbon concentration as determined by the OVA with the total hydrocarbon concentration as determined by charcoal tube methods. The OVA data reflect the light end asphyxiants (methane thru butane) that are not trapped on charcoal. The reader should be aware that the designator THC is used in this report for both the OVA measurements and the "total hydrocarbon concentration" from the charcoal tubes. With the above discussion, there should be no difficulty in interpreting the data.

The American Conference of Governmental Industrial Hygienists indicates the following exposure limits for the measured contaminants.

| Contaminant      | TLV-TWA (ppm) | TLV-STEL (ppm) |
|------------------|---------------|----------------|
| Hydrogen Sulfide | 10            | 15             |
| Benzene          | 10            | 25             |
| Toluene (skin)   | 100           | 150            |
| Hexane           | 50            | -              |

On the basis of these determinations, the desorption efficiency for THC was taken to be 100.0.

Direct reading, intrinsically safe, instruments were used to measure  $H_2S$  and hydrocarbon concentrations during various surveys as well as in the breathing zone of workers involved in cargo related activities.

The  $H_2S$  monitor uses an electrochemical sensor cell, and the instrument has a cross sensitivity to  $NO$ ,  $NO_2$ ,  $SO_2$  and  $CO$ , which are constituents in flue gas inerting systems. The interferences are on the positive side, so selective downward adjustment of recorded levels was necessary. The correction amount was based on the assumption that the interfering effects of each constituent are additive. The interference equivalents are shown below.

| Interferent Level | Interferent Equivalent<br>$H_2S$ (ppm) |
|-------------------|----------------------------------------|
| 10 ppm $SO_2$     | 1                                      |
| 2 ppm $NO$        | 1                                      |
| 28 ppm $NO_2$     | 1                                      |
| 1000 ppm $CO$     | 1                                      |

Based on data in the shipboard IGS Manual and discussions with domestic manufacturers/installers of IGS systems, the following constituent levels are representative of the gas state downstream of the scrubber.

$SO_2$  - 300 ppm  
 $NO_x$  - <150 ppm  
 $CO$  - <100 ppm

As the split between  $NO$  and  $NO_2$  in the flue gas could not be determined, it was assumed that the entire  $NO_x$  contribution of 150 ppm was present as  $NO$ . This assumption yielded a worst-case correction for oxides of nitrogen. Applying the above cross-sensitivities to the flue gas interferents resulted in an  $H_2S$  correction factor of 105 ppm. This

#### IV. Sampling and Analysis

Two types of occupational exposure dosimeters were used:

- o Passive dosimeters for hydrogen sulfide and
- o NIOSH-approved charcoal tubes and battery operated pumps for organic vapors.

The battery operated pumps carried intrinsic safety certification and were operated at a nominal flow rate of 0.2 L/min. For calculation purposes, the flow rate was based on pre- and post-use calibrations.

The charcoal tubes were analyzed by an AIHA accredited laboratory. Head space analyses of the crude oils was used to identify the compounds of interest on the tubes. All tubes were analyzed by gas chromatography (GC) for benzene (BNZ), toluene (TOL), hexane (HXA), and total hydrocarbon (THC) through xylene expressed as hexane. Nitrobenzene was used as the desorbing solution because it elutes from the GC column after xylene, and thus does not interfere with or mask the presence of low molecular weight hydrocarbon vapors. Note that the lower molecular weight hydrocarbons (methane, ethane, propane, butane) are not trapped on charcoal, and thus do not contribute to the THC determination.

Charcoal tube desorption studies were conducted for BNZ, HXA and TOL using nitrobenzene as the desorbing solvent. The spiking levels were representative of the levels on the exposed tubes. Three replicate determinations were made at each level. The desorption efficiencies were as follows.

| Compound | Desorption Efficiency (%) |
|----------|---------------------------|
| BNZ      | 102.3                     |
| HXA      | 100.7                     |
| TOL      | 106.7                     |

### III. Cargo Description

Two different grades of crude oil were transferred during the voyage. Upon arrival at the first discharge terminal, the ship carried Maya crude. The status of the cargo tanks is shown in Table I. Subsequently, the ship was loaded with Isthmus crude. The post-loading status of the cargo tanks is shown in Table II. Isthmus crude was transferred to shore at the second discharge terminal.

TABLE I. STATUS OF CARGO TANKS PRIOR TO DISCHARGE OF MAYA CRUDE

| Tank No. | Capacity, bbls | Discharge, bbls* | Percent Full+ |
|----------|----------------|------------------|---------------|
| 1P       | 27557          | 23772            | 86.3          |
| 1S       | 27557          | 23803            | 86.4          |
| 1C       | 76662          | 57852            | 75.5          |
| 2C       | 85034          | 67329            | 79.2          |
| 3C       | 85034          | 67638            | 79.5          |
| 4C       | 42517          | 34890            | 82.1          |
| 5C       | 85034          | 68680            | 80.8          |
| 5P       | 27603          | 24859            | 90.0          |
| 5S       | 27603          | 23426            | 84.9          |
| Slop P   | 20387          | 13222            | 64.8          |
| Slop S   | 20387          | 13412            | 65.8          |
|          | 525,375        | 418,883          | 79.7          |

\* Contents discharged completely

+ On arrival

TABLE II. STATUS OF CARGO TANKS AFTER LOADING ISTHMUS CRUDE

| Tank No. | Capacity, bbls | Load bbls | Percent Full |
|----------|----------------|-----------|--------------|
| 1P       | 27557          | 25556     | 92.8         |
| 1S       | 27557          | 25613     | 92.9         |
| 1C       | 76662          | 62544     | 81.6         |
| 2C       | 85034          | 72409     | 85.2         |
| 3C       | 85034          | 77418     | 91.0         |
| 4C       | 42517          | 36129     | 85.0         |
| 5C       | 85034          | 74395     | 87.5         |
| 5P       | 27603          | 26009     | 94.2         |
| 5S       | 27603          | 26064     | 94.4         |
| Slop P   | 20387          | 15845     | 77.7         |
| Slop S   | 20387          | 14269     | 70.0         |
|          | 525,375        | 456,261   | 86.8         |



## II.7 Cargo Loading

- o closed, split drop
- o cargo transfer controlled remotely at mimic board in Cargo Control Room

## II.8 Tank Cleaning Method

- o all cargo tanks were fitted with COW machines

## II.9 Inert Gas System

- o the vessel was fitted with a flue gas inerting system in accordance with USCG regulations

## II. Vessel Description

### II.1 Dimensions

- o Length overall, 800 ft
- o Molded breadth, 100 ft

### II.2 Tonnage

- o Summer draft - 68000 DWT

### II.3 Cargo/Ballast Tanks

- o 11 crude oil cargo tanks
- o 6 dedicated ballast tanks

### II.4 Cargo/Ballast Pumps

- o 3 main cargo pumps in pumproom
- o ballast water pump in pumproom
- o 1 stripping pump in pumproom

### II.5 Cargo Gauging Method

- o closed gauging with remote ullage readout in Cargo Control Room during all phases of transfer
- o open gauging prior to and at the conclusion of loading and discharge as required by cargo surveyors

### II.6 Vapor/Gas Venting

- o all cargo tanks vented through a single common, elevated mast riser vent (b/3) except when performing open gauging as described in II.5

## I. Trip Overview and Objectives

The primary objective of this voyage was to monitor occupational exposures to organic vapors and hydrogen sulfide gas during sour crude oil operations. The round trip voyage lasted nine days. The project team boarded the vessel at the initial discharge terminal where Maya crude oil was transferred to shore. Following the ballast voyage, Isthmus crude oil was loaded onto the ship. This product was subsequently discharged at LOOP (Louisiana Offshore Oil Platform), the final terminal in the voyage.

Exposure monitoring began roughly midway into the discharge of Maya crude and continued through the predischARGE gauging round at LOOP. This effort reflected operations that are unique to vessels equipped with flue gas inerting systems as well as operations that are common practice in the transport of other bulk liquids.

Occupational exposure monitoring was supplemented by area monitoring and the use of direct reading instruments for measuring instantaneous breathing zone concentrations of hydrogen sulfide and total hydrocarbon vapor. These instruments were also used in survey mode both on deck and in accommodation spaces.

## VOYAGE 4 REPORT OUTLINE

- I. Trip Overview and Objectives
- II. Vessel Description
- III. Cargo Description and Transfer Schedule
- IV. Sampling and Analysis
- V. Pumproom Environment - Initial Discharge Terminal
- VI. Tank Stripping - Initial Discharge Terminal
- VII. Tank Depressurization Prior to Loading
- VIII. Bottom Gauging Prior to Loading
- IX. Product Loading
- X. Instrument Surveys During Loading
- XI. Tank Processing - End of Loading
- XII. Tank Pressure Relief - Laden Voyage
- XIII. Entry into Ballast Tanks
- XIV. Tank Processing - Final Discharge Terminal

APPENDIX D  
VOYAGE REPORT - VOYAGE 4

period of the first tube (08-P8) was started concurrently with the initiation of tank cleaning. Primary sources of infiltration were from discharge of tank vapors venting from tanks 3P, 3S, 5A, 5B, 7P and 7S. Two forward tanks 1A and 1D were also being ventilated over this time period. The second sample, SB-8, was taken toward the end of the tank cleaning operation two days later. The chemical concentration on these samples are shown below.

| Sample<br>No. | Chemical Concentration, ppm |     |     |     |     |     |
|---------------|-----------------------------|-----|-----|-----|-----|-----|
|               | ACT                         | ICE | DCM | ICL | IIE | STY |
| 08-P8         | --                          | 4.5 | 9.9 | ND  | --  | ND  |
| SB-8          | ND                          | ND  | 0.2 | ND  | ND  | ND  |

#### Cargo Line Rupture

Rupture of two different cargo piping lines were observed. Both ruptures occurred during discharge of cargo when internal pipe pressures were the highest. The first rupture occurred in the cargo piping through which caustic was being discharged at the loading port. This line break was located in a section of piping that was below other cargo piping. The rupture was in an area not frequented by the deckwatch crew, and the piping above it shielded the release of this corrosive cargo. The product flow was stopped, and there were no injuries. The second rupture, which occurred at one of the discharge ports, was not as isolated as the first. The cargo that was being discharged through the line was lignin liquor, a relatively innocuous compound, which covered the aft port area of the deck.

Both ruptures were indicative of the condition of the cargo lines on the ship. Along with its biennial inspection, repair and/or replacement of a major portion of the ship's deck piping had been planned.

personal sample because the tanks that contained this chemical, 7P and 7S, had already been examined before the sample was started. In addition to these measurements, the Draeger tube measurements are also shown.

| Chemical/Tank No./Concentration, ppm/[entry time, min] |           |           |           |           |           |           |           |           |           |
|--------------------------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Sample<br>No.                                          | ACT<br>2D | TCE<br>1A | TCE<br>5A | TCE<br>5B | TCL<br>1D | TTE<br>3A | EDC<br>1B | STY<br>3S | STY<br>3P |
| DM-40                                                  | ND        | 9.1       |           | 5.7       |           | 5.3       | 9.2       | 0.7       |           |
| Draeger<br>Tube                                        | 0         | 0         | 0         | 0         | 0         | 0         | <5        | <15       | <15       |
| Entry<br>Time<br>[min]                                 | [1]       | [1]       | [2]       | [1]       | [1]       | [1]       | [2]       | [2]       | [2]       |

#### Deckhouse Environment

At various times during the voyage, the environment in the deckhouse was monitored for infiltration of chemical vapors. Most of the measurements were made with an Organic Vapor Analyzer (OVA). When the OVA was not available, samples were collected on personal sampling tubes located inside one of the SwRI personnel's quarters. OVA surveys taken during cargo loading, ballasting, and cargo discharge showed no apparent increase in the hydrocarbon concentration in the deckhouse above the normal background. Cross ship wind direction and tight sealing forward deckhouse doors helped eliminate the entry of chemical vapors during these ship operations.

During tank cleaning and ventilation, however, measureable increases in cargo vapors were observed in the deckhouse. Personnel sampling tubes were used to monitor the vapor infiltration during these activities. A total of two sample tubes were collected. The sampling

### Ship Inspection by Marine Chemist

The inspection team that certified the ship gas free and ready for dry dock consisted of a Marine Chemist and his two assistants entitled "competent persons". Two types of inspections were performed to certify that the ship was gas-free. The first inspection consisted of checking the contents of all cargo tanks and other enclosed spaces (cofferdams) for oxygen and combustible gas concentrations. This type of inspection was divided up between the Marine Chemist and the two competent persons. The Marine Chemist entered all tanks that had contained potentially dangerous chemicals (potentially dangerous chemicals were identical to those identified in the SwRI sampling plan) as well as all other tanks and cofferdams forward of the loading manifold. The "competent persons" inspected those tanks aft of the loading manifold. The measurement device that each used was a combination  $O_2$ /CG meter. The longest entry time was approximately three minutes, with the average being around 1.5 minutes. None of the inspectors wore any protective equipment except for cotton gloves and hard hats. After this initial inspection, the ship was cleared into the yard.

The second inspection was made when the ship arrived at the dock. During this inspection those tanks that had contained the "dangerous chemicals" were retested with a Draeger detector tube system. The Marine Chemist used the detector tube system with a drop line from the deck to test the atmosphere at the first platform level into the tank. If the atmosphere was acceptable, he entered the tank to the first platform level and repeated the drop line test. Entry times for these inspections were of short duration, lasting at most two minutes.

Occupational exposures were monitored on the Marine Chemist during these tank entries. The concentration of chemicals detected along with the entry times for each tank are shown below. DCM is not represented on the



TABLE IV. CHARCOAL TUBE ANALYSES (Continued)

| Sample No. | T(°C)* | Duration (Min) | V(L)* | Compound | W <sub>C</sub> (µg)* | C(ppm) |
|------------|--------|----------------|-------|----------|----------------------|--------|
| SC-4       | 27.0   | 31             | 6.26  | THC      | 457                  | 20.9   |
|            |        |                |       | BNZ      | 2                    | 0.10   |
|            |        |                |       | TOL      | 2                    | 0.08   |
| SC-5       | 27.0   | 28             | 5.54  | THC      | 247                  | 12.7   |
|            |        |                |       | BNZ      | 1                    | 0.056  |
|            |        |                |       | TOL      | 1                    | 0.045  |
| SC-6       | 27.0   | 45             | 9.09  | HXA      | 21                   | 1.1    |
|            |        |                |       | THC      | 73                   | 2.3    |
|            |        |                |       | BNZ      | 1                    | 0.034  |
| SC-7       | 34.8   | 218            | 37.71 | TOL      | <1                   | <0.028 |
|            |        |                |       | HXA      | <5                   | <0.16  |
|            |        |                |       | THC      | 6308                 | 49.0   |
| SC-8       | 24.8   | 11             | 2.22  | BNZ      | 32                   | 0.27   |
|            |        |                |       | TOL      | 58                   | 0.40   |
|            |        |                |       | HXA      | 780                  | 6.0    |
| SC-9       | 25.3   | 185            | 37.37 | THC      | <5                   | <0.64  |
|            |        |                |       | BNZ      | <1                   | <0.14  |
|            |        |                |       | TOL      | <1                   | <0.11  |
| SC-10      | 34.8   | 20             | 4.02  | HXA      | <5                   | <0.63  |
|            |        |                |       | THC      | 538                  | 4.1    |
|            |        |                |       | BNZ      | 2                    | 0.016  |
| SC-11      | 34.8   | 51             | 10.25 | TOL      | 6                    | 0.04   |
|            |        |                |       | HXA      | 49                   | 0.37   |
|            |        |                |       | THC      | 2970                 | 216.5  |
| SC-15      | 24.8   | 13             | 2.52  | BNZ      | 15                   | 1.2    |
|            |        |                |       | TOL      | 23                   | 1.5    |
|            |        |                |       | HXA      | 290                  | 21.0   |
| X-17       | 22.6   | 80             | 16.16 | THC      | 11880                | 339.7  |
|            |        |                |       | BNZ      | 84                   | 2.6    |
|            |        |                |       | TOL      | 110                  | 2.8    |
|            |        |                |       | HXA      | 1845                 | 52.4   |
|            |        |                |       | THC      | <5                   | <0.56  |
|            |        |                |       | BNZ      | <1                   | <0.12  |
|            |        |                |       | TOL      | <1                   | <0.10  |
|            |        |                |       | HXA      | <5                   | <0.56  |
|            |        |                |       | THC      | 1940                 | 33.8   |
|            |        |                |       | BNZ      | 15                   | 0.28   |
|            |        |                |       | TOL      | 19                   | 0.29   |
|            |        |                |       | HXA      | 200                  | 3.5    |

\*See notes at end of table

TABLE IV. CHARCOAL TUBE ANALYSES (Concluded)

| Sample No. | T(°C)* | Duration (Min) | V(L)* | Compound | W <sub>C</sub> (μg)* | C(ppm) |
|------------|--------|----------------|-------|----------|----------------------|--------|
| X-28       | 22.6   | 28             | 5.63  | THC      | 3499                 | 174.9  |
|            |        |                |       | BNZ      | 20                   | 1.1    |
|            |        |                |       | TOL      | 24                   | 1.0    |
|            |        |                |       | HXA      | 357                  | 17.7   |
| X-36       | 22.6   | 53             | 10.28 | THC      | 2922                 | 80.0   |
|            |        |                |       | BNZ      | 13                   | 0.38   |
|            |        |                |       | TOL      | 20                   | 0.48   |
|            |        |                |       | HXA      | 270                  | 7.3    |
| MC-28      | 22.6   | 26             | 5.23  | THC      | 2045                 | 110.0  |
|            |        |                |       | BNZ      | 10                   | 0.58   |
|            |        |                |       | TOL      | 12                   | 0.57   |
|            |        |                |       | HXA      | 170                  | 9.1    |

- NOTES: 1. Temperature in °C  
 2. V = Sample volume in liters  
 3. THC = Total hydrocarbon through xylene as hexane  
 BNZ = Benzene  
 TOL = Toluene  
 HXA = Hexane  
 4. W<sub>C</sub> = Weight of analyte corrected for blank

V. Pumproom Environment - Initial Discharge Terminal

At approximately midway into product discharge, the pumproom was surveyed for H<sub>2</sub>S gas concentrations. Gas concentrations were not detectible on descent into the pumproom or at the bottom of the pumproom.

An H<sub>2</sub>S area monitor was installed at the bottom of the pumproom at a location that was representative of where the Pumpman would work while checking pump suction/pressure and the separators/air extractors. The area monitor results are shown below.

| Sample No. | H <sub>2</sub> S (ppm) | Duration (min) |
|------------|------------------------|----------------|
| 96302      | 0.33                   | 266            |

During ascent from the pumproom, an H<sub>2</sub>S concentration of 1 ppm was measured by direct reading instrument.

## VI. Tank Stripping - Initial Discharge Terminal

Throughout the majority of the discharge operation, the closed gauging systems were used to monitor tank ullage at the mimic board in the Cargo Control Room. At the final stage of discharge, the tank stripping systems were brought on-line to maximize the quantity of product transferred to shore. During the stripping operation, the closed, remote gauging of tank ullage was replaced by manual open gauging in order to improve the accuracy of the measurements.

All ullage ports were closed during the bulk of the discharge because the inert gas system was in operation. The system maintained a common positive pressure of 500-700 mm H<sub>2</sub>O in all of the tanks. When a given ullage port was opened for gauging by the Quartermaster and an O/S, the entire system depressurized through that port because the other tank ullage ports were closed. While the system was depressurizing, both crew members generally stood upwind and away from the port. The length of the blowdown time before gauging could be initiated was variable and was a function of the initial tank pressure. Maximum blowdown time was 11 minutes. Blowdown time tended to become shorter as successive tanks were gauged because the inert gas pressure had not had sufficient time to recover to the operating range. Correspondingly, vapor and gas discharge flow rates varied directly with tank pressure.

The decision to approach the ullage port and initiate gauging was based on judgement. The Quartermaster functioned as an observer; the O/S did the manual gauging. The gauging tool consisted of a graduated rod at the end of a tether line. The gauging procedure involved lowering the rod into the tank until it touched the tank bottom and then retrieving the tether until the rod was close to the ullage port. During this part of the operation, the O/S's breathing zone was two to three feet from the centerline of the ullage port. The O/S would then move toward the ullage

port, remove the rod from the tank and read the gauge. In this phase of the operation, his breathing was generally 1-1.5 feet above the ullage port. The Quartermaster observed and verified the reading. The number of ullage readings per tank was variable and ranged from five to a maximum of 18 over a 20-minute period on Tank SP.

Shown below are the tanks where bottom gauging was observed and monitored. Also shown are the times when ullage ports were opened and the gauging was completed.

| Tank No. | Time Open | Time Finish |
|----------|-----------|-------------|
| 1C       | 1139      | 1204        |
| 3C       | 1312      | 1322        |
| 5P       | 1322      | 1328        |
| 5C       | 1403      | 1427        |
| SP       | 1428      | 1443        |

When the gauging was completed, the ullage port was closed and secured. With one exception, which will be discussed later, only one ullage port was open at any time.

H<sub>2</sub>S concentrations were measured at selected tanks using direct reading instrumentation. Those measurements are summarized below.

| Tank No. | Concentration (ppm) | Location           |
|----------|---------------------|--------------------|
| 1C       | 19-32               | O/S Breathing Zone |
| 1C       | 1395-1893           | Ullage Port        |
| SP       | 3-5                 | Ullage Port        |
| 3C       | 50-595              | O/S Breathing Zone |
| 5P       | 195                 | Ullage Port        |
| 5C       | 20-70               | O/S Breathing Zone |

The background levels of H<sub>2</sub>S around each tank ranged from 2-5 ppm.

Occupational exposure samples were collected on the Quartermaster and the O/S. In the case of the Quartermaster, the samples coincided with the gauging of tanks 5C and SP. The results are presented below.

#### Quartermaster

| Sample No. | Duration(min) | H <sub>2</sub> (ppm) | THC*(ppm) | HXA(ppm) | BNZ(ppm) | TOL(ppm) |
|------------|---------------|----------------------|-----------|----------|----------|----------|
| 96303      | 75            | 0.68                 | --        | --       | --       | --       |
| TX-122     | 40            | --                   | 12.5      | 0.76     | 0.035    | 0.031    |

\* Total hydrocarbon concentration as hexane

The O/S was monitored for H<sub>2</sub>S exposure during the bottom gauging of tanks 5P, 5C and SP.

#### O/S

| Sample No. | Duration (min) | H <sub>2</sub> S(ppm) |
|------------|----------------|-----------------------|
| 96310      | 85             | 1.15                  |

Normally, only one ullage port was open at a given time. In the case of tank 5P, the ullage port was open for a period of time around 1156 hours, during which tank 1C was also open. At this time, stores were being loaded onto the ship and manually transported to the deckhouse past the open ullage port on 5P. Up to seven crew members were involved in this activity. The walkway past the expansion trunk was roughly nine feet downwind of the ullage port. H<sub>2</sub>S concentration at the walkway was 8 ppm. Source concentrations were 55-180 ppm one foot above the plane of the ullage port.

During the depressurization and gauging activities, the odor of H<sub>2</sub>S was present in the lower level of the deckhouse and a concentration of 2 ppm was measured on the Captain's Deck level.

## VII. Tank Depressurization Prior to Loading

All tanks were depressurized from 900 mm H<sub>2</sub>O prior to entering the waterway leading to the loading port. The ship executed a 360° turn under low power during the depressurization. Consequently, the wind direction on the deck was variable - beginning and ending in a port/starboard direction. During the 24-minute blowdown, anemometer readings indicated a wind speed of roughly 35 mph.

The Chief Mate opened the manual valve on the vent riser at 1732. At 1750, he opened the ullage port on tank 1S to speed up the blow down. The Chief Mate's exposure to H<sub>2</sub>S and organic vapors was monitored with dosimeters. The results are shown below.

| Sample No. | Duration(min) | H <sub>2</sub> S(ppm) | THC*(ppm) | HXA(ppm) | BNZ(ppm) | TOL(ppm) |
|------------|---------------|-----------------------|-----------|----------|----------|----------|
| SC-4       | 31            | --                    | 20.9      | 2.0      | 0.10     | 0.08     |
| 94304      | 32            | 1.02                  | --        | --       | --       | -        |

\* Total hydrocarbon concentration as hexane

Dosimeters were also worn by the members of the project team. The measured exposures are presented below.

| Sample No. | Duration(min) | H <sub>2</sub> S(ppm) | THC*(ppm) | HXA(ppm) | BNZ(ppm) | TOL(ppm) |
|------------|---------------|-----------------------|-----------|----------|----------|----------|
| SC-5       | 28            | --                    | 12.7      | 1.1      | 0.056    | 0.045    |
| 96305      | 29            | 0.97                  | --        | --       | --       | -        |

\* Total hydrocarbon concentration as hexane

One project member wore Sample No. SC-5 while he accompanied the Chief Mate. Sample No. 96305 was worn by another project member who surveyed the deck for H<sub>2</sub>S concentrations using a direct reading instrument.

Survey measurement points were downwind of the elevated vent to determine if the discharge plume returned to the deck. With one exception, the wind conditions (speed and direction) did not permit the plume to return to the deck;  $H_2S$  concentrations were not detectible. In the one exception, a 12 ppm  $H_2S$  reading was obtained atop the first fire station platform forward of the deckhouse. The wind was in a bow to stern direction. At the time that this reading was taken, a concentration of 3 ppm was measured on the bridge wing.

When the Chief Mate opened the ullage port on tank 1C, his breathing zone concentration of  $H_2S$  was 25 ppm. The concentration at the ullage port was of the order of 95 ppm  $H_2S$ .



### VIII. Bottom Gauging Prior to Loading

Roughly four hours prior to the start of loading, the inert gas pressure head in the tanks was relieved by opening the manual valve on the common vent riser. Following the depressurization, the valve was closed, and the ship proceeded to the loading terminal where independent surveyors gauged residual oil and water levels on the tank bottoms. The two surveyors were accompanied by the Third Mate and the Assistant Bosun. At each tank, the Assistant Bosun's job was to open and close the ullage port. The Third Mate verified and recorded the surveyors' ullage readings. Both crew members stood upwind of the open ullage ports. At each tank, direct reading instrumentation was used to measure the instantaneous  $H_2S$  and total hydrocarbon concentrations at the open ullage port and in the Assistant Bosun's breathing zone when he opened the ullage port. The results are summarized in Table V.

Each of the crew members wore dosimetry equipment during the gauging round. The measured occupational exposures are presented below

| Sample No. | Duration(min) | $H_2S$ Conc.<br>(ppm) | THC*<br>(ppm) | Crew<br>Member |
|------------|---------------|-----------------------|---------------|----------------|
| 96306      | 47            | 0.89                  | --            | 3M             |
| TX-103     | 43            | --                    | <0.16         | 3M             |
| 96307      | 43            | 0.86                  | --            | Ass't Bosun    |
| SC-6       | 45            | --                    | 2.3           | Ass't Bosun    |

\* Total hydrocarbon concentration as hexane

TABLE V. INSTANTANEOUS BREATHING ZONE AND SOURCE CONCENTRATIONS  
DURING GAUGING PRIOR TO LOADING

| Tank No. | Time<br>Start | Time<br>Finish | H <sub>2</sub> S<br>Source | THC<br>Source | H <sub>2</sub> S<br>BZ | THC<br>BZ |
|----------|---------------|----------------|----------------------------|---------------|------------------------|-----------|
| 5S       | 2006          | 2008           | ND                         | NM            | ND                     | 8         |
| SS       | 2010          | 2012           | ND                         | NM            | ND                     | 8         |
| 5C       | 2013          | 2018           | ND                         | to 2600       | ND                     | 8         |
| 3C       | 2020          | 2022           | ND                         | 10-1200       | ND                     | 8         |
| 1S       | 2024          | 2026           | ND                         | 10-2300       | ND                     | 8         |
| 1C       | 2027          | 2028           | 5-15                       | 10-3700       | ND                     | 8         |
| 1P       | 2030          | 2031           | ND                         | to 2300       | ND                     | 8         |
| 2C       | 2032          | 2035           | ND                         | 8             | ND                     | 8         |
| 4C       | 2036          | 2038           | ND                         | 8             | ND                     | 8         |
| 5P       | 2040          | 2044           | ND                         | 8             | ND                     | 8         |
| PS       | 2045          | 2049           | 8-65                       | 8             | ND                     | 8         |

- Notes:
1. All concentration in ppm
  2. THC - total hydrocarbon concentration as hexane
  3. BZ - breathing zone, Assistant Bosun
  4. ND - not detectable
  5. NM - not measured

## IX. Product Loading

Product tanks were inerted during discharge. The tanks were sealed and isolated such that the state of the inert gas in the tanks should have remained essentially constant throughout the ballast voyage. At the loading port, tanks were loaded beneath this inert blanket. Product vapors and inert gas were vented through a common, elevated mast riser. All cargo tanks had closed gauging systems with remote readout in the Cargo Control Room.

The closed, remote gauging systems were used at all times. As a result, the cargo transfer watches consisted of a Mate in the Control Room and an A/B whose function was to tour the deck and be alert for any equipment/system malfunctions. The A/B on watch also performed minor maintenance activities such as adjusting and jacketing turnbuckles on the port and starboard gangways. Periodically, the Pumpman gauged the segregated ballast tanks. Basically, there was minimal crew activity on deck during loading.

At 11 hours into the 19-hour loading period, organic vapor and H<sub>2</sub>S dosimetry equipment was fitted to the A/B on the 0800-1200 watch. The exposure results are summarized below.

| Sample No. | Duration(min) | H <sub>2</sub> S(ppm) | THC*(ppm) | HXA(ppm) | BNZ(ppm) | TOL(ppm) |
|------------|---------------|-----------------------|-----------|----------|----------|----------|
| 96308      | 230           | 0.61                  | --        | --       | --       | --       |
| TX-111     | 230           | --                    | 15.4      | 2.0      | 0.11     | 0.25     |

\* Total hydrocarbon concentration as hexane

During that same watch, a member of the project team wore comparable dosimetry equipment. The exposure results are as follows.

| Sample No. | Duration(min) | H <sub>2</sub> S(ppm) | THC*(ppm) | HXA(ppm) | BNZ(ppm) | TOL(ppm) |
|------------|---------------|-----------------------|-----------|----------|----------|----------|
| 96309      | 144           | 0.78                  | --        | --       | --       | --       |
| TX-118     | 145           | --                    | 20.8      | 2.4      | 0.14     | 0.20     |

\* Total hydrocarbon concentration as hexane

Throughout this sampling period, the deck was surveyed for H<sub>2</sub>S concentrations using direct reading instruments. The purpose of these surveys was to detect if the vented vapor/gas plume returned to the deck as a result of ambient wind conditions. During the initial surveys, the wind was starboard to port at an estimated 4-5 knots. Under these conditions, the plume did not return to the deck. The odor of H<sub>2</sub>S was present, but instrument readings did not exceed 1 ppm. Subsequently, there was a wind shift (from roughly 30° off of the starboard bow). Under these conditions, the vented plume returned to the deck at approximately 200 feet aft of the vent and at the port gangway. H<sub>2</sub>S concentrations ranged from 34 to 80 ppm.

Area monitoring for H<sub>2</sub>S infiltration was conducted in the Deckhouse throughout the entire loading. The loading was divided into three monitoring periods. In each period, a monitor was located in the Pilot's cabin, which was on the Captain's Deck level. Two monitors were always in place in the Cargo Control Room. One monitor was located roughly eight inches below the ceiling, the second monitor was about 30 inches above the floor. The results are summarized below in the order in which the samples were collected.

#### Pilot's Cabin

| Sample No. | Duration(min) | H <sub>2</sub> S(ppm) |
|------------|---------------|-----------------------|
| 96375      | 510           | 0.08                  |
| 96376      | 410           | 0.11                  |
| 96382      | 185           | 0.38                  |

### Cargo Control Room

| Sample No. | Duration(min) | H <sub>2</sub> S(ppm) |      |
|------------|---------------|-----------------------|------|
| 96373      | 495           | 0.13                  | High |
| 96378      | 408           | 0.11                  |      |
| 96380      | 191           | 0.27                  |      |
| 96374      | 495           | 0.11                  | Low  |
| 96377      | 408           | 0.16                  |      |
| 96381      | 192           | 0.31                  |      |

During roughly the last three hours of loading, organic vapor area monitors were also located in the Cargo Control Room and the Pilot's Cabin. These monitors served to assess the level of vapor infiltration into the Deckhouse at a time when discharge concentrations were at a maximum at the vent riser. The results are shown below.

### Cargo Control Room

| Sample No. | Duration(min) | THC*(ppm) | HXA(ppm) | BNZ(ppm) | TOL(ppm) |
|------------|---------------|-----------|----------|----------|----------|
| SC-9       | 185           | 4.1       | 0.37     | 0.016    | 0.04     |

\* Total hydrocarbon concentration as hexane

### Pilot's Cabin

| Sample No. | Duration(min) | THC*(ppm) | HXA(ppm) | BNZ(ppm) | TOL(ppm) |
|------------|---------------|-----------|----------|----------|----------|
| TX-123     | 188           | 4.7       | 0.42     | 0.016    | 0.049    |

\* Total hydrocarbon concentration as hexane

X. Instrument Surveys During Loading

Loading of Isthmus crude commenced at 2100 hours and was completed at 1600 hours of the next day. Midway through the loading period, three consecutive surveys were conducted.

- o Survey No. 1 - Deck survey to measure  $H_2S$  and THC concentrations at breathing zone elevation above the deck. Measurements were made in the vicinity of tank expansion trunks and hose manifolds.
- o Survey No. 2 - This survey was conducted to detect gas and vapor leakage at the ullage port and dome seals on tank expansion trunks.
- o Survey No. 3 - Passageways on the five levels of the deckhouse and the bridge were surveyed for infiltration of  $H_2S$  and cargo vapors.

During these surveys, loading of 1P, 1S, 5P, 5S, Slop P and Slop S tanks was completed, and the total flow of cargo was being transferred to the center tanks. All cargo vapors were vented through the single common mast riser that was located forward of the 2C expansion trunk. Qualitatively, the wind was very calm in a generally bow to stern direction (one point off of port bow). Tables VI, VII and VIII summarize the results of the surveys.

Two occupational exposure samples were collected during ballast tank inspection. Sample No. TX-125 was collected on the Quartermaster during entry into Tank 3P and 3S. Total intank time was 20 minutes out of a 27-minute sample duration. The second sample, TX-101, was worn by a member of the SwRI project team who accompanied the Chief Engineer on all entries. Total entry time for the Chief Engineer was about 60 minutes out of a 65 minute sample duration. The results are summarized below.

| Sample No. | Duration (min) | THC* (ppm) |
|------------|----------------|------------|
| TX-125     | 27             | 3.4        |
| TX-101     | 65             | 0.82       |

\* Total hydrocarbon concentration as hexane

### XIII. Entry into Ballast Tanks

During the laden voyage, there was an indication of a leak in the deck hydraulic system. The suspected source of the leak was in the ballast piping where the hydraulic lines penetrate below deck bulkheads on the ballast tanks. To assess the situation, the Chief Mate, Chief Engineer and Quartermaster, and the Assistant Bosun collectively entered all six segregated ballast tanks and the forepeak fresh water ballast tank. These entries revealed that the leak was not in the hydraulic system for the ballast tanks. The entry procedure that was used is documented below.

Initially, the access ports on all tanks were opened, and each tank atmosphere was tested sequentially for oxygen concentration. Testing was under the direction of the Chief Mate. A Reiken oxygen meter was used with a 21m dropline that extended 18m into the tank. Measurements were made through one opening on each tank and at one depth into the tank. SwRI conducted independent, parallel measurements with an MSA Model 260 combination oxygen/combustible gas meter. In all cases, the oxygen concentration was 20.8% v/v as measured with the MSA Model 260.

Because the tanks had not carried cargo, the tank atmospheres were not tested for combustible gas concentrations. Using an OVA, SwRI measured total hydrocarbon concentrations of seven to 15 ppm (as methane) inside the expansion trunk coming just beneath the weather deck.

The four crew members that were identified above did not generally enter and inspect each of the seven tanks as a group. The number and title of the crew members entering a given tank varied. On occasion, the group divided and multiple tanks were inspected simultaneously. As the overall responsibility rested with the Chief Engineer, he entered all of the tanks. Entry time per tank ranged from seven to 12 minutes. Tank ventilation was not provided during entry. A deck-side safety watch was not always present at each entry.



- o 50 ppm THC and 1 ppm H<sub>2</sub>S in front of port storehouse.
- o 1900 ppm THC and 32 ppm H<sub>2</sub>S at the port manifold.
- o 50 ppm THC and 6 ppm H<sub>2</sub>S near the expansion trunk on tank 4P.

The crew member in charge of the relief valve, sat on the catwalk upwind of the vent during depressurization.

Area monitors for H<sub>2</sub>S and THC were located in the Cargo Control Room. The results are shown below.

| Sample No.    | Duration (min) | Concentration (ppm)                     |
|---------------|----------------|-----------------------------------------|
| SC-8<br>96311 | 11<br>11       | <0.64 (THC*)<br>3.88 (H <sub>2</sub> S) |

\* Total hydrocarbon concentration as hexane

The SwRI project member wore H<sub>2</sub>S dosimeter No. 96313 while he was on deck during the pressure relief. Over the 11-minute sampling period, the exposure level was 6.46 ppm.

#### Pressure Relief Episode No. 4

On approach to the discharge terminal, all tanks were depressurized using the manual method described above. Nocturnal cooling had reduced tank pressure to 700 mm H<sub>2</sub>O at 1028 when the relief valve was opened. The blowdown continued until 1036 when the pressure stabilized at 200 mm H<sub>2</sub>O. As the depressurization was unannounced, there was no opportunity to measure H<sub>2</sub>S or THC concentrations. There was a definite odor of H<sub>2</sub>S on the Captain's Deck and in the Cargo Control Room.

### Pressure Relief Episode No. 3

- o Fresh air inlets to deckhouse closed
- o Relief valve opened at 1006; line pressure 1500 mm H<sub>2</sub>O
- o Wind 18 knots from 50° off of the starboard bow
- o Doors to bridge wings closed at all times
- o No measurable H<sub>2</sub>S concentration in wheelhouse or on bridge wings
- o Relief valve closed at 1016; line pressure 700 mm H<sub>2</sub>O
- o Fresh air inlets to deckhouse opened

During this episode, H<sub>2</sub>S and total hydrocarbon (THC) area monitors were installed in the Pilot's stateroom. The results are summarized below.

| Sample No. | Duration (min) | Concentration (ppm)     |
|------------|----------------|-------------------------|
| 96314      | 13             | 3.17 (H <sub>2</sub> S) |
| SC-15      | 13             | <0.56 (THC*)            |

\* Total hydrocarbon concentration as hexane

In addition, H<sub>2</sub>S and THC dosimetry equipment was worn on the bridge by an SwRI project member. The results are as follows.

| Sample No. | Duration (min) | Concentration (ppm)     |
|------------|----------------|-------------------------|
| 96312      | 11             | 4.74 (H <sub>2</sub> S) |
| TX-121     | 11             | 3.0 (THC*)              |

\* Total hydrocarbon concentration as hexane

Background concentrations of 8 ppm THC and 0 ppm H<sub>2</sub>S were recorded prior to valve opening. After valve opening, the following concentrations were recorded.

Instrument surveys for total hydrocarbon and H<sub>2</sub>S concentrations were made on deck during the depressurization. The results are summarized below.

- o Prior to valve opening, the general background concentrations were 8 ppm THC and 0 ppm H<sub>2</sub>S.
- o Four minutes after valve opening, 3-5 ppm H<sub>2</sub>S and 200 ppm THC were recorded at the catwalk by the loading hoses.
- o Six minutes into the pressure relief, 400 ppm THC and 11 ppm H<sub>2</sub>S were measured at the SS tank.
- o One minute later, 1200 ppm THC and 31-39 ppm H<sub>2</sub>S were measured next to the 5P tank expansion trunk.
- o At eight minutes into the pressure relief, 250 ppm THC and 23 ppm H<sub>2</sub>S were measured at the port winch just aft of the PV breaker.
- o At the PV breaker the THC and H<sub>2</sub>S concentrations were 400 ppm and 48 ppm, respectively.
- o Concentrations declined to the background levels after the valve was closed.

Three passive dosimeters were used as area monitors in the deckhouse to detect H<sub>2</sub>S infiltration. These area monitors were located at breathing zone height. An H<sub>2</sub>S dosimeter was also worn by the crew member who opened and closed the vent valve and remained on deck during pressure relief. The results are presented below.

| Sample No. | Type     | Location           | H <sub>2</sub> S (ppm) | Duration (min) |
|------------|----------|--------------------|------------------------|----------------|
| 96365      | Area     | Pilot's Cabin      | 3.03                   | 14             |
| 96366      | Area     | Cargo Control Room | 4.72                   | 14             |
| 96367      | Area     | Wheel House        | 2.70                   | 14             |
| 96383      | Personal | --                 | 3.03                   | 14             |

- o Fresh air intakes to deck house closed at 0803
- o H<sub>2</sub>S concentration on bridge wing was 8-10 ppm when the line pressure was 300 mm H<sub>2</sub>O
- o Relief valve closed at 0816
- o H<sub>2</sub>S concentration in the wheelhouse at 0823 was 3 to 4 ppm as a result of infiltration through the ventilation system

During the depressurization, H<sub>2</sub>S concentrations were measured at various points on deck.

- o H<sub>2</sub>S was not detected beneath the vent riser which was located roughly midway between the 1C and 2C expansion trunks.
- o 8-12 ppm H<sub>2</sub>S on walkway over manifold deck piping (approximately 10 feet above the deck).
- o 31 ppm H<sub>2</sub>S on the starboard side of the intersection of tanks 4C and 5C. The Bosun and Chief Engineer were working on hydraulic lines at this location
- o 20-25 ppm H<sub>2</sub>S near the 5C expansion trunk
- o 26-30 ppm H<sub>2</sub>S near the SS tank expansion trunk which was located just forward of the deckhouse
- o H<sub>2</sub>S levels fell to zero after the vent valve was closed

#### Pressure Relief Episode No. 2

- o Wind bow to stern at 22 knots
- o Fresh air intake for deckhouse closed at 1256
- o Doors to bridge wings closed at all times
- o Relief valve opened at 1259; line pressure 1350 mm H<sub>2</sub>O
- o H<sub>2</sub>S concentration on starboard bridge wing was 3 to 5 ppm
- o H<sub>2</sub>S concentration on port bridge wing was nominally 6 to 8 ppm with an instantaneous maximum of 16 to 17 ppm
- o Relief valve closed at 1308; line pressure 600 mm H<sub>2</sub>O
- o Deckhouse fresh air vent opened at 1309

## XII. Tank Pressure Relief - Laden Voyage

During the laden voyage, gas pressure in the ullage space above the cargo increases as a result of deck heating and cargo sloshing. The gas pressure in each tank is uniform because all tank isolation valves are open to the inert gas deck main, the deck main isolation valve is closed and the breather and bypass valves on the forward, common vent riser are closed. The pressure could be released automatically through a P/V valve or by manually activating a parallel valve. The manual method was used.

Pressure was relieved periodically on the laden voyage when the pressure approached the high alarm level of 1400 mm H<sub>2</sub>O. Gas and vapor venting through the elevated mast riser continued until the inert gas main line pressure was reduced to roughly 300-400 mm H<sub>2</sub>O. The valve was then manually closed. This operation involved one crew member who operated the valve and remained at the valve site during the pressure relief. Directions were received from the bridge by walkie-talkie.

During pressure relief, H<sub>2</sub>S and total hydrocarbon area monitors were installed in the cargo control room and in the wheel house. Portable H<sub>2</sub>S monitoring equipment was used on-deck on the bridge wings and in the wheel house. Personal dosimetry was also performed on the crew member who operated the bypass valve. The objective of the measurements was to assess the potential for gas and vapor exposures on the deck and in the accommodation spaces as a result of infiltration. The results of these measurements are summarized below.

### Pressure Relief Episode No. 1

- o Wind bow to stern at 21 knots
- o Relief valve opened at 0801; line pressure 1350 mm H<sub>2</sub>O
- o H<sub>2</sub>S concentration on the bridge wing after valve opening was nominally 27-30 ppm with a maximum of 37 ppm
- o Doors to the wheelhouse from the bridge wings closed at all times

surveyors while they collected product samples from 1P, 1C, 1S, 5P and 5S. In this activity, the Quartermaster opened the ullage ports, stood back while the tanks depressurized and the surveyors collected their samples and then closed the ullage ports. Full watch occupational exposure samples for organic vapors and H<sub>2</sub>S were collected on the Quartermaster. These samples reflect his exposure during product sampling and the final ullage round. The results are shown below.

| Sample No. | Duration (min) | H <sub>2</sub> S (ppm) | THC* (ppm) | HXA (ppm) | BNZ (ppm) | TOL (ppm) |
|------------|----------------|------------------------|------------|-----------|-----------|-----------|
| SC-7       | 218            | --                     | 49.0       | 6.0       | 0.27      | 0.40      |
| 96379      | 218            | 0.96                   | --         | --        | --        | --        |

\*Total hydrocarbon concentration as hexane

Occupational exposure monitoring was conducted during the tank processing activity. The results are summarized below.

Assistant Bosun - Period I

| Sample No. | Duration (min) | H <sub>2</sub> S (ppm) | THC* (ppm) | HXA (ppm) | BNZ (ppm) | TOL (ppm) |
|------------|----------------|------------------------|------------|-----------|-----------|-----------|
| SC-10      | 20             | --                     | 216.5      | 21.0      | 1.2       | 1.5       |
| 96361      | 20             | 5.87                   | --         | --        | --        | --        |

\* Total hydrocarbon concentration as hexane

Assistant Bosun - Period II and III

| Sample No. | Duration (min) | H <sub>2</sub> S (ppm) | THC* (ppm) | HXA (ppm) | BNZ (ppm) | TOL (ppm) |
|------------|----------------|------------------------|------------|-----------|-----------|-----------|
| SC-11      | 51             | --                     | 339.7      | 52.4      | 2.6       | 2.8       |
| TX-126     | 31             | --                     | 193.8      | 15.9      | 1.2       | 1.6       |
| 96362      | 83             | 12.98                  | --         | --        | --        | -         |

\* Total hydrocarbon concentration as hexane

Note: SC-11 and TX-126 are consecutive samples.

Period III

| Sample No. | Duration (min) | H <sub>2</sub> S (ppm) | Individual |
|------------|----------------|------------------------|------------|
| 96363      | 68             | 3.70                   | 2M         |
| 96364      | 68             | 1.65                   | SwRI       |

Note: Monitor on SwRI employee who measured Assistant Bosun's breathing zone concentrations with direct reading instruments.

The Quartermaster was on watch from 1200-1600 hours, which included the end of loading. As indicated earlier, he was one of three crew members who were involved in the final ullage gauging with the product surveyors. Earlier in the watch, the Quartermaster accompanied the

surrounding deck structures shielded the work area from the ambient wind and did not permit vapor to be transported away from the work area. During the gauging round, direct reading instruments were used to measure gas and vapor concentrations in the Assistant Bosun's breathing zone. As before, these instantaneous grab sample measurements were made at the time when the maximum concentration was anticipated. Therefore, the concentration data that are summarized in Table X should not be assumed to be constant over the time interval at each tank.

TABLE X. BREATHING ZONE CONCENTRATIONS DURING ULLAGE ROUND WITH SURVEYORS AT END OF LOADING

| Tank No. | Time Open* | Time Close* | H <sub>2</sub> S (ppm) | THC (ppm)+ |
|----------|------------|-------------|------------------------|------------|
| 5S       | 1432       | 1440        | 5-100                  | >4000      |
| SS       | 1441       | 1447        | 140                    | >4000      |
| 5C       | 1448       | 1452        | 455                    | >4000      |
| 3C       | 1453       | 1459        | 32-495                 | >4000      |
| 1S       | 1501       | 1505        | 75                     | >4000      |
| 1C       | 1505       | 1510        | 175                    | >4000      |
| 1P       | 1511       | 1516        | 42                     | >4000      |
| 2C       | 1516       | 1521        | 35                     | 910        |
| 4C       | 1522       | 1527        | 109                    | >4000      |
| 5P       | 1528       | 1533        | 3                      | 15         |
| PS       | 1534       | 1539        | 130                    | >4000      |

\* Ullage port opening and closing times

+ Total hydrocarbon concentration as hexane



TABLE IX. BREATHING ZONE CONCENTRATIONS DURING THERMOMETER  
INSERTION INTO CARGO TANKS

| Tank No.         | Time Open** | Time Close** | H <sub>2</sub> S (ppm)* | THC (ppm)*+ |
|------------------|-------------|--------------|-------------------------|-------------|
| <u>PERIOD I</u>  |             |              |                         |             |
| 5P               | 1336        | 1337         | 95                      | 1900        |
| SP               | 1337        | 1339         | 4                       | 17          |
| 4C-aborted       | 1339        | 1341         | 4                       | 20          |
| 1P               | 1342        | 1344         | 3                       | 16          |
| 1S               | 1345        | 1347         | 4-11                    | 15-910      |
| 5C               | 1348        | 1350         | 4                       | 15-20       |
| SS               | 1350        | 1351         | 145-445                 | 500->4000   |
| 5S               | 1352        | 1353         | 10                      | 100         |
| <u>PERIOD II</u> |             |              |                         |             |
| 4C               | 1415        | 1416         | 1                       | 15          |
| 2C               | 1417        | 1418         | 1                       | 15          |
| 3C               | 1419        | 1420         | 1                       | 15          |

\*\* Ullage port opening and closing times

\* Instantaneous grab samples. Constancy over time/tank  
should not be inferred.

+ Total hydrocarbon concentration as hexane

- o Period III involved three crew members and a group of shore-based independent cargo surveyors. The crew members were the Second Mate, Assistant Bosun and the Quartermaster. These three individuals accompanied the surveyors to each tank where the surveyors measured cargo temperature and gauged the tanks for cargo and residual water content. During this operation, the Assistant Bosun opened the ullage port and retrieved the thermometer from the tank by winding the tether onto a spool. The 2M verified and recorded the surveyors measurements while the Quartermaster was responsible for closing the ullage port and wiping up any spilled oil with rags. During the majority of these operations, the crew members stood upwind or crosswind of the ullage ports. On occasion, this practice was not possible because of physical constraints imposed by deck piping or because

## XI. Tank Processing - End of Loading

The processing of cargo tanks at the end of loading involved three distinct periods of activity.

- o Period I included the time between 1333 and 1352 hours. During this time period, the Assistant Bosun went to each cargo tank, except 2C and 3C, opened the ullage port, lowered a tethered thermometer into the cargo and then closed the ullage port. This operation was attempted at 4C but was aborted because loading of the 2, 3, and 4 center tanks was still in progress. The ullage port on 4C was opened, but insertion of the thermometer was not possible due to the intensity of the vapor discharge plume. The loading of all other tanks had been completed.

At each tank, the Assistant Bosun opened the ullage port and quickly moved to an upwind position until excess tank pressure had been partially relieved. During thermometer insertion his breathing zone was generally two feet above and two feet crosswind or upwind of the ullage port opening. Direct reading instruments were used to measure his instantaneous breathing zone concentrations of  $H_2S$  and total hydrocarbon at a time when the maximum concentration level was anticipated. The results are summarized in Table IX.

- o Period II began at 1415 hours when the loading of 2C, 3C and 4C had been completed. The Assistant Bosun returned to these tanks to insert thermometers into the cargo space. His procedure was the same as described above. Breathing zone measurements for this activity are also shown in Table IX.

TABLE VIII. DECKHOUSE SURVEY

| Level        | H <sub>2</sub> S (ppm)                                                  | THC* (ppm) | Status of Port and Starboard Access Doors |
|--------------|-------------------------------------------------------------------------|------------|-------------------------------------------|
| Main Deck    | <div style="text-align: center;"> ↑<br/>Not<br/>Detectable<br/>↓ </div> | 12         | Port Open - Stbd Closed                   |
| Boat Deck    |                                                                         | 18-20      | Closed                                    |
| Lower Bridge |                                                                         | 18         | Closed                                    |
| Upper Bridge |                                                                         | 15         | Closed                                    |
| Captain      |                                                                         | 16         | Closed                                    |
| Bridge       |                                                                         | 18         | Closed                                    |

\* Total hydrocarbon concentration as hexane.

Note: Access door did not have a positive seal. Infiltration cracks were apparent around the jamb.

TABLE VI. DECK SURVEY OF GAS AND VAPOR CONCENTRATION AT BREATHING ZONE HEIGHT DURING LOADING

| Tank No. or Location | H <sub>2</sub> S (ppm)                                                                                                                                                                                                       | THC* (ppm) |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| 1P                   | <div style="display: flex; align-items: center; justify-content: center;"> <div style="margin-right: 10px;">↑</div> <div style="text-align: center;">Not<br/>Detectable</div> <div style="margin-left: 10px;">↓</div> </div> | 10         |
| 1C                   |                                                                                                                                                                                                                              | 8          |
| 1S                   |                                                                                                                                                                                                                              | 8          |
| 2P                   |                                                                                                                                                                                                                              | 10         |
| 2C                   |                                                                                                                                                                                                                              | 10         |
| 2S                   |                                                                                                                                                                                                                              | 8          |
| Port Manifold        |                                                                                                                                                                                                                              | 8          |
| Starboard Manifold   |                                                                                                                                                                                                                              | 10         |
| 4P                   |                                                                                                                                                                                                                              | 9          |
| 4S                   |                                                                                                                                                                                                                              | 10 to 50   |
| 5P                   |                                                                                                                                                                                                                              | 10         |
| 5S                   |                                                                                                                                                                                                                              | 20         |

\*Total hydrocarbon concentration as hexane

General total hydrocarbon background = 8 ppm

TABLE VII. LEAK DETECTION SURVEY OF ULLAGE PORT AND DOME SEALS

| Tank No.  | Ullage Port |                        | Dome       |                        |
|-----------|-------------|------------------------|------------|------------------------|
|           | THC* (ppm)  | H <sub>2</sub> S (ppm) | THC* (ppm) | H <sub>2</sub> S (ppm) |
| 1P        | 15          | ND+                    | ND         | ND                     |
| 1S        | 10          | 1                      | ND         | ND                     |
| 1C        | <910        | <8                     | ND         | ND                     |
| 2C        | 30          | ND                     | ND         | ND                     |
| 3C        | **          | **                     | **         | **                     |
| 4C        | >4000       | <1895                  | ND         | ND                     |
| 5C        | >4000       | ≤ 104                  | 10         | 10                     |
| 5P        | 10          | ND                     | ND         | ND                     |
| 5S        | 10-50       | ND                     | 10         | 10                     |
| Slop Port | <910        | 12-20                  | ND         | ND                     |
| Slop Stbd | <910        | 20-25                  | 10         | ND                     |

\* Total hydrocarbon concentration as hexane

\*\* Distinct leaks not discernable because the gas and vapor plume from the mast riser vent descended to the region around the 3C expansion trunk.

+ ND - Not detectable

#### XIV. Tank Processing - Final Discharge Terminal

Prior to start of discharge, an independent cargo surveyor boarded the vessel to gauge all cargo tanks for oil and water content. The Chief Mate, Assistant Bosun and an A/B accompanied the surveyor on the gauging round. The C/M's duty was to verify the surveyor's measurements. The Assistant Bosun opened and closed the ullage ports. Because the gauging took place at night, the A/B held a flashlight so that the surveyor and the C/M could read the ullage tape.

After the Assistant Bosun opened the ullage port, he consistently attempted to take up a position several feet upwind or crosswind of the expansion trunk and out of the vapor plume. He was able to accomplish this on the majority of the tanks except for those that were not affected by the prevailing wind or where movement was constrained by deck piping.

The gauging operation had two parts. Initially, the surveyor gauged the depth of the oil free surface. After this was completed, the surveyor lowered the gauging bob to the tank bottom to measure residual water content. From several feet away, the surveyor reeled in the bob until it was near the tank top; he then approached the ullage port, finished the reeling process and read the water level on the graduated bob. During both of these gauging operations, the Chief Mate was next to the surveyor. At the ullage port, the Chief Mate's breathing zone was nominally one to three feet from the open port. The smaller distance coincided with reading of the tape or bob scale. During these observations, the Chief Mate frequently had to take up his position downwind of the ullage port, which was within the plume that was being discharged from the ullage port. At three ullage ports, the intensity of the gas and vapor plume exposure caused the C/M to cough, gag, expectorate and move away from the expansion trunk. In response to these encounters, the C/M shielded his nose and mouth with his arm when he returned to the tank. On two other occasions, he used the same shielding procedure when approaching a ullage port so as to prevent the exposure reaction.

The A/B who held the flashlight would stand behind the C/M and surveyor or to either side of one of them when the tape was being read. At the various tanks, these positions placed him upwind, crosswind or downwind of the vapor plume and generally within one to four feet of the ullage port.

At each tank, the Chief Mate's breathing zone concentration of H<sub>2</sub>S and total hydrocarbon was measured at a time when the maximum level was anticipated. These data are presented in Table XI. In addition, occupational exposure monitoring was performed on the Chief Mate, Assistant Bosun and the A/B, and the results are summarized below. The sampling periods shown below can be correlated with gauging times in Table XI. Note that all concentrations are in ppm.

#### Chief Mate

| Sample No | Time Start | Time Stop | H <sub>2</sub> S | THC*  | HXA  | BNZ    | TOL    |
|-----------|------------|-----------|------------------|-------|------|--------|--------|
| X-28      | 0019       | 0047      | -                | 174.9 | 17.7 | 1.1    | 1.0    |
| TX-110    | 0048       | 0108      | -                | 11.8  | 0.76 | <0.076 | <0.061 |
| MC-28     | 0112       | 0138      | -                | 110.0 | 9.1  | 0.58   | 0.57   |
| 96384     | 0024       | 0108      | 6.05             | -     | -    | -      | -      |
| 96369     | 0111       | 0138      | 8.10             | -     | -    | -      | -      |

\* Total hydrocarbon concentration as hexane

#### Assistant Bosun

| Sample No | Time Start | Time Stop | H <sub>2</sub> S | THC* | HXA | BNZ  | TOL  |
|-----------|------------|-----------|------------------|------|-----|------|------|
| X-17      | 0019       | 0139      | -                | 33.8 | 3.5 | 0.28 | 0.29 |
| 96370     | 0020       | 0139      | 1.47             | -    | -   | -    | -    |

\* Total hydrocarbon concentration as hexane

## AB

| Sample No     | Time Start   | Time Stop    | H <sub>2</sub> S | THC*      | HXA      | BNZ       | TOL       |
|---------------|--------------|--------------|------------------|-----------|----------|-----------|-----------|
| X-36<br>96368 | 0059<br>0037 | 0152<br>0152 | -<br>9.98        | 80.0<br>- | 7.3<br>- | 0.38<br>- | 0.48<br>- |

\*Total hydrocarbon concentration as hexane

TABLE XI. CHIEF MATE'S INSTANTANEOUS BREATHING ZONE CONCENTRATIONS DURING ULLAGE ROUND AT DISCHARGE TERMINAL

| Tank No. | Time Open+ | Time Closed+ | H <sub>2</sub> S (ppm) | THC (ppm)* |
|----------|------------|--------------|------------------------|------------|
| 5P       | 0020       | 0027         | 945                    | NM         |
| SP       | 0028       | 0032         | 1295                   | >4000      |
| 4C       | 0032       | 0038         | 375                    | >4000      |
| 2C       | 0040       | 0048         | 95-1895                | >4000      |
| 1P       | 0049       | 0054         | 30                     | 910        |
| 1C       | 0054       | 0101         | >1895                  | >4000      |
| 1S       | 0102       | 0106         | 5-95                   | 50-1500    |
| 3C       | 0113       | 0119         | 125-195                | >4000      |
| 5C       | 0119       | 0127         | 595                    | >4000      |
| SS       | 0128       | 0135         | 65                     | >4000      |
| 5S       | 0135       | 0138         | 20                     | NM         |

+ Ullage port opening and closing times

\* THC - Total hydrocarbon concentration as hexane

Gauging of the final tank was completed at 0138. Between 0138 and 0152, the A/B helped the surveyor collect product samples from tanks 4C and 5P. Maximum breathing zone concentrations of H<sub>2</sub>S and total hydrocarbon were greater than 1895 ppm and greater than 4000 ppm, respectively.

APPENDIX E  
VOYAGE REPORT - VOYAGE 5



## VOYAGE 5 REPORT OUTLINE

- I. Voyage Overview and Objectives
- II. Vessel Description
- III. Cargo Description and Transfer Operations
- IV. Sampling Strategy and Sample Analysis
- V. Tank Washing
- VI. Tank Entry
- VII. Open Tank Gauging

## I. Voyage Overview and Objectives

The objective of this voyage was to monitor occupational exposures of Deck Department personnel to product vapors during tank washing, tank entry and open tank gauging of cargo ullage during product loading. Transfer hose connect/disconnect was not monitored because this task was performed by terminal personnel rather than by members of the deck crew. Exposure monitoring during cargo discharge operations was not a voyage objective because of the low exposure potential.

A wide variety of cargos were handled throughout the voyage. The cargos that were selected for exposure monitoring were those that had

- o the potential for generating measurable airborne concentrations,
- o existing exposure limits,
- o established sampling and analysis procedures and
- o identifiable components of interest in the case of products that were complex mixtures.

## II. Vessel Description

### II.1. Dimensions

- o Length overall, 650 feet
- o Breadth molded, 70 feet

### II.2. Tonnage

- o 24,000 DWT

### II.3. Propulsion

- o Steam, 10000 hp

### II.4. Cargo/Ballast Tanks

- o 28 independent, integral cargo tanks
- o 3 deck tanks
- o 10 double bottom ballast tanks

### II.5. Cargo Pumps

- o Dedicated deepwell pumps on all integral tanks

### II.6. Cargo Loading

- o Open drop, short and full loading, ship stop

### II.7. Cargo Gauging Method

- o Open gauging through open ullage ports
- o Closed gauging with overflow protection available on 11 integral cargo tanks and three deck tanks

## II.8. Vapor Venting System

- o Product tanks open vented through ullage ports during loading and discharging
- o B/3 vent configuration on two cargo tanks
- o 4m vent configuration on nine cargo tanks
- o Reasonable height vents on 17 cargo tanks. These vents are located at or below ullage port height with P/V valves covered with canvas bags during all transfer operations.

## II.9. Tank Cleaning Method

- o Hot and cold water washing with portable Butterworth machines.
- o Number of machine drops and washing profile dependent on tank size as well as previous and next cargos.
- o Sumps stripped with steam eductors using hard piping from sump to expansion trunk combing.
- o Gas freeing using portable Coppus blowers. Number of blowers per tank dependent upon tank size and required turnaround time.

## II.10. Deck Department Staffing

- o Four Mates
- o Seven A/Bs
- o Three O/Ss
- o Bosun
- o Two Pumpmen (discharge and tank washing)

### III. Cargo Description and Transfer Operations

Cargo transfer operations were conducted at 9 terminals. At each terminal, these operations included either loading, discharging or a combination of discharging and loading. The cargos that were transferred as well as the transfer mode are summarized in Table I. The amount of cargo in a tank together with the tank capacity from the ullage tables was used to calculate the entries in the column labeled "% Full." In the case of cargo loading, these entries provide additional information for interpreting occupational exposures during open gauging. Table I indicates that several tanks were short-loaded. This condition can reflect either trim and load distribution considerations or economic conditions.

Transfer operations were observed and monitored at all terminals except Terminal Nos. 2, 3, 4 and 5.

All of the products in Table I, with the exception of vinyl acetate, are classified as Subchapter D products by the USCG. Vinyl acetate is a Subchapter O chemical. All of these products can be open gauged.

TABLE I. CARGO TRANSFER SUMMARY

Terminal No. 1

| <u>Tank No.</u> | <u>Cargo</u>        | <u>Transfer Code*</u> | <u>Quantity (gal)</u> | <u>% Full</u> |
|-----------------|---------------------|-----------------------|-----------------------|---------------|
| 2P              | Ethyl Acetate       | D                     | 96,150                | 32.0          |
| 2S              | Cellosolve          | D                     | 92,100                | 30.7          |
| 3P              | Butanol             | D                     | 299,400               | 98.0          |
| 3S              | Butanol             | D                     | 299,700               | 98.0          |
| 7CS             | Butanol             | D                     | 107,300               | 74.0          |
| 3CS             | Cellosolve          | D                     | 116,200               | 40.1          |
| 4CP             | Glycol              | D                     | 116,900               | 80.6          |
| 5CP             | Isobutanol          | D                     | 142,400               | 98.0          |
| 5CS             | Glycol              | D                     | 117,800               | 81.2          |
| DT-1            | Carbitol            | D                     | 47,200                | 98.0          |
| DT-2            | Carbitol            | D                     | 47,200                | 98.0          |
| 1P              | Denatured Ethanol   | L                     | 151,200               | 56.0          |
| 1S              | Cellosolve Acetate  | L                     | 124,600               | 46.1          |
| 2P              | Isopropanol         | L                     | 269,800               | 89.9          |
| 2S              | Isopropanol         | L                     | 270,600               | 90.2          |
| 1CP             | HPH Fuel            | L                     | 281,000               | 96.9          |
| 1CS             | HPH Fuel            | L                     | 280,000               | 96.6          |
| 7CP             | HPH Fuel            | L                     | 49,000                | 33.8          |
| 4CP             | 2 Ethyl Hexanol     | L                     | 143,000               | 98.0          |
| 4CS             | Butyl Cellosolve    | L                     | 80,600                | 55.6          |
| 5CP             | Monoethanolamine    | L                     | 72,400                | 49.9          |
| 5CS             | Denatured Ethanol   | L                     | 82,600                | 57.0          |
| 6CS             | Denatured Ethanol   | L                     | 95,600                | 65.9          |
| 8CP             | Glycol              | L                     | 74,300                | 26.6          |
| 10CP            | Vinyl Acetate       | L                     | 196,400               | 60.4          |
| 10CS            | Vinyl Acetate       | L                     | 197,800               | 60.9          |
| DT-3            | 2 Ethyl Hexoic Acid | L                     | 44,800                | 95.3          |
| 3CP             | n-Propyl Acetate    | L                     | 83,000                | 28.6          |
| 4P              | n-Propanol          | L                     | 151,200               | 46.5          |
| 4S              | Amyl Alcohol        | L                     | 149,800               | 46.1          |

Terminal No. 2

|     |             |   |         |      |
|-----|-------------|---|---------|------|
| 6CP | Xylenes     | L | 144,100 | 98.0 |
| 7CS | VMP Naphtha | L | 122,900 | 84.8 |
| 8CS | Hexane      | L | 139,300 | 48.4 |

TABLE I. CARGO TRANSFER SUMMARY (Continued)

Terminal No. 3

| <u>Tank No.</u> | <u>Cargo</u>    | <u>Transfer Code*</u> | <u>Quantity (gal)</u> | <u>% Full</u> |
|-----------------|-----------------|-----------------------|-----------------------|---------------|
| 2CP             |                 | L                     | 272,100               | 97.5          |
| 2CS             |                 | L                     | 269,000               | 93.4          |
| 9CP             | Methyl Tertiary | L                     | 286,500               | 98.0          |
| 9CS             | Butyl Ether     | L                     | 284,600               | 98.0          |
| 3P              |                 | L                     | 297,300               | 98.0          |
| 3S              |                 | L                     | 297,600               | 98.0          |

Terminal No. 4

|     |               |   |         |      |
|-----|---------------|---|---------|------|
| 3CS | Ethyl Acetate | L | 171,500 | 59.1 |
|-----|---------------|---|---------|------|

Terminal No. 5

|     |                 |   |         |      |
|-----|-----------------|---|---------|------|
| 2CP |                 | D | 270,700 | 97.0 |
| 2CS |                 | D | 269,100 | 93.4 |
| 9CP | Methyl Tertiary | D | 284,700 | 98.0 |
| 9CS | Butyl Ether     | D | 284,600 | 98.0 |
| 3P  |                 | D | 295,700 | 98.0 |
| 3S  |                 | D | 295,800 | 98.0 |

Terminal No. 6

|     |                    |   |         |      |
|-----|--------------------|---|---------|------|
| 1P  | Denatured Ethanol  | D | 150,800 | 55.8 |
| 1S  | Cellosolve Acetate | D | 124,200 | 46.0 |
| 2P  | Isopropanol        | D | 268,800 | 89.6 |
| 2S  | Isopropanol        | D | 269,800 | 89.9 |
| 4P  | n-Propanol         | D | 149,100 | 45.9 |
| 4S  | Amyl Alcohol       | D | 149,800 | 46.1 |
| 3CP | n-Propyl Acetate   | D | 84,000  | 29.0 |
| 3CS | Ethyl Acetate      | D | 170,400 | 58.8 |
| 4CP | 2 Ethyl Hexanol    | D | 143,300 | 98.0 |
| 4CS | Butyl Cellosolve   | D | 80,300  | 55.4 |
| 5CP | Monoethanolamine   | D | 72,600  | 50.0 |
| 5CS | Denatured Ethanol  | D | 82,500  | 56.9 |
| 6CS | Denatured Ethanol  | D | 95,000  | 65.5 |
| 8CP | Glycol             | D | 75,100  | 26.1 |

TABLE I. CARGO TRANSFER SUMMARY (Continued)

Terminal No. 6 (Continued)

| <u>Tank No.</u> | <u>Cargo</u>        | <u>Transfer Code*</u> | <u>Quantity (gal)</u> | <u>% Full</u> |
|-----------------|---------------------|-----------------------|-----------------------|---------------|
| 10CP            | Vinyl Acetate       | D                     | 196,800               | 60.6          |
| 10CS            | Vinyl Acetate       | D                     | 197,600               | 60.8          |
| DT-3            | 2 Ethyl Hexoic Acid | D                     | 44,600                | 94.9          |
| 3CP             | Methanol            | L                     | 74,600                | 25.7          |
| 6CP             | Methyl Ethyl Ketone | L                     | 143,800               | 98.0          |

Terminal No. 7

|     |                     |   |         |      |
|-----|---------------------|---|---------|------|
| 6CP | Xylenes             | D | 143,800 | 98.0 |
| 6CS | Methyl Ethyl Ketone | D | 143,900 | 98.0 |
| 7CS | VMP Naphtha         | D | 121,400 | 83.7 |
| 8CS | Hexane              | D | 137,500 | 47.7 |

Terminal No. 8

|      |                   |   |         |      |
|------|-------------------|---|---------|------|
| 1P   | Cellosolve        | L | 262,000 | 97.0 |
| 1S   | Cellosolve        | L | 261,500 | 96.8 |
| 6CP  | Cellosolve        | L | 97,700  | 67.4 |
| 2P   | Glycol            | L | 286,300 | 95.4 |
| 2S   | Glycol            | L | 287,500 | 98.0 |
| 4P   | Glycol            | L | 316,300 | 97.3 |
| 4S   | Glycol            | L | 317,700 | 97.7 |
| 3CP  | Glycol            | L | 274,300 | 94.6 |
| 4CS  | Glycol            | L | 107,800 | 74.3 |
| 6CS  | Glycol            | L | 90,100  | 62.1 |
| DT-3 | Glycol            | L | 47,200  | 98.0 |
| 1CP  | Glycol            | L | 215,700 | 74.4 |
| 1CS  | Glycol            | L | 215,900 | 74.4 |
| 2CP  | Denatured Ethanol | L | 267,400 | 95.8 |
| 8CP  | Denatured Ethanol | L | 264,800 | 94.9 |
| 8CS  | Denatured Ethanol | L | 265,900 | 92.3 |
| 3CS  | Butanol           | L | 285,800 | 98.0 |
| 4CP  | Butanol           | L | 144,100 | 98.0 |
| 10CP | Butanol           | L | 321,200 | 98.0 |
| 10CS | Butanol           | L | 321,900 | 98.0 |
| 5CP  | Carbitol          | L | 86,600  | 59.7 |
| 7CS  | Carbitol          | L | 86,400  | 59.6 |
| 1CP  | HPH Fuel          | D | 280,000 | 96.6 |
| 1CS  | HPH Fuel          | D | 280,600 | 96.8 |
| 7CP  | HPH Fuel          | D | 49,000  | 33.8 |
| 3CP  | Methanol          | D | 73,900  | 25.5 |



TABLE I. CARGO TRANSFER SUMMARY (Concluded)

Terminal No. 9

| <u>Tank No.</u> | <u>Cargo</u> | <u>Transfer Code*</u> | <u>Quantity (gal)</u> | <u>% Full</u> |
|-----------------|--------------|-----------------------|-----------------------|---------------|
| 2CS             | Ortho Xylene | L                     | 285,700               | 98.0          |
| 7CP             | Ortho Xylene | L                     | 61,400                | 42.3          |
| 9CP             | Ortho Xylene | L                     | 282,700               | 97.8          |
| 9CS             | Ortho Xylene | L                     | 283,600               | 98.0          |
| 3P              | Ortho Xylene | L                     | 297,000               | 98.0          |
| 3S              | Ortho Xylene | L                     | 297,000               | 98.0          |

\*Transfer Code: L = Load, D = Discharge

. Sampling Strategy and Sample Analysis

Occupational exposures to cargo vapors during open tank gauging, tank washing and tank entry were emphasized on this voyage. The products that were selected for exposure monitoring are summarized in Table II. These products met of the following criteria.

- o The product has an established NIOSH sampling and analysis method.
- o The product has an equivalent sampling and analysis method that is either published in the open literature or has been independently developed by private industry.
- o The product has an ACGIH Threshold Limit Value.
- o The product is a mixture that contains discrete compounds of interest, and these compounds satisfy the first three criteria.
- o The product has the potential for generating measurable airborne concentrations.

Large (400/200) and small (100/50) charcoal tubes and passive dosimeters were used for the majority of the sample collection. Special purpose tubes were used for vinyl acetate. All samples were analyzed by an AIHA credited laboratory. Desorption efficiencies were determined for each combination of chemical constituent and sorptive medium for which the analyte was detectable on the sample tube. These efficiencies reflect two replicate determinations at two loading levels. Desorption efficiency information is summarized in Table III.

AD-A157 308

A CREW EXPOSURE STUDY PHASE II VOLUME 2 AT SEA PART B  
(U) SOUTHWEST RESEARCH INST SAN ANTONIO TX DIV OF  
ENGINEERING AND... W J ASTLEFORD ET AL. APR 85

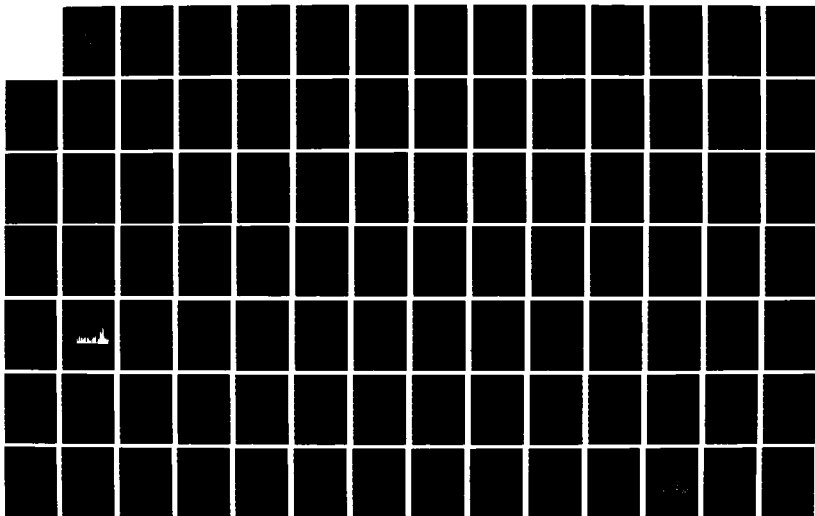
4/5

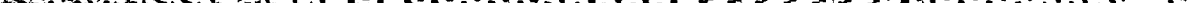
UNCLASSIFIED

USCG-D-12-85 DTCG23-80-C-20015

F/G 6/10

NL





All charcoal tube samples were collected at a nominal flow rate of 0.2 L/min. Dosimetry pumps were calibrated before and after use. Five replicate flow rate determinations were made at each calibration. All concentration calculations reflect the average of the pre- and post-test calibrations.

Table IV contains sampling rates for the passive dosimeters.

TABLE II. PRODUCTS SELECTED FOR EXPOSURE MONITORING

| <u>Chemical</u>     | <u>NIOSH Sampling<br/>Method No.</u> | <u>TLV-TWA*<br/>(ppm)</u> | <u>TLV-STEL*<br/>(ppm)</u> |
|---------------------|--------------------------------------|---------------------------|----------------------------|
| Cellosolve Acetate  | S-41                                 | 5 (skin)                  | --                         |
| Ethyl Acetate       | S-49                                 | 400                       | --                         |
| n-Propyl Acetate    | S-48                                 | 200                       | 250                        |
| Methyl Ethyl Ketone | S-3                                  | 200                       | 300                        |
| Hexane              | S-90                                 | 50                        | --                         |
| Xylenes (o, m or p) | S-318                                | 100                       | 150                        |
| Methanol            | +                                    | 200 (skin)                | 250 (skin)                 |
| Isobutanol          | S-64                                 | 50                        | 75                         |
| Butanol             | S-66                                 | 50 (C-skin)               | --                         |
| n-Propanol          | S-62                                 | 200 (skin)                | 250 (skin)                 |
| Ethanol             | S-56                                 | 1000                      | --                         |
| Isopropanol         | S-65                                 | 400                       | 500                        |
| Butyl Cellosolve    | S-76                                 | 25 (skin)                 | 75 (skin)                  |
| Vinyl Acetate       | ++                                   | 10                        | 20                         |
| HPH Fuel            |                                      |                           |                            |
| o Isophorone        | S-367                                | 5 (C)                     | --                         |
| o Diisobutyl Ketone | S-358                                | 25                        | --                         |
| o Dicyclopentadiene | **                                   | 5                         | --                         |

\* Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment, ACGIH, 1984-85.

\*\*Private industry - adsorption on charcoal, desorption with CS<sub>2</sub> + 10% acetone V/V.

+ Private industry - adsorption on charcoal, desorption with acetonitrile.

++American Industrial Hygiene Association Journal, Vol. 43, No. 3, 1982.

TABLE III. SUMMARY OF DESORPTION EFFICIENCIES

| <u>Compound</u>     | <u>Small<br/>Charcoal<br/>Tube</u> | <u>Large<br/>Charcoal<br/>Tube</u> | <u>Passive<br/>Dosimeter</u> | <u>Special<br/>Charcoal<br/>Tube</u> |
|---------------------|------------------------------------|------------------------------------|------------------------------|--------------------------------------|
| Cellosolve Acetate  | 0.805                              | --                                 | 0.960                        | --                                   |
| Ethyl Acetate       | 0.880                              | --                                 | --                           | --                                   |
| n-Propyl Acetate    | 0.890                              | 0.755                              | 0.838                        | --                                   |
| Methyl Ethyl Ketone | 0.842                              | 0.89                               | --                           | --                                   |
| Hexane              | 1.045                              | 0.989                              | --                           | --                                   |
| Xylenes             | 0.995                              | 0.994                              | 0.98                         | --                                   |
| Methanol            | --                                 | 0.96                               | --                           | --                                   |
| Isobutanol          | 0.850                              | --                                 | --                           | --                                   |
| Butanol             | 0.859                              | 0.836                              | --                           | --                                   |
| n-Propanol          | 0.760                              | --                                 | --                           | --                                   |
| Ethanol             | 0.726                              | --                                 | --                           | --                                   |
| Isopropyl Alcohol   | 0.880                              | --                                 | 0.466                        | --                                   |
| Butyl Cellosolve    | 0.936                              | --                                 | --                           | --                                   |
| Vinyl Acetate       | --                                 | --                                 | --                           | 0.985                                |
| HPH Fuel            |                                    |                                    |                              |                                      |
| o Isophorone        | 0.876                              | 0.838                              | --                           | --                                   |
| o Diisobutyl Ketone | *                                  | *                                  | --                           | --                                   |
| o Dicyclopentadiene | 0.938                              | 0.936                              | --                           | --                                   |

\* Desorption study deleted as analytes not detectible in personal samples

TABLE IV. PASSIVE DOSIMETER SAMPLING RATES

| <u>Compound</u>    | <u>Sampling Rate (cc/min)*</u> |
|--------------------|--------------------------------|
| Isopropyl Alcohol  | 26.9                           |
| Cellosolve Acetate | 22.2                           |
| n-Propyl Acetate   | 28.0                           |
| Isobutanol         | 32.1                           |
| Butanol            | 31.4                           |
| Ethanol            | 37.5                           |
| Butyl Cellosolve   | 24.8                           |
| Isophorone         | 21.9                           |
| Diisobutyl Ketone  | 20.6                           |
| Dicyclopentadiene  | 41.6**                         |
| Xylenes            | 27.4                           |
| n-Propyl Alcohol   | 35.0                           |

\* DuPont GBB badge or GAA badge with one cover off. Sampling rate equals twice value shown for GAA badge with two covers off. All values are manufacturer's data except as noted.

\*\* Sampling rate not available from badge manufacturer for this compound. Value shown is for cyclopentadiene.

Based on the analytical chemistry results, vapor concentrations were calculated by the methods that are shown below.

o Adsorbent Tubes

$$C \text{ (ppm)} = \frac{W_C}{nQt} \frac{24.45}{MW} \left( \frac{T + 273}{298} \cdot \frac{760}{P} \right)$$

where

$W_C$  = cumulative weight of analyte on the tube corrected for blank,  $\mu\text{g}$

= desorption efficiency as a decimal

$Q$  = sampling flow rate, LPM

$T$  = sampling temperature,  $^{\circ}\text{C}$

$p$  = sampling barometric pressure, mm Hg

o Passive Dosimeters

$$C \text{ (ppm)} = \left( \frac{W_{CF} + 2.2 W_{CB}}{n(SR) T} \right) \left( \frac{24.45}{MW} \cdot \frac{T + 273}{298} \cdot \frac{760}{P} \right)$$

where

$W_{CF}$  = weight of analyte on exposed front strip corrected for blank, ng

$W_{CB}$  = weight of analyte on backup strip corrected for blank, ng

$SR$  = passive sampling rate,  $\text{cm}^3/\text{min}$ .

Other quantities are as defined for the adsorbent tubes. The pressure correction was not applied as all samples were collected at sea level conditions.

The resulting concentration data are presented in subsequent sections of this report that deal with specific operations. A total of nearly 90 samples were collected during the voyage. There was roughly an equal distribution of these samples between tank washing, tank entry and open gauging. For completeness, the USCG CHRIS code abbreviations for the chemicals of interest are presented in Table V.

TABLE V. U. S. COAST GUARD CHRIS CODE ABBREVIATIONS

| <u>Chemical</u>     | <u>CHRIS Code</u> |
|---------------------|-------------------|
| Cellosolve Acetate  | EGE               |
| Ethyl Acetate       | ETA               |
| n-Propyl Acetate    | PAT               |
| Methyl Ethyl Ketone | MEK               |
| n-Hexane            | HXA               |
| Xylenes (o,m,p)     | XLO,XLM,XLP       |
| Methanol            | MAL               |
| Isobutanol          | IAL               |
| n-Butanol           | BAN               |
| n-Propanol          | PAL               |
| Ethanol             | EAL               |
| Isopropyl Alcohol   | IPA               |
| Butyl Cellosolve    | EGM               |
| Vinyl Acetate       | VAM               |
| Isophorone          | IPH               |
| Diisobutyl Ketone   | DIK               |
| Dicyclopentadiene   | DPT               |



## V. Tank Washing

Tank washing and ventilating are the first two steps in preparing a tank for back loading of the next cargo. On this voyage, cargo tanks were washed and ventilated both at-sea between consecutive terminals and at terminal facilities where rapid tank turnaround was needed to meet the vessel's loading plan.

Sixteen tanks were monitored during washing. Table VI identifies the products that had been carried in each of these tanks as well as the details of the in-tank washing operation. Portable Butterworth machines and portable Coppus blowers were used to wash and ventilate the tanks. In all cases, a single blower was used on each tank. A second blower was subsequently added to both 1CP and 1CS.

A more comprehensive washing procedure was used on the HPH Fuel tanks, 7CP, 1CP and 1CS.

### Tank 7CP

1. 30-minute cold wash, 1 washing machine, 15 minutes each at 10 and 20 feet
2. 30-minute cold wash with surfactant at 15 foot depth, recirculate through loading drop and pump
3. Pump stops before
4. 45-minute hot wash, 1 washing machine, 15 minutes each at 10, 20 and 35 feet

TABLE VI. SUMMARY OF TANK WASHING DATA

| Tank No.          | Previous Contents                       | Water               | No. Washing Machines | Drop Depths, Ft | Time/Depth, Min | Total Wash Time, Min |
|-------------------|-----------------------------------------|---------------------|----------------------|-----------------|-----------------|----------------------|
| 3CP<br>6CS        | n-Propyl Acetate<br>Ethanol             | Hot                 | 2                    | 10,20,30        | 15              | 45                   |
|                   |                                         | Hot                 | 1                    | 10,20,30        | 10              | 30                   |
| 4P                | n-Propyl Alcohol                        | Hot                 | 5(3+2)               | 10,20,30        | 10              | 60                   |
| 10CP,10CS         | Vinyl Acetate                           | Cold (Hot)          | 3                    | 10(10,20,30)    | 15(15)          | 60                   |
| 9CS               | Wash Slops 3CP,6CS                      | Hot with Surfactant | 1                    | 10,20,30        | 15              | 45                   |
| 2P,2S             | Isopropyl Alcohol                       | Hot                 | 2                    | 10,20,30        | 10              | 30                   |
| 3CS               | Ethyl Acetate                           | Hot                 | 2                    | 10,20,30        | 10              | 30                   |
| 8CS<br>6CS<br>6CP | Hexane<br>Methyl Ethyl Ketone<br>Xylene | Hot                 | 2                    | 10,20,30        | 10              | 30                   |
|                   |                                         | Hot                 | 1                    | 10,20,30        | 10              | 30                   |
|                   |                                         | Hot                 | 1                    | 10,20,30        | 10              | 30                   |

### ICP and ICS

1. 30-minute cold wash, 3 washing machines, 10 minutes each at 10, 20 and 30 feet
2. Let slops soak on tank bottom for 15 minutes
3. 30-minute cold wash with surfactant at 15 foot depth, recirculate through loading drop and pump
4. Pump slops ashore
5. 45-minute hot wash, 3 washing machines, 15 minutes each at 10, 20 and 35 feet.

Washing of the HPH Fuel tanks was conducted in two phases. Phase 1 included the complete washing procedure on 7CP and the first two steps in the procedure for ICP and ICS. The final three steps in the ICP and ICS procedure constituted Phase 2.

The number of crew members that were involved in the tank washing was dependent on the number of drops (washing machines) per tank and the number of tanks that were being washed simultaneously. For example, seven crew members were involved in the simultaneous washing of ICP and ICS while 4P required four crew members. The washing crew consisted of one or two Pumpmen, the Bosun and a complement of A/Bs and O/Ss.

The Pumpman's duty was to periodically discharge the wash residues from the tank to either a cargo tank that was designated as a slop tank, to shore or to the drip pan through an open manifold. The A/Bs and O/Ss manually lowered the washing hoses and machines into the tank at the times indicated in the washing plan. They also removed the machines at the conclusion of washing. The Bosun functioned in a supervisory capacity but also assisted with pump operation and hose manipulation as needed.

The odor of product vapor was more pronounced at the beginning of a tank washing when the machines were at the highest elevation in the tank. Generally, odor levels declined as the machines were lowered further into the tank and the residues were pumped from the tank.

Toward the end of the washing procedure, the main cargo pump was used to strip as much liquid residue as possible from the tank bottom and sump. In this operation, the status of the discharge pump must be carefully monitored to avoid loss of suction head and pump cavitation. The pump discharge pressure gage was monitored for incipient loss of pressure head, and the pump was either shut down or the discharge valve was further closed to increase discharge pressure. Discharge of wash residue was visually verified by opening a bypass spigot on the pump discharge line. A reduced flow from the spigot indicated the approach of suction loss; the pump was then shut down. Opening of the bypass spigot resulted in discharge of wash residues onto the deck.

At the conclusion of a given washing operation, the tank dome was fully opened, the inside surface of the expansion trunk was rinsed with fresh water, the hard piped sump eductor was hooked up, the blower(s) was turned on and the washing crew moved to the next series of tanks to be washed.

On each tank, the discharge pump station was located next to the expansion trunk. The normal procedure was to crack the dome on the expansion trunk for vapor release during washing. Consequently, the Pumpman was consistently selected for occupational exposure monitoring because his primary function was to control pump operation. Other crew members that manipulated the washing hoses were selectively monitored for vapor exposure as was the Bosun.

The occupational exposure monitoring results for tank washing are presented in Table VII.

TABLE VII. OCCUPATIONAL EXPOSURES DURING TANK WASHING

| Tank No.   | Sample No.     | Q(Lpm)      | t(min)   | T(°C)        | Sorbent*    | Chemical                      | M <sub>c</sub> (µg)+ | Concentration (ppm)+ | Personnel          |
|------------|----------------|-------------|----------|--------------|-------------|-------------------------------|----------------------|----------------------|--------------------|
| 3CP, 6CS   | SC-22          | 0.196       | 56       | 21.4         | SC          | n-Propyl Acetate<br>Ethanol   | 244<br>ND            | 5.9<br>ND            | Bosun              |
|            | SC-31          | 0.193       | 56       | 21.4         | SC          | n-Propyl Acetate<br>Ethanol   | 110<br>ND            | 2.7<br>ND            | A/B-5              |
|            | SC-24          | 0.204       | 56       | 21.4         | SC          | n-Propyl Acetate<br>Ethanol   | 125<br>ND            | 2.9<br>ND            | A/B-1              |
|            | 62077<br>SC-28 | --<br>0.204 | 28<br>56 | 21.4<br>21.4 | GAA-2<br>SC | n-Propyl Acetate<br>Ethanol   | 164<br>376<br>ND     | 29.5<br>8.7<br>ND    | Pumpman-1<br>A/B-3 |
| 4P         | SC-23          | 0.202       | 53       | 21.2         | SC          | n-Propyl Alcohol              | 17                   | 0.8                  | A/B-4              |
|            | SC-33          | 0.200       | 52       | 21.2         | SC          | n-Propyl Alcohol              | 37                   | 1.9                  | A/B-1              |
|            | SC-38          | 0.197       | 78       | 21.2         | SC          | n-Propyl Alcohol              | 35                   | 1.2                  | Bosun              |
|            | SC-26          | 0.200       | 72       | 21.2         | SC          | n-Propyl Alcohol              | 78                   | 2.9                  | Pumpman-2          |
| 10CP, 10CS | V5             | 0.0966      | 61       | 28.1         | XLC         | Vinyl Acetate                 | 1400                 | 69.2                 | Pumpman-1          |
|            | V1             | 0.0950      | 46       | 28.1         | XLC         | Vinyl Acetate                 | 940                  | 62.6                 | AB-2               |
| 2P, 2S     | SC-39          | 0.202       | 34       | 28.7         | SC          | Isopropyl Alcohol             | ND                   | ND                   | A/B-4              |
|            | SC-55          | 0.200       | 30       | 28.7         | SC          | Isopropyl Alcohol             | ND                   | ND                   | Pumpman-1          |
| 3CS        | SC-54          | 0.200       | 36       | 29.2         | SC          | Ethyl Acetate                 | 838                  | 37.2                 | Pumpman-1          |
| 9CS        | VCC-113        | 0.200       | 22       | 28.1         | LC          | n-Propyl Acetate<br>Ethanol   | 40<br>ND             | 2.9<br>ND            | Pumpman-1          |
| 3CP        | 06-P9          | 0.202       | 24       | 25.9         | LC          | Methanol                      | 693                  | 113.9                | A/B-6              |
|            | CG2-108        | 0.202       | 12       | 25.9         | LC          | Methanol                      | 224                  | 73.7                 | Pumpman-2          |
|            | SC-67          | 0.198       | 62       | 28.7         | SC          | Hexane                        | 1270                 | 28.4                 | SwRI               |
|            |                |             |          |              |             | Methyl Ethyl Ketone<br>Xylene | 10<br>358            | 0.3<br>6.8           |                    |
| 8CS, 6CS   | SC-12          | 0.200       | 39       | 28.7         | SC          | Hexane<br>Methyl Ethyl Ketone | 9055<br>ND           | 319.1<br>ND          | Pumpman-1          |
|            | CG2-106        | 0.200       | 23       | 28.7         | LC          | Hexane<br>Methyl Ethyl Ketone | 1650<br>ND           | 104.2<br>ND          | A/B-3              |

TABLE VII. OCCUPATIONAL EXPOSURES DURING TANK WASHING (Concluded)

| Tank No.                 | Sample No. | Q(Lpm) | Δt(min) | T(°C) | Sorbent* | Chemical                                             | W <sub>c</sub> (μg)+ | Concentration (ppm)+ | Personnel                            |
|--------------------------|------------|--------|---------|-------|----------|------------------------------------------------------|----------------------|----------------------|--------------------------------------|
| 8CS,6CS<br>(cont)<br>6CP | CG2-105    | 0.202  | 22      | 28.7  | LC       | Hexane<br>Methyl Ethyl Ketone                        | 573<br>ND            | 37.4<br>ND           | O/S-2                                |
|                          | SC-65      | 0.200  | 25      | 28.7  | SC       | Xylene<br>Hexane                                     | 1690<br>128          | 79.2<br>7.0          | A/B-6 on<br>pump                     |
|                          | CG2-110    | 0.204  | 44      | 28.7  | LC       | Methyl Ethyl Ketone<br>Xylene                        | ND<br>ND             | ND<br>ND             | A/B-3                                |
|                          | BF-8       | 0.202  | 98      | 28.7  | LC       | Hexane<br>Methyl Ethyl Ketone                        | ND<br>1340           | ND<br>15.9           | O/S-2                                |
| 7CP + #1<br>(1CP,1CS)    | DO-19      | 0.200  | 165     | 29.2  | LC       | Hexane<br>Methyl Ethyl Ketone                        | 330<br>32            | 4.8<br>0.6           | Pumpman-2                            |
|                          | CG2-109    | 0.202  | 150     | 29.2  | LC       | Isophorone<br>Diisobutyl Ketone<br>Dicyclopentadiene | ND<br>ND<br>ND       | ND<br>ND<br>ND       |                                      |
| #2(1CP,1CS)              | BF-25      | 0.202  | 90      | 30.9  | LC       | Isophorone<br>Diisobutyl Ketone<br>Dicyclopentadiene | ND<br>ND<br>ND       | ND<br>ND<br>ND       | O/S-1                                |
|                          | BF-24      | 0.202  | 112     | 30.9  | LC       | Isophorone<br>Diisobutyl Ketone<br>Dicyclopentadiene | ND<br>ND<br>ND       | ND<br>ND<br>ND       | Bosun                                |
|                          |            |        |         |       |          |                                                      |                      |                      | Pumpman-3<br>(Replaced<br>Pumpman-1) |

\*SORBENT KEY

SC = Small Charcoal (100/50)  
LC = Large Charcoal (400/200)  
XLC = Special Purpose VAM Tube  
GAA-2 = Passive Dosimeter, 2 Covers Removed

+ND = Not Detectable

Several tanks were washed simultaneously.

- o 3CP - n-Propyl acetate, 6CS - Ethanol
- o 10CP, 10CS - Vinyl acetate
- o 2P, 2S - Isopropyl alcohol
- o 8CS - Hexane, 6CS - Methyl ethyl ketone
- o 7CP, 1CS, 1CP - HPH Fuel

In the case of 6CP, which had carried xylene, other exposure chemicals were included in the analysis because of the proximity of 8CS and 6CS, which were being ventilated concurrently. The three compounds listed for 7CP, 1CP and 1CS were chemicals of interest in the HPH Fuel.

The use of personal protective equipment varied between members of the washing crew. Chemical goggles were available for splash protection when washing hoses were lowered in the tank. Some crew members wore the goggles properly, others wore the goggles on top of their hats and some individuals did not carry goggles. On a given tank, the level of goggle usage varied among the washing crew. Similar variability existed in glove usage for dermal protection. Some crew members wore rubber gloves while others had rubber gloves but did not use them. Other crew members either did not wear gloves or wore conventional work gloves.

The expansion trunk and pump for Tank 9CS was located in an area of the deck that was highly shielded from the ambient wind. The Pumpman anticipated the potential for vapor accumulation and wore an organic vapor cartridge respirator.

On one occasion, a member of the washing crew collected some wash residues from the pump bypass spigot in an unprotected hand. The purpose of this practice was to smell the wash water for product odor; lack of odor was an indication of tank cleanliness.

## VI. Tank Entry

Following washing and ventilating, crew members entered cargo tanks as the final step in preparing the tanks for a change in cargo grade. Nineteen separate tanks were monitored during entry. These entries, which involved 15 products, resulted in 29 occupational exposure samples. Fourteen of these products were simple chemicals; one product, HPH Fuel, was a complex mixture of three hydrocarbon processing streams. All of the products were classified under Subchapter D with the exception of Vinyl Acetate, which is a Subchapter O chemical.

Each tank entry usually involved one or two crew members. The work to be conducted included sweeping of debris and damp mopping of residual liquid on the tank bottom and vacuuming the pump sump to remove wash slops. The equipment that was used to accomplish these tasks included buckets, mop, dust pan, broom and vacuum eductor hose.

Observations regarding the tank entry procedure are as follows.

- o All tank entries were authorized without testing the atmospheres for oxygen, combustible gas or toxicity levels.
- o During entry, ventilation was provided to eight of the 19 tanks.
- o Tank entries were performed without respiratory protection (SCBA, EEBA or air-purifying).
- o With one exception, a safety watch was present at each open expansion trunk during tank entry.
- o Protective equipment such as chemical goggles and chemical-resistant "rubber" boots were not used. Cloth work gloves were used by the crew members with the exception of one A/B who used "rubber" gloves.



and the use of permanently-installed, in-tank stripper pumps to minimize either the need for tank entry or the exposure levels during entry following washing and ventilation.

Occupational exposure monitoring was supplemented by area monitoring and the use of direct reading instruments for measuring instantaneous breathing zone concentrations of total hydrocarbon vapor.

Additionally, noise dosimetry data were collected during many phases of the voyage to characterize noise levels encountered during various activities possibly unique to this ship.

The data in this Voyage Report were collected on a new tanker that was roughly one year old. The vessel was still in a transition with respect to installation of final, permanent equipment, systems and procedures. Therefore, certain operations or situations that were observed could be considered temporary or non-routine in nature.

Certain work practice procedures had been developed by the company. But because of the changing conditions described above, the final work environment had not been fully surveyed; therefore, some of the procedures could not be fully implemented. For example, a hearing conservation program had been developed, and implementation is planned after the working environment stabilizes. Consequently, the noise data that are presented in this report were collected primarily to characterize noise levels as opposed to evaluation of exposures relative to a selected guideline. A tank entry procedure and permit system had been developed by the company.

## I. Trip Overview and Objectives

The primary objective of this voyage was to monitor occupational exposures to cargo vapors during Deck Department operations aboard a state-of-the-art chemical tanker. The voyage lasted 14 days. The project team boarded the vessel at the initial discharge terminal. The remainder of the voyage included:

- o four additional discharge terminals,
- o a back loading of a pure chemical at one of the discharge terminals,
- o the ballast voyage, during which tank processing and entry were performed,
- o a stop at a repair facility, Terminal 6, for installation of equipment,
- o discharging of a pure chemical onto a barge while at the repair facility, and
- o loading at a seventh terminal.

Exposure monitoring began just after the start of discharge at the first terminal and continued through a major portion of the loading at the seventh terminal. This effort reflected operations that are unique to vessels equipped with certain cargo handling systems that have been installed to minimize exposures. Examples of such systems include closed cargo transfer during loading and discharge, high velocity vapor venting during loading, closed gauging up to top off, use of a portable restricted gauge device at top off, smooth tank interiors, slopes tank bottoms to stripper sumps, higher than conventional ventilation system capacities,

## VOYAGE 6 REPORT OUTLINE

- I. Trip Overview and Objectives
- II. Vessel Description
- III. Cargo Description
- IV. Sampling and Sample Analysis
- V. Product Discharging
- VI. Tank Processing
- VII. Tank Entries
- VIII. Product Loading
- IX. Miscellaneous Activities/Samples

APPENDIX F  
VOYAGE REPORT - VOYAGE 6

TABLE IX. OCCUPATIONAL EXPOSURES DURING OPEN TANK GAUGING (Concluded)  
(PERIODIC AND TOP OFF)

| Tank No.                                   | Sample No. | Q(Lpm) | t(min) | T(°C) | Sorbent* | Chemical     | W <sub>c</sub> (µg)+ | Concentration (ppm)+ | Personnel | Comment                           |
|--------------------------------------------|------------|--------|--------|-------|----------|--------------|----------------------|----------------------|-----------|-----------------------------------|
| 10CP<br>4CP<br>4CP                         | SC-16      | 0.205  | 17     | 27.0  | SC       | Butanol      | 47                   | 5.2                  | 3M-2      | Tank Top Off                      |
|                                            | DM-22      | 0.200  | 31     | 27.0  | SC       | Butanol      | 230                  | 14.3                 | AB-2      | Standby Cargo Valve and Assist 3M |
|                                            | DD-18      | 0.204  | 6      | 27.0  | LC       | Butanol      | 560                  | 181.7                | 3M-2      | Tank Top Off                      |
| 9CS<br>9CP<br>9CP, 9CS<br>9CS              | SC-45      | 0.193  | 142    | 27.0  | SC       | Ortho Xylene | 1820                 | 15.5                 | AB-5      | Periodic Gauge                    |
|                                            | SC-77      | 0.222  | 138    | 27.0  | SC       | Ortho Xylene | 297                  | 2.2                  | AB-7      | Periodic Gauge                    |
|                                            | SC-19      | 0.193  | 110    | 27.0  | SC       | Ortho Xylene | 595                  | 6.5                  | 3M-2      | Periodic Gauge                    |
|                                            | SB-211     | 0.201  | 12     | 27.0  | LC       | Ortho Xylene | 1240                 | 119.9                | 3M-2      | Tank Top Off                      |
| 9CP<br>7CP, 2CS<br>2CS<br>3P, 3S<br>3P, 3S | BF-9       | 0.191  | 4      | 27.0  | LC       | Ortho Xylene | 30                   | 9.2                  | 3M-2      | Tank Top Off                      |
|                                            | 62065      | --     | 104    | 28.7  | GB8      | Ortho Xylene | 1330                 | 111.0                | 2M        | Top Off 7CP then 2CS              |
|                                            | SB-210     | 0.191  | 29     | 28.7  | LC       | Ortho Xylene | 2750                 | 116.4                | 2M        | Tank Top Off, Maltzing Sampler    |
|                                            | SC-78      | 0.202  | 146    | 30.3  | SC       | Ortho Xylene | 594                  | 4.7                  | 3M-1      | Periodic Gauge                    |
|                                            | SC-79      | 0.211  | 15     | 32.6  | SC       | Ortho Xylene | 565                  | 42.4                 | 3M-2      | Tank Top Off                      |

\*SORBENT KEY

SC = Small Charcoal Tube (100/50)  
LC = Large Charcoal Tube (400/200)  
GAA-2 = Passive Dosimeter, Two Covers Off  
GB8 = Passive Dosimeter with Backup Section

+ND = Not Detectable

TABLE IX. OCCUPATIONAL EXPOSURES DURING OPEN TANK GAUGING  
(PERIODIC AND TOP OFF)

| Tank No.                                                                | Sample No. | Q(Lpm) | t(min) | T(°C) | Sorbent* | Chemical            | W <sub>c</sub> (µg)+ | Concentration<br>(ppm)+ | Personnel | Comment                                   |
|-------------------------------------------------------------------------|------------|--------|--------|-------|----------|---------------------|----------------------|-------------------------|-----------|-------------------------------------------|
| 1S<br>6CS<br>10CP, 10CS<br>10CP, 10CS<br>10CS                           | 48955      | --     | 7      | 36.4  | GAA-2    | Cellosolve Acetate  | 20                   | 12.9                    | 2M        | Tank Top Off                              |
|                                                                         | 62079      | --     | 26     | 36.4  | GAA-2    | Ethanol             | ND                   | ND                      | 2M        | Tank Top Off                              |
|                                                                         | V9         | 0.0966 | 184    | 29.2  | XLC      | Vinyl Acetate       | 1300                 | 21.4                    | 3M-1      | Periodic Gauging                          |
|                                                                         | V2         | 0.0985 | 12     | 27.0  | XLC      | Vinyl Acetate       | 2                    | 0.5                     | 2M        | Tank Top Off, Waiting Sampler             |
|                                                                         | V3         | 0.0966 | 73     | 28.1  | XLC      | Vinyl Acetate       | 12000                | 495.7                   | --        | Area Sample Above Ullage Port             |
| 2P, 2S<br>2P, 2S<br>2S<br>2P<br>2P, 2S                                  | 62791      | --     | 164    | 29.2  | G88      | Isopropyl Alcohol   | 561                  | 112.6                   | 3M-1      | Periodic Gauge                            |
|                                                                         | 63779      | --     | 115    | 28.1  | G88      | Isopropyl Alcohol   | 1320                 | 376.4                   | 2M        | Periodic Gauge                            |
|                                                                         | SC-21      | 0.194  | 62     | 29.2  | SC       | Isopropyl Alcohol   | 16850                | 656.8                   | 3M-2      | Periodic Gauge                            |
|                                                                         | SC-25      | 0.196  | 73     | 29.2  | SC       | Isopropyl Alcohol   | 6754                 | 221.3                   | A/B-2     | Periodic Gauge                            |
|                                                                         | SC-18      | 0.204  | 9      | 29.8  | SC       | Isopropyl Alcohol   | 933                  | 238.7                   | 3M-2      | Tank Top Off                              |
| 4P<br>1CP, 1CS<br>6CS                                                   | 62078      | --     | 67     | 35.3  | GAA-2    | n-Propyl Alcohol    | ND                   | ND                      | 2M        | Periodic Gauge and Top Off                |
|                                                                         | 48954      | --     | 26     | 29.2  | G88      | HPH Fuel            | ND                   | ND                      | 3M-1      | Periodic Gauge and Top Off                |
|                                                                         | SC-40      | 0.204  | 159    | 17.6  | SC       | Methyl Ethyl Ketone | 117                  | 1.4                     | 3M-2      | Periodic Gauge                            |
|                                                                         | SC-29      | 0.193  | 57     | 17.6  | SC       | Methyl Ethyl Ketone | 1400                 | 50.0                    | 3M-2      | Tank Top Off                              |
|                                                                         |            |        |        |       |          |                     |                      |                         |           |                                           |
| 10CP, 10CS<br>3CS, 4CP<br>3CS, 4CP<br>3CS<br>10CP, 10CS<br>10CS<br>10CP | 63780      | --     | 126    | 29.2  | G88      | Butanol             | ND                   | ND                      | 2-M       | Periodic Gauge                            |
|                                                                         | SC-70      | 0.202  | 96     | 28.1  | SC       | Butanol             | 1810                 | 36.2                    | 3M-1      | Periodic Gauge                            |
|                                                                         | SC-73      | 0.205  | 10     | 28.1  | SC       | Butanol             | 70                   | 13.2                    | C/M       | Tank Top Off                              |
|                                                                         | SC-76      | 0.205  | 81     | 27.0  | SC       | Butanol             | 731                  | 17.0                    | 3M-2      | Periodic Gauge                            |
|                                                                         | X-31       | 0.200  | 22     | 27.0  | SC       | Butanol             | 929                  | 81.6                    | 3M-2      | Tank Top Off                              |
|                                                                         | DM-42      | 0.200  | 7      | 27.0  | SC       | Butanol             | 10                   | 2.8                     | AB-2      | Open Valve on 10CP during 10CS<br>Top Off |
|                                                                         |            |        |        |       |          |                     |                      |                         |           |                                           |

requested by the purchaser. The final seven minutes included continuous gauging of 6CS as the incremental quantity of MEK was loading into the tank. On the basis of 17 minutes of actual gauging time, a maximum estimated exposure concentration of 167.6 ppm MEK was calculated.

Open tank gauging from deck level produces the maximum exposure potential. One of the Third Mates (designated 3M-2 in the subsequent tables) routinely used an organic vapor cartridge respirator when topping off tanks as well as during the latter half of a loading when he was conducting periodic gauging. Other Mates and A/Bs on cargo transfer watch did not use respiratory protection.

Generally, two crew members were involved in a tank top off. The Mate performed the ullage gauging, and an A/B manned the cargo valve near the expansion trunk. If the same cargo was being delivered to two tanks simultaneously, the A/B would open the cargo drop on the tank that was not being topped so as to divert maximum flow away from the tank being topped. One Third Mate (3M-2) dismissed the A/B crew as soon as possible at top off time so as to minimize their exposure.

Table IX summarizes the results of the occupational exposure samples that were collected during open tank gauging. The table contains several natural groupings of samples. The second, fourth and fifth groups each deal with the loading of a large quantity of a single product; and, in general, the samples within each of these three groups are arranged sequentially in time from the beginning of product loading through top off of the final tank.

The term "waltzing sampler" appears twice in Table IX. In both cases, the sampling equipment was held in the 2M's breathing zone by a member of the SwRI project team. As such, these two samples approximate the 2M's exposure, but correctly they are not true occupational exposure samples.

Sample No. SC-29 was collected during top off of tank 6CS which held MEK. The actual top off consisted of a 10-minute interval and a seven-minute interval separated by 40 minutes of non-contact time. After the first 10-minute period, cargo transfer was terminated at the predetermined stop ullage. The succeeding 40 minutes were spent in the deck house determining if the tank could accommodate an additional quantity of MEK as



- o the quantity of cargo to be loaded in relationship to the tank capacity and
- o the use of personal protective equipment.

The predominant gauging technique consisted of viewing through the open ullage port to visually verify contact of the tape bob with the liquid surface. This technique was applied while standing on the deck next to the expansion trunk with the breathing zone within one to two feet of the ullage port opening. Generally, there was a tendency to stand upwind or crosswind, if possible. Using this method, the potential for vapor exposure increases throughout loading and is maximum at tank top off. The Second Mate occasionally used an alternate technique of standing on the expansion trunk dome. This method effectively increased the separation distance between the ullage port and breathing zone, which permitted vapors to be diluted and dispersed by local wind currents. The Second Mate conscientiously held his breath when viewing into the tank from either on top of the dome or from deck level. The Chief Mate demonstrated a third gauging technique for topping off Tank 3CS. Contact of the gauging bob with the liquid surface was determined by "feel". His gauging position was some distance away from the expansion trunk with the breathing zone out the main body of the vapor plume. Because 3CS was to be loaded to 98 percent of capacity, he could also see the liquid surface contact the tank access ladder from his gauging position.

The amount of cargo to be loaded into a tank correlates with the exposure potential. Section III of this report indicates that several tanks were short-loaded, i.e. the quantity loaded was significantly less than the tank capacity. During periodic gauging and top off of a short-loaded tank, vapor discharge concentrations are less than when the tank is to be fully loaded.

## VII. Open Tank Gauging

The quantity or volume of a product that was to be loaded into a given tank was established at a pre-loading conference. The ullage tables for a given tank were then used to define the final or "stop ullage" that corresponded to the predetermined product volume. While a given tank was being loaded, it was periodically gauged to determine the current ullage, the loading rate and a projected time to completion of product transfer. During the initial stages of loading, the frequency of periodic gauging was guided by the tank size, the loading rate and the "stop ullage." At an ullage slightly greater than the final ullage, the periodic gauging phase terminated, and the top off phase was initiated. This top off phase was relatively short and was characterized by very frequent and sometimes continuous gauging until the "stop ullage" was reached. In all cases the loading of a given product was terminated by the ship, i.e. ship stop.

The cargo transfer officer on watch was responsible for all gauging. In all cases, the top off phase was performed by the Mate on watch. The periodic gauging activity was performed either by the Mate or it was delegated to an A/B under supervision of the Mate.

In accordance with USCG cargo classification criteria, open gauging of ullage was permitted for all cargos that were associated with this voyage. The majority of the periodic gauging and all of the top off gauging was performed through open ullage ports using a Lufkin tape. On occasion, the closed gauging system in the ship's office was used for tanks with long loading times.

In addition to the cargo properties, the potential for occupational exposure to product vapors is a combined function of

- o the gauging technique,

TABLE VIII. OCCUPATIONAL EXPOSURES DURING TANK ENTRY (Concluded)

| Tank No.        | Sample No. | Q(Lpm) | $\Delta t(\text{min})$ | T( $^{\circ}\text{C}$ ) | Sorbent* | Chemical                                             | $W_c(\mu\text{g})^+$ | Concentration (ppm) <sup>+</sup> | Personnel |
|-----------------|------------|--------|------------------------|-------------------------|----------|------------------------------------------------------|----------------------|----------------------------------|-----------|
| ICP-2<br>(cont) | BF-26      | 0.204  | 52                     | 28.7                    | LC       | Isophorone<br>Diisobutyl Ketone<br>Dicyclopentadiene | 15<br>ND<br>160      | 0.3<br>ND<br>3.0                 | Bosun     |
| ICS             | CG2-103    | 0.200  | 37                     | 28.1                    | LC       | Isophorone<br>Diisobutyl Ketone<br>Dicyclopentadiene | 15<br>ND<br>120      | 0.4<br>ND<br>3.2                 | A/B-6     |
|                 | CG2-102    | 0.204  | 25                     | 28.1                    | LC       | Isophorone<br>Diisobutyl Ketone<br>Dicyclopentadiene | 10<br>ND<br>120      | 0.4<br>ND<br>4.7                 | A/B-3     |

\*SORBENT KEY

SC = Small Charcoal (100/50)  
 LC = Large Charcoal (400/200)  
 XLC = Special Purpose VAM Tube

+ND = Not Detectable

TABLE VIII. OCCUPATIONAL EXPOSURES DURING TANK ENTRY

| Tank No. | Sample No. | Q(Lpm) | t(min) | T(°C) | Sorbent* | Chemical             | $V_c$ (μg)+ | Concentration (ppm)+ | Personnel |
|----------|------------|--------|--------|-------|----------|----------------------|-------------|----------------------|-----------|
| 5CP      | SC-35      | 0.194  | 10     | 33.7  | SC       | Isobutanol           | 81          | 16.7                 | A/B-3     |
|          | SC-36      | 0.196  | 10     | 33.7  | SC       | Isobutanol           | 124         | 25.3                 | A/B-2     |
|          | SC-37      | 0.196  | 9      | 37.0  | SC       | Ethyl Acetate        | 25          | 4.6                  | SwRI      |
| 2P       | SC-30      | 0.204  | 10     | 35.3  | SC       | Butanol              | 510         | 99.3                 | A/B-2     |
| 3S       | SC-34      | 0.196  | 22     | 29.8  | SC       | n-Propyl Acetate     | 94          | 5.9                  | A/B-3     |
| 3CP      | SC-32      | 0.204  | 13     | 29.8  | SC       | Ethanol              | 46          | 12.9                 | A/B-5     |
| 6CS      | SC-51      | 0.202  | 14     | 32.6  | SC       | Cellulosolve Acetate | 1940        | 161.8                | A/B-5     |
| 1S       | SC-27      | 0.200  | 14     | 32.6  | SC       | Ethanol              | 872         | 233.8                | A/B-7     |
| 1P       | V-15       | 0.095  | 9      | 28.1  | XLC      | Vinyl Acetate        | 7           | 2.4                  | A/B-3     |
| 10CS     | V-4        | 0.095  | 13     | 28.1  | XLC      | Vinyl Acetate        | 7           | 1.6                  | A/B-2     |
| 10CP     | V-6        | 0.0966 | 11     | 28.1  | XLC      | Vinyl Acetate        | 7           | 1.9                  | A/B-3     |
| 4P       | SC-56      | 0.200  | 26     | 29.8  | SC       | n-Propyl Alcohol     | 99          | 10.4                 | A/B-2     |
|          | SC-58      | 0.202  | 19     | 29.8  | SC       | Isopropyl Alcohol    | 85          | 12.0                 | SwRI      |
| 2S       | MC-27      | 0.197  | 11     | 29.2  | SC       | Isopropyl Alcohol    | 281         | 60.8                 | A/B-1     |
|          | SC-57      | 0.200  | 8      | 29.2  | SC       | Isopropyl Alcohol    | 244         | 71.5                 | A/B-4     |
| 2P       | SC-59      | 0.200  | 11     | 29.8  | SC       | Isopropyl Alcohol    | 15          | 3.2                  | A/B-3     |
| 4CS      | SC-52      | 0.197  | 15     | 29.8  | SC       | Butyl Cellulosolve   | 110         | 8.4                  | A/B-1     |
| 6CS      | SC-60      | 0.198  | 28     | 28.7  | SC       | Methyl Ethyl Ketone  | 299         | 22.0                 | A/B-2     |
| 8CS      | SC-63      | 0.205  | 23     | 28.7  | SC       | Hexane               | 1470        | 85.7                 | A/B-3     |
|          | SC-62      | 0.200  | 25     | 28.7  | SC       | Hexane               | 2850        | 156.7                | A/B-4     |
| 6CP      | SC-69      | 0.200  | 24     | 28.7  | SC       | Xylene               | 713         | 34.8                 | A/B-3     |
| 3CP      | CGS-104    | 0.202  | 19     | 29.2  | LC       | Methanol             | 133         | 27.9                 | A/B-7     |
| 1CP, 1CS | SC-61      | 0.200  | 5      | 28.7  | SC       | Isophorone           | ND          | ND                   | Bosun     |
|          |            |        |        |       |          | Diisobutyl Ketone    | ND          | ND                   |           |
| 1CP-1    | DM-43      | 0.205  | 24     | 28.7  | SC       | Dicyclopentadiene    | 8           | 1.6                  | A/B-3     |
|          |            |        |        |       |          | Isophorone           | 5           | 0.2                  |           |
|          |            |        |        |       |          | Diisobutyl Ketone    | ND          | ND                   |           |
|          |            |        |        |       |          | Dicyclopentadiene    | 46          | 1.9                  |           |
|          |            |        |        |       |          | Isophorone           | 5           | 0.2                  | Bosun     |
|          |            |        |        |       |          | Diisobutyl Ketone    | ND          | ND                   |           |
|          |            |        |        |       |          | Dicyclopentadiene    | 48          | 2.2                  |           |
| 1CP-2    | DM-13      | 0.200  | 37     | 28.7  | LC       | Isophorone           | ND          | ND                   | A/B-3     |
|          |            |        |        |       |          | Diisobutyl Ketone    | ND          | ND                   |           |
|          |            |        |        |       |          | Dicyclopentadiene    | 88          | 2.4                  |           |

Information concerning the bulk composition of HPH Fuel indicated that isophorone, diisobutyl ketone and dicyclopentadiene were the chemical components of interest for occupational exposures.

Table VIII summarizes the results of the occupational exposures that were monitored during tank entry. Exposure monitoring opportunities did not materialize for every crew member that entered a tank because

- o it was not uncommon for one crew member to have entered a tank prior to the time that a second crew member entered the same tank to perform the directed cleaning,
- o some crew members entered tanks apparently on their own initiative, and
- o some cleaning entries were performed out of sequence while other planned washing and entry activities were in progress.

- o Material Safety Data Sheets (MSDS) were available on the ship for all products except HPH Fuel.
- o A Confined Space Entry Procedure and Entry Permit System had been initiated by the ship operator but was not followed.

The objective of the washing, ventilating and manual cleaning operations was to generate a dry tank which was free of the odor of the last product. These two conditions were necessary for the tanks to be approved for product loading by the independent cargo surveyors.

On two of the tanks, 1CP and 1CS, these conditions could not be achieved without extensive in-tank mucking. Product odor remained after washing, ventilating and injecting of an odor masking liquid through the Coppus blowers. These two uncoated tanks carried HPH Fuel. Rust and scale sludges on the tank bottom contained residues of product and wash water. The sludge served as a source of vapor regeneration. Two hours prior to manual cleaning of either tank, an A/B entered and quickly exited 1CP as the vapors were too strong. The tanks were ventilated for an additional 105 minutes. At the end of that time, the Bosun briefly entered both tanks and indicated that additional ventilation was needed. A second blower was installed on each tank. Seventeen minutes later 1CP was entered for cleaning.

Tank 1CP was mucked first. The cleaning equipment was the same as was used on all tank entries with the addition of an air operated winch that was used to hoist buckets of sludge to the deck. Initially, the Bosun and an A/B entered the tank for a period of 22 and 24 minutes, respectively. During this time, roughly 19 2-1/2 gallon buckets of sludge were removed. A short time after egress, the same two crew members re-entered 1CP for an additional 37 and 25 minutes, respectively. On the second entry, 14 buckets of sludge were removed from the tank. The Chief Mate also entered the tank twice to assist with the mucking. Cleaning of 1CS followed the same procedure with seven buckets of sludge being removed from the tank.

## II. Vessel Description

### II.1. Dimensions

- o Length overall, 630 feet
- o Breadth, 110 feet

### II.2. Tonnage

- o 42000 DWT

### II.3. Cargo/Ballast Tanks

- o 43 cargo tanks
- o 4 segregated ballast wing tanks
- o 10 double bottom ballast compartments
- o 1 forepeak ballast tank
- o 3 gale ballast/cargo tanks

### II.4. Cargo/Ballast Pumps

- o 43 independent deepwell cargo pumps controlled at the pump and in the Cargo Control Room.
- o 28 permanently installed, compressed air sump stripper pumps.
- o Portable stripper pumps for sump stripping on tanks without permanent strippers.
- o 2 ballast pumps.
- o Ballast pumps and routing valves controlled remotely in Cargo Control Room.

## II.5. Cargo Gauging Systems

- o Two closed gauging systems on each tank, both with local and remote readout.
- o Portable Restricted Gauging System on each tank.

## II.6. Vapor/Gas Venting

All cargo transfer took place with ullage ports and expansion trunks dogged down. During loading, vapor venting was accomplished through elevated Pres-Vac high velocity vents. Vacuum relief valves permitted ingestion of fresh air into the tanks during discharge for those not inerted.

Bypass lines, which enabled venting to the atmosphere without going through the high velocity vents, were available for each of the tanks. These lines were opened by loosening wing nuts and opening the cap. This bypass system was used during tank ventilation to allow the ullage ports, expansion trunks, and Butterworth plates to remain dogged down.

## II.7. Cargo Loading

All products were closed-loaded. Each cargo tank had a dedicated manifold flange and dedicated deck piping. For flexibility, additional deck piping and mix-masters were available to expedite cargo transfer in special situations.



## II.8. Tank Cleaning Method

Thirty tanks are fitted with fixed Butterworth washing machines. The remaining tanks are washed with portable machines. Wash water flowrates for the fixed machines range from about 150 to 250 gpm. Hot or cold, fresh or salt water can be used in tank washing.

The main cargo pumps are used to discharge the majority of the wash residue to a slop tank, which also serves as a cargo tank. Slops are discharged to shore. Sumps are stripped with fixed and portable air strippers. These strippers can be powered by dehumidified air, inert gas or compressed air.

Following washing, gas freeing can be accomplished by using either the dehumidified air system, which is hard-piped to the tanks, or the conventional portable blowers or both.

## II.9. Inert Gas System

The vessel was fitted with a diesel fired gas inerting system. Inert gas service is available to 14 tanks that carry products that are unaffected by the gas blanket.

## II.10. Dehumidified Air System

Dehumidified air service is available to 42 tanks. It is used primarily to maintain a dry atmosphere in tanks at all times and secondarily for tank purging or gas freeing operations following tank washing. In the latter case, the use of dehumidified air expedites tank drying. This air service can also be used to drive sump stripping pumps and to blow cargo transfer lines at the end of discharge.

II.11. Deck Department Staffing

- o Four Mates (CM, 2M, 3M, 3M)
- o Six Able-bodied Seamen (AB)
- o One or Two Ordinary Seamen (OS)
- o Two Pumpmen (PM)

### III. Cargo Description

A total of 24 different pure chemicals, gasolines, solvents, intermediate streams, and oils were handled on this voyage. The status of the cargo tanks upon arrival at the first discharge terminal is shown in Table III.1. Prior to leaving the third discharge terminal, MEK was backloaded into cargo tank 4CA for transport to the sixth discharge terminal. The status of the cargo tanks after the loading at the last terminal is shown in Table III.2.

TABLE III.1. STATUS OF CARGO TANKS PRIOR TO DISCHARGE AT TERMINAL 1

| Tank No. | Chemical              | Capacity<br>(BBL) | Quantity*<br>(BBL) | Percent Full |
|----------|-----------------------|-------------------|--------------------|--------------|
| 1P       | Paraxylene            | 7495              | 7187               | 95.9         |
| 1C       | Stoddard Solvent A    | 12539             | 10996              | 87.7         |
| 1S       | Aromatic Solvent      | 7495              | 7239               | 96.6         |
| 2P       | Stoddard Solvent B    | 6941              | 6668               | 96.1         |
| 2CF      | Toluene               | 4301              | 4128               | 96.0         |
| 2CA      | Empty                 | 4301              | -0-                | 0.0          |
| 2S       | VM&P Naphtha          | 6941              | 2958               | 42.6         |
| 3P       | Empty                 | 3740              | -0-                | 0.0          |
| 3C       | Stoddard Solvent A    | 1724              | 1650               | 95.7         |
| 3S       | Empty                 | 3740              | -0-                | 0.0          |
| 4P       | Paraxylene            | 11581             | 9386               | 81.0         |
| 4CF      | Stoddard Solvent A    | 2151              | 2056               | 95.6         |
| 4CA      | Acetone               | 12476             | 10369              | 83.1         |
| 4S       | Stoddard Solvent B    | 11581             | 9993               | 86.3         |
| 5P       | Paraxylene            | 15525             | 15026              | 96.8         |
| 5CF      | Paraxylene            | 8600              | 8243               | 95.8         |
| 5CA      | Paraxylene            | 8192              | 7851               | 95.8         |
| 5S       | Paraxylene            | 15525             | 15026              | 96.8         |
| 6P       | White Oil A           | 7764              | 7536               | 97.1         |
| 6CF      | Isoparaffinic Solvent | 4748              | 3020               | 63.6         |
| 6CA      | Lube Oil              | 4301              | 3941               | 91.6         |
| 6S       | Empty                 | 7764              | -0-                | 0.0          |
| 7P       | Process Oil B         | 7764              | 3051               | 39.3         |
| 7CF      | Empty                 | 4301              | -0-                | 0.0          |
| 7CA      | White Oil B           | 4301              | 3017               | 70.1         |
| 7S       | Process Oil A         | 7764              | 4912               | 63.3         |
| 8P       | Refinery Feed Stock   | 11644             | 7503               | 64.4         |
| 8CF      | Bright Stock          | 4301              | 3926               | 91.3         |
| 8CM      | Process Oil C         | 4301              | 4053               | 94.2         |
| 8CA      | Empty                 | 1724              | -0-                | 0.0          |
| 8S       | Refinery Feed Stock   | 11644             | 11298              | 97.0         |
| 9P       | Ballast               | --                | --                 | --           |
| 9CF      | Empty                 | 2151              | -0-                | 0.0          |
| 9CM      | Process Oil D         | 8178              | 4937               | 60.4         |
| 9CA      | White Oil A           | 8600              | 8251               | 95.9         |
| 9S       | Ballast               | --                | --                 | --           |
| 10P      | Refinery Feed Stock   | 19406             | 18807              | 96.9         |
| 10C      | Refinery Feed Stock   | 21088             | 10079              | 47.8         |
| 10S      | Refinery Feed Stock   | 19406             | 18837              | 97.1         |
| 11PF     | Paraxylene            | 11626             | 4898               | 42.1         |
| 11PA     | Unleaded Gas          | 11315             | 10844              | 95.8         |
| 11C      | Unleaded Gas          | 25387             | 23932              | 94.3         |
| 11SF     | Paraxylene            | 11626             | 11302              | 97.2         |
| 11SA     | Unleaded Gas          | 11315             | 10898              | 96.3         |

\*Net Barrels

TABLE III.2. STATUS OF CARGO TANKS AFTER LOADING AT TERMINAL 7

| Tank No. | Chemical                | Capacity<br>(BBL) | Quantity*<br>(BBL) | Percent Full |
|----------|-------------------------|-------------------|--------------------|--------------|
| 1P       | Naphtha                 | 7495              | 6000               | 80.1         |
| 1C       | Stoddard Solvent B      | 12539             | 10000              | 79.8         |
| 1S       | VM&P Naphtha            | 7495              | 6000               | 80.1         |
| 2P       | Heptane                 | 6941              | 6000               | 86.4         |
| 2CF      | Xylene                  | 4301              | 3300               | 76.7         |
| 2CA      | Xylene                  | 4301              | 3300               | 76.7         |
| 2S       | Paraffinic Solvent      | 6941              | 6000               | 86.4         |
| 3P       | Empty                   | 3740              | -0-                | 0.0          |
| 3C       | Empty                   | 1724              | -0-                | 0.0          |
| 3S       | Empty                   | 3740              | -0-                | 0.0          |
| 4P       | Paraxylene              | 11581             | 11400              | 98.4         |
| 4CF      | Empty                   | 2151              | -0-                | 0.0          |
| 4CA      | Stoddard Solvent A      | 12476             | 9000               | 72.1         |
| 4S       | Extra Unleaded Gasoline | 11581             | 11400              | 98.4         |
| 5P       | Paraxylene              | 15525             | 15250              | 98.2         |
| 5CF      | Paraxylene              | 8600              | 8350               | 97.1         |
| 5CA      | Stoddard Solvent B      | 8192              | 8000               | 97.7         |
| 5S       | Extra Unleaded Gasoline | 15525             | 15250              | 98.2         |
| 6P       | White Oil A             | 7764              | 7600               | 97.9         |
| 6CF      | Lube Oil                | 4748              | 4600               | 96.9         |
| 6CA      | White Oil B             | 4301              | 3000               | 69.8         |
| 6S       | Insulating Oil          | 7764              | 3000               | 38.6         |
| 7P       | Lube Oil                | 7764              | 7600               | 97.9         |
| 7CF      | Hydraulic Oil           | 4301              | 4200               | 97.7         |
| 7CA      | White Oil A             | 4301              | 4200               | 97.7         |
| 7S       | Lube Oil                | 7764              | 7600               | 97.9         |
| 8P       | Extra Unleaded Gasoline | 11644             | 11400              | 97.9         |
| 8CF      | White Oil A             | 4301              | 4200               | 97.7         |
| 8CM      | Lube Oil                | 4301              | 4200               | 97.7         |
| 8CA      | Hydraulic Oil           | 1724              | 800                | 46.4         |
| 8S       | Extra Unleaded Gasoline | 11644             | 11400              | 97.8         |
| 9P       | Ballast                 | --                | --                 | --           |
| 9CF      | Empty                   | 2151              | -0-                | 0.0          |
| 9CM      | Process Oil A           | 8178              | 5000               | 61.1         |
| 9CA      | Lube Oil                | 8600              | 6000               | 69.8         |
| 9S       | Ballast                 | --                | --                 | --           |
| 10P      | Gasoline Blend Stock    | 19406             | 19000              | 97.9         |
| 10C      | Gasoline Blend Stock    | 21088             | 20500              | 97.2         |
| 10S      | Gasoline Blend Stock    | 19406             | 19000              | 97.9         |
| 11PF     | Hexane                  | 11626             | 3000               | 25.8         |
| 11PA     | Gasoline Blend Stock    | 11315             | 11100              | 98.1         |
| 11C      | Extra Unleaded Gasoline | 25387             | 24700              | 97.3         |
| 11SF     | Paraxylene              | 11626             | 11400              | 98.1         |
| 11SA     | Extra Unleaded Gasoline | 11315             | 11100              | 98.1         |

\*Quantities (net barrels) as indicated in the loading plan

#### IV. Sampling Strategy and Sample Analysis

The bulk liquid products that were handled during this voyage are summarized in Table IV.1. Also listed in this table are the chemicals' corresponding ACGIH TLVs or company Occupational Exposure Limits (OEL).

TABLE IV.1. PRODUCTS HANDLED DURING THIS VOYAGE

| Chemical                  | ACGIH<br>TLV-TWA<br>(ppm) | ACGIH<br>TLV-STEL<br>(ppm) | Company<br>OEL*        |
|---------------------------|---------------------------|----------------------------|------------------------|
| Acetone                   | 750                       | 1000                       | --                     |
| Aromatic Solvent          | --                        | --                         | 50 ppm THC             |
| Bright Stock              | --                        | --                         | 5 mg/m <sup>3</sup>    |
| Unleaded Gasolines        | 300                       | 500                        | 100 ppm THC, 5 ppm BNZ |
| Heptane                   | 400                       | 500                        | --                     |
| Hexane                    | 50                        | --                         | --                     |
| Isoparaffinic Solvent     | --                        | --                         | 300 ppm THC            |
| Lube Oil                  | --                        | --                         | 5 mg/m <sup>3</sup>    |
| Methyl Ethyl Ketone       | 200                       | 300                        | --                     |
| Paraxylene                | 100                       | 150                        | --                     |
| Process Oil A             | --                        | --                         | 5 mg/m <sup>3</sup>    |
| Process Oil B             | --                        | --                         | 5 mg/m <sup>3</sup>    |
| Process Oil C             | --                        | --                         | 5 mg/m <sup>3</sup>    |
| Process Oil D             | --                        | --                         | 5 mg/m <sup>3</sup>    |
| Refinery Feed Stock (RFS) | --                        | --                         | 100 ppm THC, 5 ppm BNZ |
| Stoddard Solvent A        | 100                       | 200                        | 100 ppm THC            |
| Stoddard Solvent B        | --                        | --                         | 200 ppm THC            |
| Toluene                   | 100                       | 150                        | --                     |
| VM&P Naphtha              | 300                       | 400                        | --                     |
| White Oil A               | --                        | --                         | 5 mg/m <sup>3</sup>    |
| White Oil B               | --                        | --                         | 5 mg/m <sup>3</sup>    |

\*Occupational Exposure Limit

THC = total hydrocarbon concentration

The products selected for exposure monitoring are listed in Table IV.2. With one exception the oils, including bright stock, lube oil, process oils, and white oils, were not monitored. The decision not to generally sample for these oils was based on the fact that the company OELs were based on mists, and the potential for the presence of oil mists, under most operations, was very low. One oil mist sample, for Process Oil B, was taken during a tank entry to document that oil mists were not present.

Large (400/200) and small (100/50) charcoal tubes and passive dosimeters were used for sample collection of vapors. All charcoal tube samples were collected at a nominal flowrate of 0.2 L/min. Dosimetry pumps were calibrated before and after use. Five replicate flow rate determinations were taken during each calibration. The actual sample flowrates used in concentration calculations represent averages of the pre- and post-test calibrations.

A mixed esters of cellulose (0.8 micron pore size) filter was used on one occasion for sample collection of oil mist. This sample was collected at a nominal flowrate of 1.5 L/min. The dosimetry pump was calibrated using the method discussed above for the charcoal tube pumps.

Many of the products handled during this voyage were not pure chemicals. Therefore, it was necessary to identify the compounds of interest for analysis for each of the products. These compounds for analysis, which took into consideration the product material safety data sheet information, are summarized in Table IV.2. For the products with multiple compounds of interest, the compounds were assigned priorities of 1, highest priority, to 3, lowest priority. During the first round of analysis, only the concentrations of the highest priority compounds were quantified. As warranted, based on the results from previous analysis rounds, additional analysis rounds quantified the concentrations of the lower priority compounds.

TABLE IV.2. PRODUCTS SELECTED FOR EXPOSURE MONITORING

| Product                                                 | Compounds<br>for Analysis |
|---------------------------------------------------------|---------------------------|
| Acetone                                                 | ACT                       |
| Aromatic Solvent<br>XLO,M,P                             | THC                       |
| Extra Unleaded Gasoline<br>BNZ<br>HXA<br>TOL<br>XLO,M,P | THC                       |
| Heptane                                                 | HPT                       |
| Hexane                                                  | HXA                       |
| Isoparaffinic Solvent                                   | THC                       |
| Methyl Ethyl Ketone                                     | MEK                       |
| Paraxylene                                              | XLP                       |
| Process Oil B                                           | Process Oil B             |
| Refinery Feed Stock<br>BNZ<br>HXA<br>TOL<br>XLO,M,P     | THC                       |
| Stoddard Solvent A                                      | THC                       |
| Stoddard Solvent B                                      | THC                       |
| Toluene                                                 | TOL                       |
| VM&P Naphtha                                            | THC                       |



When a sample was associated with a single pure compound, the recommended NIOSH analysis method for that chemical was followed.

When there was a potential for a sample to contain a mixture of vapors from (1) pure chemicals of interest and (2) wide boiling point compounds with OELs based on total hydrocarbon, then nitrobenzene was used as the desorption solution. These samples were analyzed for total hydrocarbon concentration through xylene expressed as hexane. The remainder of the chemicals of interest on these samples were quantified using the nitrobenzene desorption solution.

Desorption efficiencies were determined for each combination of chemical constituent, sorptive medium, and desorption solution for which the analyte was detected on the sample. These efficiencies reflect two replicate determinations at two loading levels. Desorption efficiency information is summarized in Table IV.3.

Passive dosimeter sampling rates are generally not available for complex vapor mixtures from products with wide boiling point ranges. A nominal sampling rate of 30 cc/min was assumed when passive dosimeters were used under these conditions.

Based on the analytical chemistry results, vapor concentrations were calculated by the methods that are shown below.

o Adsorbent Tubes

$$C \text{ (ppm)} = \frac{W_C}{nQt} \cdot \frac{24.45}{MW} \left( \frac{T + 273}{298} \cdot \frac{760}{P} \right)$$

where

- $W_C$  = cumulative weight of analyte on the tube corrected for blank,  $\mu\text{g}$
- $n$  = desorption efficiency as a decimal
- $Q$  = sampling flow rate, LPM
- $T$  = sampling temperature,  $^{\circ}\text{C}$
- $MW$  = molecular weight
- $P$  = sampling barometric pressure, mm Hg
- $t$  = sampling time, min.

TABLE IV.3. SUMMARY OF DESORPTION EFFICIENCIES

| Desorption with Nitrobenzene |       |       |       |
|------------------------------|-------|-------|-------|
| Chemical                     | SC*   | LC*   | GBB*  |
| Acetone                      | 0.795 |       | 1.010 |
| Benzene                      | 1.023 | 1.044 |       |
| Heptane                      |       | 0.980 |       |
| Hexane                       | .96   | 1.04  |       |
| Toluene                      | 1.067 | 1.000 |       |
| Xylene (p)                   | 0.994 | 1.015 |       |

| Desorption with Carbon Disulfide |       |
|----------------------------------|-------|
| Chemical                         | SC    |
| Hexane                           | 1.045 |
| Methyl Ethyl Ketone              | 0.842 |
| Xylene (p)                       | 0.995 |

- \* GBB - passive badge dosimeter  
 SC - small charcoal tube  
 LC - large charcoal tube

o Passive Dosimeters

$$C \text{ (ppm)} = \left( \frac{W_{CF} + 2.2 W_{CB}}{n(SR) T} \right) \frac{24.45}{MW} \left( \frac{T + 273}{298} \cdot \frac{760}{P} \right)$$

where

$W_{CF}$  = weight of analyte on exposed front strip corrected for blank, ng

$W_{CB}$  = weight of analyte on backup strip corrected for blank, ng

SR = passive sampling rate,  $\text{cm}^3/\text{min}$ .

Other quantities are as defined for the adsorbent tubes. The pressure correction was not applied as all samples were collected at sea level conditions.

The resulting concentration data are presented in subsequent sections of this report that deal with specific operations. For completeness, Table IV.4 summarizes the product abbreviation codes used throughout this report.

TABLE IV.4. PRODUCT ABBREVIATION CODE

Compound Key

ACT - Acetone  
 BNZ - Benzene  
 HPT - Heptane  
 HXA - Hexane  
 MEK - Methyl Ethyl Ketone  
 RFS - Refinery Feed Stock  
 THC - Total Hydrocarbon Concentration  
       through Xylene, expressed as Hexane  
 TOL - Toluene  
 XLO,M,P - Meta-ortho, paraxylene

In order to characterize noise levels possibly unique to this ship, noise dosimetry data were collected utilizing the Metrosonics dB-301P/652 Metrologgers and Metroreader. These units were programmed with an 82 dB(A) criterion level, 80 dB(A) threshold level, and a 5dB exchange rate as recommended in USCG Navigation and Vessel Inspection Circular No. 12-82. The units sampled four times per second, and the  $L_{OSHA}$  exposure was computed using the following equation.

$$L_{OSHA} = 16.6 \text{ LOG } \frac{1}{480} \sum_{i=1}^{480} 10^{L_i/16.6} \quad (1)$$

where

$L_i$  is the sound pressure level (SPL) in dB.

The Metrologgers are capable of storing a maximum of 480 such values, providing a total sample duration of 16 hours when 2 minute averaging times are used. The system has a resolution of 1 dB and sampling range of 70 to 134 dB.

At the completion of the sampling durations these calculated value were printed by the Metroreader as a quasi-graphical time history. These data were used to make two graphs for each sample taken. The first graph represents a graphical display of the time history data in histogram form. The second graph shows the cumulative effective exposure during the course of the sample and the permissible exposure per NVC 12-82. The permissible exposures were calculated by the following equation.

$$(2) \quad L_{eff} = 16.61 \text{ LOG } \frac{1}{T} \sum_{i=1}^m 10^{L_{Ai}/16.61} \Delta t_i$$

where

$L_{Ai}$  = A-weighted sound pressure level (dB(A)) during the i-th time interval,  $\Delta t_i$

$t_i$  = i-th time interval

$T = \sum_{i=1}^m = \text{total time interval}$

TABLE V.7. SUMMARY OF NOISE DATA TAKEN ON MATES DURING PRODUCT DISCHARGING

| Sample Number | Worker | Duration (min) | Noise Source                         | Max. Sound Pressure Level over 2 Minute Period (db(A)) | Cumulative Exp. Over Monitoring Period (db(A)) |
|---------------|--------|----------------|--------------------------------------|--------------------------------------------------------|------------------------------------------------|
| 8             | 2M     | 456            | Cargo Pumps (5 products discharging) | 112                                                    | 89.8                                           |
| 10            | 3M1    | 165            | Cargo Pumps (3 products discharging) | 107                                                    | 92.8                                           |
| 13            | 2M     | 199            | Cargo Pumps (3 products discharging) | 92                                                     | 78.8                                           |

TABLE V.8. SUMMARY OF NOISE DATA TAKEN ON ABs DURING PRODUCT DISCHARGING

| Sample Number | Worker | Duration (min) | Noise Source                         | Max. Sound Pressure Level over 2 Minute Period (db(A)) | Cumulative Exp. Over Monitoring Period (db(A)) |
|---------------|--------|----------------|--------------------------------------|--------------------------------------------------------|------------------------------------------------|
| 1             | AB4    | 218            | Cargo Pumps (6 products discharging) | 95                                                     | 85.6                                           |
| 3             | AB1    | 215            | Cargo Pumps (3 products discharging) | 95                                                     | 85.5                                           |
| 6             | AB5    | 207            | Cargo Pumps (3 products discharging) | 95                                                     | 80.3                                           |
| 11            | AB6    | 129            | Cargo Pumps (3 products discharging) | 94                                                     | 84.3                                           |
| 14            | AB3    | 205            | Cargo Pumps (3 products discharging) | 95                                                     | 82.3                                           |

Noise: The noise dosimetry data taken during product discharging are summarized in Tables V.7, V.8, and V.9 for Mates, ABs, and Pumpmen, respectively. Indicated in parenthesis in the noise source column of these tables are the number of products being discharged to give an indication of how many pumps may have been running. The area noise data taken during product discharging are shown in Table V.10. The noise dosimetry data for samples taken during discharging are presented in Appendix A.

Figure V.2 shows a set of noise data taken on the 2M during discharging. The peak noise levels coincide with times when the Mate was starting a cargo pump from on the deck.

On two occasions more than one noise sample was taken on an individual in a 24-hour time period. For these two cases the data are presented separately and also together assuming no exposure was received between the sampling periods. These results are also presented in Appendix A.

#### Protective Equipment

During the product discharge activities, chemical resistant gloves were occasionally worn by the workers while collecting product samples and handling hoses.

TABLE V.6. AREA SAMPLES TAKEN DURING DISCHARGE OPERATIONS

| Sample Number | T (°C) | Duration (min) | Volume (L) | Sorbent* | Chemical          | W <sub>c</sub> (µg) | Concentration (ppm)  | Area                                                                                                               |
|---------------|--------|----------------|------------|----------|-------------------|---------------------|----------------------|--------------------------------------------------------------------------------------------------------------------|
| FT-14         | 26.7   | 31             | 6.2        | LC       | THC<br>BNZ<br>HXA | 2839<br>23<br>685   | 125.6<br>1.1<br>30.3 | By leaking flange at 10S (RFS)                                                                                     |
| 62818         | 25.3   | 502            | --         | PC       | THC               | 132                 | 0.003                | By Port Forward Manifold during discharge of Stoddard Solvents A and B, VM&P Naphtha, Aromatic Solvent and Toluene |
| FT-19         | 14.4   | 258            | 51.6       | LC       | THC               | 3685                | 18.8                 | By Aft Starboard Manifold containing several inches of Refinery Feed Stock                                         |
| V6-13         | 20.0   | 59             | 12.0       | SC       | XLP               | 28                  | 0.5                  | By Paraxylene Manifold Valve                                                                                       |
| V6-27         | 24.4   | 372            | 76.6       | SC       | THC<br>TOL        | 422<br>62           | 1.6<br>0.2           | By 4CF Pump Discharging Stoddard Solvent A                                                                         |
| V6-10         | 16.1   | 146            | 29.49      | SC       | XLP               | 160                 | 1.2                  | By workers changing a gasket in the XLP cargo line                                                                 |

\* SC - small charcoal (100/50)  
 LC - large charcoal (400/200)  
 PC - passive charcoal

TABLE V.5. OCCUPATIONAL EXPOSURE MONITORING TAKEN DURING MISCELLANEOUS DISCHARGE OPERATIONS

| Sample Number | T (°C) | Duration (min) | Volume (L) | Sorbent* | Chemical   | W <sub>C</sub> (µg) | Concentration (ppm) | Personnel | Activity                           |
|---------------|--------|----------------|------------|----------|------------|---------------------|---------------------|-----------|------------------------------------|
| FT-3          | 23.9   | 39             | 7.8        | LC       | THC        | 846                 | 29.5                | AB5       | Pump out drip tray                 |
| V6-18         | 21.1   | 63             | 11.6       | SC       | THC<br>XLP | 56<br>39            | 1.4<br>0.7          | OS1       | Pump out drip tray                 |
| V6-20         | 22.2   | 24             | 5.0        | SC       | THC<br>XLP | 151<br>141          | 8.9<br>6.4          | AB5       | Pump out drip tray                 |
| V6-22         | 23.9   | 39             | 8.0        | SC       | THC        | 664                 | 24.4                | AB6       | Pump out drip tray                 |
| FT-10         | 26.7   | 11             | 2.2        | LC       | THC        | 19                  | 2.4                 | AB1       | Clean spill from deck at 10S (RFS) |

\* LC - large charcoal (400/200)  
SC - small charcoal (100/50)



TABLE V.4. OCCUPATIONAL EXPOSURES DURING DISCHARGE TENDING - PUMPMEN

| Sample Number | T (°C) | Duration (min) | Volume (L) | Sorbent* | Chemical   | W <sub>c</sub> (µg)+ | Concentration (ppm)+ | Personnel |
|---------------|--------|----------------|------------|----------|------------|----------------------|----------------------|-----------|
| FT-18         | 17.8   | 433            | 89.2       | LC       | THC<br>XLP | 286<br>137           | 0.9<br>0.3           | PM2       |
| V6-1          | 25.8   | 206            | 41.4       | SC       | THC<br>TOL | 404<br>25            | 2.9<br>0.2           | PM2       |
| V6-6          | 25.3   | 241            | 48.9       | SC       | THC        | 653                  | 4.0                  | PM1       |
| V6-30         | 14.4   | 390            | 79.2       | SC       | ACT<br>THC | ND<br>389            | ND<br>1.4            | PM2       |
| V6-35         | 18.3   | 374            | 76.3       | SC       | THC<br>XLP | 367<br>285           | 1.4<br>0.9           | PM1       |

\* SC - small charcoal (100/50)  
 LC - large charcoal (400/200)  
 + ND - not detectable

TABLE V.3. OCCUPATIONAL EXPOSURES DURING DISCHARGE TENDING - ABS

| Sample Number | T (°C) | Duration (min) | Volume (L) | Sorbent* | Chemical   | W <sub>c</sub> (µg)+ | Concentration (ppm)+ | Personnel |
|---------------|--------|----------------|------------|----------|------------|----------------------|----------------------|-----------|
| V6-2          | 25.8   | 208            | 42.2       | SC       | THC<br>TOL | 566<br>59            | 4.0<br>0.4           | AB4       |
| V6-4          | 25.3   | 231            | 46.4       | SC       | THC        | 745                  | 4.8                  | AB2       |
| V6-15         | 18.3   | 170            | 34.3       | SC       | THC<br>XLP | 162<br>149           | 1.4<br>1.0           | AB1       |
| V6-26         | 24.4   | 201            | 39.6       | SC       | THC<br>TOL | 566<br>46            | 4.2<br>0.3           | AB3       |
| V6-29         | 25.3   | 229            | 45.1       | SC       | THC<br>TOL | 145<br>ND            | 1.0<br>ND            | AB1       |
| V6-31         | 11.9   | 205            | 41.2       | SC       | ACT<br>THC | 270<br>12,380        | 3.3<br>84.9          | AB5       |
| V6-33         | 11.9   | 206            | 41.4       | SC       | ACT<br>THC | 840<br>4,713         | 10.3<br>32.2         | AB6       |

\* SC - small charcoal (100/50)

+ ND - not detectable

TABLE V.2. OCCUPATIONAL EXPOSURES DURING DISCHARGE TENDING - MATES

| Sample Number | T (°C) | Duration (min) | Volume (L) | Sorbent* | Chemical   | W <sub>C</sub> (μg)+ | Concentration (ppm)+ | Personnel |
|---------------|--------|----------------|------------|----------|------------|----------------------|----------------------|-----------|
| V6-21         | 17.2   | 195            | 37.6       | SC       | ACT<br>THC | ND<br>12             | ND<br>0.1            | 2M        |
| V6-28         | 20.0   | 122            | 23.6       | SC       | ACT<br>THC | 225<br>413           | 5.0<br>5.1           | 3M1       |

\* SC - small charcoal (100/50)

+ ND - not detectable

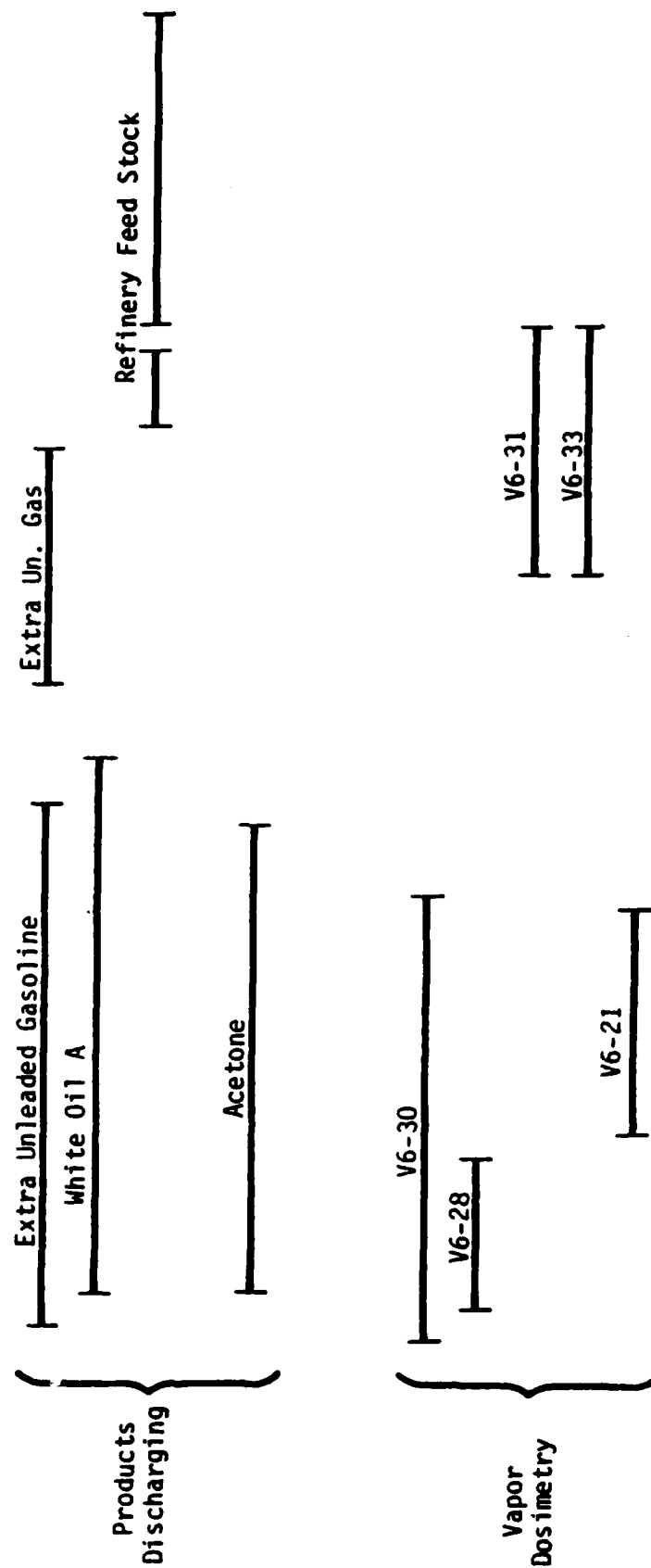


FIGURE V.1. CORRELATION OF VAPOR EXPOSURE SAMPLES WITH PRODUCTS BEING DISCHARGED (CONCLUDED)

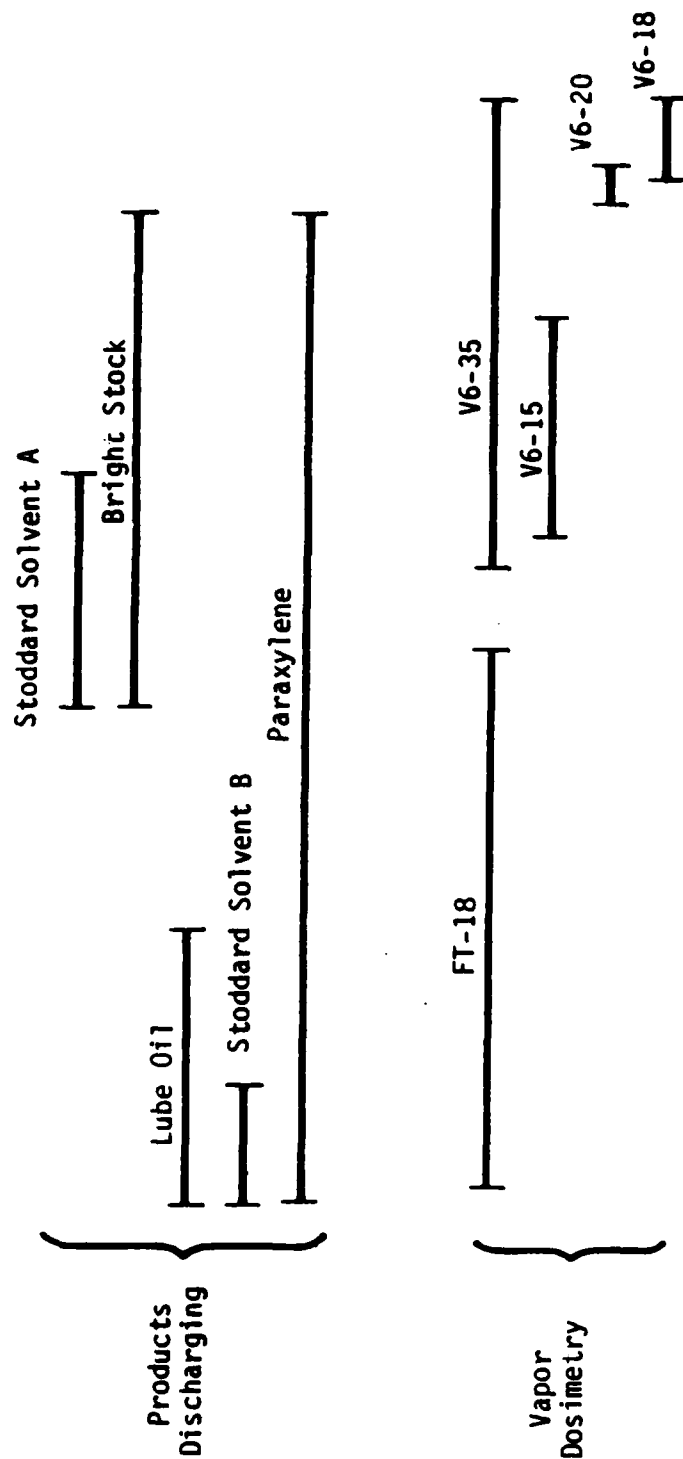


FIGURE V.1. CORRELATION OF VAPOR EXPOSURE SAMPLES WITH PRODUCTS BEING DISCHARGED (CONTINUED)

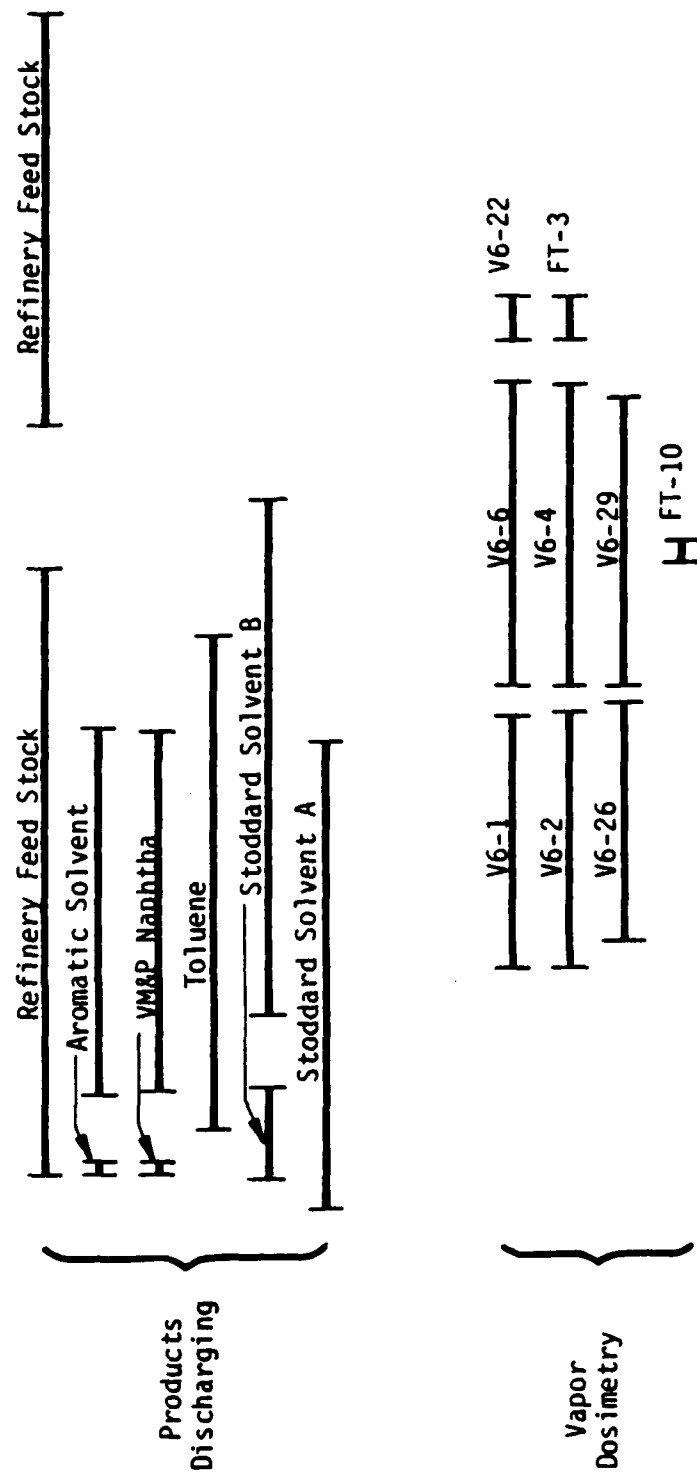


FIGURE V.1. CORRELATION OF VAPOR EXPOSURE SAMPLES WITH PRODUCTS BEING DISCHARGED

TABLE V.1. WORKER ACTIVITIES ASSOCIATED WITH PRODUCT DISCHARGING (Concluded)

| Activity                                                  | Worker* |         |       |
|-----------------------------------------------------------|---------|---------|-------|
|                                                           | Mate    | Pumpman | AB/OS |
| <b>E. Discharge Monitoring</b>                            |         |         |       |
| 1. Monitor status of tanks from cargo control room        | X       | X       | X     |
| 2. Periodic rounds on deck looking for problems           | X       | X       | X     |
| 3. Repair leaks as necessary                              | 0       | 0       | 0     |
| 4. Check valve line up for future transfers               | 0       | 0       | 0     |
| 5. Monitor status of tanks from on deck                   | 0       | 0       | 0     |
| 6. Jiggle tank gauging tapes                              | 0       | X       | X     |
| <b>F. Discharge Stripping</b>                             |         |         |       |
| 1. Stand by cargo pump for shut down                      | 0       | X       | X     |
| 2. Shut down cargo pumps                                  | 0       | X       | X     |
| 3. Hook up compressed air to stripper pump                | 0       | 0       | X     |
| 4. Start stripper pump                                    | X       | X       | X     |
| 5. Stand by and stop stripper pump                        | X       | X       | X     |
| 6. Open and close stripper valve at manifold to drip tray | 0       | 0       | X     |
| 7. Close manifold valve                                   | 0       | 0       | X     |
| <b>G. Line Blowdown</b>                                   |         |         |       |
| 1. Hook up air or inert gas                               | 0       | X       | X     |
| 2. Turn on line pressure                                  | 0       | X       | X     |
| 3. Valve appropriately                                    | 0       | X       | X     |
| 4. Open stripper valve at manifold to drip tray           | 0       | 0       | X     |
| <b>H. Post Discharge Activities</b>                       |         |         |       |
| 1. Make round with surveyor                               | X       | X       | 0     |
| 2. Supervise hose disconnect                              | 0       | X       | 0     |
| 3. Replace blinds on ship's manifold                      | 0       | X       | 0     |
| 4. Pump out drip trays to the slop line                   | 0       | 0       | X     |
| 5. Roll up tank gauging tapes                             | 0       | X       | 0     |
| 6. Disconnect jumper hoses                                | 0       | 0       | X     |
| 7. Stow jumper hoses                                      | 0       | 0       | X     |
| 8. Help dock personnel with hose disconnect               | 0       | 0       | 0     |

\* X - routinely  
0 - occasionally

TABLE V.1. WORKER ACTIVITIES ASSOCIATED WITH PRODUCT DISCHARGING

| Activity                                                       | Worker* |         |       |
|----------------------------------------------------------------|---------|---------|-------|
|                                                                | Mate    | Pumpman | AB/OS |
| A. Prearrival Preparations for Discharge                       |         |         |       |
| 1. Set valve line up for discharge lines                       | X       | X       | X     |
| 2. Line up crossovers and jumper hoses                         |         | X       | 0     |
| 3. Roll down tank gauging tapes                                |         | X       |       |
| 4. Recheck valve lineup                                        | X       | X       |       |
| B. Hose Hookup                                                 |         |         |       |
| 1. Oversee hose hookup                                         | 0       | X       | 0     |
| 2. Remove blinds from ship's manifold                          |         | X       | X     |
| 3. Attach reducers where appropriate                           |         | X       | X     |
| 4. Switch jumper hoses                                         | 0       | 0       | 0     |
| 5. Help dock personnel with hose hookup                        |         | 0       |       |
| C. Final Preparations for Cargo Transfer Prior to Pump Startup |         |         |       |
| 1. Recheck valve line up                                       | X       | X       | 0     |
| 2. Make round with surveyor                                    | X       |         |       |
| D. Pump Startup                                                |         |         |       |
| Start pump on slow from cargo control room                     | X       |         |       |
| 2. Start pump on slow at pump                                  | X       | X       |       |
| 3. Observe pressure gauges at pump                             | X       | X       |       |
| 4. Observe pressure gauges at manifolds                        |         |         | X     |
| 5. Adjust manifold valve on main cargo line                    |         |         | X     |
| 6. Adjust valve at pump                                        | X       | X       |       |
| 7. Change pump speed to fast                                   | X       | X       |       |
| 8. Restart pumps as necessary                                  | X       | X       |       |

\* X - routinely  
0 - occasionally



## V. Product Discharging

Product discharging was monitored closely on this voyage even though it is normally a low exposure potential situation. Monitoring was conducted during this portion of the voyage in order to observe any new technology being used during discharge and the resulting work procedures and associated exposure levels.

### Worker Activities

The normal watch complement of workers during product discharging consisted of a Mate (deck officer), a Pumpman, and two ABs. During day hours, 0800-1700, an OS joined the watch complement and most often functioned as a third AB. The Chief Mate often assisted the Mate on watch and was on call during all shifts. The work responsibilities of each of these workers during product discharging, and its associated activities, are summarized in Table V.1.

### Occupational Exposure Monitoring

Vapor: The occupational exposure monitoring samples taken during discharge tending are summarized in Tables V.2, V.3, and V.4 for Mates, ABs, and Pumpmen, respectively. Figure V.1 correlates the vapor exposure samples collected with the products being discharged for those samples summarized in Tables V.2, V.3, V.4, and V.5. Table V.5 summarizes occupational exposure monitoring taken during miscellaneous discharge operations including pumping out of drip trays and spill cleanup. Area samples taken during discharge operations are summarized in Table V.6.

This equation assumes a 5 dB exchange rate, and all levels below 80 dB(A) may be disregarded. Cumulative effective exposure graphs are not included for area noise samples since they are not representative of actual exposures.

TABLE V.9. SUMMARY OF NOISE DATA TAKEN ON PUMPMAN DURING PRODUCT DISCHARGING

| Sample Number | Worker | Duration (min) | Noise Source                                             | Max. Sound Pressure Level over 2 Minute Period (db(A)) | Cumulative Exp. Over Monitoring Period (db(A)) |
|---------------|--------|----------------|----------------------------------------------------------|--------------------------------------------------------|------------------------------------------------|
| 2             | PM2    | 219            | Cargo Pumps (6 products discharging)                     | 100                                                    | 86.1                                           |
| 4             | PM1    | 242            | Cargo Pumps (3 products discharging)                     | 92                                                     | 84.9                                           |
| 7             | PM1    | 451            | Cargo Pumps (5 products discharging)                     | 109                                                    | 87.3                                           |
| 9             | PM2    | 243            | Cargo Pumps (3 products discharging)                     | 99                                                     | 83.9                                           |
| 12            | PM2    | 400            | Cargo Pumps (3 products discharging)                     | 110                                                    | 86.5                                           |
| 16            | PM1    | 142            | Cargo Pumps and Cop-pus Blowers (3 products discharging) | 92                                                     | 78.5                                           |
| 20            | PM2    | 434            | Cargo Pumps (3 products discharging)                     | 110                                                    | 87.7                                           |

TABLE V.10. AREA NOISE DATA TAKEN DURING PRODUCT DISCHARGING

| Sample Number | Duration (min) | Noise Source          | Max. Sound Pressure Level over 2 Minute Period (dB A)) | Cumulative Effective Exposure over Monitoring Period (dB(A)) |
|---------------|----------------|-----------------------|--------------------------------------------------------|--------------------------------------------------------------|
| 19            | 72             | Cargo Pump 5P on slow | 81                                                     | 81.0                                                         |

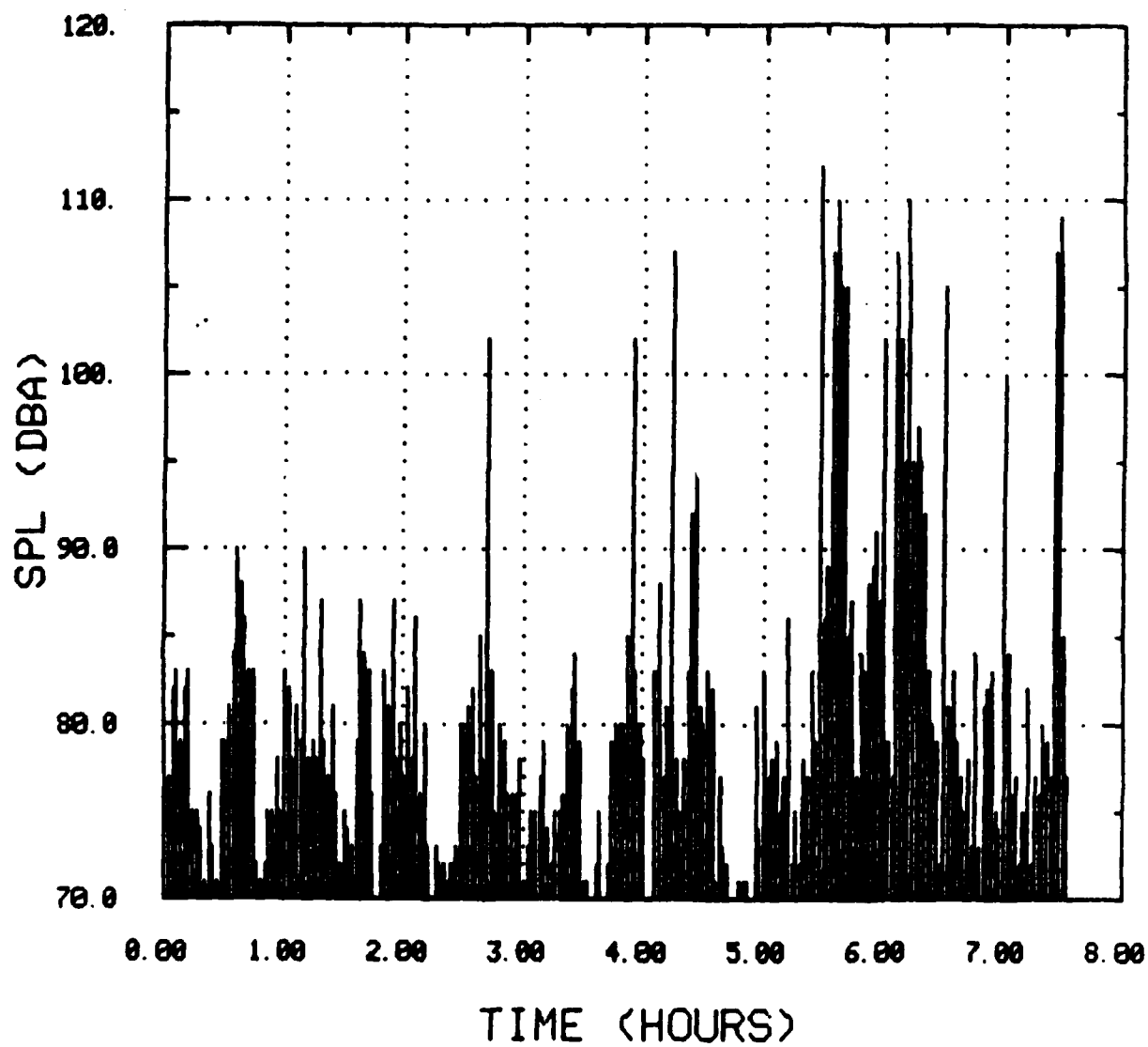


FIGURE V.2. NOISE DOSIMETRY DATA - SAMPLE 8

## VI. Tank Processing

Many of the cargo tanks were processed during this voyage as summarized in Table VI.1. The reasons for the processing of these tanks were

- o to ensure the quality of the next cargo to be loaded into the tank,
- o to replace a cargo pump, and/or
- o to enable tank entry for the purpose of installing permanent, in-tank stripping pumps (a non-routine activity)

The design philosophy that has been used on other modern parcel chemical tankers and was used on this vessel incorporates tanks that are void of internal structure and tank bottoms that slope to the main cargo pump sump. These features promote more efficient product discharge and tank washing.

### Tank Processing Methods

In general, there were several methods used for processing of the cargo tanks. The method used for processing a particular tank was determined by what equipment for washing and stripping was permanently installed in the tanks.

A. For tanks with fixed, in-tank washing machines and permanent, in-tank stripping pumps the processing procedure was as follows.

1. The washing was begun by opening the appropriate valves that sent wash water to the Butterworth machine.

TABLE VI.1. TANK PROCESSING SUMMARY

| Tank No. | Reason for Processing      | Previous Cargo          | Tank Washing*               | Tank Stripping |          | Tank Ventilation |           |
|----------|----------------------------|-------------------------|-----------------------------|----------------|----------|------------------|-----------|
|          |                            |                         |                             | Permanent      | Portable | DHA†             | Inert Gas |
| 1P       | Cargo Quality Control      | Paraxylene              | 20CF (F)                    | X              |          | X                |           |
| 1C       | Cargo Quality Control      | Stoddard Solvent A      | 20CF (F)                    | X              |          | X                |           |
| 1S       | Cargo Quality Control      | Aromatic Solvent        | 20CF (F)                    | X              |          | X                |           |
| 2P       | Cargo Quality Control      | Stoddard Solvent B      | 20CF (F)                    | X              |          | X                |           |
| 2CF      | Cargo Pump Replacement     | Toluene                 | 20CF (F)                    | X              |          | X                |           |
| 2S       | Cargo Quality Control      | VM&P Naphtha            | 20CF (F)                    | X              |          | X                |           |
| 3C       | Cargo Quality Control      | Stoddard Solvent A      | 20CF (F)                    | X              |          | X                |           |
| 3S       | Cargo Quality Control      | Isoparaffinic Solvent   | 20CF (F)                    | X              |          | X                |           |
| 4CF      | Cargo Quality Control      | Stoddard Solvent A      | 20CF (F)                    | X              |          | X                |           |
| 4CA      | Cargo Quality Control      | Acetone                 | 20CF (F)                    | X              |          | X                |           |
| 4CA      | Cargo Quality Control      | Methyl Ethyl Ketone     | 20CF (F)                    | X              |          | X                |           |
| 5CA      | Cargo Quality Control      | Paraxylene              | 5CF, 30HF (F, P)            | X              |          | X                |           |
| 6CF      | Cargo Quality Control      | Isoparaffinic Solvent   | 5CF, 30HF (P)               |                | X        | X                |           |
| 7P       | Stripper Pump Installation | Process Oil B           | 5CF, 40HS, 20HF (P)         |                | X        | X                |           |
| 7CF      | Cargo Quality Control      | White Oil B             | 40HS, 20CF, 180HS, 20CF (F) |                | X        | X                |           |
| 7S       | Stripper Pump Installation | Process Oil A           | 5CF, 40HS, 20HF (P)         |                | X        | X                |           |
| 8P       | Stripper Pump Installation | Refinery Feed Stock     | 40HS, 20HF (P)              |                | X        | X                | X**       |
| 8CF      | Cargo Quality Control      | Bright Stock            | None                        |                | X        | X                | X**       |
| 8S       | Stripper Pump Installation | Refinery Feed Stock     | 40HS, 20HF (P)              |                | X        | X                | X**       |
| 10S      | Cargo Quality Control      | Wash Slops              | 5CF, 40HS, 20CF (F)         | X              |          | X                | X         |
| 11PF     | Cargo Quality Control      | Paraxylene              | 5CF, 40HS, 20CF (F, P)      | X              |          | X                | X**       |
| 11C      | Stripper Pump Installation | Extra Unleaded Gasoline | 40HS, 20CF (F)              | X              |          | X                | X**       |

\* Tank washing code indicates time in minutes and type of wash water.

CF = cold fresh, HF = hot fresh, HS = hot salt

For example, 20 CF means a wash for 20 minutes with cold, fresh water.

Codes in parenthesis indicated if fixed (F) or portable (P) washing machines were used.

\*\* Inert gas ventilation was used on these tanks during tank washing.

† DHA = dehumidified air

2. The cargo pump for that tank was started to prevent a large volume of wash water from accumulating in the tank. This also ensured a good tank bottom wash.
3. During the washing, the tank was sometimes ventilated with either inert gas (IG) or dehumidified air (DHA). If the tank already contained inert gas, then inert gas was supplied during the washing.
4. The p/v valve bypass riser line was opened to allow atmospheric venting well above deck level. All other tank openings were normally closed.
5. Upon completion of the washing procedure, the appropriate valves were closed to stop the flow of wash water.
6. Just as the cargo pump was about to lose suction the cargo pump was turned off.
7. The stripper pump was then started to strip the remaining liquid from the tank.
8. When the stripper had removed almost all of the liquid, a valve on the stripper line was opened by the tank which allowed the sump to be stripped more completely. This resulted in wash water flowing onto the deck. The pumpman would often let the liquid spray onto his hand then smell his hand for residual product vapors. In one case a tank was rewashed because of a distinct smell of the residual chemical during this "test".
9. When the wash water stopped flowing from the open valve onto the deck, the stripper pump was turned off.

10. If the tank was not yet being ventilated the DHA ventilation was turned on at this point. If the tank had been washed under inert gas the inert gas was turned off and DHA was turned on. If the tank was already being ventilated with DHA, ventilation was continued. In one instance two Coppus blowers were used in addition to the DHA system to speed the ventilation process.

11. Ventilation was continued for as long as possible or as long as necessary. Ventilation times ranged from several hours to an entire day.

B. For tanks with fixed, in-tank washing machines but no permanent stripping pumps the processing procedure was as follows.

1. The washing, liquid removal using the cargo pump and initial ventilation followed steps A1, A2, A3, A4, A5, and A6 as discussed above.

2. Since the tanks were not equipped with permanent stripping pumps the next step was to ventilate the tank as described in steps A10 and A11 above to prepare the tank for entry.

3. After appropriate ventilation, a given tank was tested and eventually entered for stripping with a portable diaphragm pump and possible further cleaning using a squeegee, bilge pump, and rags. The work performed during the tank entry portion of the processing procedure is further explained in Section VII, Tank Entry.

C. For tanks that were not equipped with fixed, in-tank washing machines, the processing procedure was as follows.



1. The tank to be processed was prepared for washing with portable machines by opening the appropriate Butterworth deck plates. The washing machine was attached to the wash hose then dropped through the deck opening into the tank. A hose holder was then fit over the opening. The hose was dropped to the first washing depth then secured with a rope to the holder.
2. The wash water was turned on to commence the washing.
3. The cargo pump for that tank was started as discussed in step A2 above.
4. Ventilation was supplied to the tank as described in steps A3 and A4 above.
5. Throughout the washing it was necessary to drop the washing machines to different heights in the tank. This entailed untieing the secured hose, allowing the hose to drop the appropriate amount, and resecurig the hose with the rope.
6. At the completion of washing the wash water was stopped, hoses removed from the tank, and Butterworth deck plates replaced.
7. The stripping and ventilation activities were as described in steps A6 through A11 above for tanks with permanent, in-tank strippers or as described in steps B2 and B3 above for tanks with no permanent stripping pumps.

Traditionally, tanks on parcel chemical and product tankers have been washed using portable washing machines that are manually lowered into the tank. Tanks are normally ventilated after washing. The two operations do not normally occur simultaneously.

No matter which method was used, part of the washing procedure involved clearing the deck piping of residual liquid. This was accomplished by opening the drain line at the appropriate manifold(s) and allowing the line to drain into the drip tray. This drip tray was then emptied into the slop line using a diaphragm pump.

### Worker Activities

The people most intimately involved in the tank processing were the Pumpmen, the Able-Bodied Seamen (ABs), the Ordinary Seamen (OS), and the Chief Mate (CM). Occasionally another deck officer would assist the CM. The team of workers usually consisted of two pumpmen, 3 ABs, 1 OS, and the CM. The individual roles of these workers are summarized in Table VI.2.

### Tank Washing

The tank washing procedures varied from tank to tank but were generally dependent on the type of cargo previously in the tank, type of cargo to be loaded into the tank, and configuration of the tank.

Three types of wash water were used.

- o cold fresh water (CF)
- o hot fresh water (HF), or
- o hot salt water (HS).

The types of washes used for each tank are summarized in Table VI.1. In general the wash times were a multiple of 20 minutes since that was the time that it took the Butterworth machines to complete a full wash cycle. The 5-minute cold fresh water wash/strip/blow procedure was completed prior to several hot water washes to reduce the vapor concentrations in the tank to well below the LEL.

TABLE VI.2. TANK PROCESSING WORK ACTIVITIES

| Activity                                                              | Worker* |       |      |
|-----------------------------------------------------------------------|---------|-------|------|
|                                                                       | Pumpmen | AB/OS | Mate |
| 1. Hookup jumper hoses for washing                                    | X       | X     |      |
| 2. Start and stop fixed washing machines                              | X       |       |      |
| 3. Setup of portable washing machines                                 | 0       | X     |      |
| 4. Handling of washing hoses                                          | 0       | X     |      |
| 5. Start and stop cargo pumps                                         | X       |       | 0    |
| 6. Start and stop ventilation                                         | X       |       | 0    |
| 7. Open p/v valve bypass line                                         | X       |       |      |
| 8. Start and stop permanent stripping pumps                           | X       |       |      |
| 9. Open deck valve at end of stripping when using permanent strippers |         |       |      |
| 10. Smell wash water for product odor                                 | X       |       |      |
| 11. Tank atmosphere testing                                           | X       |       |      |
| 12. Stripping tank bottom with portable diaphragm pump                |         |       | X    |
| 13. Squeegee tank bottom                                              |         | X     |      |
| 14. Pump out sump with bilge pump                                     |         | X     |      |
| 15. Dry tank bottom with rags                                         |         | X     |      |
| 16. Draining of deck piping into the drip tray                        |         | X     |      |
| 17. Pumping of liquid in drip tray to slop line                       | X       | X     |      |
| 18. Disconnect and drain jumper hoses                                 | 0       | X     |      |

\* X - routinely  
0 - occasionally

The tank washing using portable washing machines was accomplished by using either two or three different drops. For washing with two drops the distances the machines were lowered into the tank were 15 and 40 feet. For washing with three drops the distances were 15, 25, and 40 feet.

#### Occupational Exposure Monitoring

Vapor: The occupational exposure vapor samples taken during tank processing are summarized in Tables VI.3 and VI.4 for ABs and Pumpmen, respectively. Table VI.5 presents an area sample taken during tank processing. Figure VI.1 correlates the vapor exposure samples collected with the products in the tanks being processed for those samples summarized in Tables VI.3, VI.4, and VI.5.

Noise: The noise measurements taken during the processing of the tanks, excluding tank entries which will be discussed in the next section, are summarized in Table VI.6. The noise dosimetry data for these samples are presented in Appendix B.

Sample 24 was taken on a pumpman who was processing six tanks. The major noise sources to which the pumpman was exposed to were the cargo pumps. As discussed earlier, the pumpman is responsible for starting and stopping these pumps as well as ensuring that suction is not lost. Other sources of noise during this time period were minor but included noise from the in-tank stripper and the wash water hitting the deck.

Sample 15 was taken in an area where two Coppus blowers were used to supplement the DHA system and speed the ventilation process. These blowers were in a very shielded area. Workers were required to spend some time in this area to finish the stripping activity. The total time spent in this area totaled only several minutes.

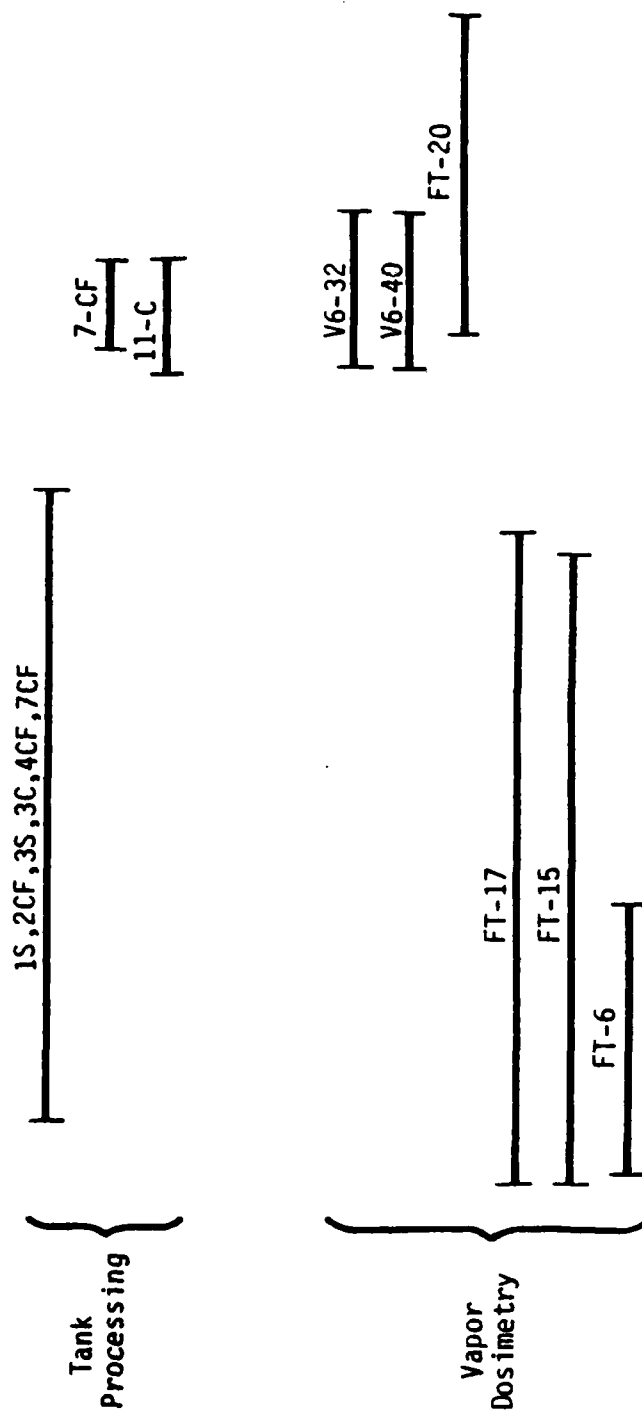


FIGURE VI.1. CORRELATION OF VAPOR EXPOSURE SAMPLES WITH TANKS BEING PROCESSED

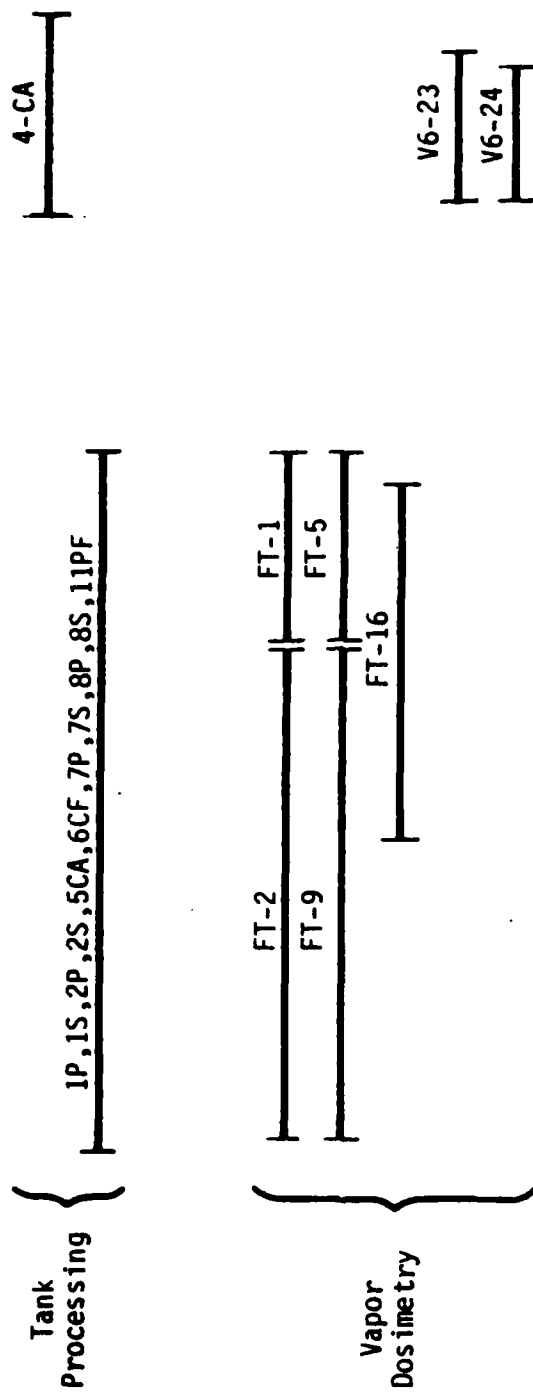


FIGURE VI.1. CORRELATION OF VAPOR EXPOSURE SAMPLES WITH TANKS BEING PROCESSED (CONCLUDED)

| Sample Number | T (°C) | Duration (min) | Volume (L) | Sorbent* | Chemical   | W <sub>C</sub> (μg) | Concentration (ppm) | Personnel |
|---------------|--------|----------------|------------|----------|------------|---------------------|---------------------|-----------|
| FT-6          | 25.8   | 212            | 42.2       | LC       | THC        | 1000                | 6.5                 | AB1       |
| FT-16         | 26.7   | 297            | 58.2       | LC       | THC<br>XLP | 2957<br>1124        | 13.9<br>4.4         | AB5       |
| V6-23         | 13.3   | 117            | 23.5       | SC       | ACT<br>THC | 190<br>255          | 4.1<br>3.1          | AB1       |
| V6-24         | 13.3   | 107            | 20.7       | SC       | ACT<br>THC | 640<br>474          | 15.8<br>6.5         | AB2       |

\* SC - small charcoal (100/50)  
LC - large charcoal (400/200)

TABLE VI.4. OCCUPATIONAL EXPOSURES DURING TANK PROCESSING - CONTINUED

| Sample Number | T (°C) | Duration (min) | Volume (L) | Sorbent* | Chemical   | W <sub>c</sub> (µg) | Concentration (ppm) | Personnel |
|---------------|--------|----------------|------------|----------|------------|---------------------|---------------------|-----------|
| FT-1          | 31.1   | 147            | 29.4       | LC       | THC        | 565                 | 5.4                 | PM1       |
| FT-2          | 31.1   | 399            | 79.8       | LC       | THC<br>XLP | 11747<br>3250       | 41.0<br>9.4         | PM1       |
| FT-5          | 31.1   | 147            | 29.4       | LC       | THC        | 410                 | 3.9                 | PM2       |
| FT-9          | 31.1   | 398            | 79.6       | LC       | THC<br>XLP | 6979<br>2680        | 24.4<br>7.8         | PM2       |
| FT-15         | 25.6   | 507            | 101.9      | LC       | THC<br>TOL | 4937<br>1400        | 13.2<br>3.7         | PM1       |
| FT-17         | 25.6   | 526            | 106.3      | LC       | THC<br>TOL | 2052<br>186         | 5.3<br>0.5          | PM2       |
| V6-32         | 25.6   | 123            | 24.9       | SC       | THC        | 415                 | 5.0                 | PM1       |
| V6-40         | 26.5   | 124            | 24.4       | SC       | THC        | 63                  | 0.8                 | PM2       |

\* SC - small charcoal (100/50)  
LC - large charcoal (400/200)



eight to descend into the tank and readings to be taken. The portable system is fitted with (1) a seal at the pipe/monitor interface and (2) elastomeric wipers by the tape in order to minimize vapor discharge, and thus occupational exposures, during tank top off.

Gauging of a tank with the portable system usually began with five feet to go in the loading, although this varied to as low as two feet to go during busy periods. The worker assigned to perform the top off gauging would remove the cover on the mounting pipe and then attach the portable unit. The valve in these mounting pipes did not have a positive seal and thus the workers were exposed to the vapors emitted from the tank. After the portable unit was in place and the valve in the pipe was opened the positive pressure in the tanks permitted some vapor to escape at the wiper/tape interface and the riser screw connections.

Various workers used the portable restricted gauging device in different ways. The method used by AB5 and OS1 was to constantly take readings during the entire time they were topping off the tank. This resulted in their breathing zone being approximately two feet away from the vapor sources discussed above. This distance was reduced to the order of a few inches when the audible alarm could not be heard because of the noise emitted from activated high velocity vents. 3M2, 3M3, and AB4 took frequent readings but would stand up and away from the portable between readings. (The frequency of readings was determined by how fast the level was changing). 3M3 used a rag wrapped around the portable unit by the tape wiper to reduce the jet of vapor emitted from this source. AB3 and OS2 set the portable gauge tape to the reading of interest and then stood back and listened for the audible alarm indicating that the liquid had reached the tape bottom. The tape was then reset to the next reading of interest and the process continued. The end of a tank loading, however, required constant gauging for the last several inches.

TABLE VIII.1. WORKER ACTIVITIES ASSOCIATED WITH PRODUCT LOADING (Concluded)

| Activity                                                  | Worker |         |       |
|-----------------------------------------------------------|--------|---------|-------|
|                                                           | Mate   | Pumpman | AB/OS |
| E. Continued                                              |        |         |       |
| 4. Check valve line up for future transfers               | 0      | 0       | X     |
| 5. Close cargo valve at manifold at completion of loading | 0      | X       | 0     |
| 6. Monitor status of tanks from on deck                   | 0      | 0       | X     |
| 7. Jiggle tank gauging tapes                              | 0      | X       |       |
| F. Tank Top Off                                           |        |         |       |
| 1. Observe tank gauging readouts in cargo control room    | X      | 0       | X     |
| 2. Use portable restricted gauging device                 |        | X       | X     |
| 3. Close valves after shore line blowdown                 | 0      | X       | X     |
| 4. Keep tank gauging tape from sticking                   | 0      | X       | X     |
| 5. Observe tank gauging readouts on deck                  | 0      | X       | X     |
| G. Post Loading Activities                                |        |         |       |
| 1. Make round with gauger                                 | X      |         | 0     |
| 2. Supervise hose disconnect                              | 0      | X       | 0     |
| 3. Replace blinds on ship's manifold                      |        | X       | X     |
| 4. Pump out drip trays to the slop line                   |        | 0       | 0     |
| 5. Roll up tank gauging tapes                             |        | X       | X     |
| 6. Disconnect jumper hoses                                |        | 0       | X     |
| 7. Stow jumper hoses                                      |        |         | X     |
| 8. Help dock personnel with hose disconnect               |        | 0       | 0     |

\* X - routinely  
0 - occasionally

TABLE VIII.1.1. WORKER ACTIVITIES ASSOCIATED WITH PRODUCT LOADING

| Activity                                               | Worker* |         | AB/OS |
|--------------------------------------------------------|---------|---------|-------|
|                                                        | Mate    | Pumpman |       |
| A. Prearrival Preparations for Discharge               |         |         |       |
| 1. Set valve line up for discharge lines               | X       | X       | X     |
| 2. Line up crossovers and jumper hoses                 |         | X       | 0     |
| 3. Roll down tank gauging tapes                        |         | X       |       |
| 4. Recheck valve line up                               | X       | X       |       |
| B. Hose Hookup                                         |         |         |       |
| 1. Oversee hose hook up                                | 0       | X       |       |
| 2. Remove blinds from ship's manifold                  |         | X       | 0     |
| 3. Attach reducers where appropriate                   |         | X       | X     |
| 4. Switch jumper hoses                                 | 0       | 0       | X     |
| 5. Help dock personnel with hose hookup                |         | 0       | 0     |
| C. Final Preparations for Cargo Transfer               |         |         |       |
| 1. Recheck valve lineup                                | X       | X       | 0     |
| 2. Make round with surveyor                            | X       |         |       |
| D. Loading Startup                                     |         |         |       |
| 1. Observe pressure gauges at manifolds                |         |         | X     |
| 2. Adjust manifold valve on main cargo line            |         |         | X     |
| 3. Observe tank gauging readouts at tank               | 0       | X       | X     |
| 4. Observe tank gauging readouts in cargo control room | X       |         |       |
| E. Loading Monitoring                                  |         |         |       |
| 1. Monitor status of tanks from cargo control room     | X       | X       | X     |
| 2. Periodic rounds on deck looking for problems        | X       | X       |       |
| 3. Repair leaks as necessary                           | 0       | X       | X     |

## VIII Product Loading

The products loaded at the final terminal are summarized in Table III.2.

### Worker Activities

The normal watch complement of workers during loading was the same as for discharging, that is a Mate, a Pumpman and two ABs with possibly an additional Mate and/or day OS. The work responsibilities of each of these workers during product loading, and its associated activities, are summarized in Table VIII.1.

Many of the activities performed during product loading were identical to activities performed during discharging. One of the additional activities which took place during loading is tank top off.

Tank top offs were performed in one of two fashions. One method was to simply use either of the two closed gauging systems that were permanently installed in each tank. This top off procedure required one person, usually an AB or PM, at the gauge site to jiggle the tape (to ensure proper readings) and obtain ullage readings. Usually a Mate was also reading the ullages from the instrument readouts in the cargo control room.

The other method of topping off tanks involved the use of the third gauging system, the portable restricted gauging system. The device is an intrinsically safe, ullage monitor that provides a digital display of cargo temperature in addition to an audible sound when the tape weight contacts the liquid surface. The portable monitor mounts via a threaded connection onto a deck riser pipe near the pump column. The deck riser pipe is fitted with a valve, which is normally closed, downstream of where the monitor attaches. This valve is opened in order to permit the tape

TABLE VII.4. SUMMARY OF IN-TANK NOISE DATA

| Sample Number | Worker | Duration (min) | Activity                            | Noise Source                | Max. Sound Pressure Level over 2 Minute Period (db(A)) | Cumulative Exp. Over Monitoring Period (db(A)) |
|---------------|--------|----------------|-------------------------------------|-----------------------------|--------------------------------------------------------|------------------------------------------------|
| 21            | OS1    | 23             | Stripper pump suction hose handling | Portable stripper pump, DHA | 106                                                    | 95.0                                           |
| 22            | SwRI   | 20             | Observe work activities             | DHA                         | 92                                                     | 87.9                                           |
| 23            | SwRI   | 32             | Observe stripping operation         | Portable stripper pump, DHA | 93                                                     | 87.9                                           |
| 25            | AB2    | 41             | Stripper pump suction hose handling | Portable stripper pump, DHA | 106                                                    | 95.5                                           |
| 26            | AB6    | 37             | Stripper pump operation             | Portable stripper pump, DHA | 110                                                    | 101.0                                          |

For those samples where the worker wore some respiratory protection, the actual exposure received does not equal, and should have been less than, the exposure measured by the dosimetry device. Samples SC-82, V6-16, and V6-38 were taken on the CM during tank atmosphere testing. Samples SC-80 and V6-12 were taken on various workers during the opening of blanked-off stripper lines. Sample SC-87 was taken on an AB who was involved in tank stripping and then opening of the blanked-off stripper lines. Samples SC-86 and SC-84 were taken on the pumpmen during intake maintenance activities. The remainder of the samples were taken during tank stripping and/or squeegeeing/towel drying activities as outlined in Table VII.1.

Noise - The noise measurements taken during the tank entries are summarized in Table VII.4. Samples 22 and 23 were placed on project team members to obtain background noise levels in the tanks during operations with ventilation air only and portable stripper pump operation, respectively. The noise dosimetry data for these samples are presented in Appendix C.

#### Protective Equipment

During the stripping and squeegee/towel drying activities the workers generally, but not consistently, wore hard hats and chemical resistant gloves. At least one of the workers in the tank carried a two-way radio allowing communication with the workers on deck.

Organic vapor cartridge respirators were worn by the ABs and the Chief Mate from just before the blanked off lines in 7P, 7S, 8P, and 11C were opened until the workers exited the tanks. Chemical resistant gloves were also worn during this operation.

As stated earlier, the Chief Mate wore an SCBA (MSA Model 401) during initial testing of the tank atmospheres in 8P, 8S, and 11C. He also wore an SCBA during blank removals in 8S.

Hearing protection was not worn by the workers entering the tanks.

TABLE VII.3. OCCUPATIONAL EXPOSURES DURING TANK ENTRY

| Tank Number | Sample Number | T (°C) | Duration (min) | Volume (L) | Trap*  | Chemical      | W <sub>C</sub> (µg)+ | Concentration (ppm)+ | Personnel         | Respiratory Protection worn                 | Product In Tank       |
|-------------|---------------|--------|----------------|------------|--------|---------------|----------------------|----------------------|-------------------|---------------------------------------------|-----------------------|
| 6CF         | SC-89         | 25.8   | 23             | 4.5        | SC     | THC           | 289                  | 18.9                 | SwRI              | None                                        | Isoparaffinic Solvent |
| 5CA         | SC-84         | 27.8   | 18             | 3.6        | SC     | XLP           | 86                   | 5.7                  | PM2               | None                                        | XLP                   |
| 7P          | M-145         | 25.0   | 73             | 103.4      | Filter | Process Oil B | ND                   | ND                   | AB2               | None                                        | Process Oil B         |
| 7P, 8P      | SC-80         | 25.0   | 88             | 17.3       | SC     | THC           | 138                  | 2.4                  | CH                | Organic Vapor Cartridge                     | Process Oil B, RFS    |
| 8P          | SC-82         | 25.0   | 19             | 3.5        | SC     | THC           | 22                   | 1.9                  | CH                | SCBA                                        | RFS                   |
| 8P          | SC-88         | 25.6   | 10             | 2.02       | SC     | THC           | 44                   | 6.5                  | OS1               | None                                        | RFS                   |
| 8S          | V6-49         | 25.6   | 25             | 5.05       | SC     | THC           | 61                   | 3.6                  | OS1               | None                                        | RFS                   |
| 8S          | V6-16         | 25.6   | 12             | 2.4        | SC     | THC           | 11                   | 1.4                  | CH<br>(2nd entry) | SCBA                                        | RFS                   |
| 11C         | SC-87         | 26.4   | 72             | 13.3       | SC     | THC           | 1685                 | 37.8                 | AB6               | Organic Vapor Cartridge for last 30 minutes | Unleaded Gas          |
| 11C         | V6-12         | 26.4   | 47             | 9.5        | SC     | THC           | 3906                 | 122.7                | CH                | Organic Vapor Cartridge                     | Unleaded Gas          |
| 11C         | V6-38         | 26.1   | 16             | 2.9        | SC     | THC           | 30                   | 3.0                  | CH                | SCBA                                        | Unleaded Gas          |
| 11PF        | SC-86         | 27.8   | 16             | 2.9        | SC     | XLP           | 44                   | 3.5                  | PM2               | None                                        | XLP                   |

\* SC - small charcoal (100/50)

Filter - mixed esters of cellulose filter

+ ND - not detectable

In addition to the on-deck testing, the tank atmospheres for three tanks that had previously contained inert gas (8P, 8S, and 11C) were tested internally. The Chief Mate entered these tanks using a self-contained breathing apparatus and equipped with an MSA 260 O<sub>2</sub>/CGI instrument, an MSA 70 CO instrument, and Draeger pump and tubes (CO and NO<sub>x</sub>). The Chief Mate surveyed the tanks' atmospheres with the MSA 260 for oxygen and combustible gas, MSA 70 for carbon monoxide, and Draeger tubes for carbon monoxide and nitrous oxides.

The tank atmosphere measured by the Chief Mate inside 8P and 11C were 20.8% O<sub>2</sub>, 0% LEL, 0 ppm CO, and 0 ppm NO + NO<sub>2</sub>. The initial atmosphere inside 8S was measured by the MSA 260 and MSA 70 to contain 20.8% O<sub>2</sub>, 0% LEL, and 0 ppm CO. However, the Chief Mate, while still wearing the self-contained breathing apparatus, removed the blanks from the stripper line flanges. A high pressure stream of inert gas and liquid product was released into the tank from these lines. Subsequent to this event the atmosphere in the center bottom of the tank was tested and found to contain 20.8% O<sub>2</sub>, up to 40% LEL, up to 500 + ppm CO, and 0 ppm NO + NO<sub>2</sub>. After appropriate ventilation the Chief Mate, again wearing an SCBA, reentered 8S to retest the environment. The atmosphere was measured to contain 20.8% O<sub>2</sub>, 0% LEL, 0 ppm CO, and 0 ppm NO + NO<sub>2</sub>. The workers were then allowed inside 8S.

At each tank the MSA 260 was left on the deck with the dropline into the tank as a monitor during the entire tank entry. The % O<sub>2</sub> and % LEL alarms were set at 16 and 50, respectively. The MSA 70 was also left on the deck with a dropline into the tank at the three previously inerted tanks (8P, 8S, and 11C).

#### Occupational Exposure Monitoring

Vapor - The occupational vapor exposure samples taken during tank entries are summarized in Table VII.3. This table also summarizes the respiratory protection worn by the workers during the tank entries.



Two tanks were entered (5CA and 11PF) to replace inoperable, fixed Butterworth washing machines with spare operational machines. This operation involved the two pumpmen. One of the pumpmen entered the tank and climbed to the top of the Butterworth stand where he removed the bolts from the flange. From the deck level, the other pumpman dropped a rope into the tank by the inoperable washing machine. When the pumpman inside the tank had secured the inoperable machine to the rope, the pumpman on the deck would hoist the machine out of the tank and then lower the new machine into the tank. The pumpman in the tank then secured the machine to the Butterworth stand and exited the tank.

During the in-tank operations, ventilation air was provided to all but two of the tanks (11PF and 5CA).

#### Tank Atmosphere Testing

All of the tanks entered had previously been processed as explained in Section VI, Tank Processing. In summary, all but one of the tanks entered had been washed and ventilated. The remaining tank, which previously carried bright stock, had been ventilated but not washed.

A tank entry procedure and permit system had been developed by the company and copies of the blank permits were available on the ship. Preentry gas and vapor atmosphere tests were conducted, as required on the permit.

The tank atmospheres of each of the tanks entered were tested by either the CM or 2M for oxygen and combustible gas concentrations prior to entry. This was accomplished using an MSA 260 O<sub>2</sub>/CGI instrument with an appropriate length dropline. All measurements from the main deck indicated safe tank conditions of 20.8% O<sub>2</sub> and 0% LEL. Three of these tanks, which had been inerted, were also checked with an MSA 70 from the deck level for CO concentration. All concentrations from the main deck indicated 0 ppm CO.

Stripping of residual liquid from the tank bottoms and sumps was necessary in all of the processed tanks that were not equipped with permanently-installed in-tank strippers. This operation usually involved two ABs in the tank and two ABs at the expansion trunk on the deck. The ABs on the deck lowered, then later raised, equipment necessary for the operation in the tank, including a portable stripper pump, compressed air hose (for powering the pump), pump discharge hose, and pump suction hose. The ABs in the tank connected the hoses to the pump and then worked together to strip the tank. One AB would sit or stand by the pump to control the pump speed. The other AB handled the pump suction hose to strip the liquid from the tank bottom and the sump. He was always within 10 feet of the pump and was usually working against a wall or in a corner while stripping the sump.

Squeegeeing and towel drying the tank bottoms and sumps was necessary in those processed tanks which required strict quality control for the product which was due to be loaded next into the tanks. This operation usually involved two or three ABs in the tank and two ABs at the expansion trunk on the deck. The ABs on the deck lowered, then later raised, equipment necessary to the operation into the tank, including a manually-operated bilge pump, bucket, squeegees, and rags. The ABs in the tanks would squeegee the liquid to the sump then use the bilge pump to empty the sump into the bucket. The tank bottom and sump were then wiped with rags to get them completely dry.

Five of the tanks entered (7P,7S,8P,8S,11C) were being prepared for the installation of fixed stripper pumps onto the previously installed, and blanked stripper lines in the tanks. To completely clean the tank and piping in the tank, the blanks were removed from these stripper lines. The liquid was drained into a bucket and the lines were then blown with compressed air to remove as much liquid from the lines as possible. This operation involved the Chief Mate and one or two ABs to assist him.

TABLE VII.2. SUMMARY OF IN-TANK WORK ACTIVITIES

| Activity                                                              | Worker* |         |
|-----------------------------------------------------------------------|---------|---------|
|                                                                       | Mate    | Pumpman |
| 1. Tank atmosphere testing                                            | X       |         |
| 2. Operating portable diaphragm pump                                  |         |         |
| 3. Handling of portable pump suction line                             |         |         |
| 4. Squeegee tank bottom                                               |         |         |
| 5. Pump out sump with bilge pump                                      |         |         |
| 6. Dry tank bottom with rags                                          |         |         |
| 7. Open blanked-off in-tank lines<br>(one-time, non-routine activity) | X       |         |
| 8. Replace washing machines (an occasional activity)                  |         | X       |

\* X - routinely

## VII. Tank Entries

During the ballast voyage, 10 cargo tanks, which had previously been processed, were entered.

### In-Tank Work Activities

Tables VII.1 and VII.2 summarize the tank entries including information about the in-tank activities. The processing of these tanks was summarized in the previous section in Table VI.1. The work activities that required the tank entries were one or more of the following:

- o Stripping of residual liquid (lube oil or wash slops) from the tank bottom and sump for tanks without permanent stripper pumps.
- o Squeegeeing and towel drying the tank bottom and sump.
- o Opening of blanked-off in-tank lines to prepare for installation of stripping pumps, a one-time, non-routine operation.
- o Replacing of non-operational washing machines with new machines.

TABLE VII.1. SUMMARY OF IN-TANK WORK PERFORMED

| Tank No. | In-Tank Work Activities |                    |             |
|----------|-------------------------|--------------------|-------------|
|          | Strip                   | Squeegee/Towel Dry | Maintenance |
| 5CA      |                         |                    | X           |
| 6CF      | X                       | X                  |             |
| 7P       | X                       | X                  | X           |
| 7CF      | X                       | X                  |             |
| S        | X                       | X                  | X           |
| 8P       | X                       |                    | X           |
| 8CF      | X                       | X                  |             |
| 8S       | X                       |                    | X           |
| 11PF     |                         |                    | X           |
| 11C      | X                       | X                  | X           |

TABLE VI.6. TANK PROCESSING NOISE DATA

| Sample Number | Worker                        | Duration (min) | Noise Source                | Max. Sound Pressure Level over 2 Minute Period (db(A)) | Cumulative Exp. Over Monitoring Period (db(A)) |
|---------------|-------------------------------|----------------|-----------------------------|--------------------------------------------------------|------------------------------------------------|
| 24            | Pumpman 1                     | 497            | Cargo pumps, stripper pumps | 109                                                    | 83.4                                           |
| 15            | Area Sample by Coppus blowers | 165            | 2 Coppus blowers            | 104                                                    | 100.6                                          |

#### Protective Equipment

During the tank processing activities, chemical resistant gloves were occasionally worn by the ABs and OS.

TABLE VI.5. AREA SAMPLES TAKEN DURING TANK PROCESSING

| Sample Number | T (°C) | Duration (min) | Volume (L) | Sorbent* | Chemical | W <sub>C</sub> (μg) | Concentration (ppm) | Area      |
|---------------|--------|----------------|------------|----------|----------|---------------------|---------------------|-----------|
| FT-20         | 26.7   | 11             | 2.2        | LC       | THC      | 35                  | 0.2                 | In Bridge |

\* LC - large charcoal (400/200)

### Occupational Exposure Monitoring

Vapor - The occupational vapor exposure samples taken during product loading monitoring are summarized in Table VIII.2. Table VIII.3 summarizes samples taken during tank top offs with the portable restricted gauging system.. Area samples taken during loading are summarized in Table VIII.4. Figure VIII.1 correlates the vapor exposure samples collected with the products being loaded for these samples summarized in Tables VIII.2 and VIII.4.

Noise - The noise measurements taken during product loading, including tank top offs, are summarized in Table VIII.5. Indicated in parenthesis in the noise source column of this table are the number of products being loaded to give an indication of how many high velocity vents may have been popping off. The noise dosimetry data for these samples are presented in Appendix D.

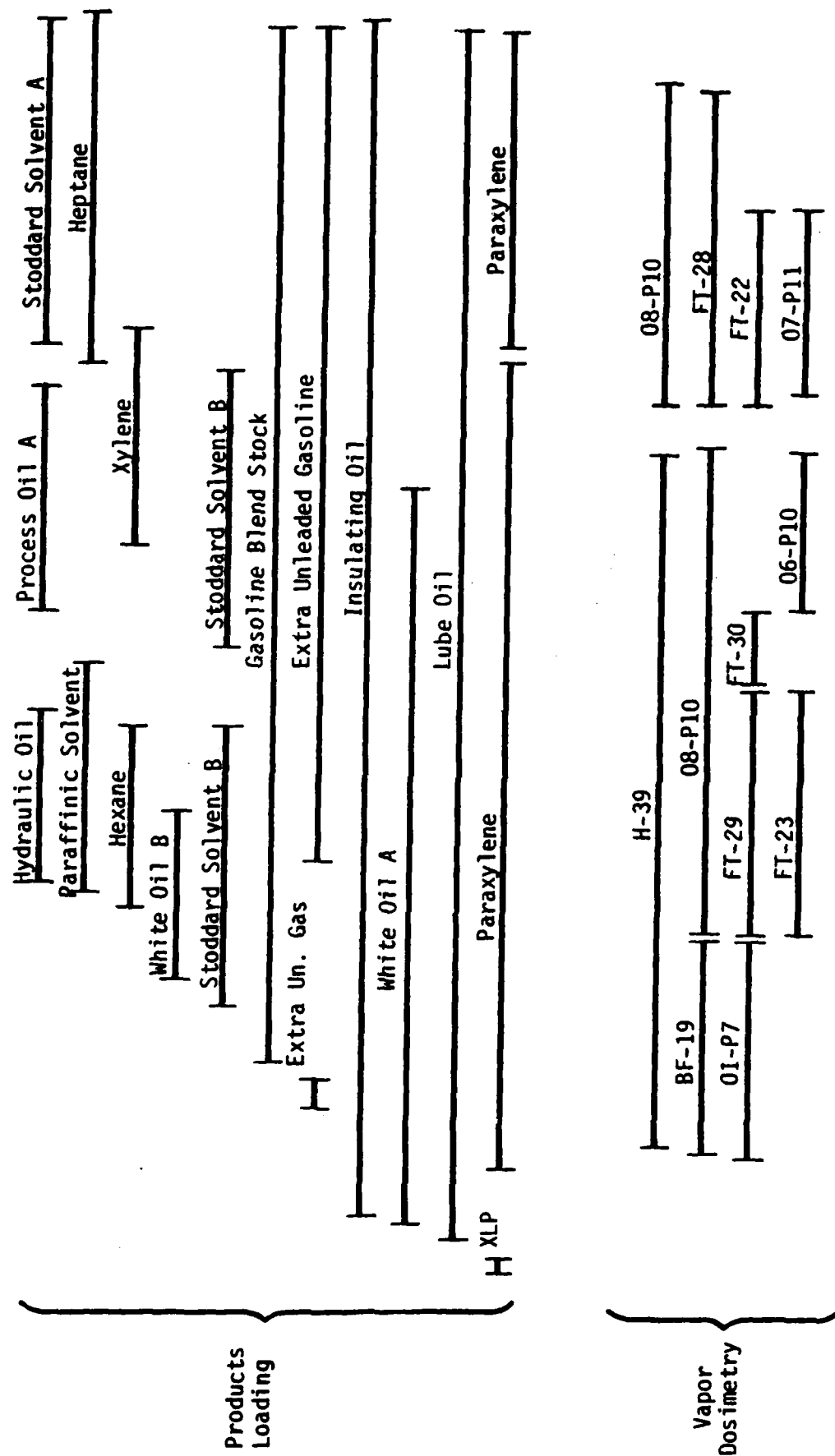


FIGURE VIII.1.1. CORRELATION OF VAPOR EXPOSURE SAMPLES WITH PRODUCTS BEING LOADED



TABLE VIII.2. OCCUPATIONAL EXPOSURES DURING PRODUCT LOADING MONITORING

| Sample Number | T (°C) | Duration (min) | Volume (L) | Sorbent* | Chemical          | W <sub>C</sub> (µg)+ | Concentration (ppm)+ | Personnel |
|---------------|--------|----------------|------------|----------|-------------------|----------------------|----------------------|-----------|
| BF-19         | 26.1   | 204            | 40.4       | LC       | THC<br>XLP        | 1574<br>9            | 10.7<br>0.1          | AB2       |
| FT-22         | 25.8   | 201            | 39.4       | LC       | HPT<br>THC<br>XLP | 170<br>1808<br>176   | 1.08<br>12.6<br>1.01 | AB2       |
| FT-23         | 25.0   | 249            | 49.3       | LC       | HXA<br>THC<br>XLP | 60<br>305<br>50      | 0.4<br>1.7<br>0.2    | AB6       |
| FT-29         | 25.0   | 249            | 49.3       | LC       | HXA<br>THC<br>XLP | ND<br>2439<br>ND     | ND<br>13.5<br>ND     | AB5       |
| FT-30         | 24.4   | 76             | 15.2       | LC       | THC<br>XLP        | 1131<br>102          | 20.3<br>1.5          | AB3       |
| 01-P7         | 26.1   | 209            | 41.6       | LC       | THC<br>XLP        | 499<br>131           | 3.3<br>0.7           | AB1       |
| 06-P10        | 24.4   | 147            | 29.3       | LC       | THC<br>XLP        | 3087<br>1524         | 28.7<br>11.8         | AB4       |
| 07-P11        | 26.7   | 176            | 35.2       | LC       | HPT<br>THC<br>XLP | 185<br>12,160<br>195 | 1.3<br>94.8<br>1.3   | AB1       |
| FT-28         | 26.4   | 309            | 61.8       | LC       | HPT<br>THC<br>XLP | 125<br>1705<br>212   | 0.5<br>7.6<br>0.8    | PM1       |
| 08-P10        | 25.0   | 471            | 92.3       | LC       | HXA<br>THC<br>XLP | 860<br>5150<br>1024  | 2.7<br>15.2<br>2.5   | PM2       |

\* LC - large charcoal (400/200)

+ ND - not detectable

TABLE VIII.3. OCCUPATIONAL EXPOSURES DURING TANK TOP OFF  
WITH THE PORTABLE RESTRICTED GAUGING DEVICE

| Tank Number | Sample Number | T (°C) | Duration (min) | Volume (L) | Sorbent* | Chemical          | W <sub>C</sub> (μg) | Concentration (ppm)   | Personnel | Product Loading         |
|-------------|---------------|--------|----------------|------------|----------|-------------------|---------------------|-----------------------|-----------|-------------------------|
| 1C          | V6-86         | 26.7   | 5              | 0.9        | SC       | THC               | 78                  | 25.2                  | 3M3       | Stoddard Solvent B      |
| 2S          | SC-85         | 25.0   | 10             | 1.8        | SC       | THC               | 49                  | 7.9                   | AB6       | Paraffinic Solvent      |
| 4CA         | V6-34         | 12.2   | 29             | 5.9        | SC       | MEK               | 1010                | 66.4                  | 3M2       | MEK                     |
| 4CA         | V6-44         | 25.0   | 29             | 5.7        | SC       | THC               | 650                 | 33.7                  | AB5       | Stoddard Solvent A      |
| 5S          | V6-81         | 27.2   | 28             | 5.2        | SC       | THC<br>BNZ<br>HXA | 3820<br>16<br>830   | 220.9<br>1.0<br>48.0  | AB1       | Extra Unleaded Gasoline |
| 10S         | SC-81         | 27.2   | 25             | 5.0        | SC       | THC               | 1227                | 73.1                  | OS2       | Gasoline Blend Stock    |
| 11PF        | SC-83         | 25.0   | 19             | 3.7        | SC       | HXA               | 317                 | 23.0                  | AB5       | HXA                     |
| 11PA        | V6-45         | 26.7   | 14             | 2.8        | SC       | THC<br>BNZ<br>HXA | 7514<br>3<br>3860   | 809.3<br>0.3<br>399.1 | AB5       | Gasoline Blend Stock    |
| 11SF        | V6-47         | 24.4   | 43             | 8.5        | SC       | XLP               | 1888                | 51.6                  | AB4       | XLP                     |

\* SC - small charcoal (100/50)

TABLE VIII.4. AREA SAMPLES TAKEN DURING LOADING OPERATIONS

| Sample Number | T (°C) | Duration (min) | Volume (L) | Sorbent* | Chemical          | W <sub>c</sub> (μg) | Concentration (ppm) | Area               |
|---------------|--------|----------------|------------|----------|-------------------|---------------------|---------------------|--------------------|
| H-39          | 20.0   | 436            | 86.8       | LC       | HXA<br>THC<br>XLP | 135<br>1169<br>194  | 0.4<br>3.6<br>0.5   | Cargo Control Room |
| 08-P9         | 20.0   | 306            | 60.9       | LC       | HPT<br>THC<br>XLP | 50<br>1178<br>14    | 0.2<br>5.2<br>0.1   | Cargo Control Room |

\* LC - large charcoal (400/200)

TABLE VIII.5. SUMMARY OF NOISE DATA TAKEN DURING PRODUCT LOADING

| Sample Number | Worker | Duration (min) | Activity                             | Noise Source                                   | Max. Sound Pressure Level over 2 Minute Period (db(A)) | Cumulative Exp. Over Monitoring Period (db(A)) |
|---------------|--------|----------------|--------------------------------------|------------------------------------------------|--------------------------------------------------------|------------------------------------------------|
| 18            | 3M2    | 23             | Tank Top Off                         | Vent Popoffs (1 product loading)               | 84                                                     | 82.3                                           |
| 27            | AB6    | 238            | Loading monitoring and tank top off  | Vent Popoffs (11 products loading)             | 95                                                     | 82.7                                           |
| 28            | PM2    | 472            | Loading monitoring and tank process- | Vent Popoffs (13 products loading), Cargo Pump | 101                                                    | 86.3                                           |
| 29            | 3M2    | 180            | Loading monitoring and tank top off  | Vent Popoffs (11 products loading)             | 90                                                     | 82.6                                           |
| 30            | AB1    | 170            | Loading monitoring and tank top off  | Vent Popoffs (7 products loading)              | 100                                                    | 87.8                                           |

#### Protective Equipment

Chemical resistant gloves were occasionally worn by the ABs and OS during hose handling activities.

## IX. Miscellaneous Activities/Samples

Besides the activities already discussed, three additional activities were also monitored during this voyage. Vapor monitoring was performed during deck cleaning with a degreaser. The material safety data sheet for the degreaser was provided by the manufacturer. Based on this data sheet, the compound for analysis was total hydrocarbon. The occupational exposure sample taken during the deck cleaning, V6-36 is summarized in Table IX.1.

During the voyage between two of the discharge ports, an intraship transfer of XLP took place. The purpose of this transfer was to eliminate the need for a jumper hose at the next discharge terminal. Sample V6-14 was taken on a pumpman during this activity.

Samples FT-8 and FT-13 were collected near the starboard, port, aft diesel and fuel oil vents, respectively, and the results are summarized in Table IX.1. The port side sample was set up to collect diesel fuel vapors that were evolving from residue in a drip pan beneath the diesel vent. The sampling location was downwind (to stern) of the diesel vent. The starboard area sample was located at the fuel oil vent to collect bunker fuel vapors. These non-breathing zone area samples were motivated by the persistent odor of the respective liquids, although odor is no indication of a potential health hazard.

Noise sample 5 was taken on the 2M while he was tending mooring lines on the poop deck during docking. The noise source was the DHA bleed during depressurization of the DHA system. The data from this sample are shown in Figures IX.1 and IX.2. The maximum sound pressure level over a two-minute period was 99 db(A). The cumulative effective exposure over the monitoring period was 87.1 db(A).

TABLE IX.1. MISCELLANEOUS SAMPLES

| Sample Number | T (°C) | Duration (min) | Volume (L) | Sorbent* | Chemical   | W <sub>C</sub> (μg)+ | Concentration (ppm)+ | Personnel/Area                     |
|---------------|--------|----------------|------------|----------|------------|----------------------|----------------------|------------------------------------|
| V6-36         | 26.5   | 132            | 26.5       | SC       | THC        | 54                   | 0.6                  | AB6 (Deck Cleaning)                |
| V6-14         | 21.1   | 58             | 11.72      | SC       | XLP        | 407                  | 7.9                  | PM2 (Intraship Transfer)           |
| FT-8          | 28.3   | 320            | 64.3       | LC       | THC        | 23,900               | 102.5                | Starboard aft fuel oil vent source |
| FT-13         | 28.3   | 334            | 66.5       | LC       | THC<br>HXA | 34,072<br>3,260      | 141.3<br>13.5        | Port aft fuel oil vent source      |

\* SC - small charcoal (100/50)  
 LC - large charcoal (400/200)  
 + ND - not detectable

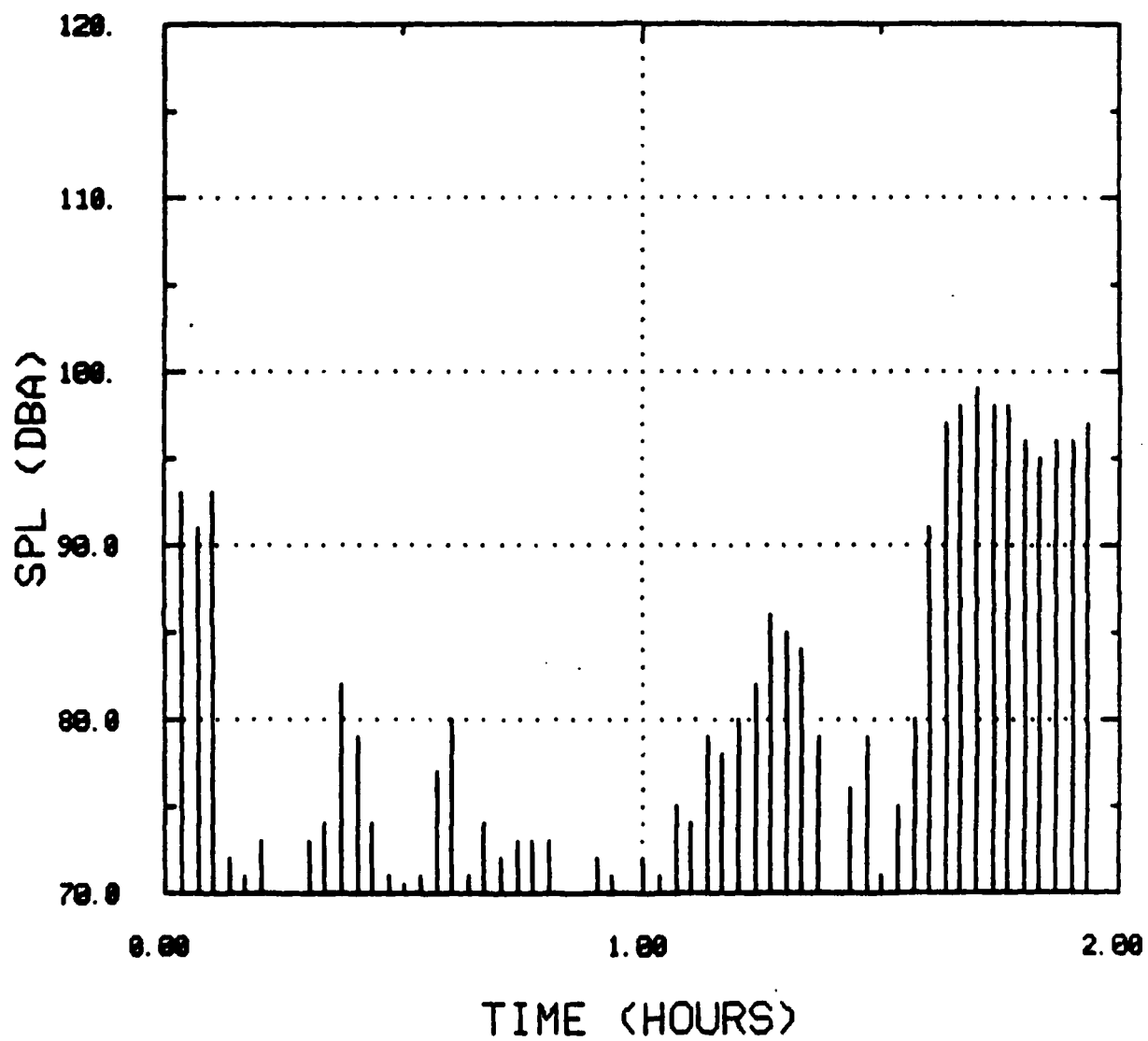


FIGURE IX.1. NOISE DOSIMETRY - SAMPLE 5

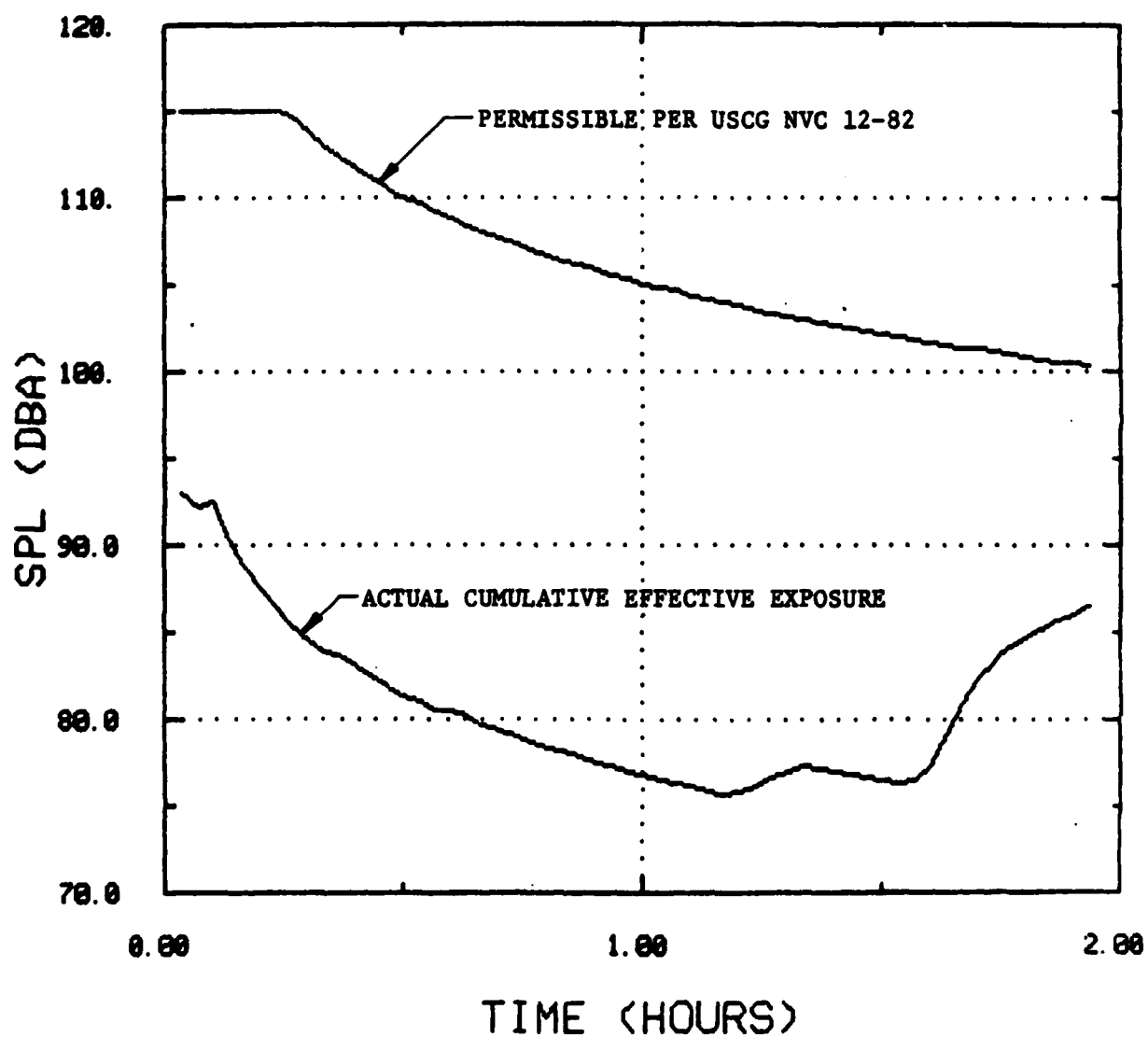
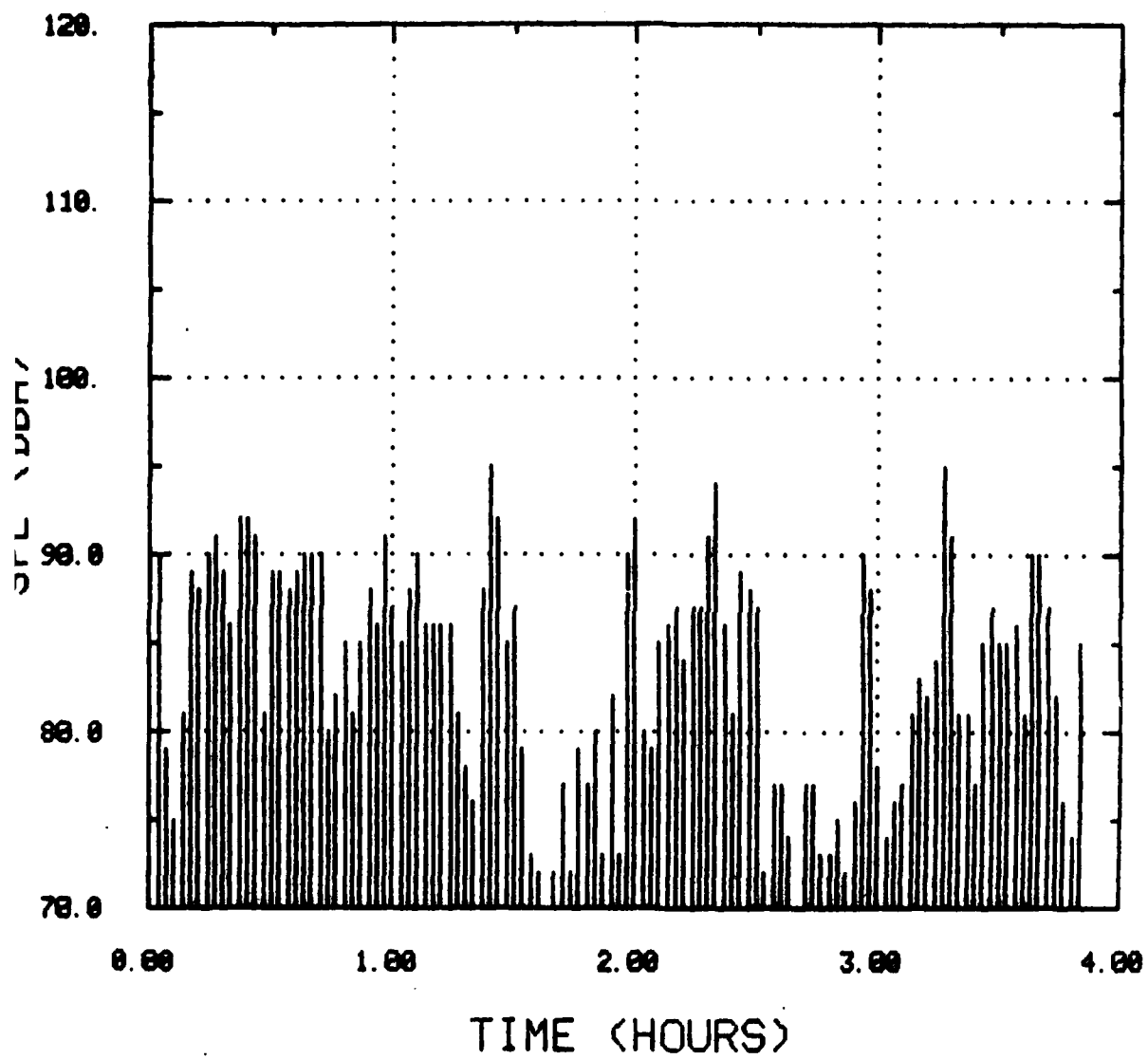


FIGURE IX.2. CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 5

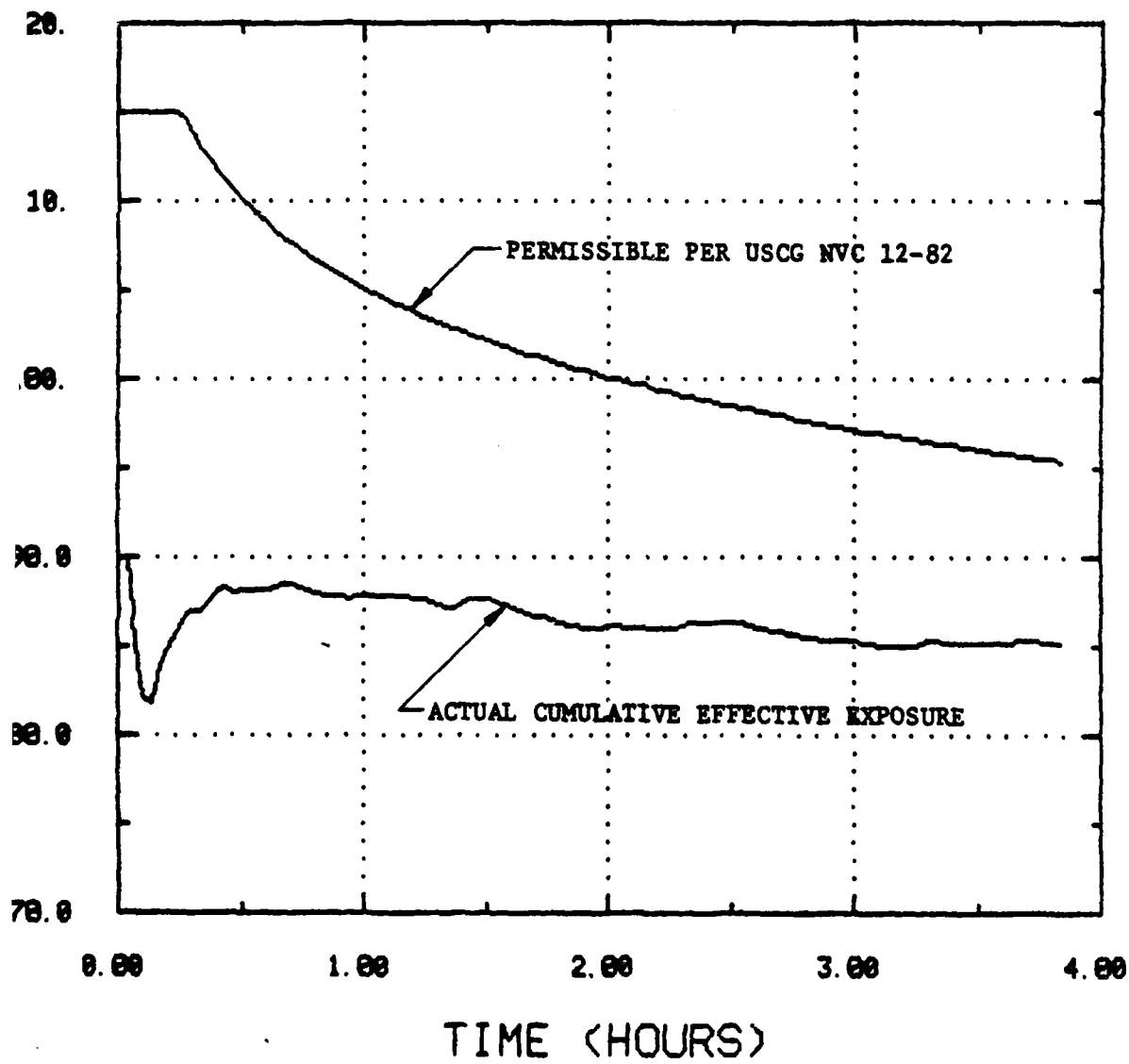


**APPENDIX F-1**

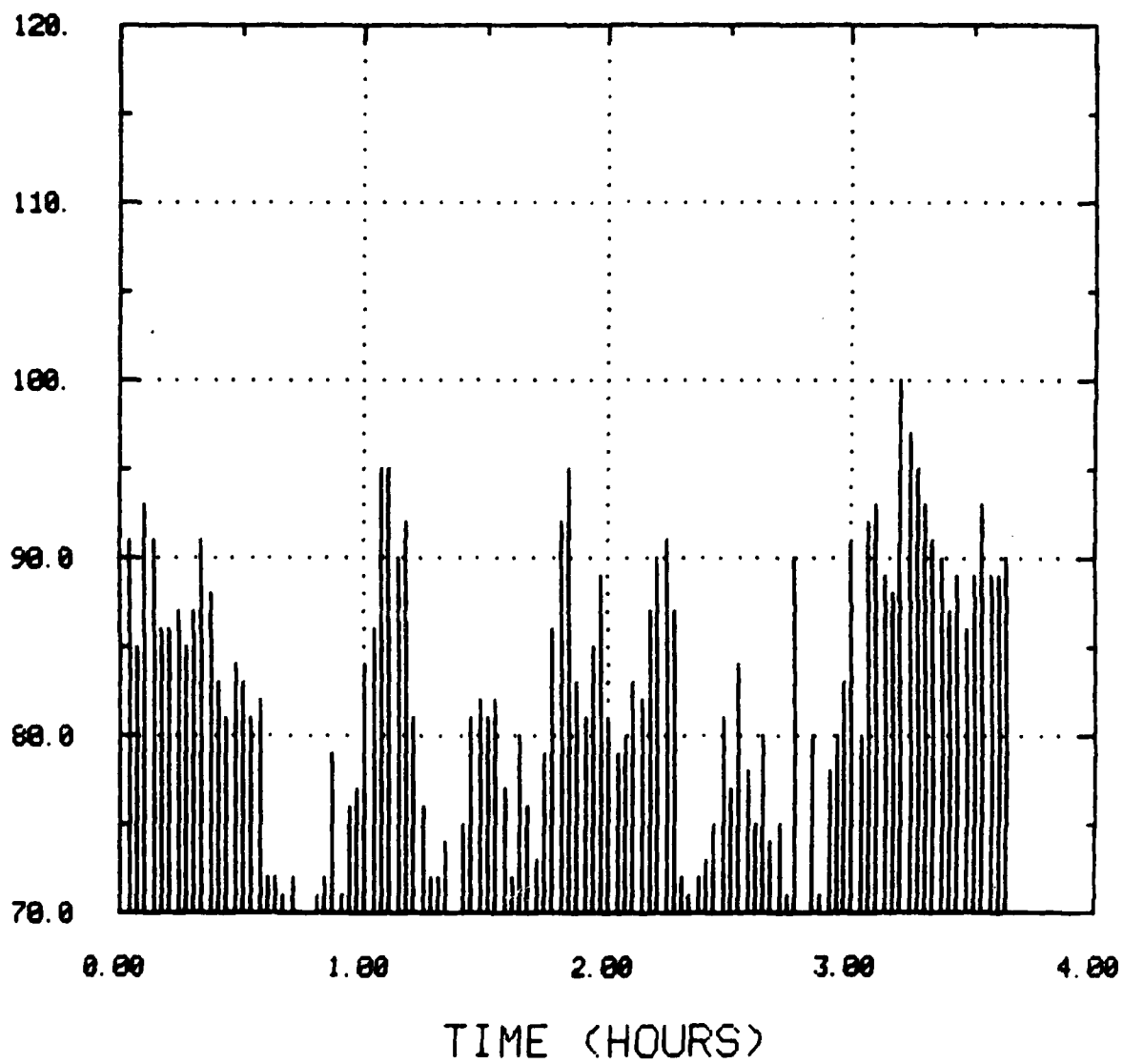
**NOISE DOSIMETRY DURING PRODUCT DISCHARGING**



NOISE DOSIMETRY - SAMPLE 1



CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 1

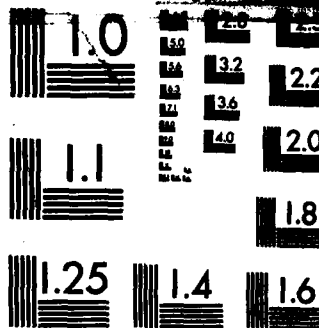


NOISE DOSIMETRY - SAMPLE 2

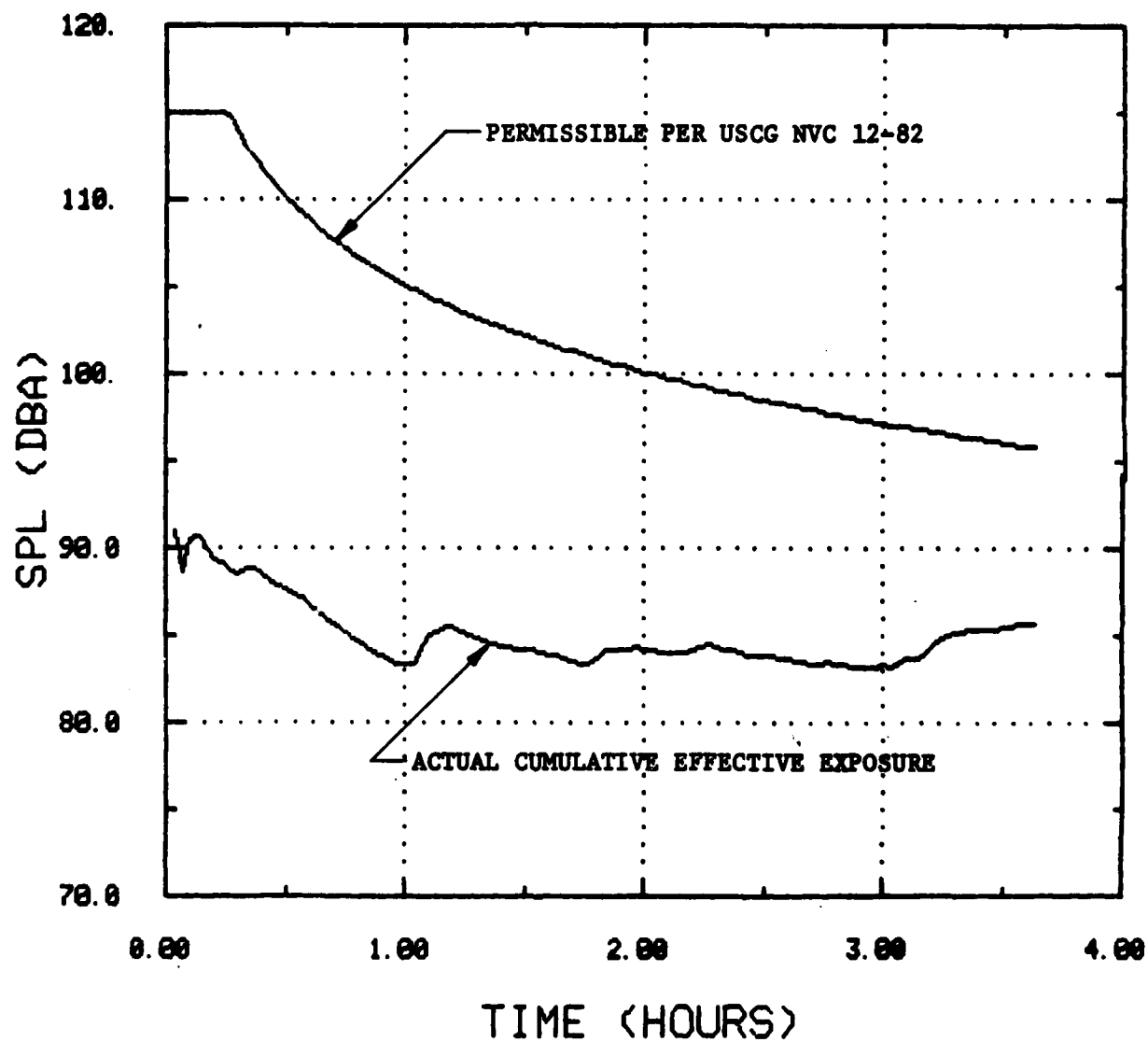
5/5

NL

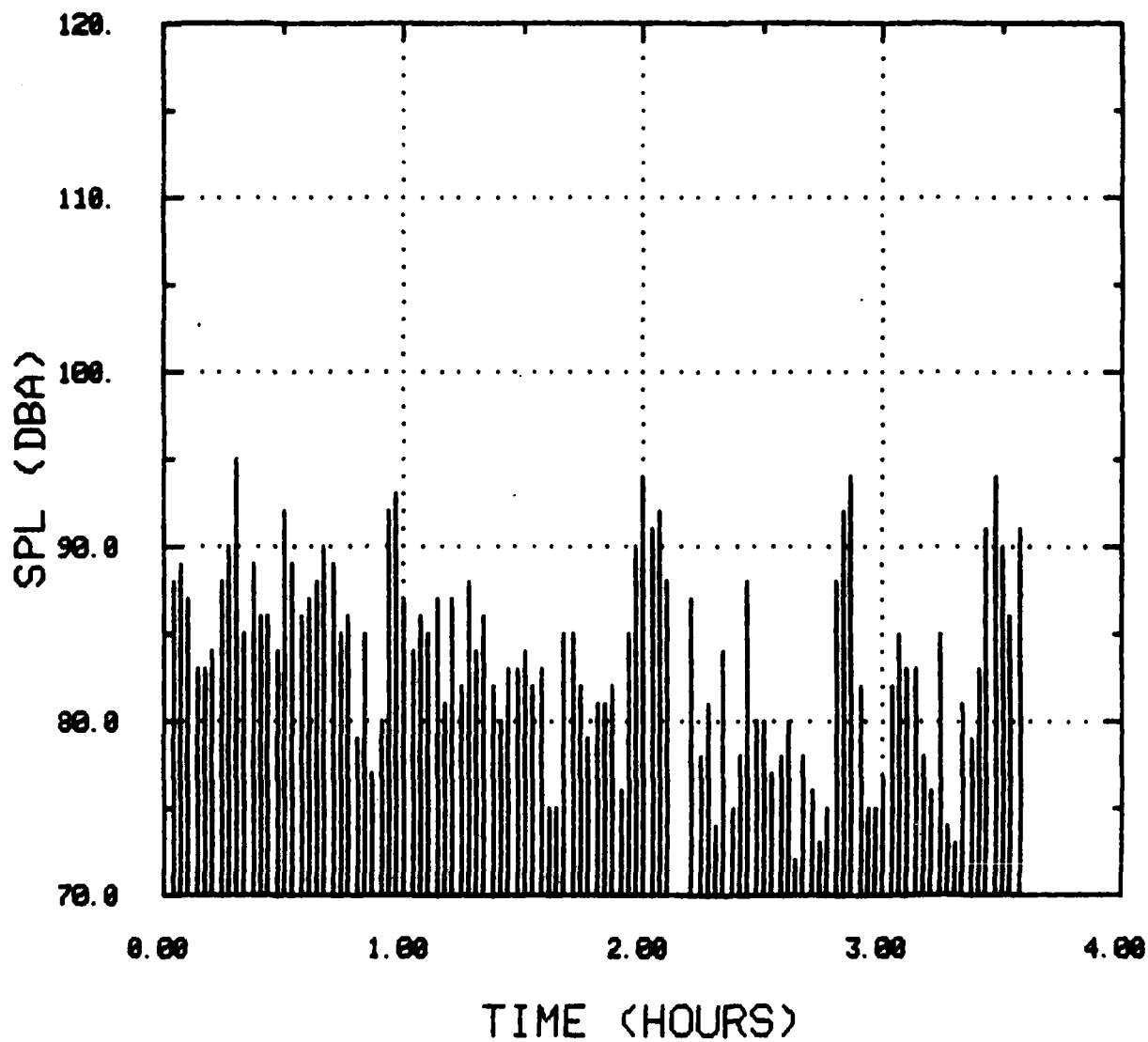
[illegible]



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

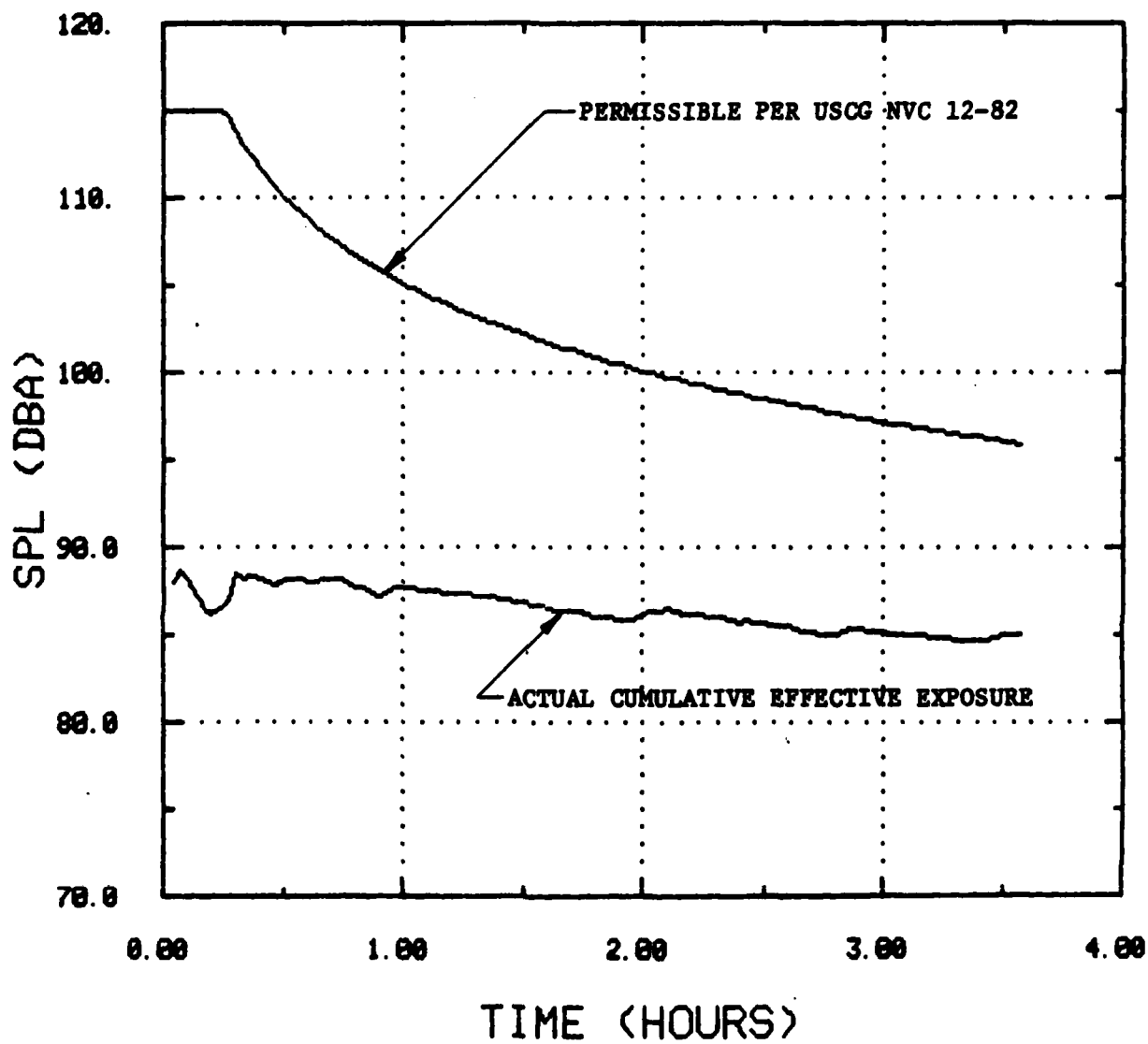


CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 2

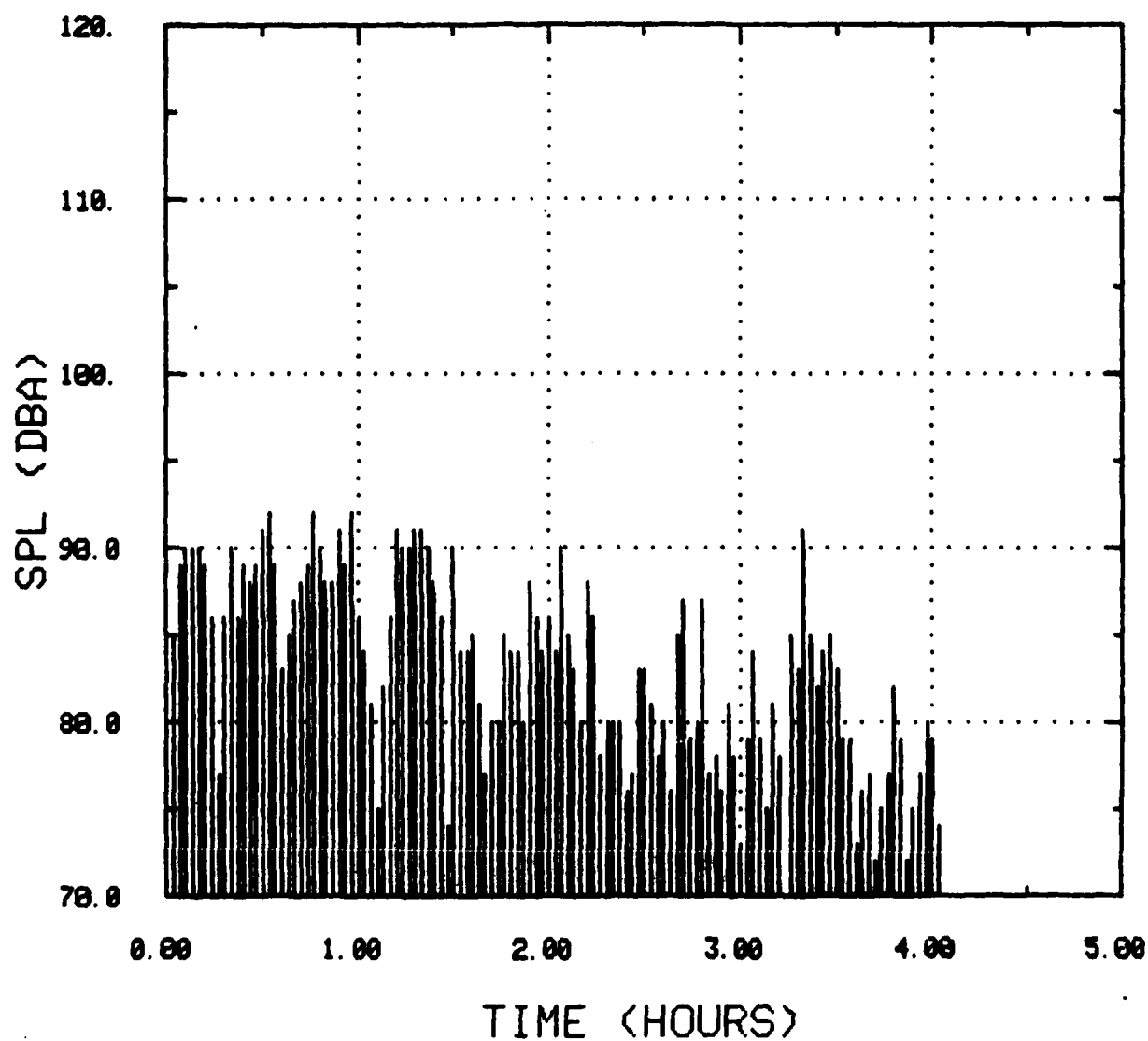


NOISE DOSIMETRY - SAMPLE 3

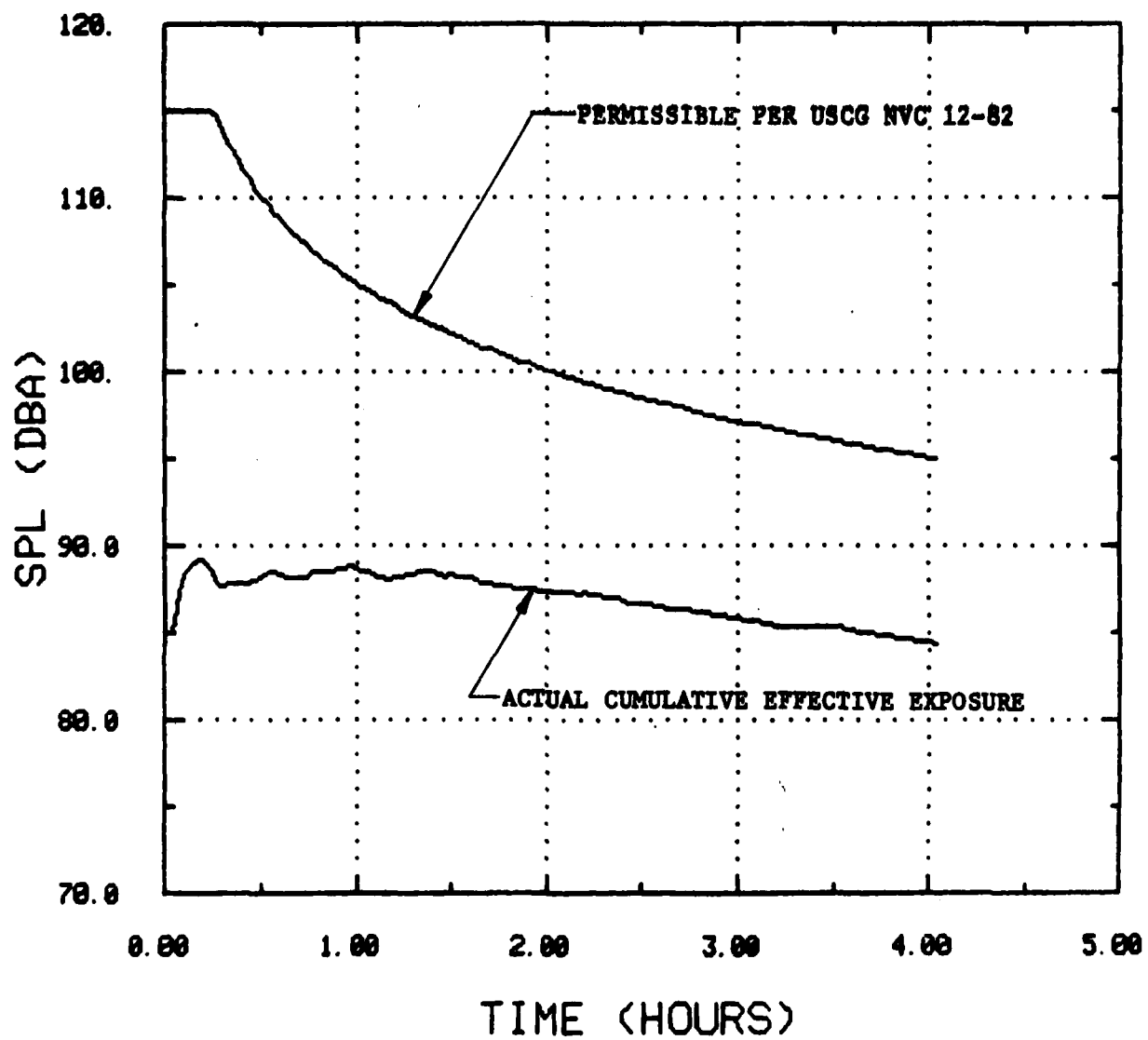




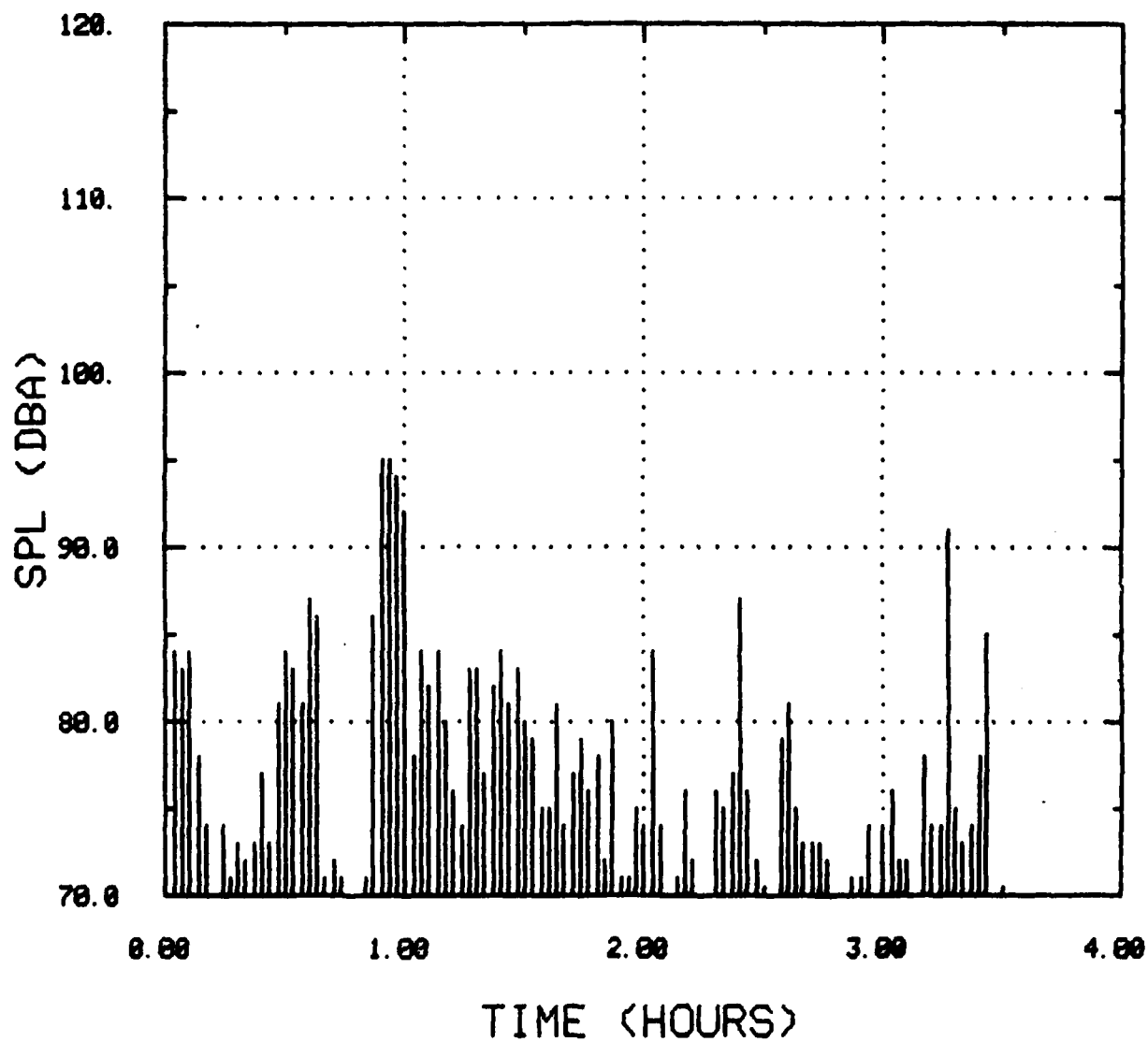
CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 3



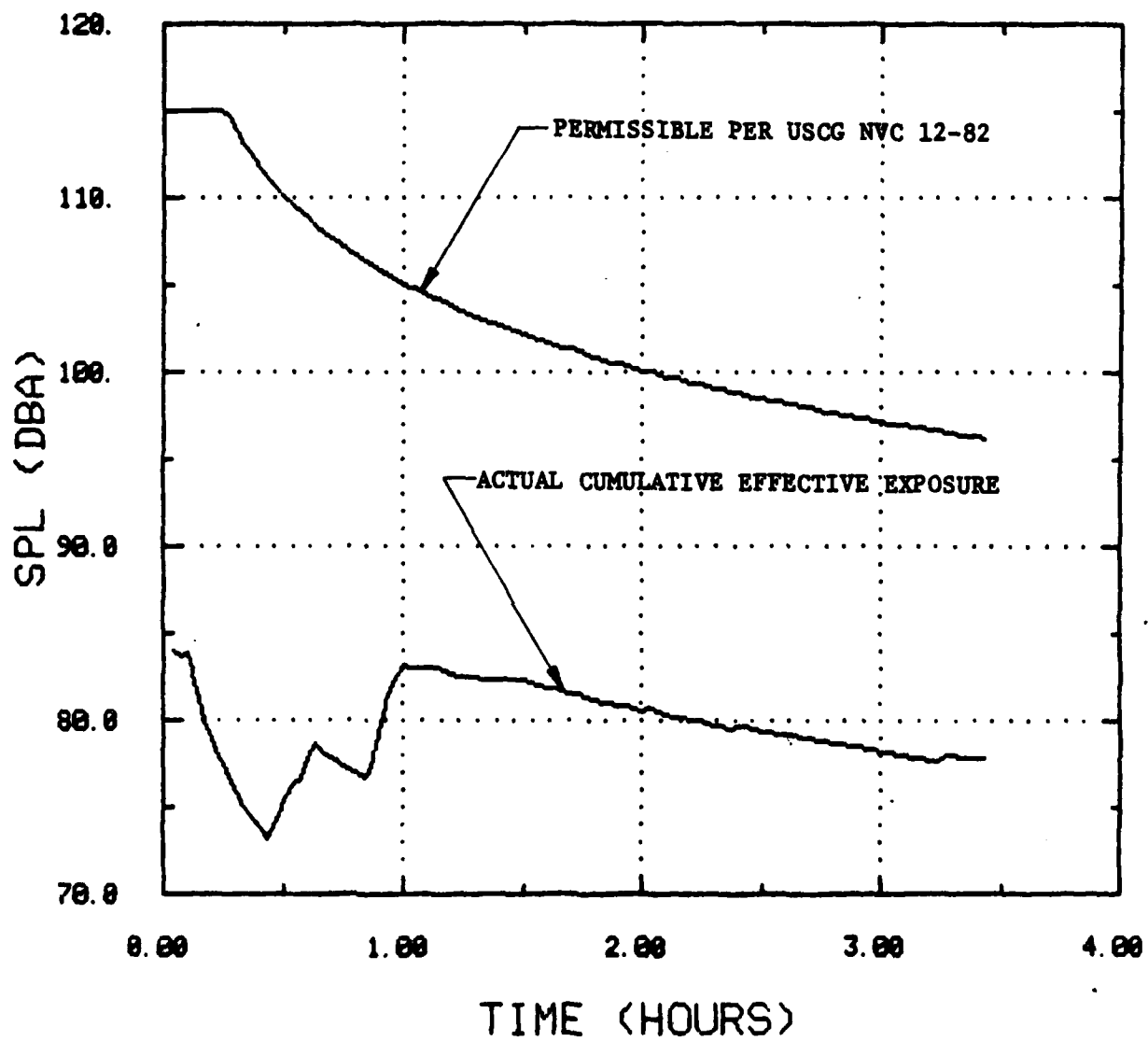
NOISE DOSIMETRY - SAMPLE 4



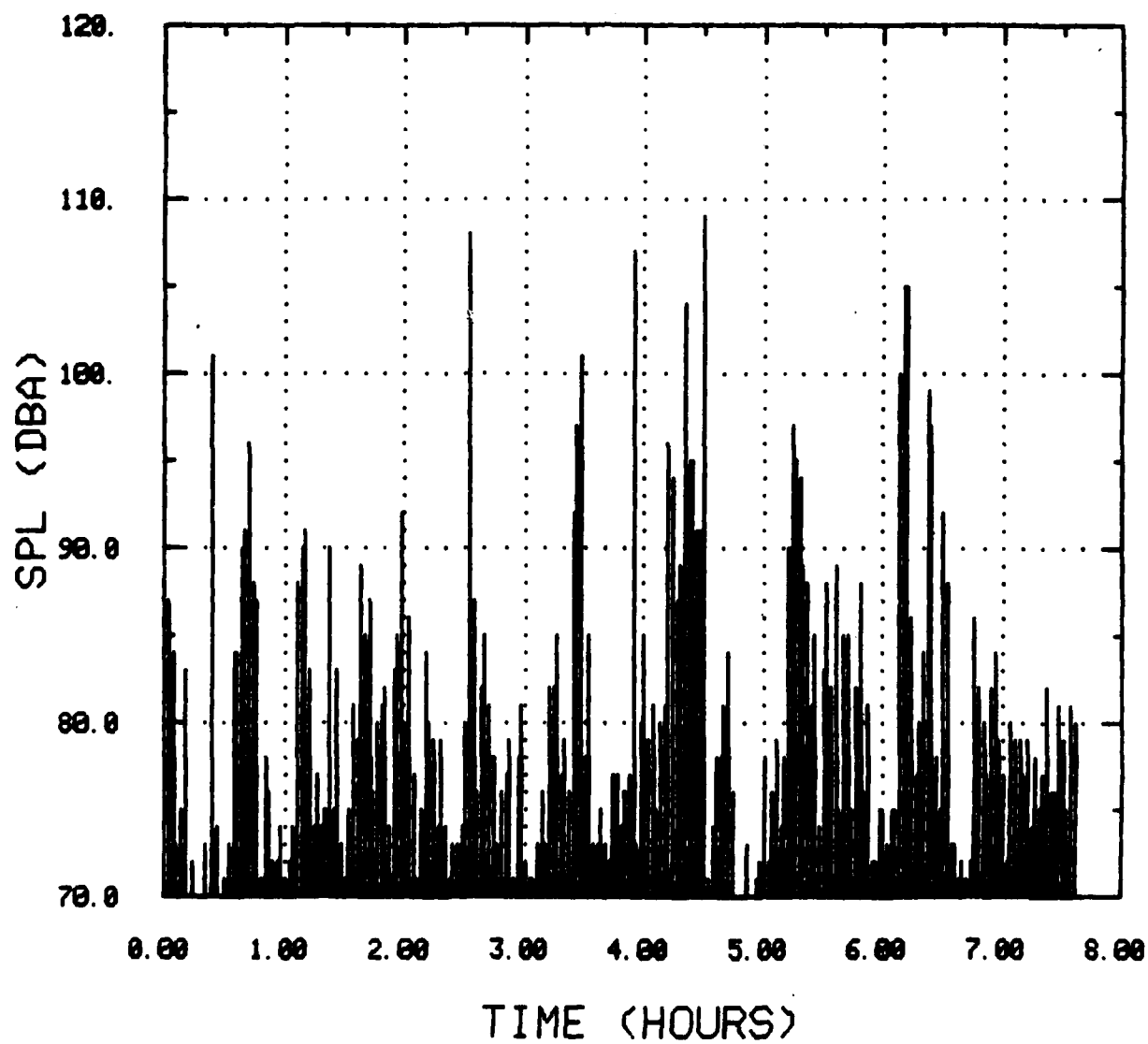
CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 4



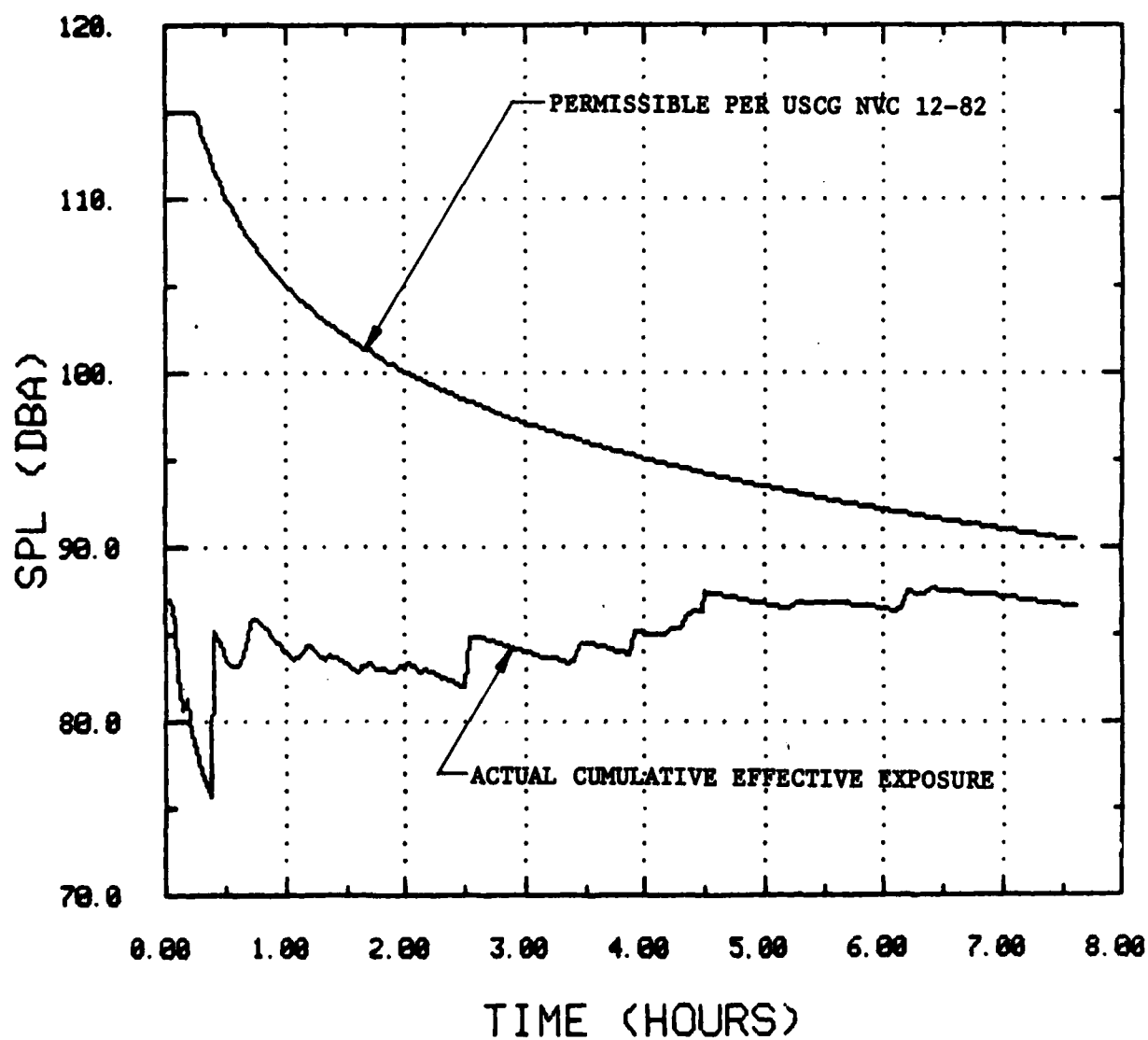
NOISE DOSIMETRY - SAMPLE 6



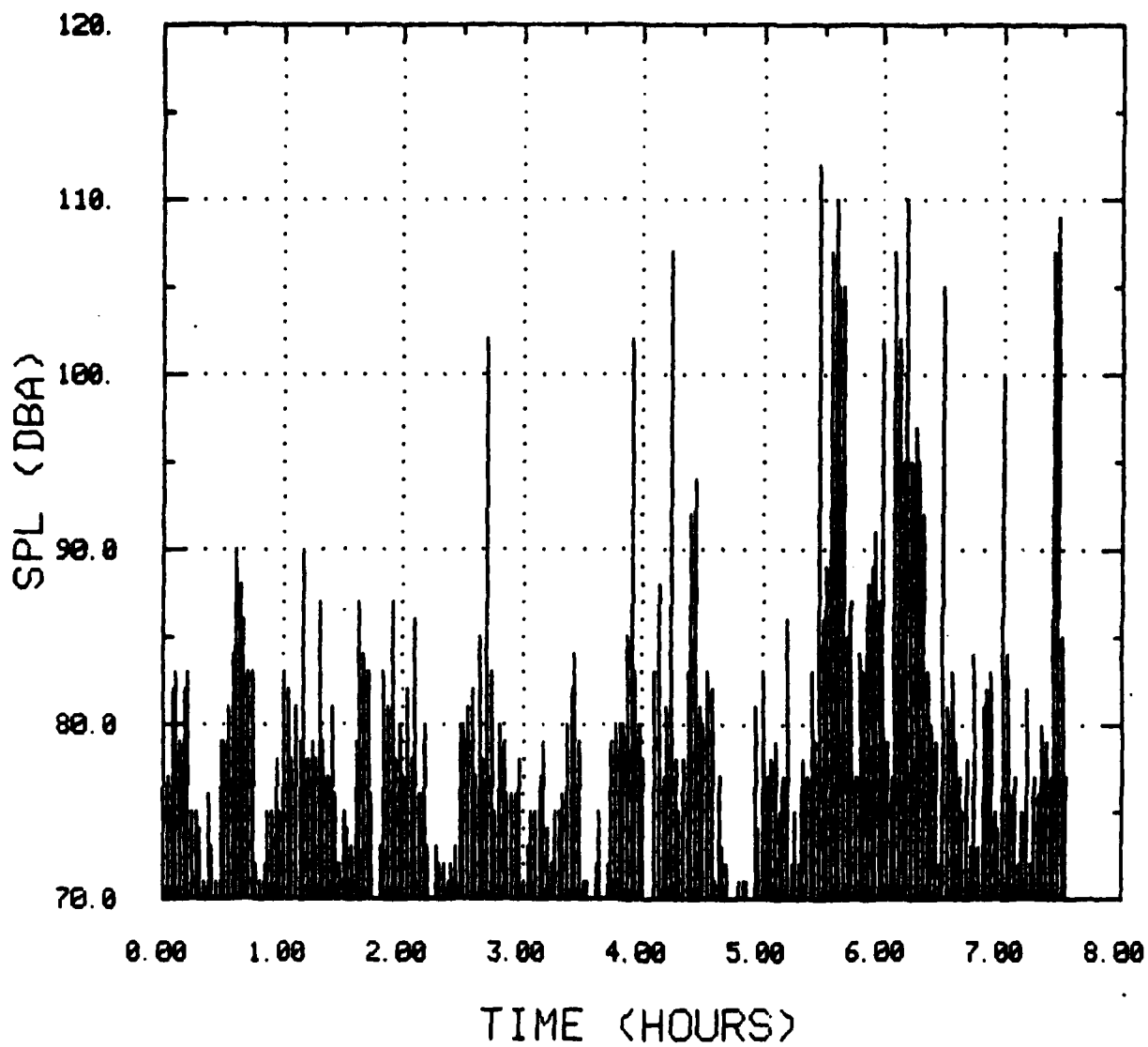
CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 6



NOISE DOSIMETRY - SAMPLE 7

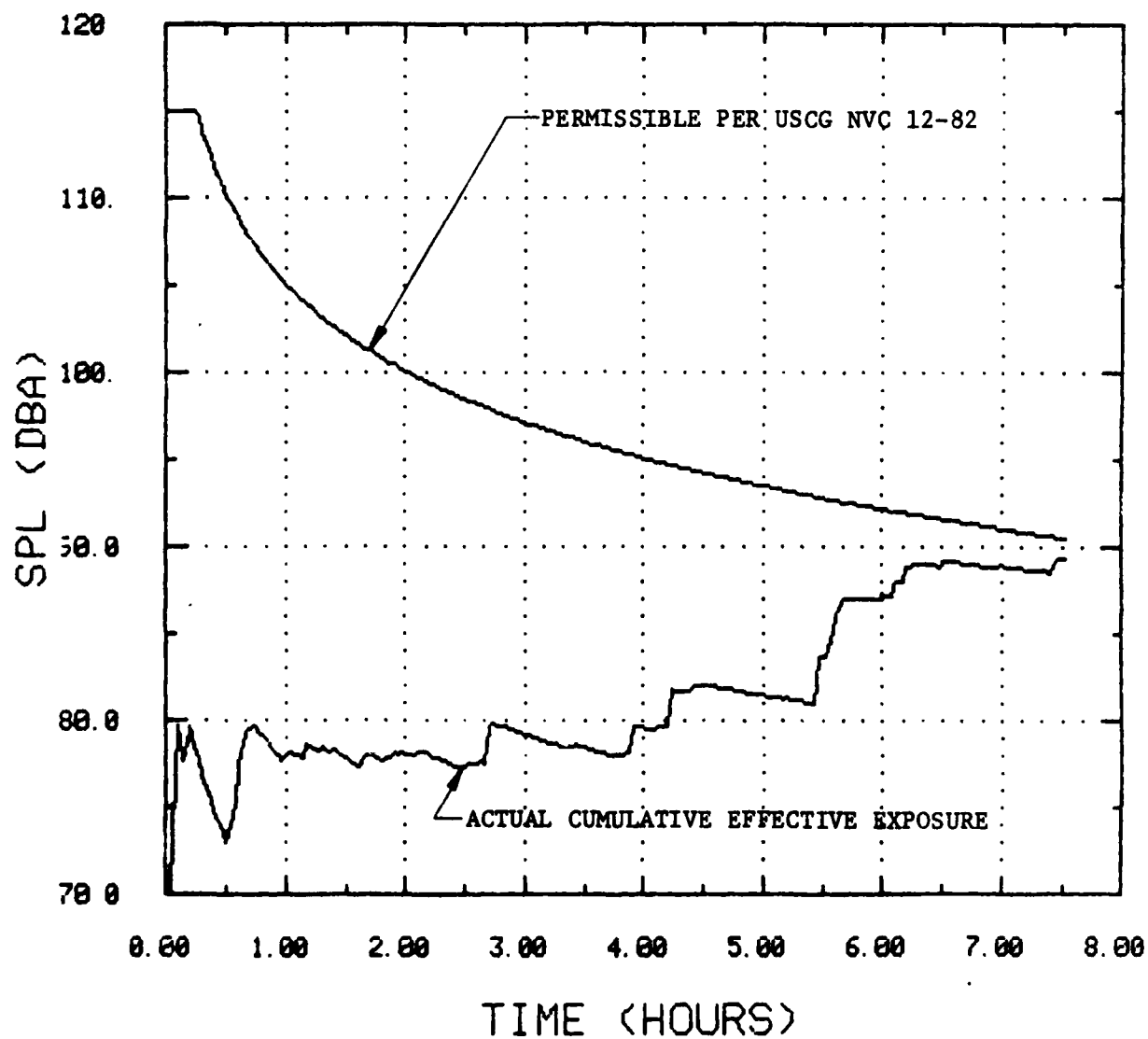


CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 7

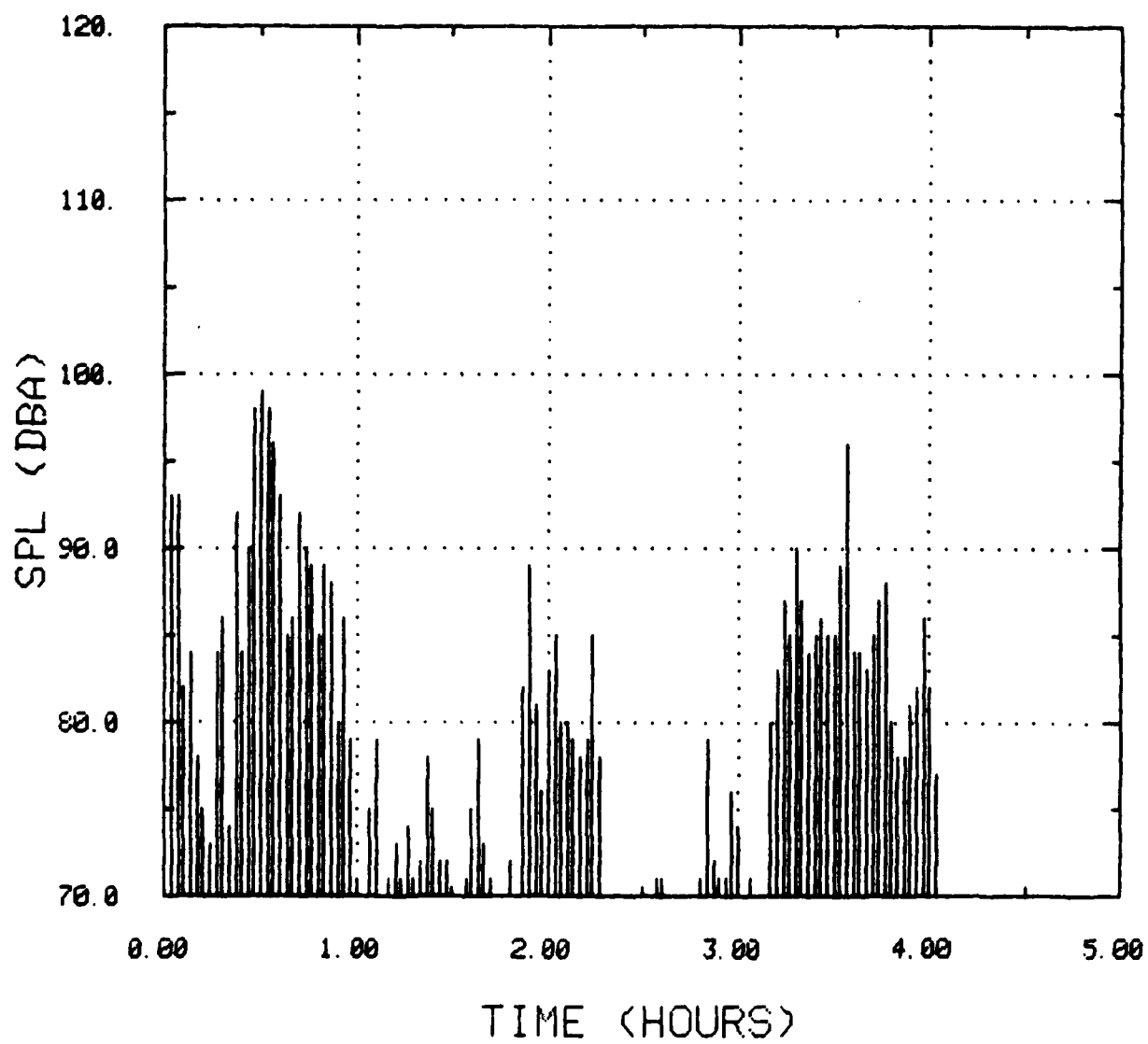


NOISE DOSIMETRY - SAMPLE 8

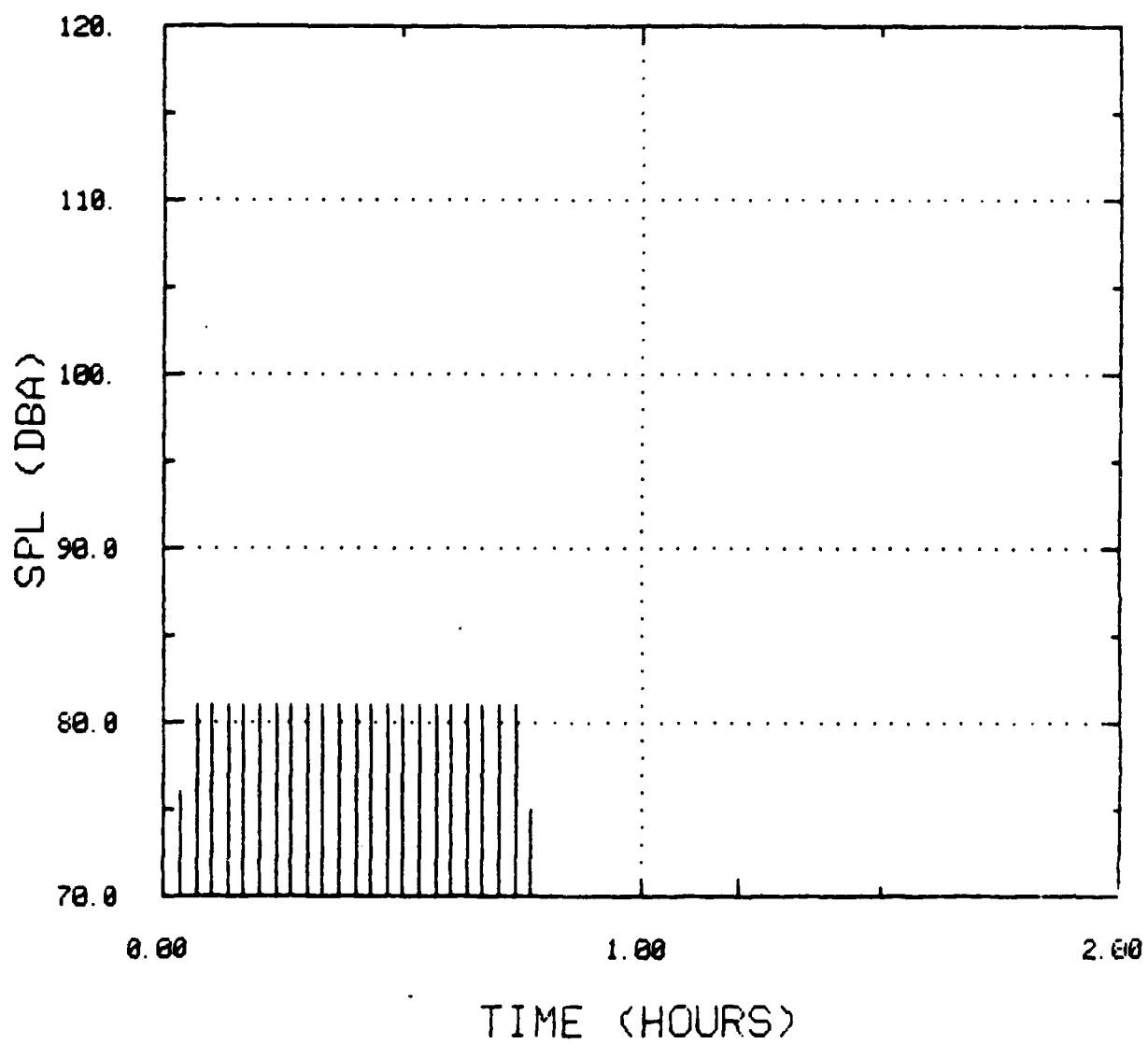




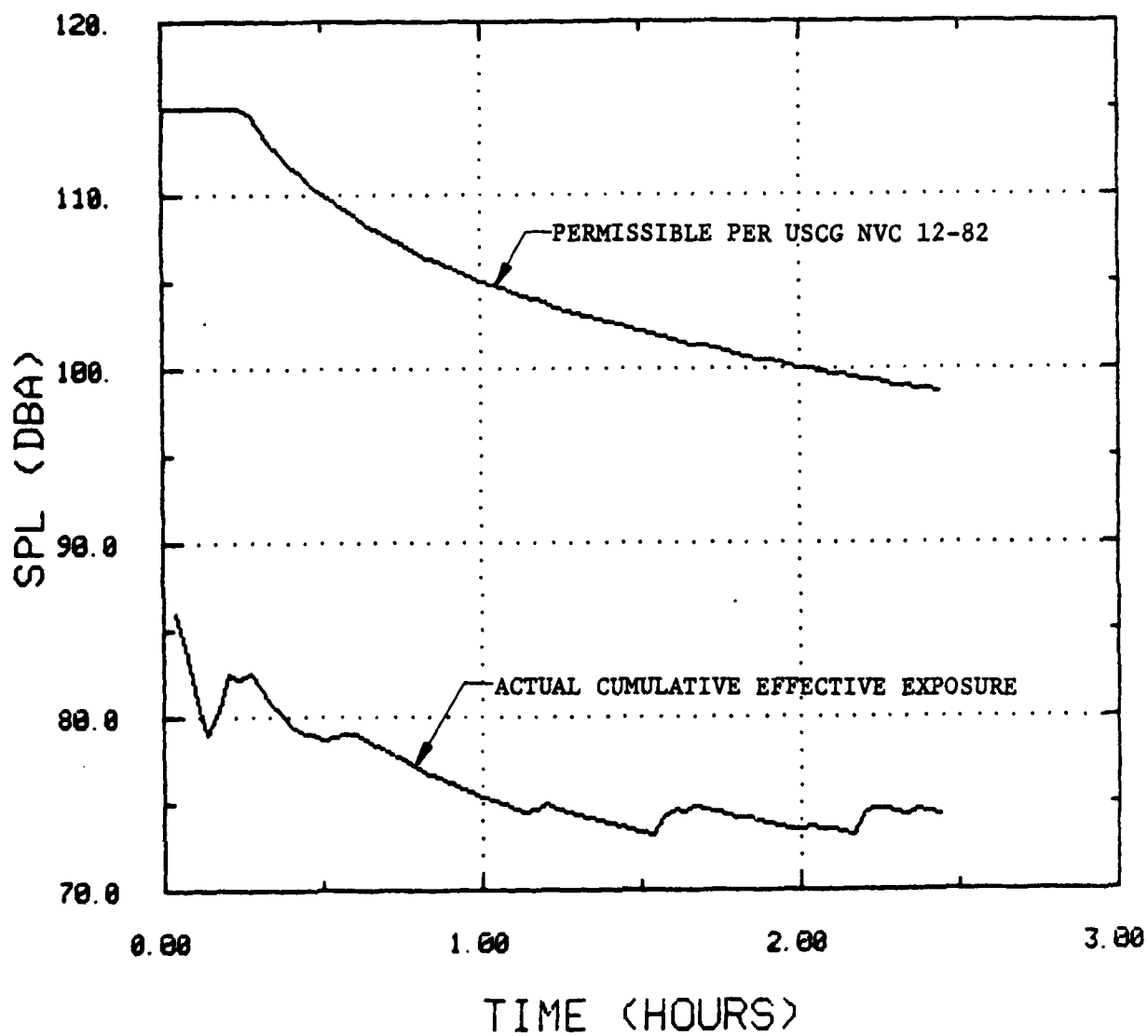
CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 8



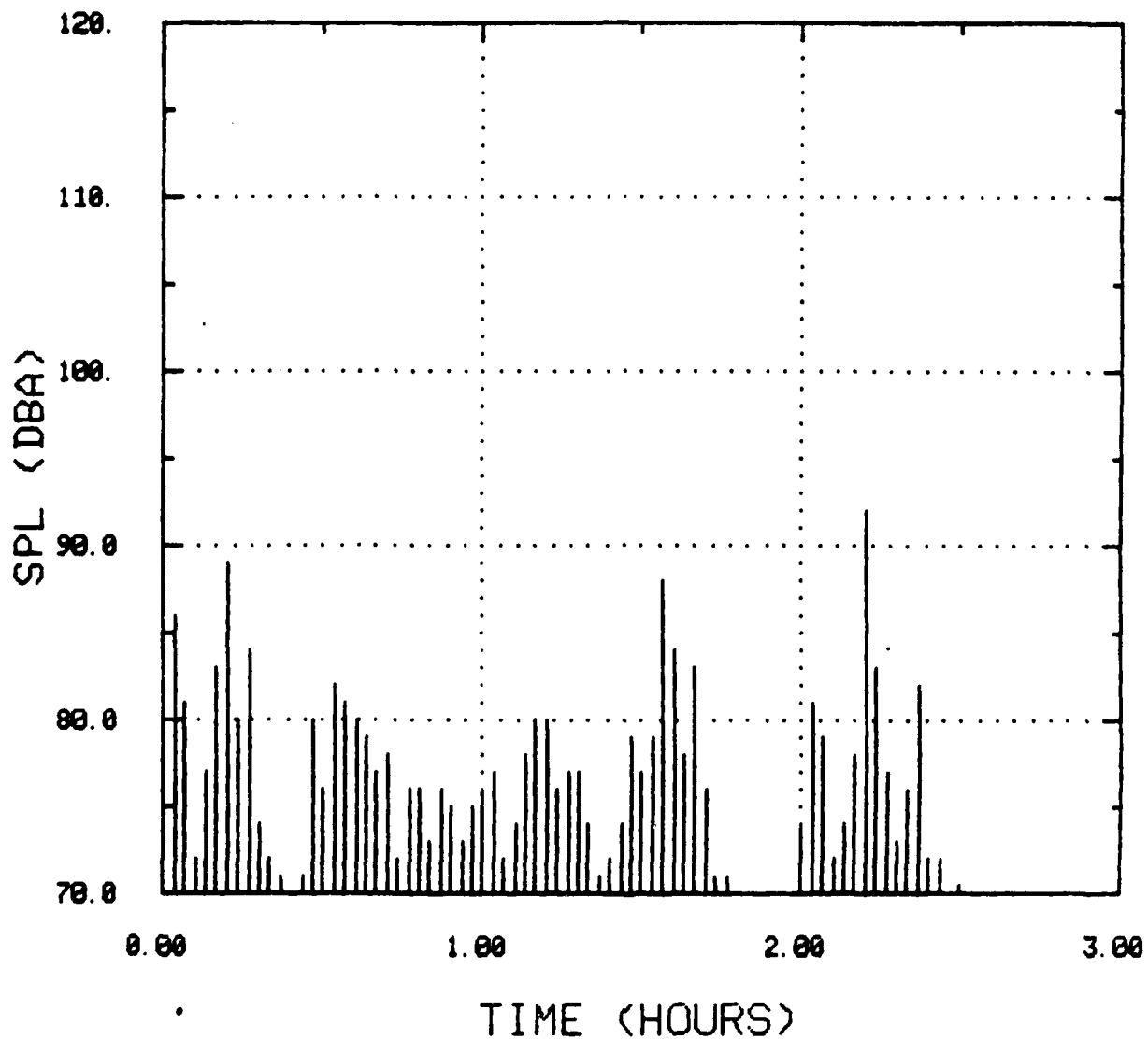
NOISE DOSIMETRY - SAMPLE 9



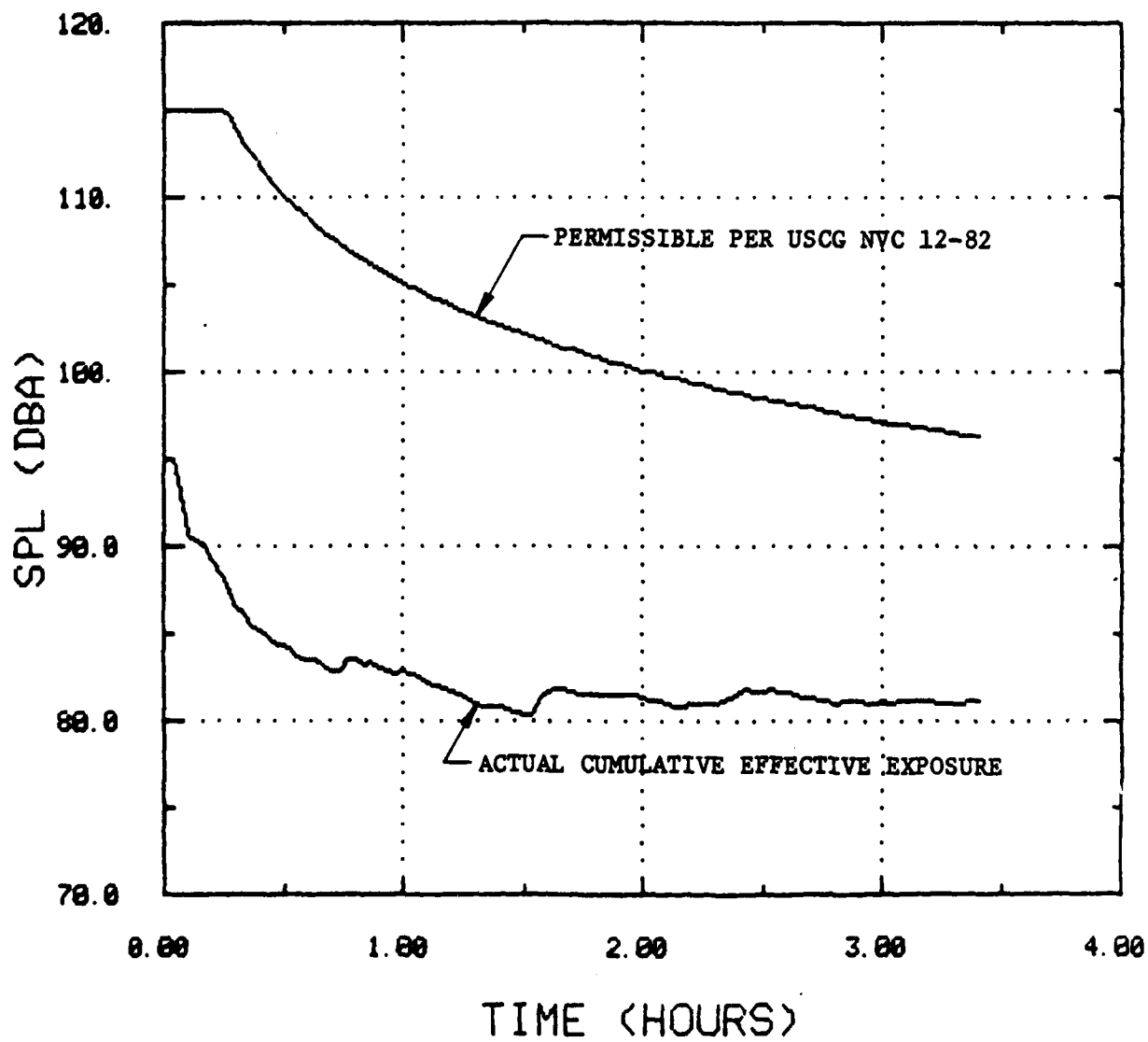
NOISE DOSIMETRY - SAMPLE 19



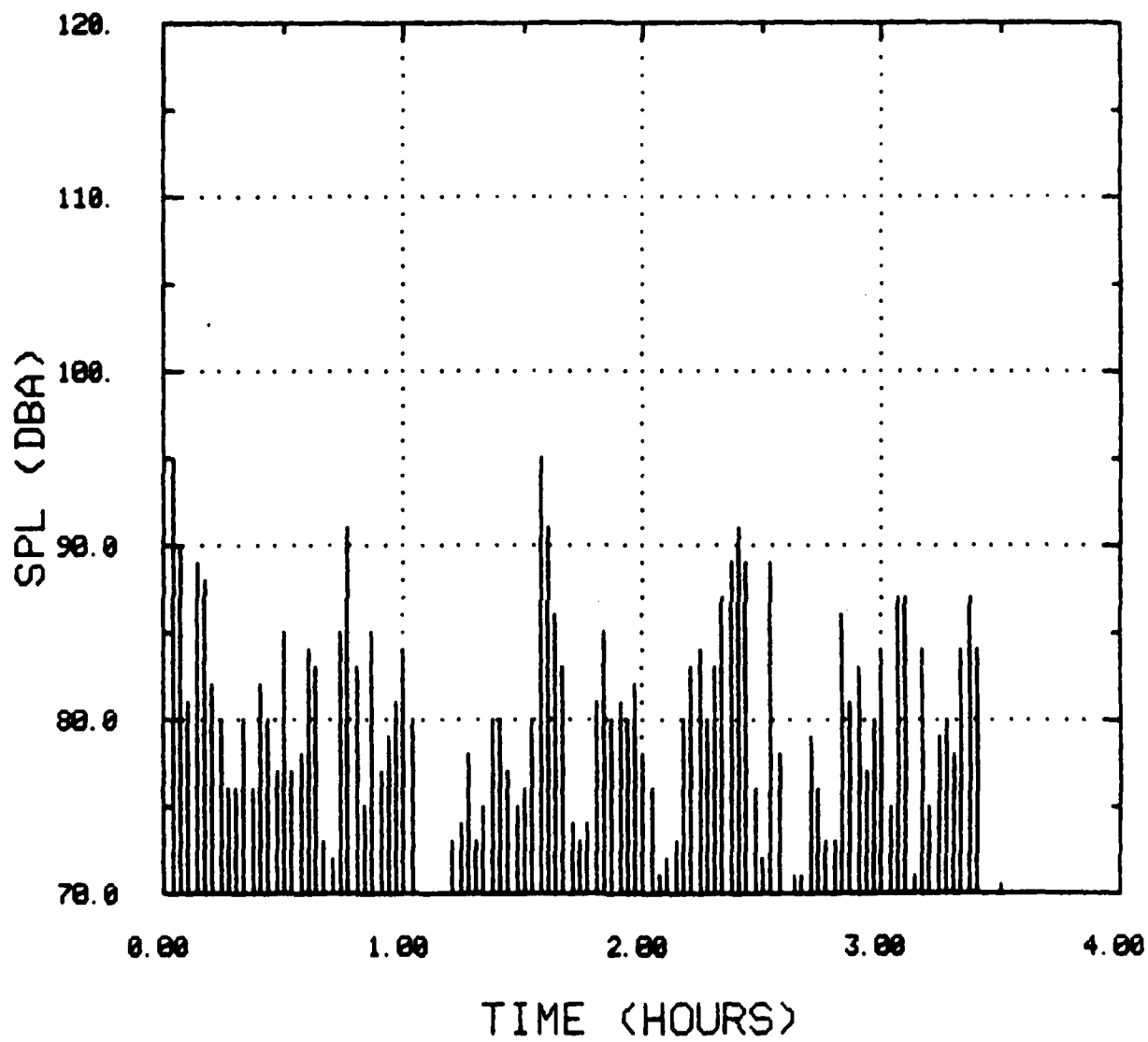
CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 16



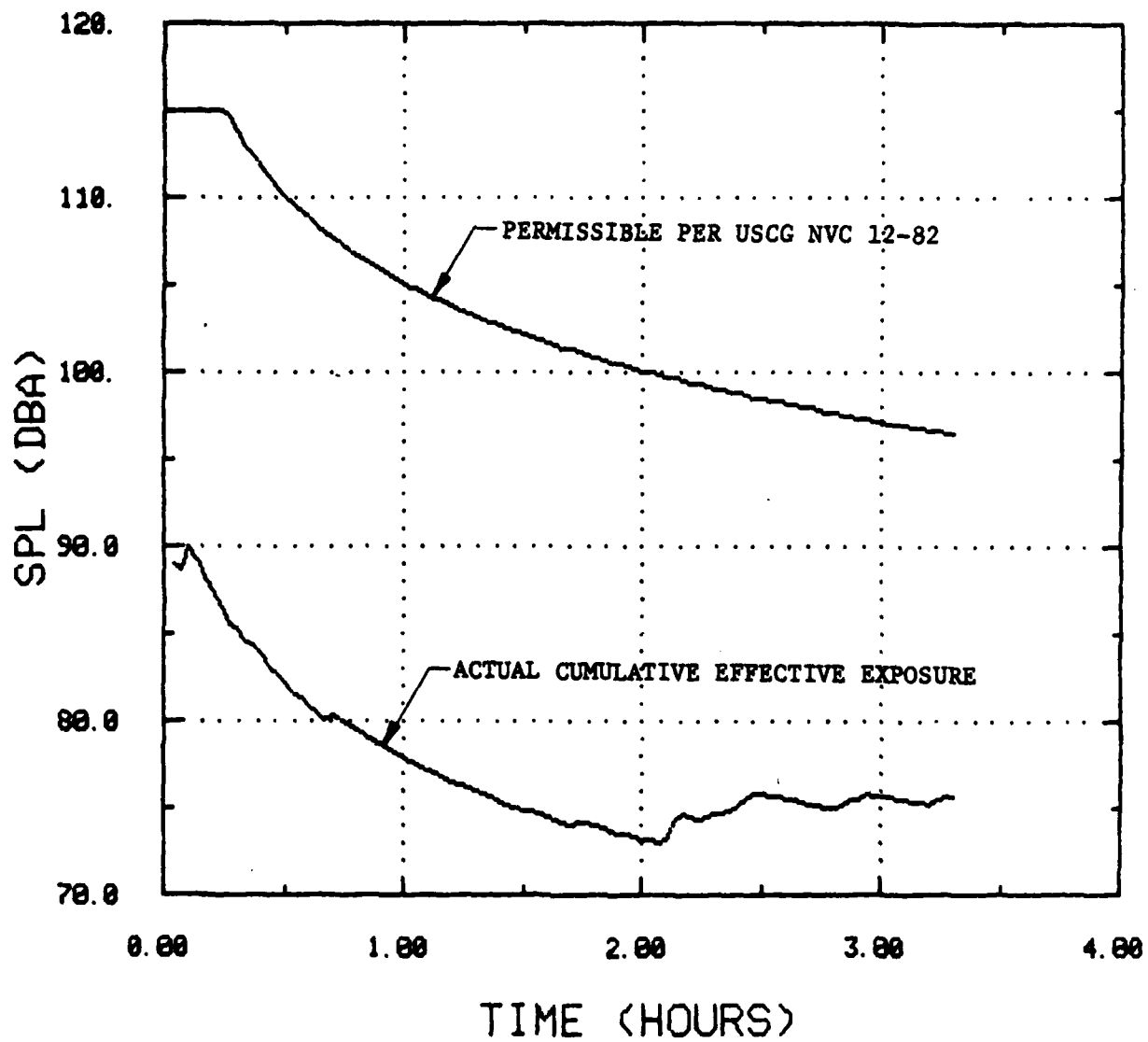
NOISE DOSIMETRY - SAMPLE 16



CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 14

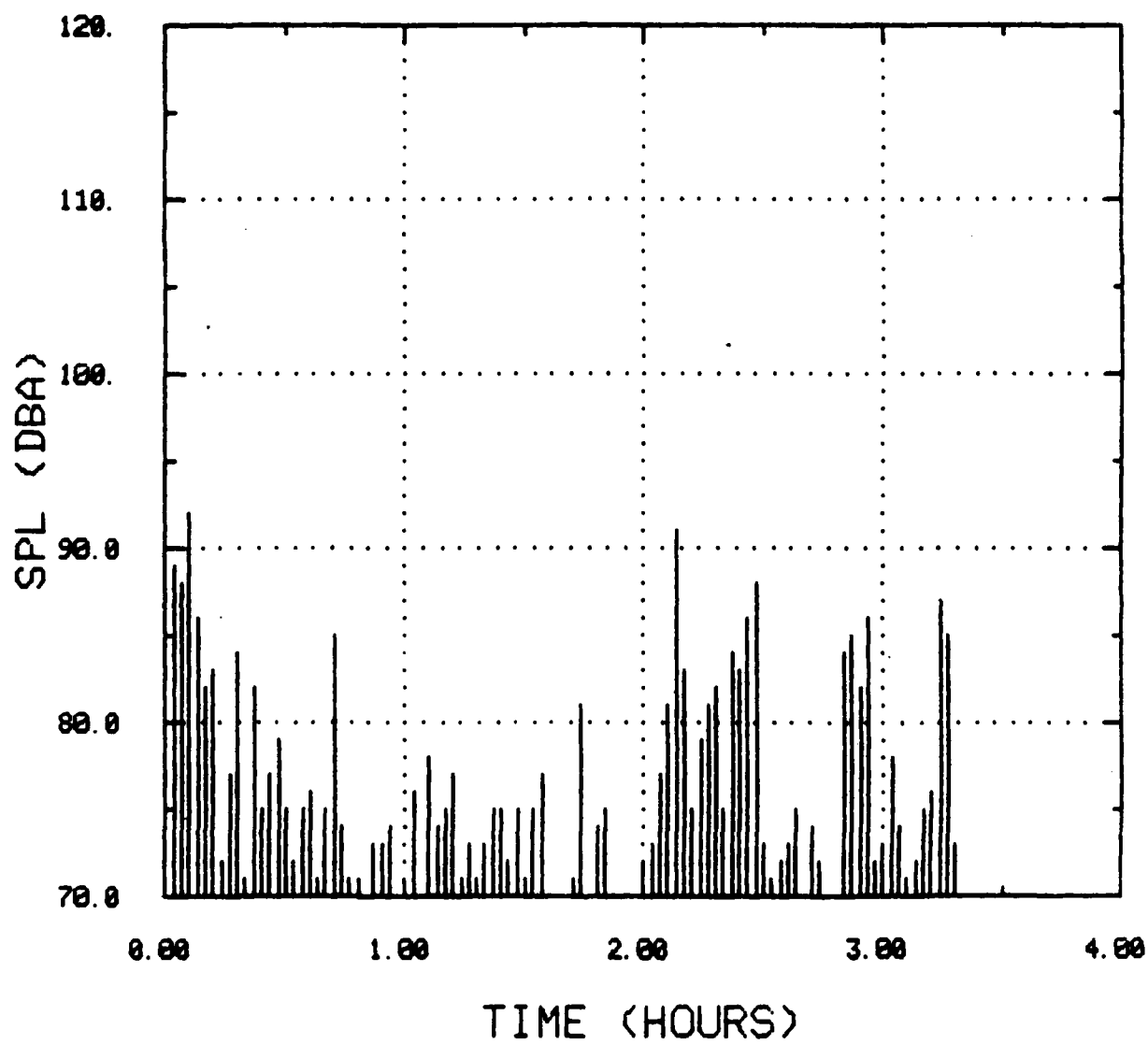


NOISE DOSIMETRY - SAMPLE 14

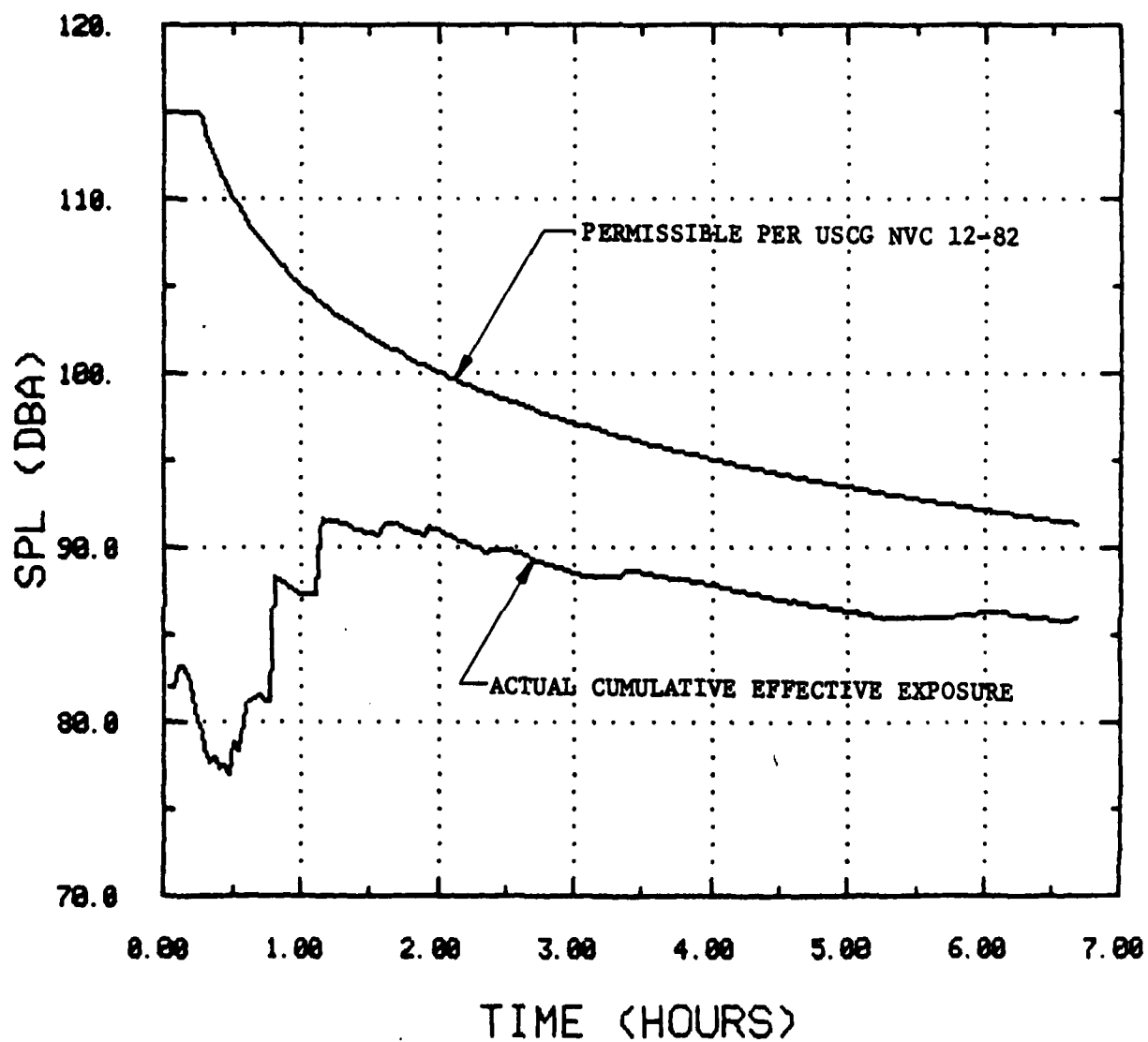


CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 13

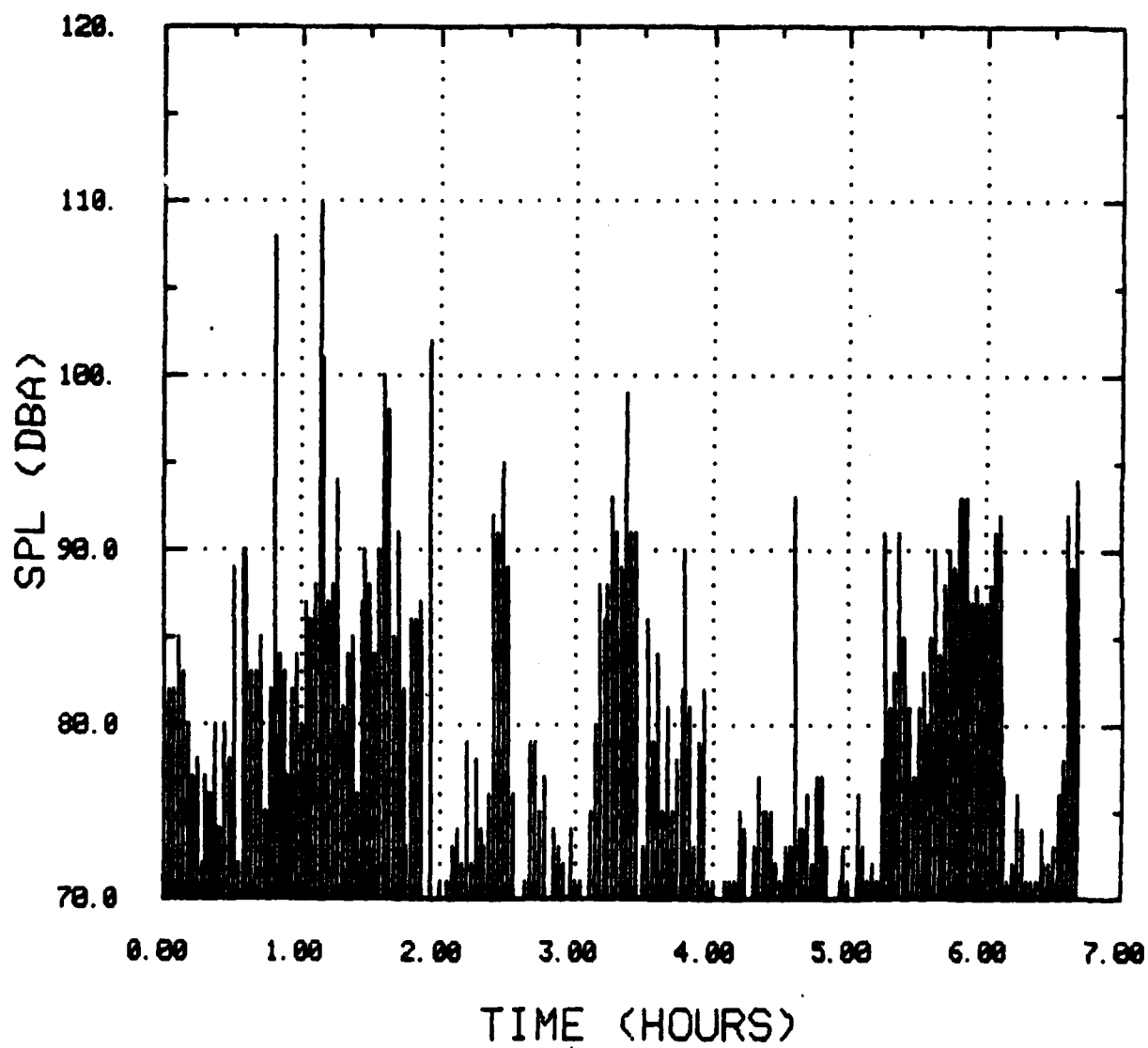




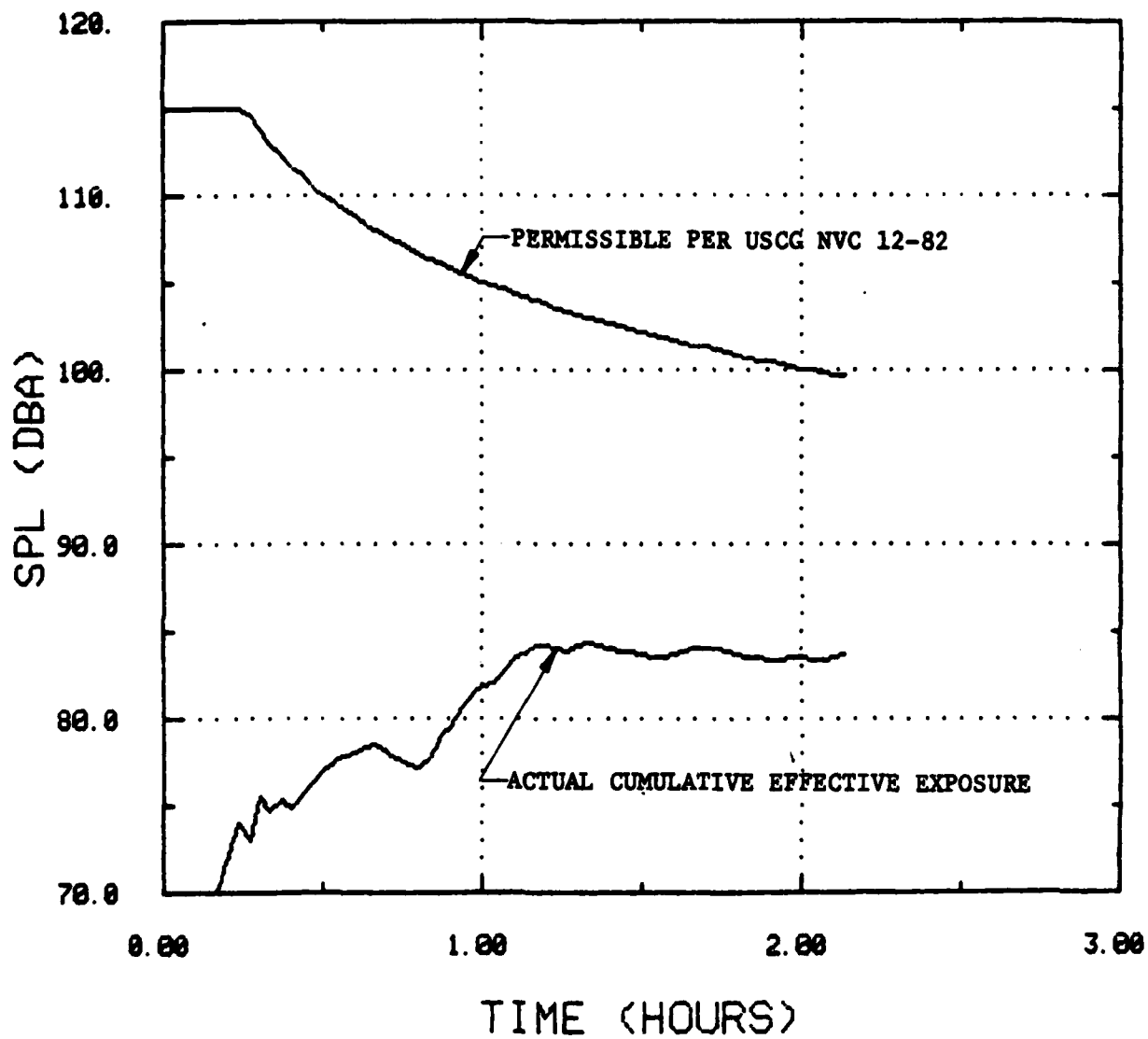
NOISE DOSIMETRY - SAMPLE 13



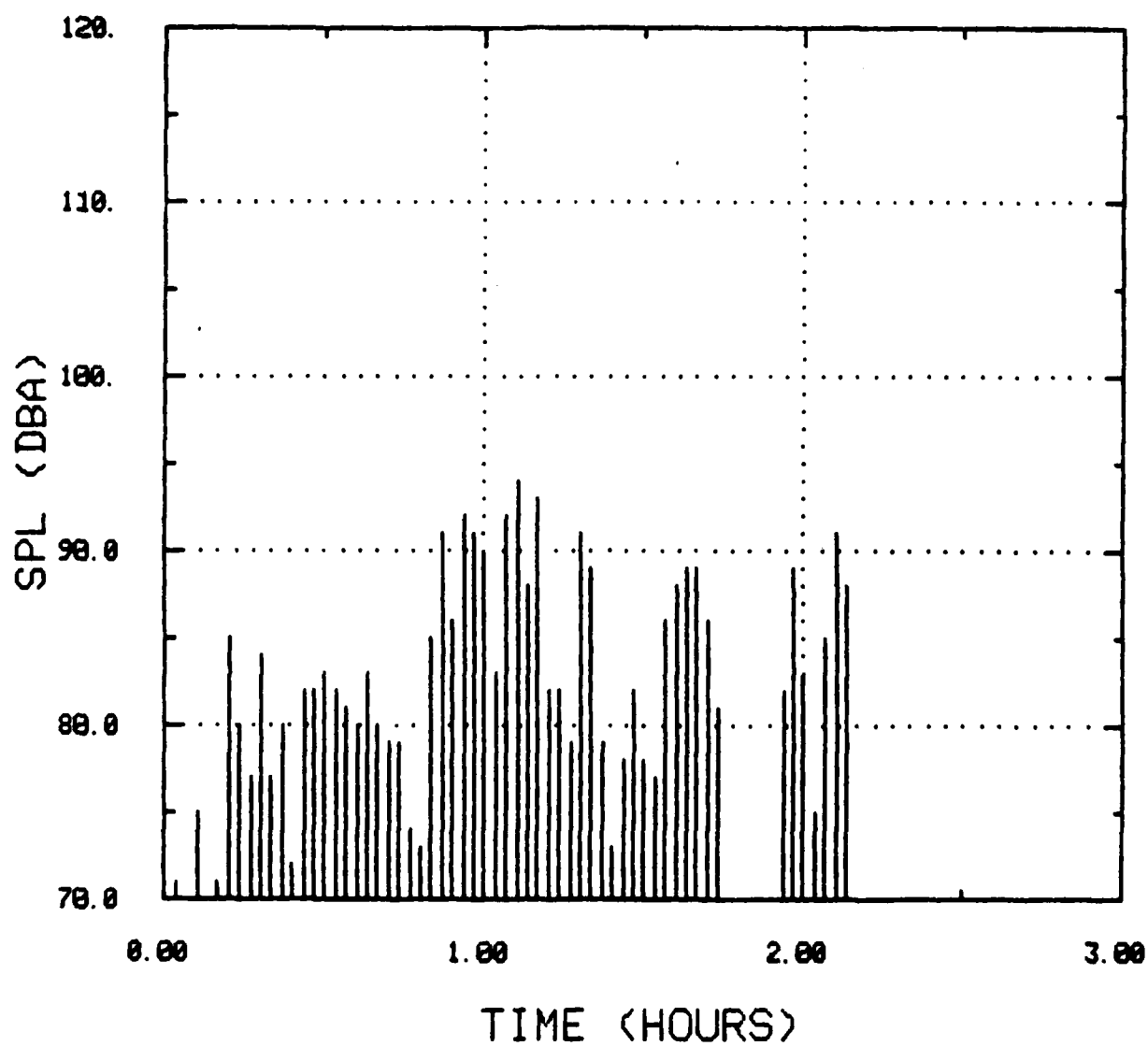
CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 12



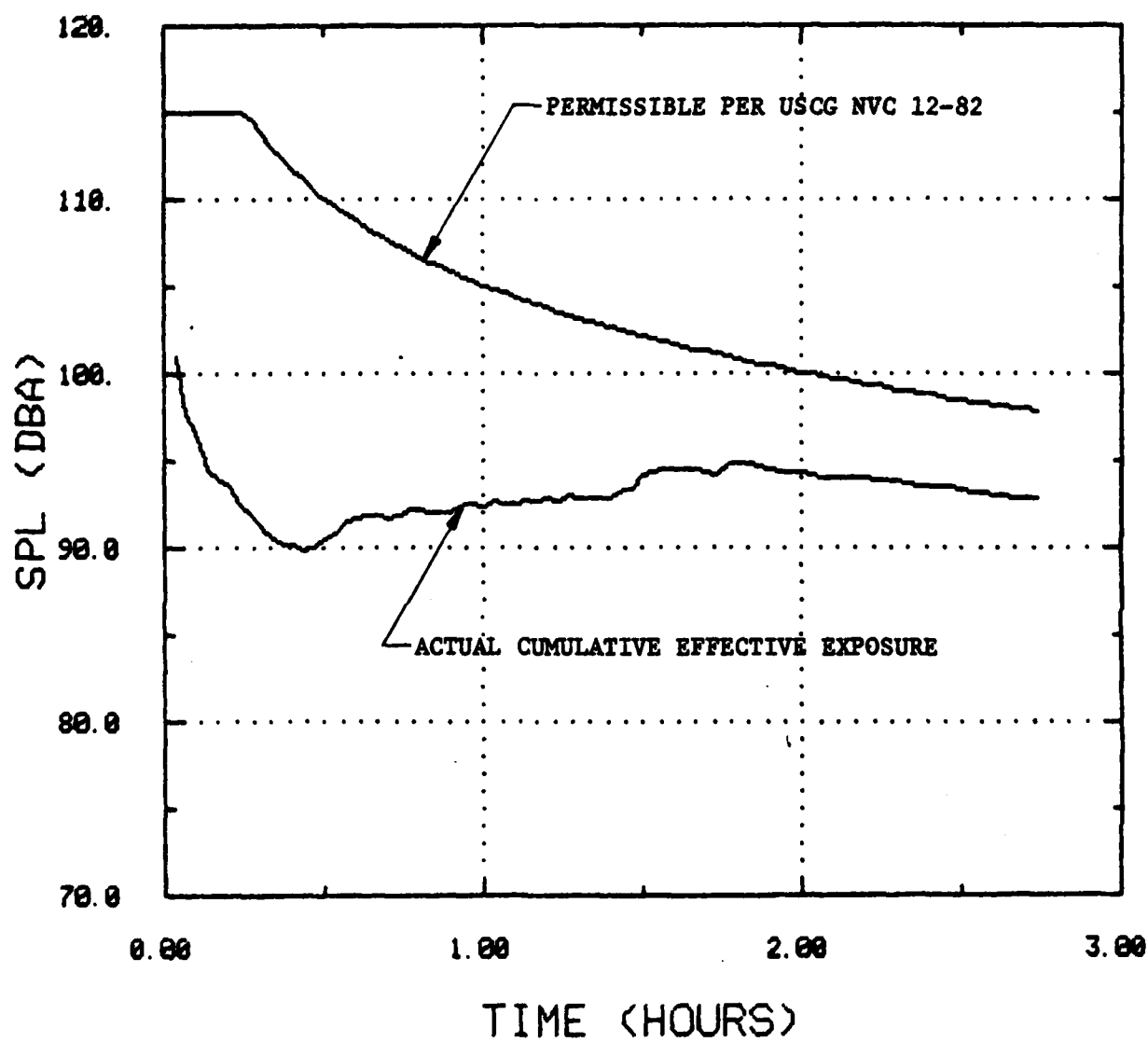
NOISE DOSIMETRY - SAMPLE 12



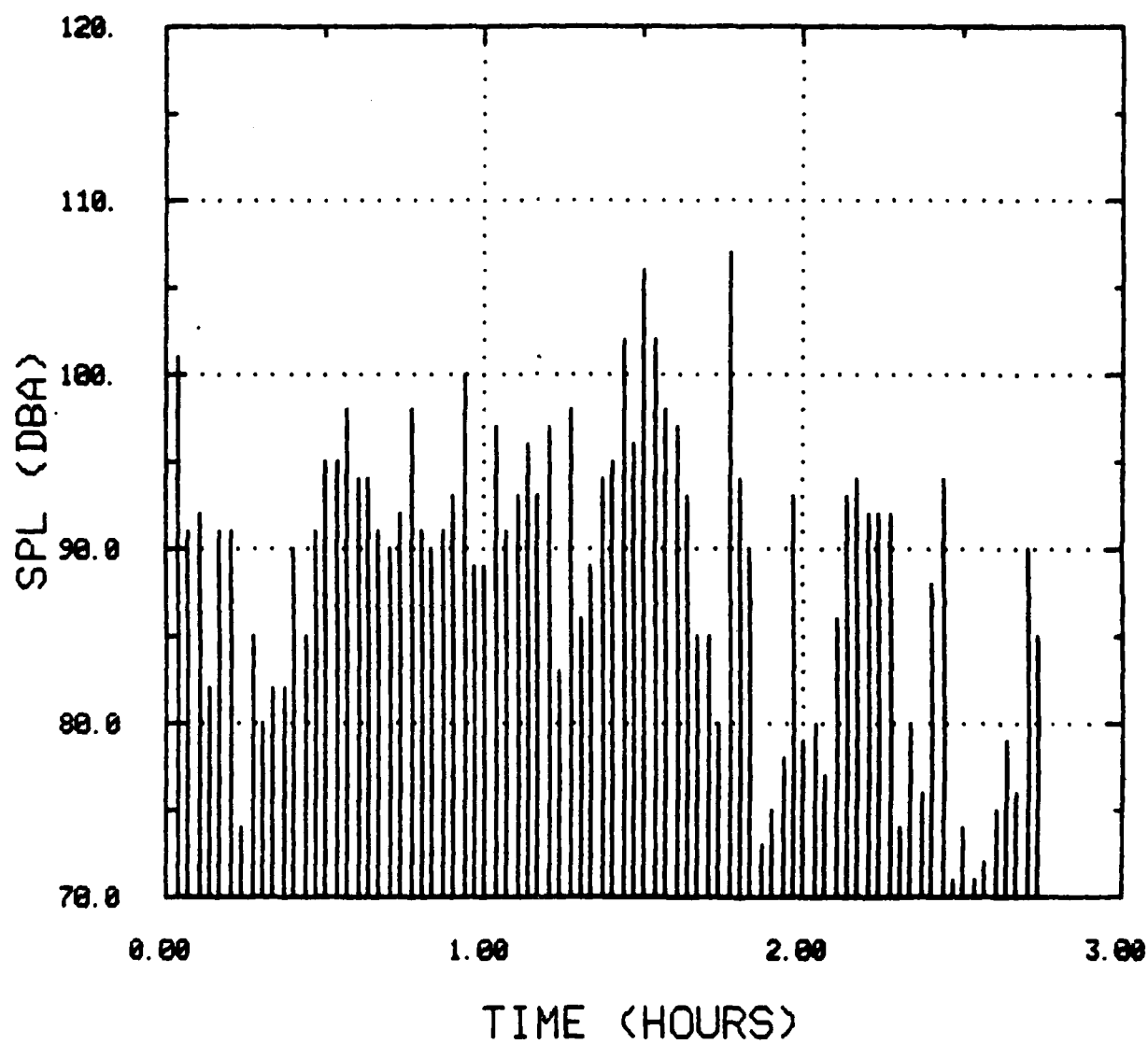
CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 11



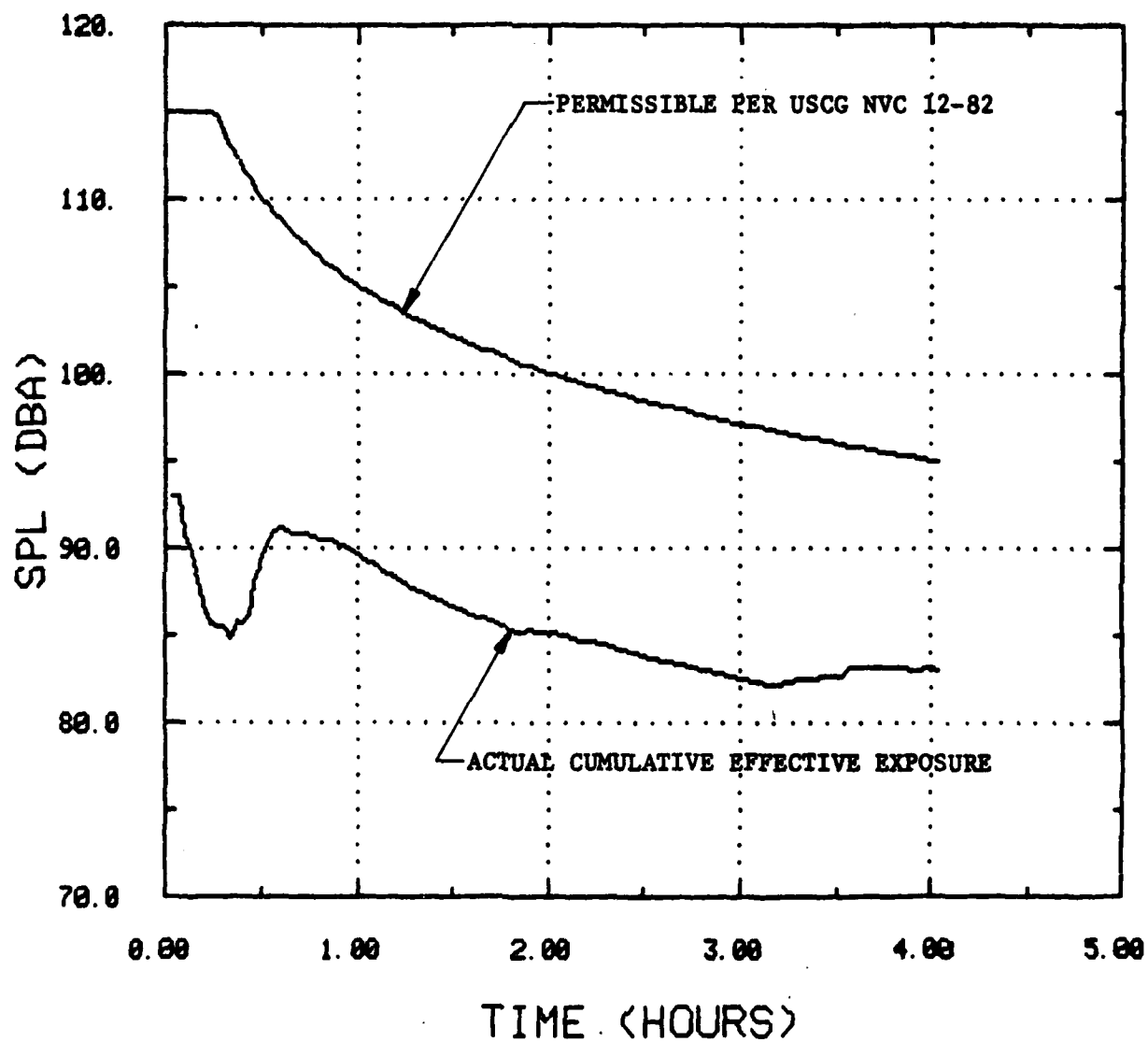
NOISE DOSIMETRY - SAMPLE 11



CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 10



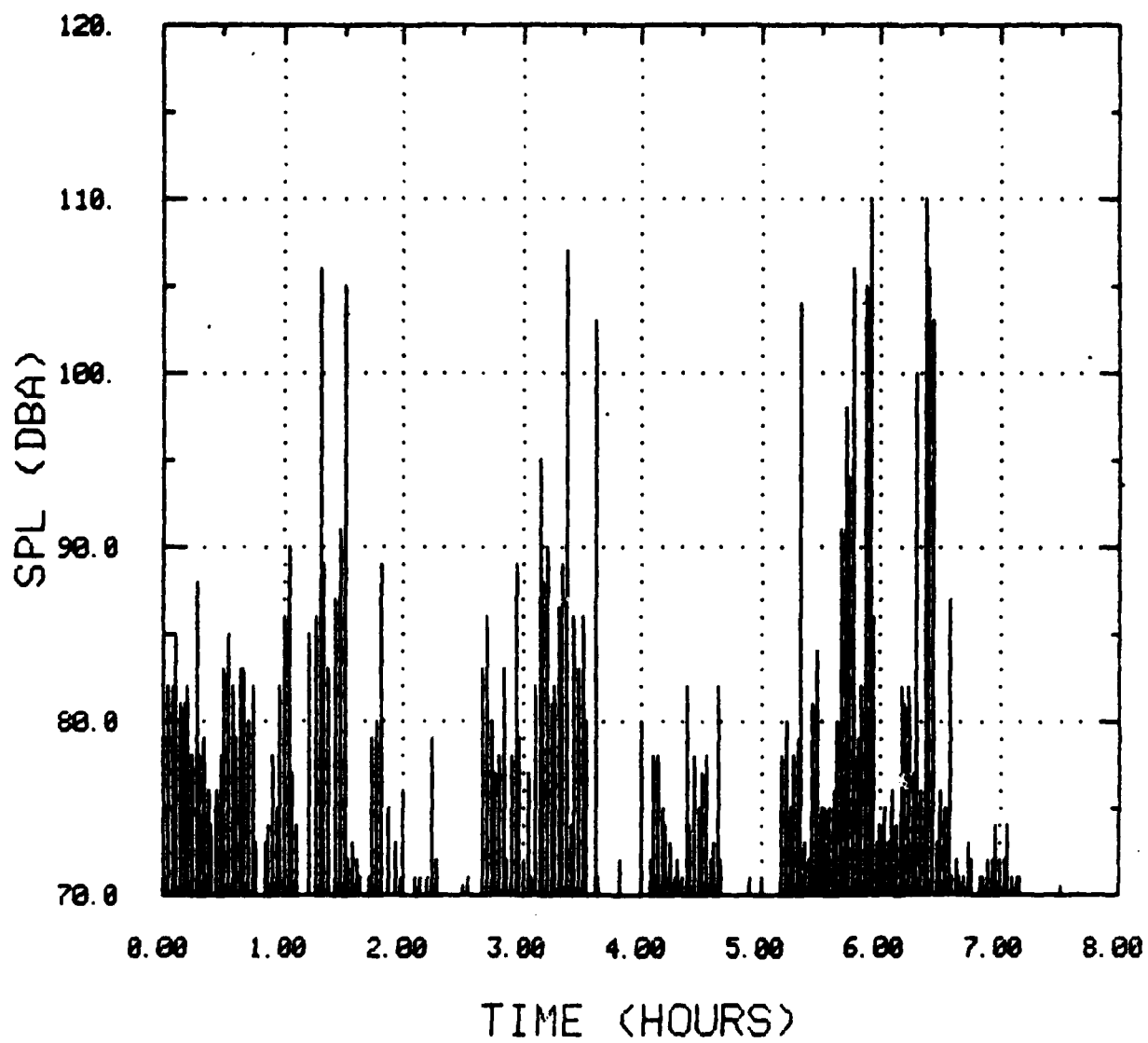
NOISE DOSIMETRY - SAMPLE 10



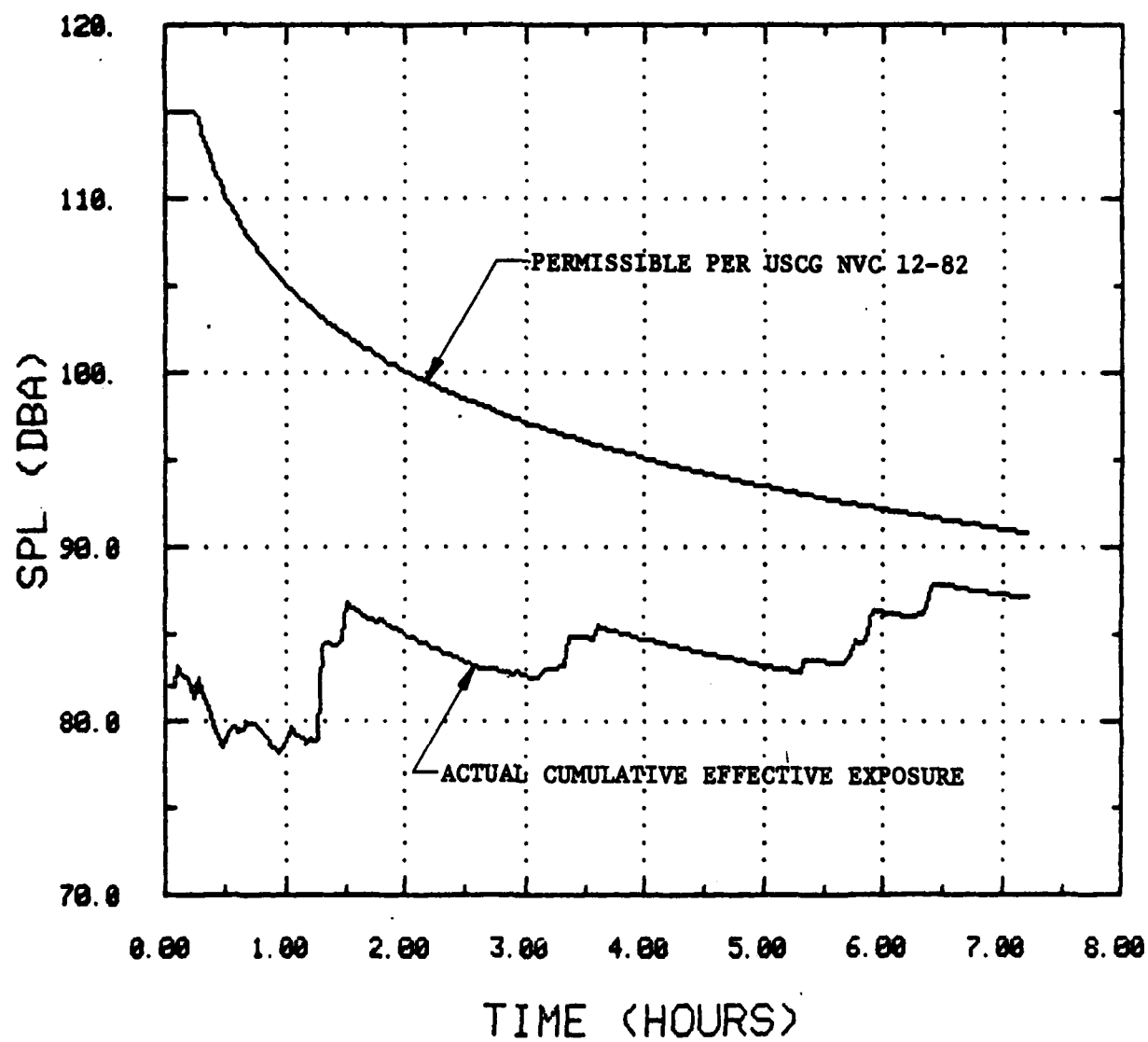
CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 9



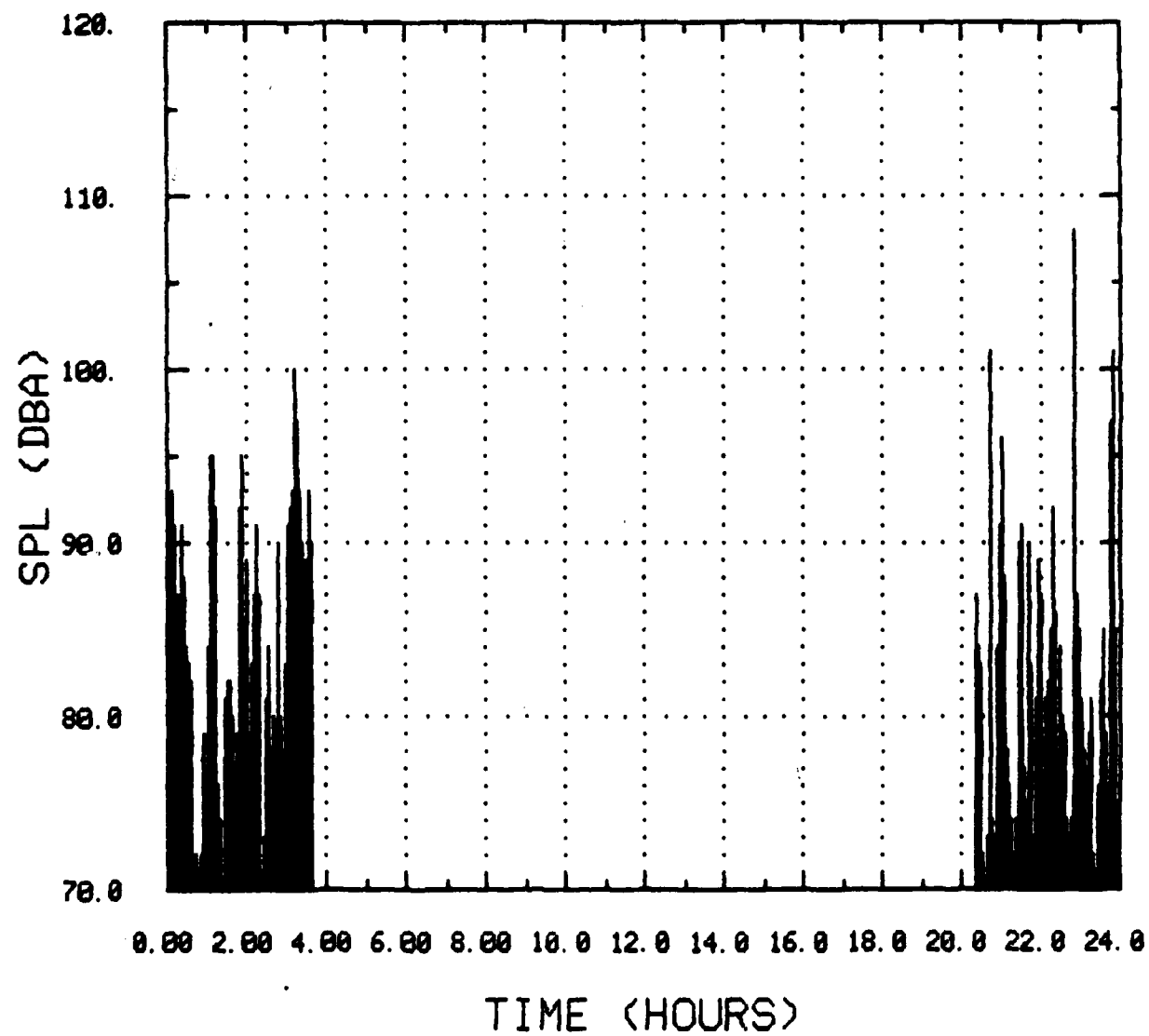




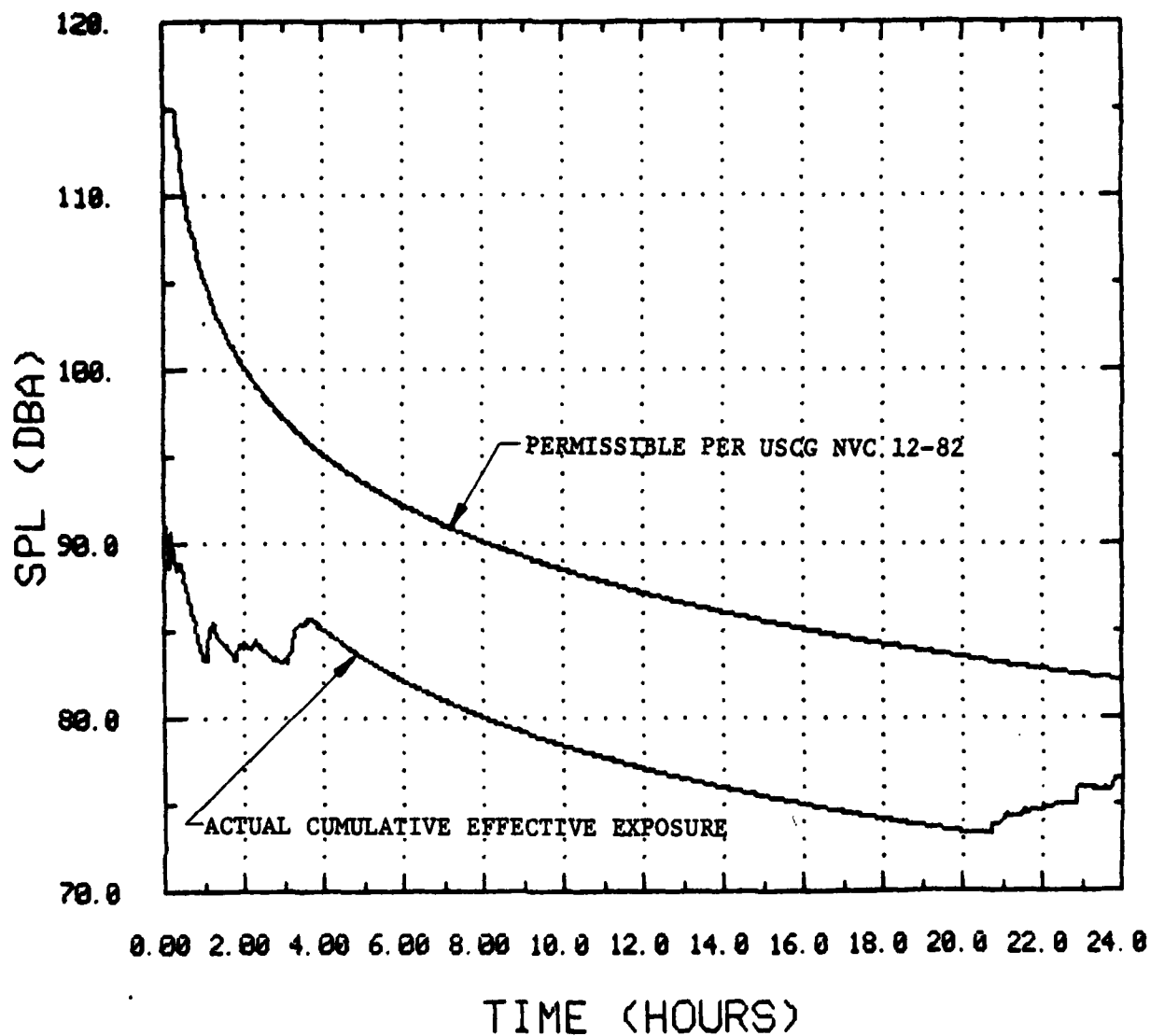
NOISE DOSIMETRY - SAMPLE 20



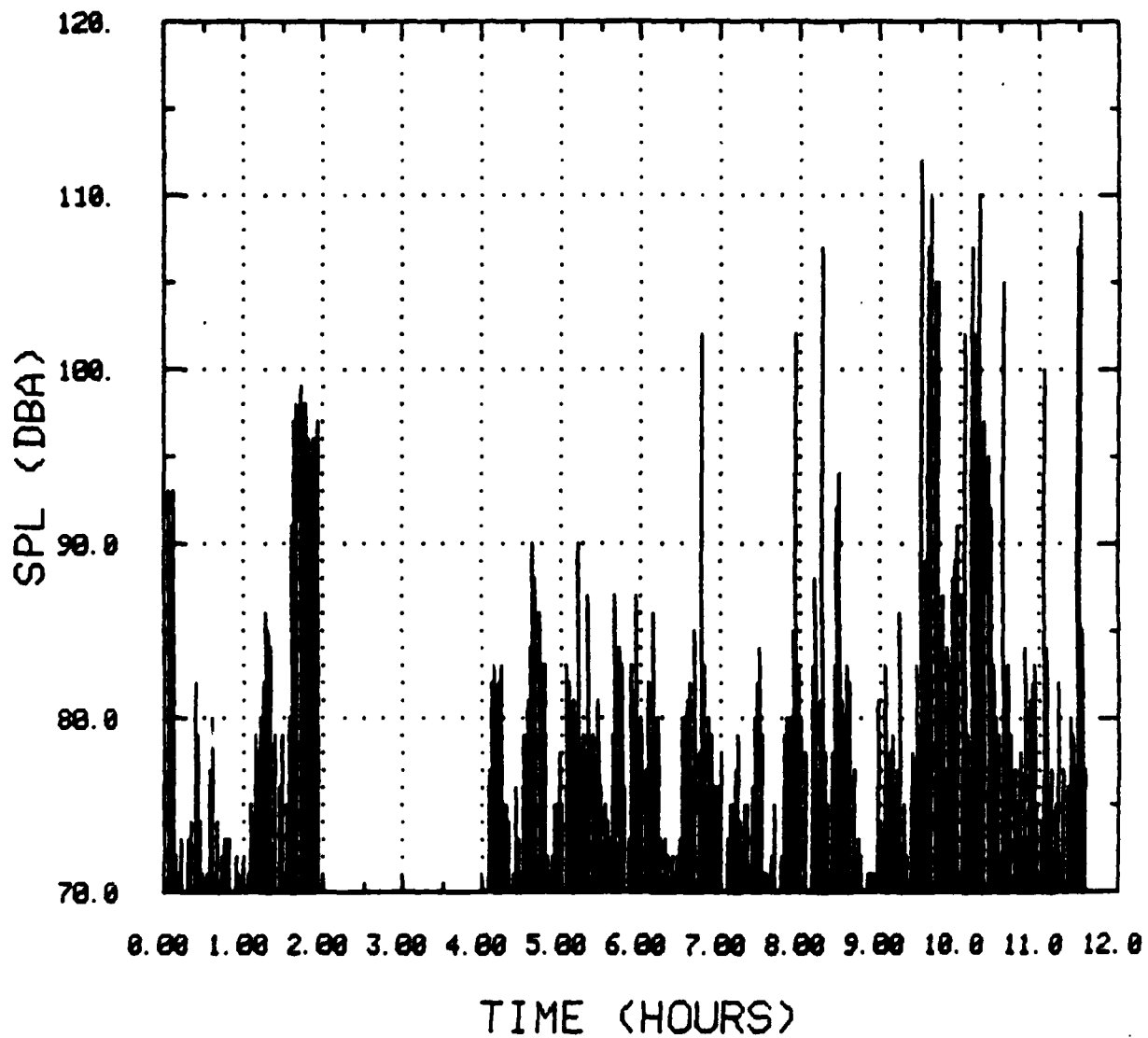
CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 20



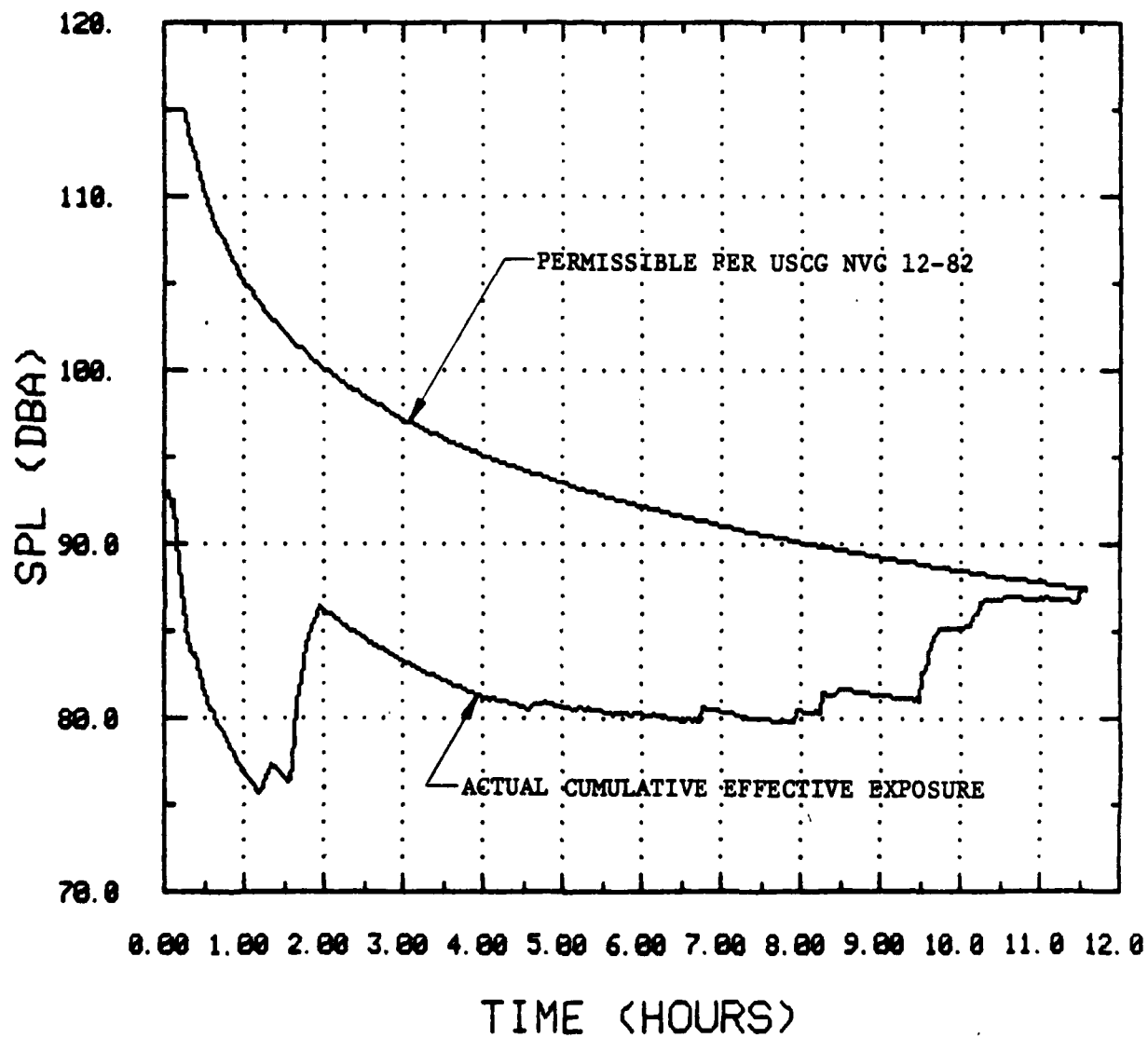
NOISE DOSIMETRY - 24 HOUR SAMPLE (SAMPLES 2 AND 7)



CUMULATIVE EFFECTIVE EXPOSURE - 24 HOUR SAMPLE (SAMPLES 2 AND 7)



NOISE DOSIMETRY - 12 HOUR SAMPLE (SAMPLES 5 AND 8)

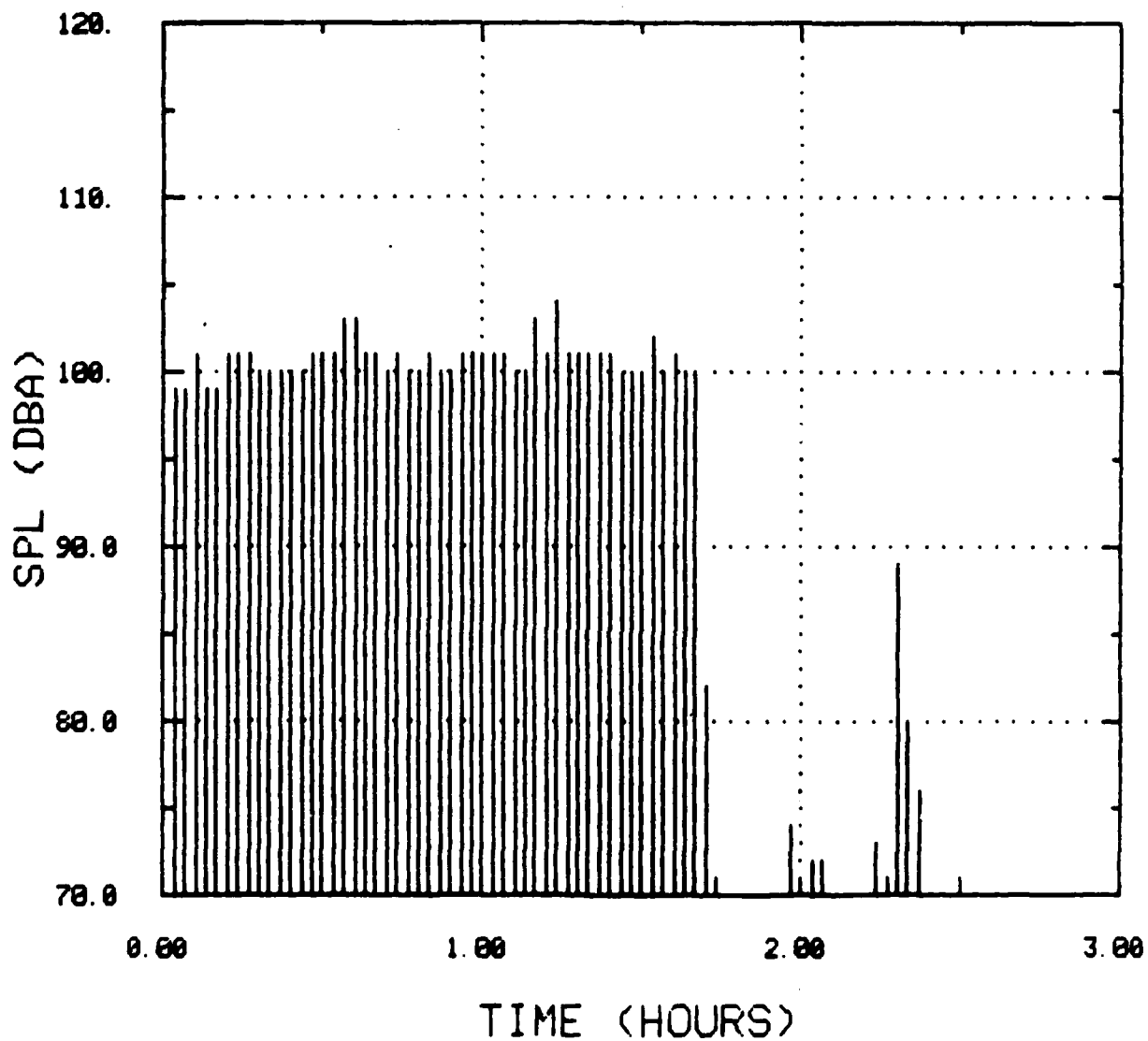


CUMULATIVE EFFECTIVE EXPOSURE - 12 HOUR SAMPLE (SAMPLES 5 AND 8)

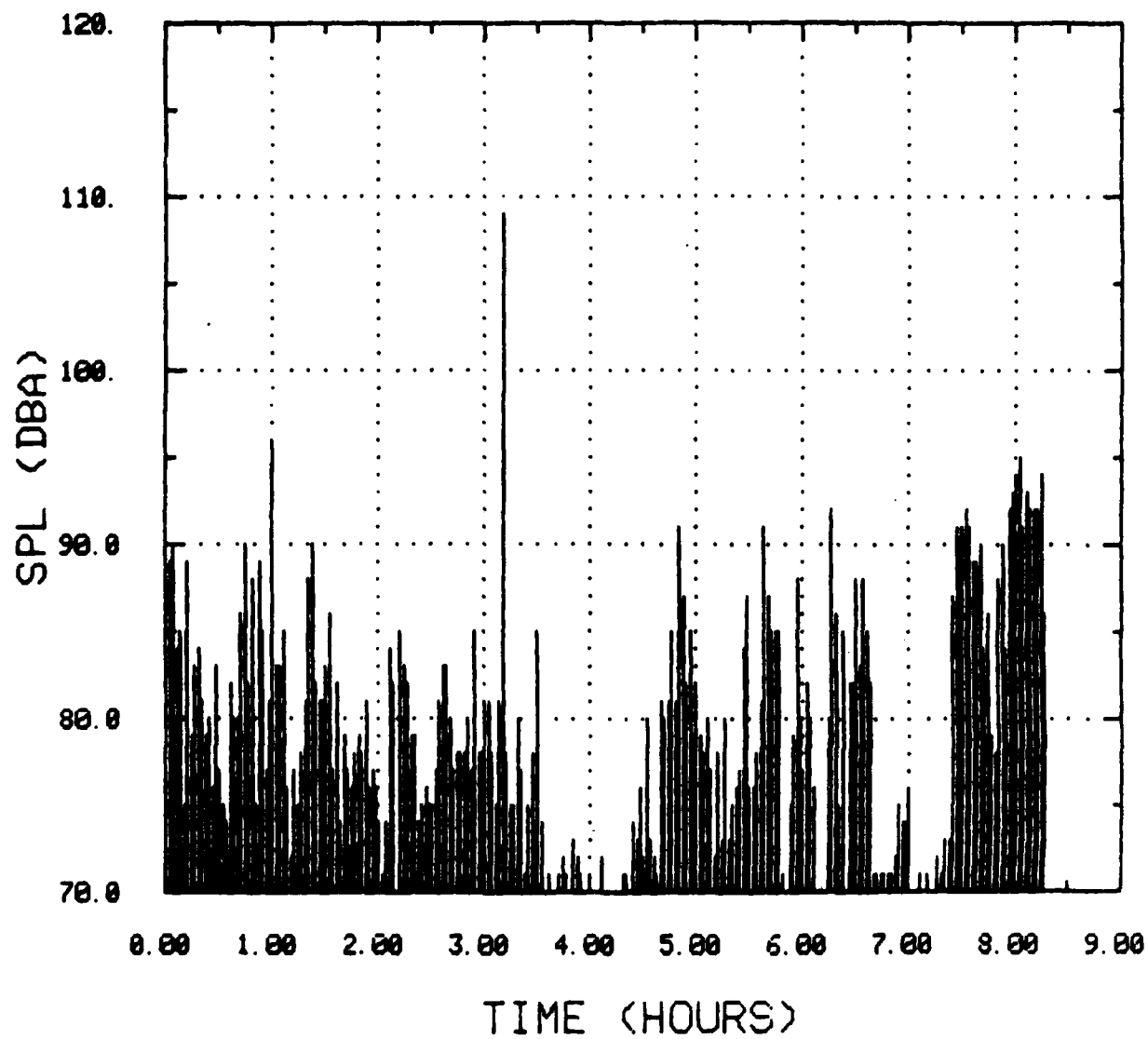
**APPENDIX F-2**

**NOISE DOSIMETRY DURING TANK PROCESSING**

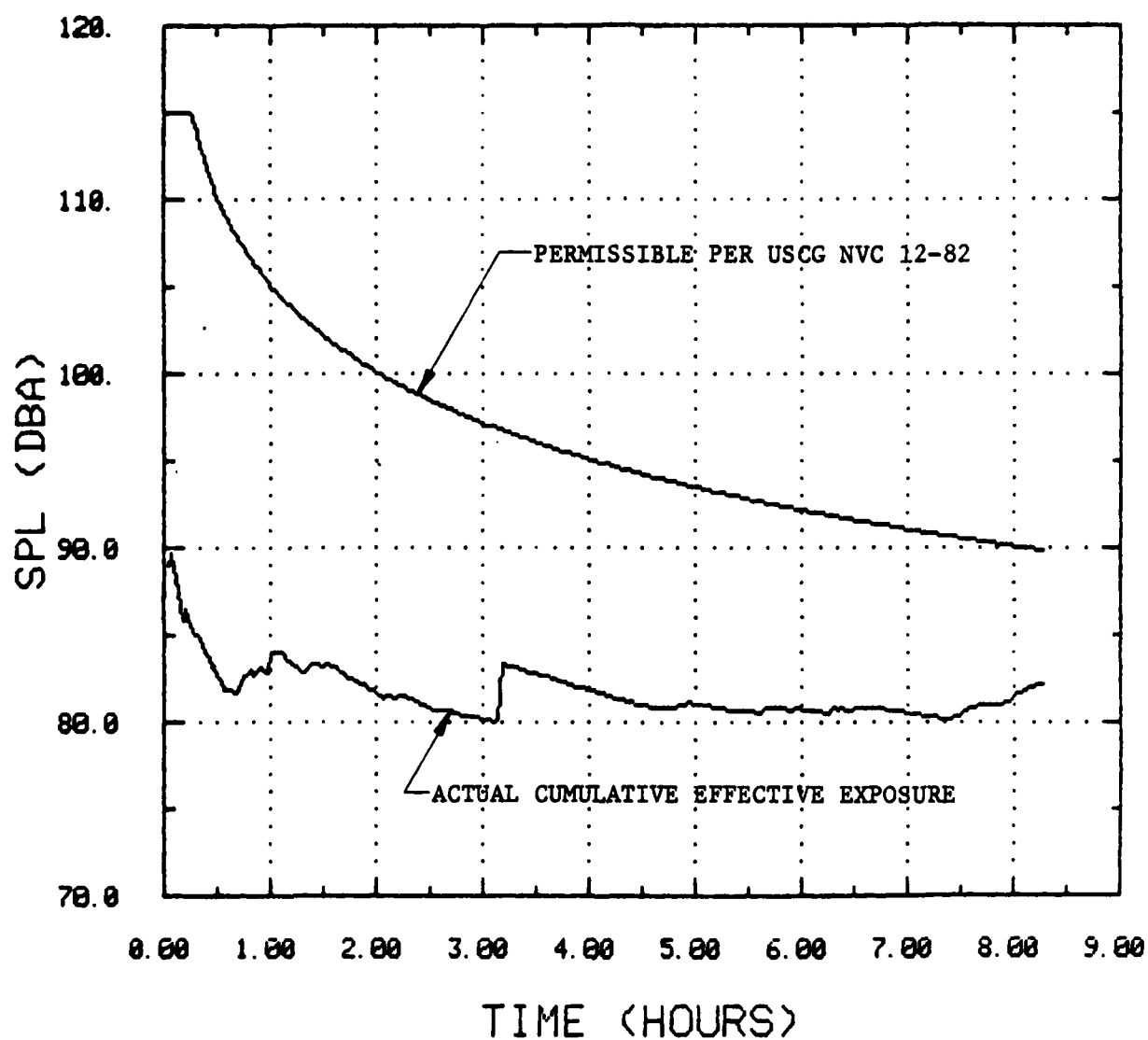




NOISE DOSIMETRY - SAMPLE 15

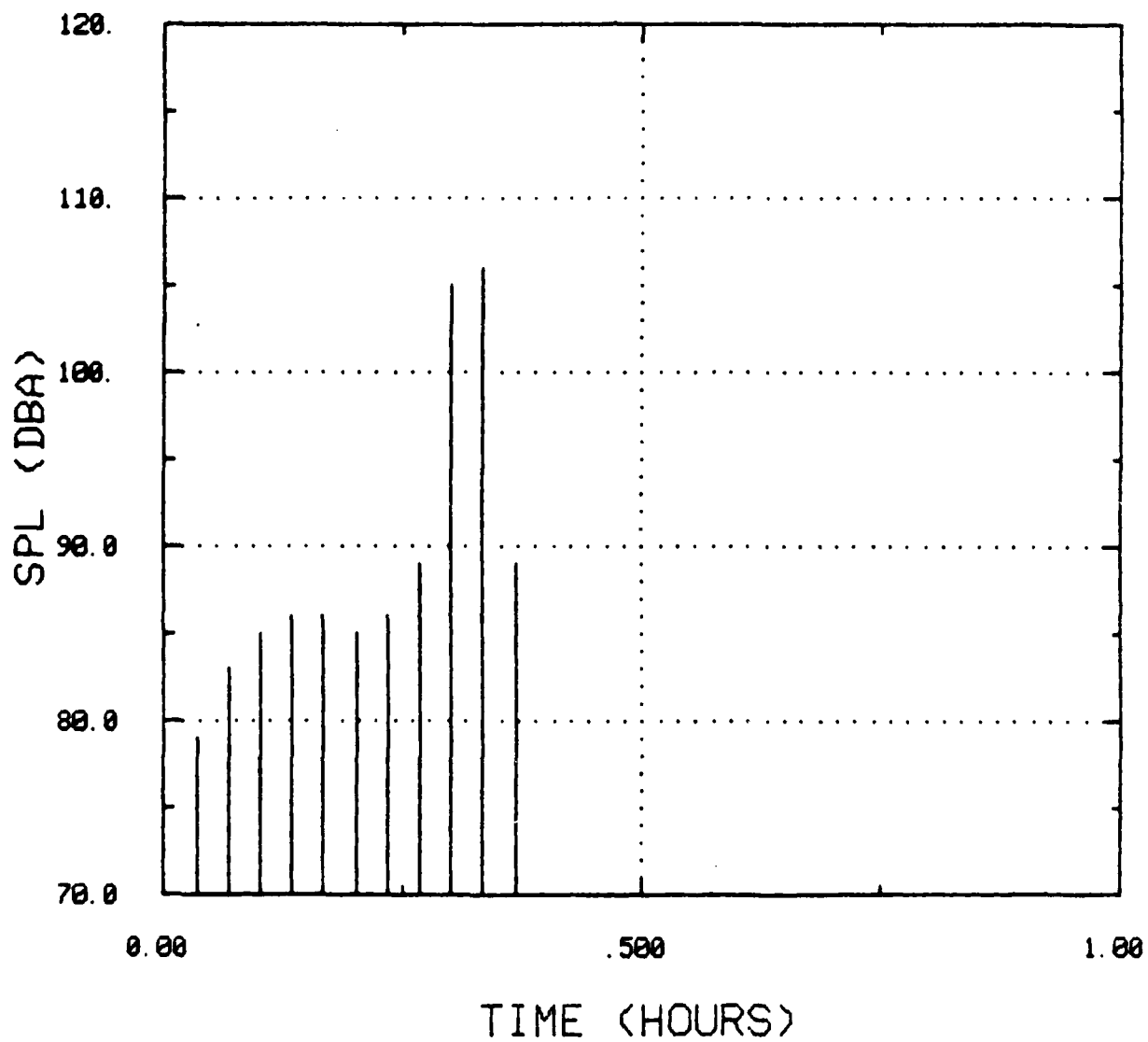


NOISE DOSIMETRY - SAMPLE 24

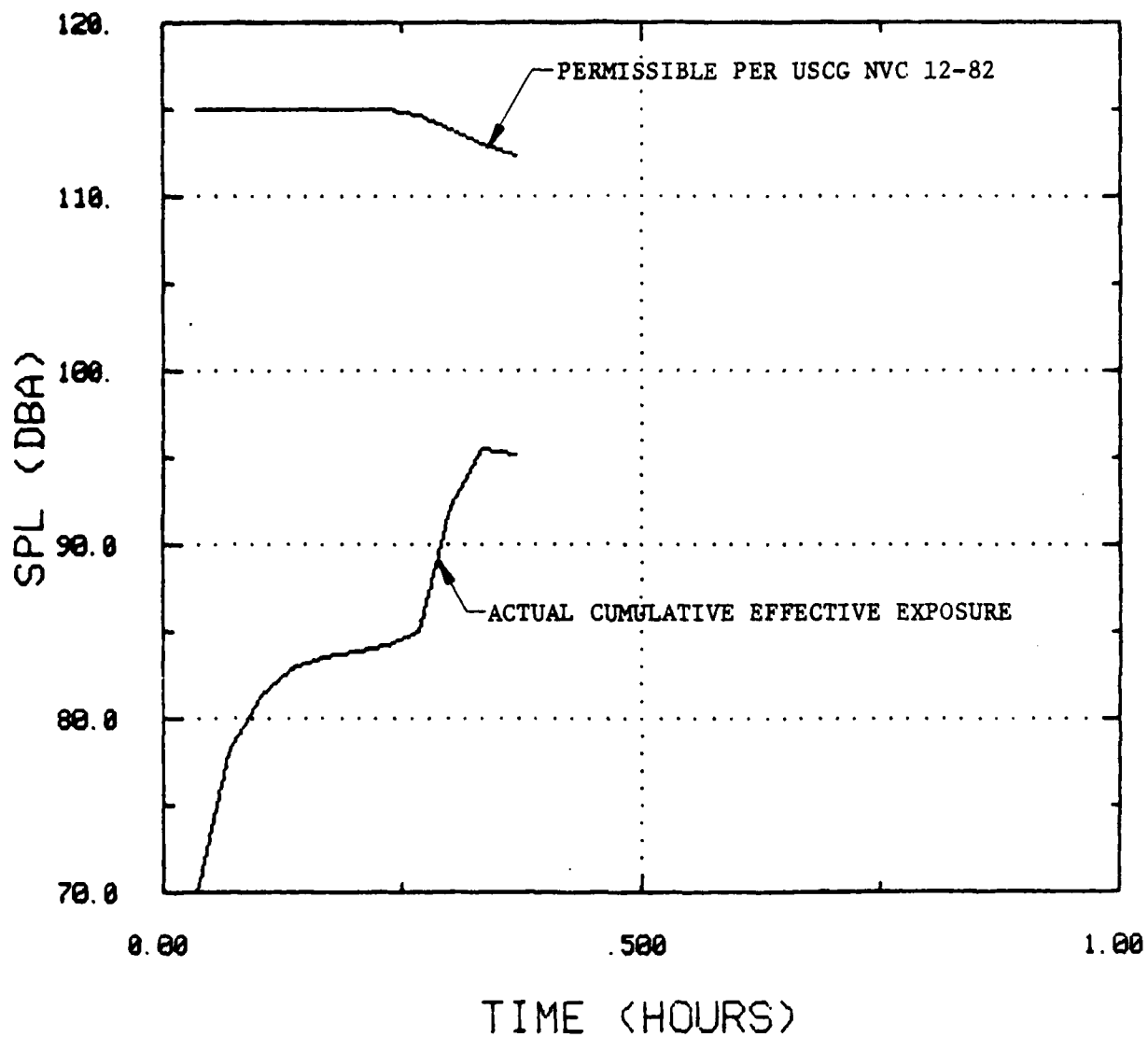


CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 24

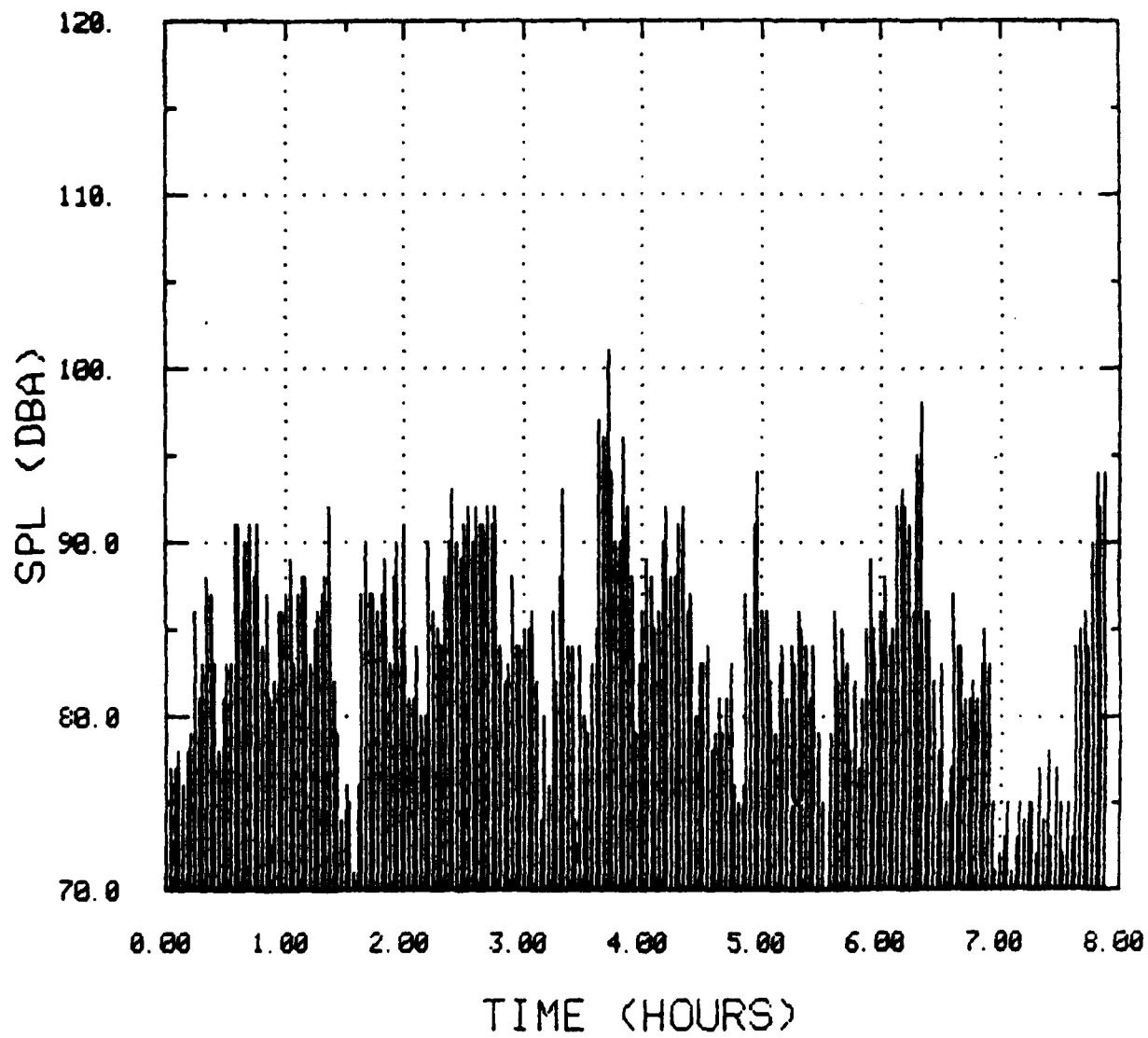
APPENDIX F-3  
NOISE DOSIMETRY DURING TANK ENTRIES



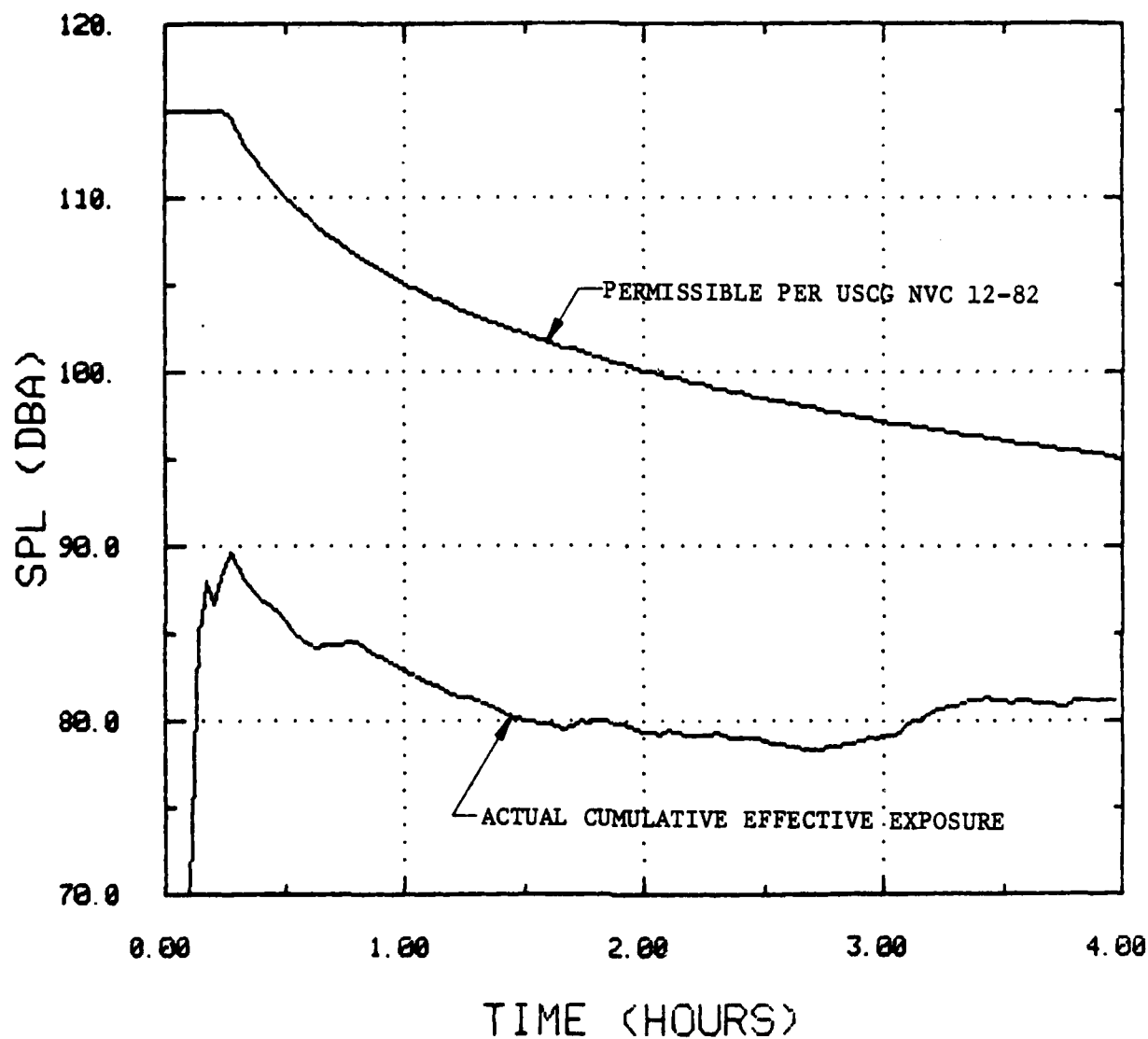
NOISE DOSIMETRY - SAMPLE 21



CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 21

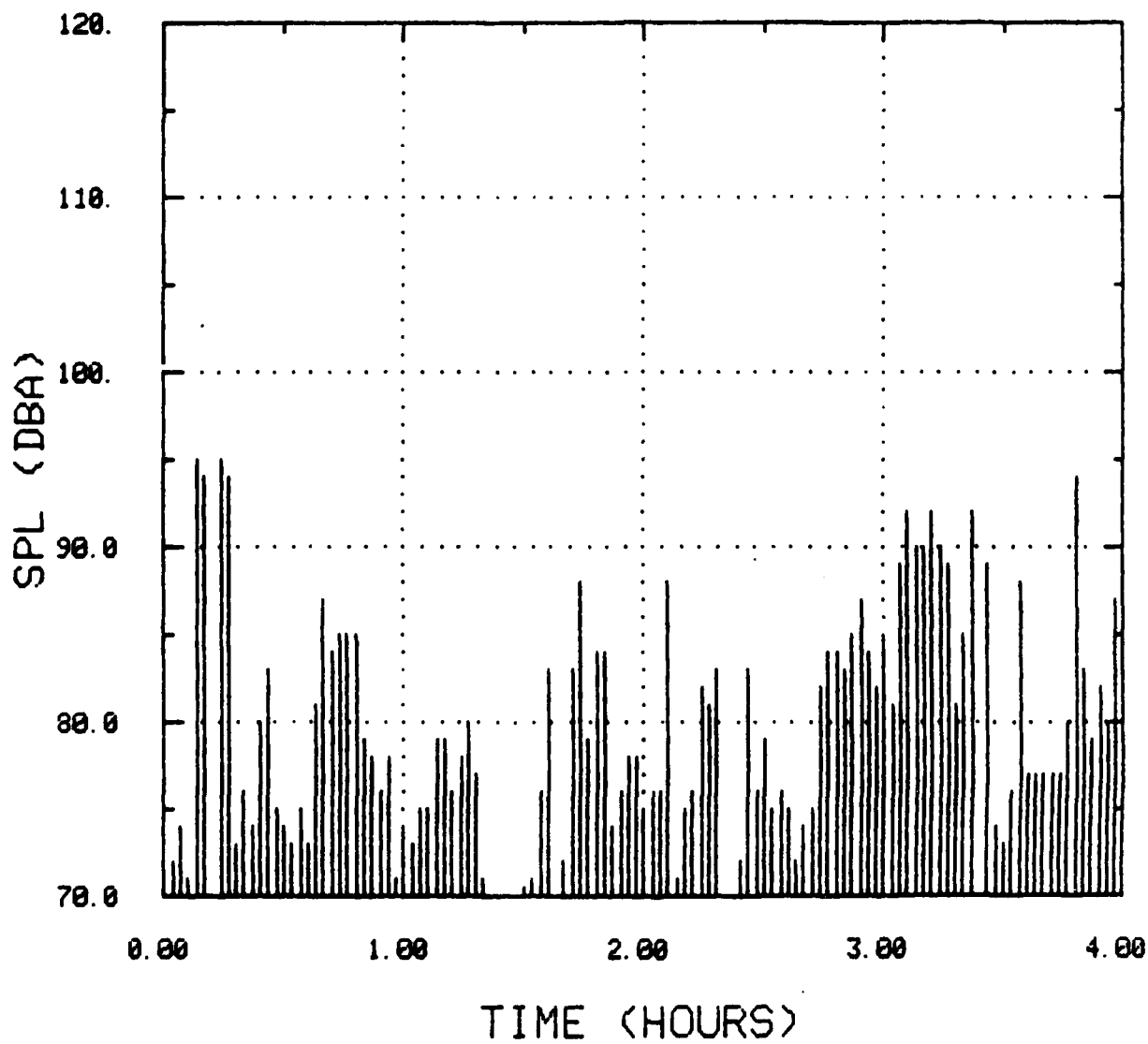


NOISE DOSIMETRY - SAMPLE 28

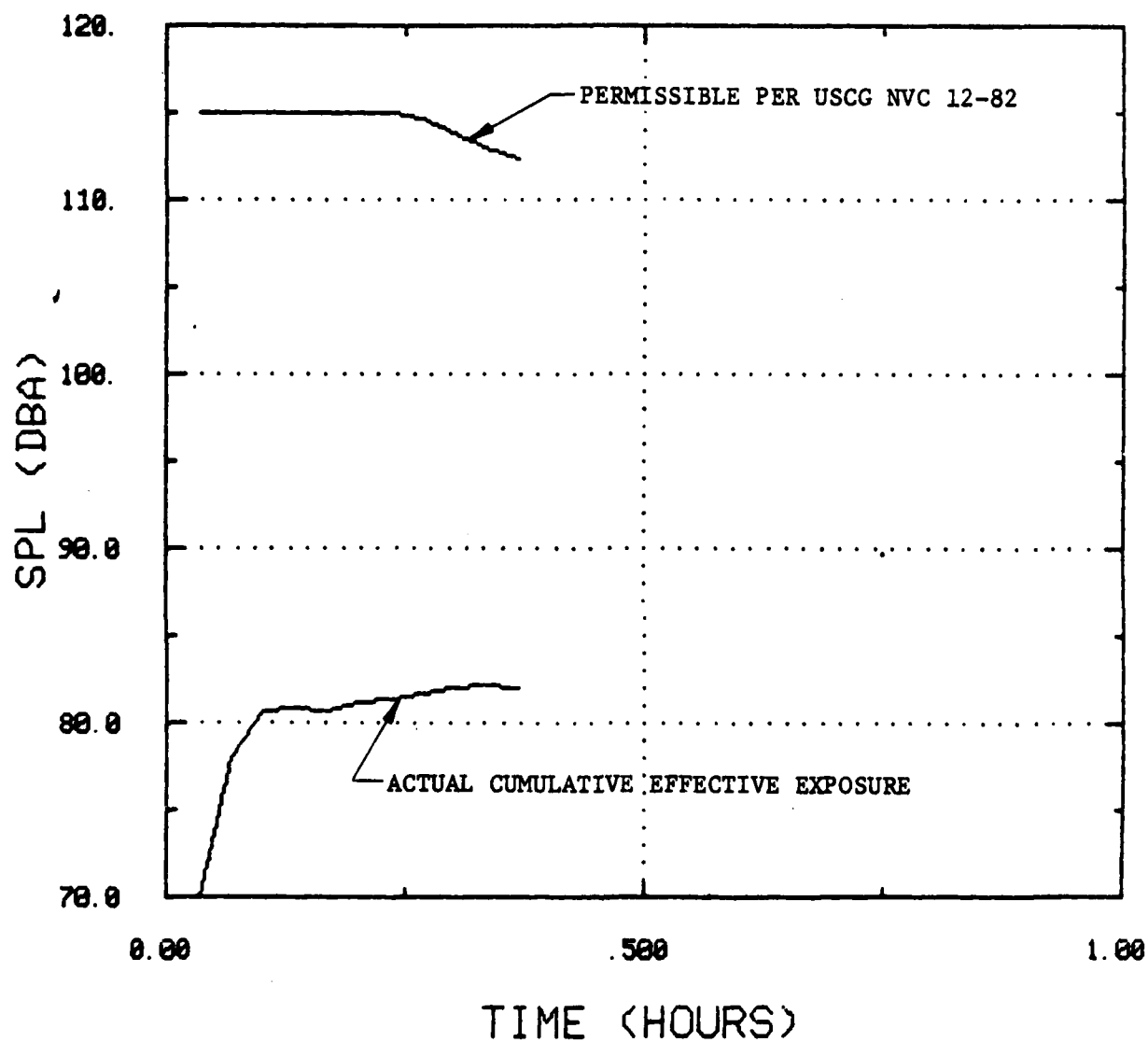


CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 27

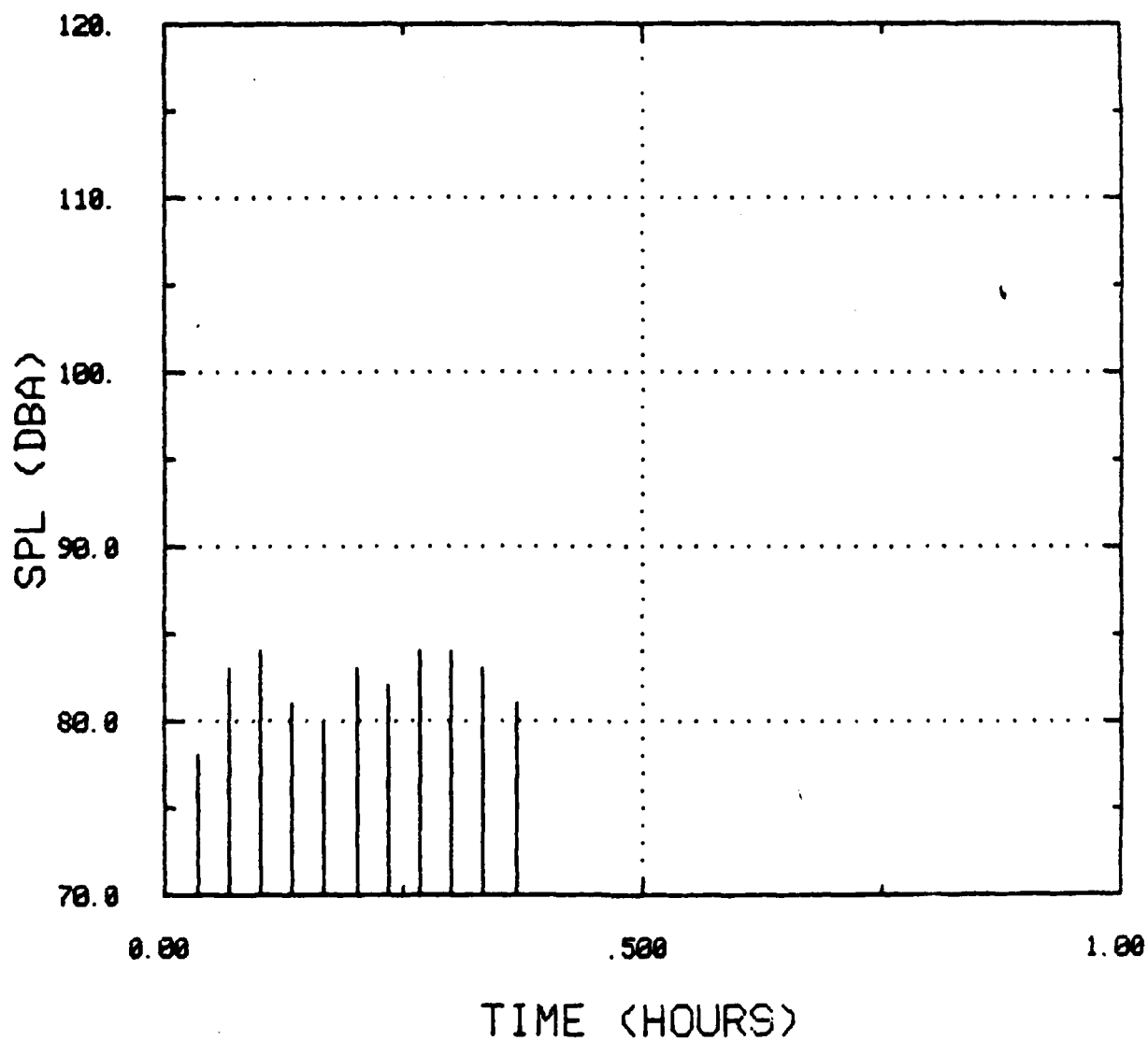




NOISE DOSIMETRY - SAMPLE 27

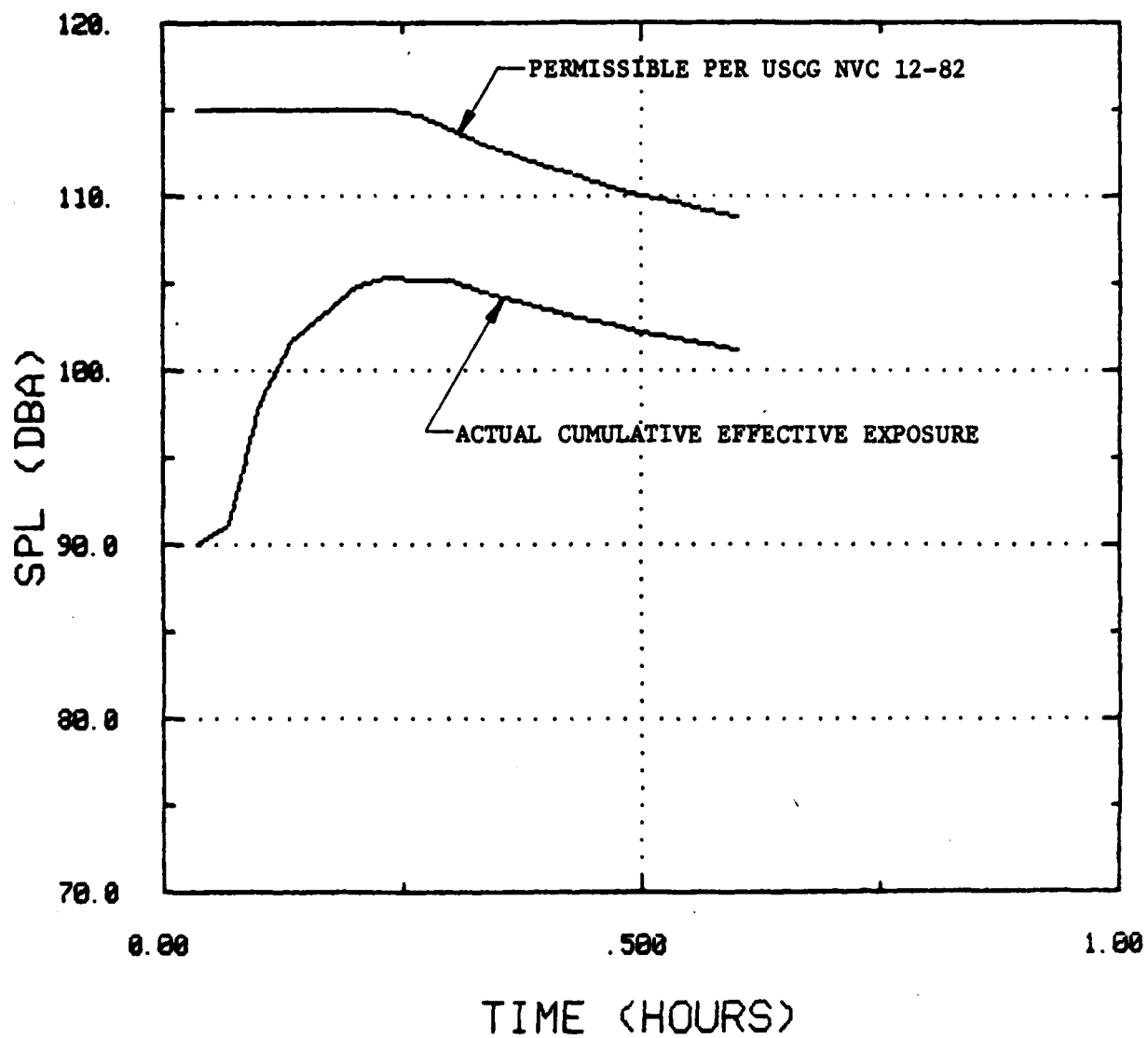


CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 18

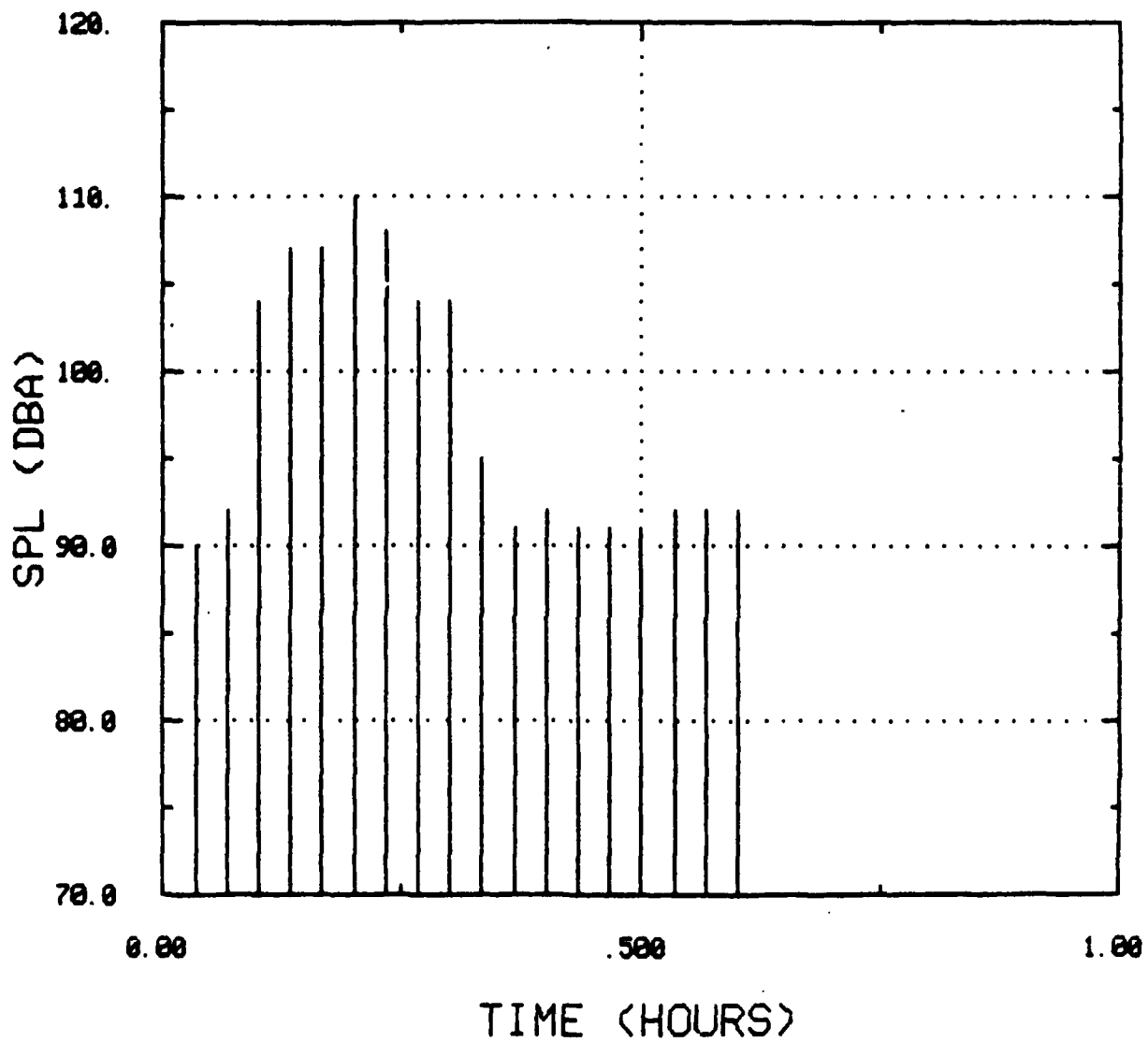


NOISE DOSIMETRY - SAMPLE 18

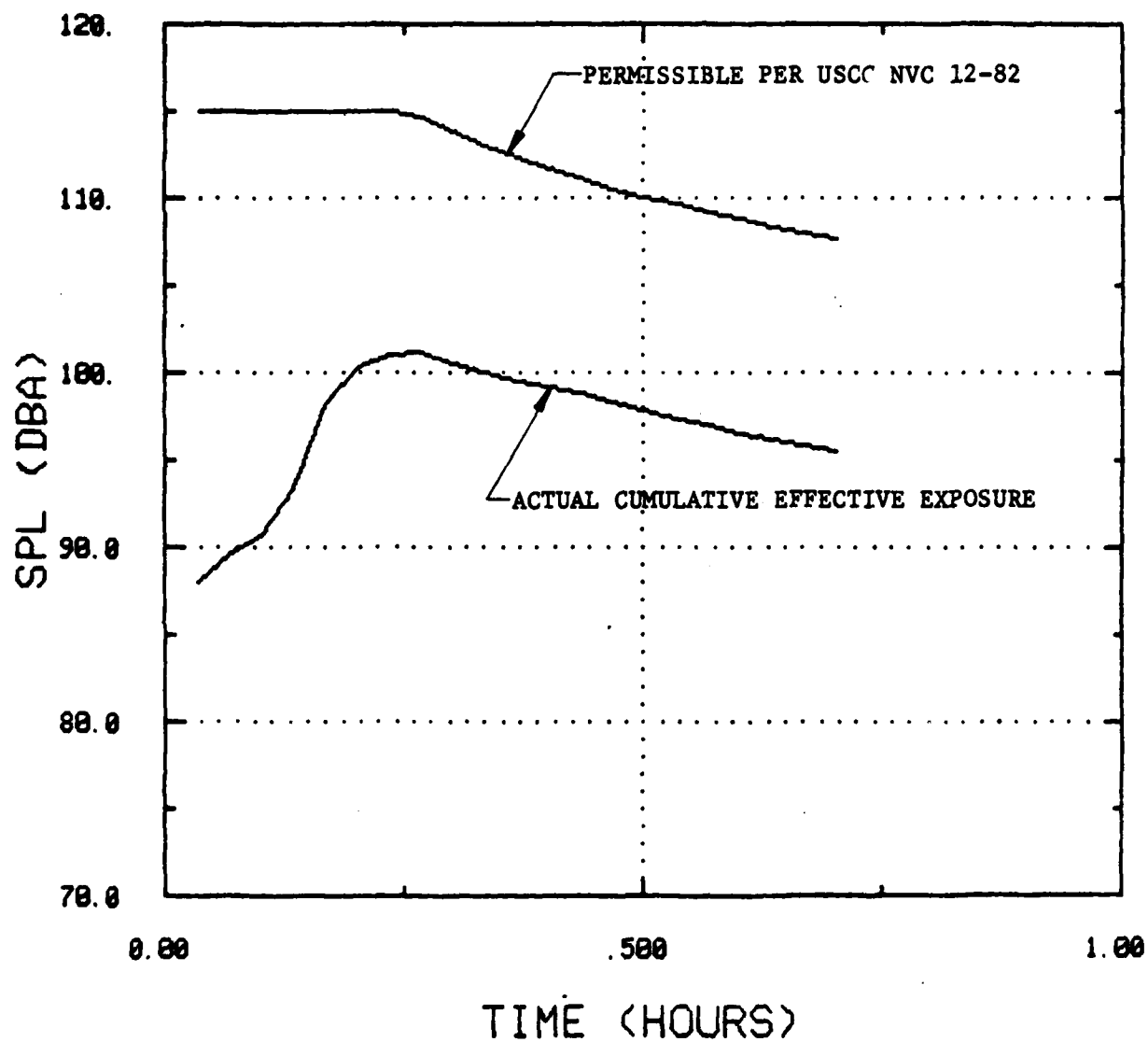
APPENDIX F-4  
NOISE DOSIMETRY DURING PRODUCT LOADING



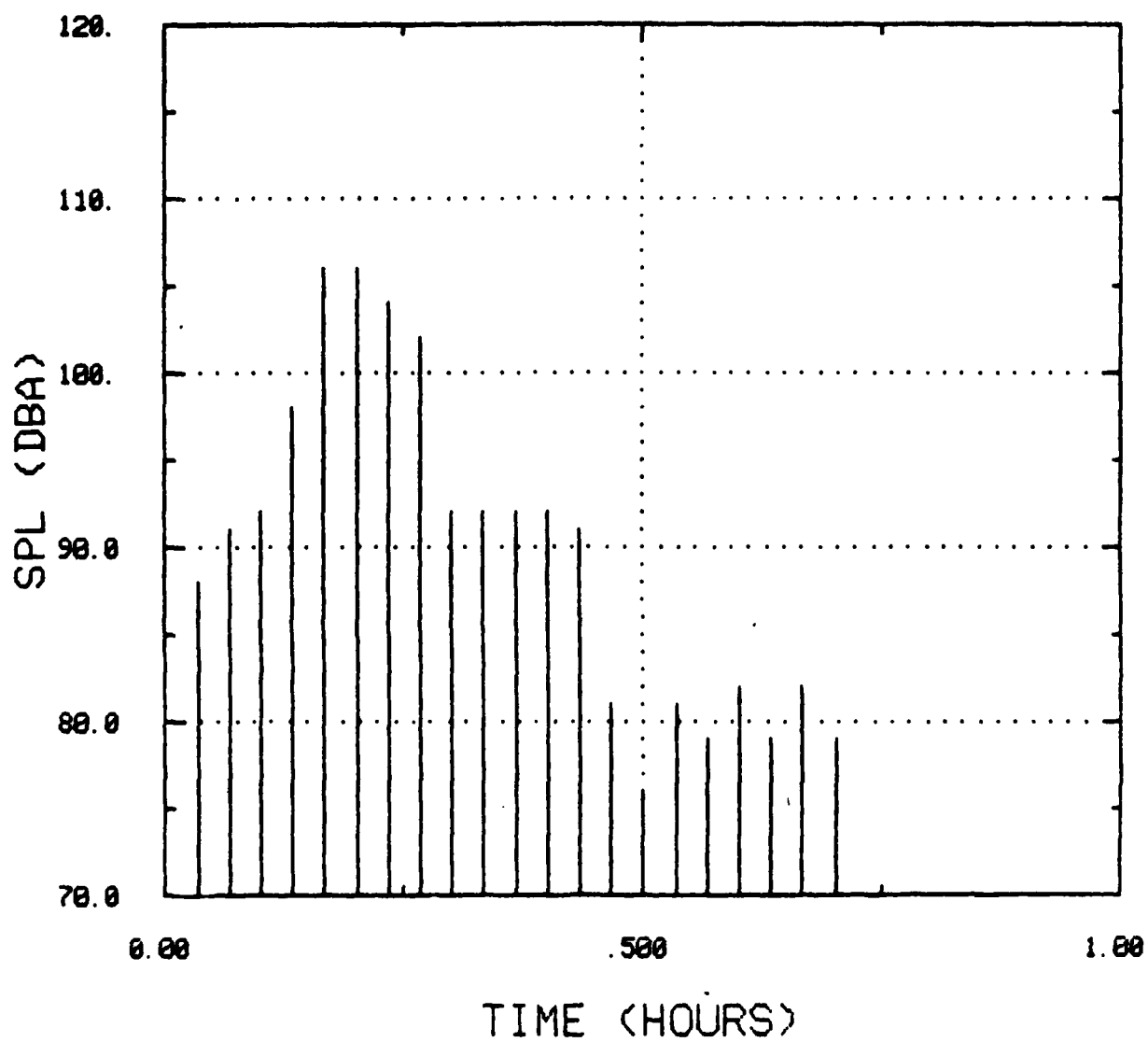
CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 26



NOISE DOSIMETRY - SAMPLE 26

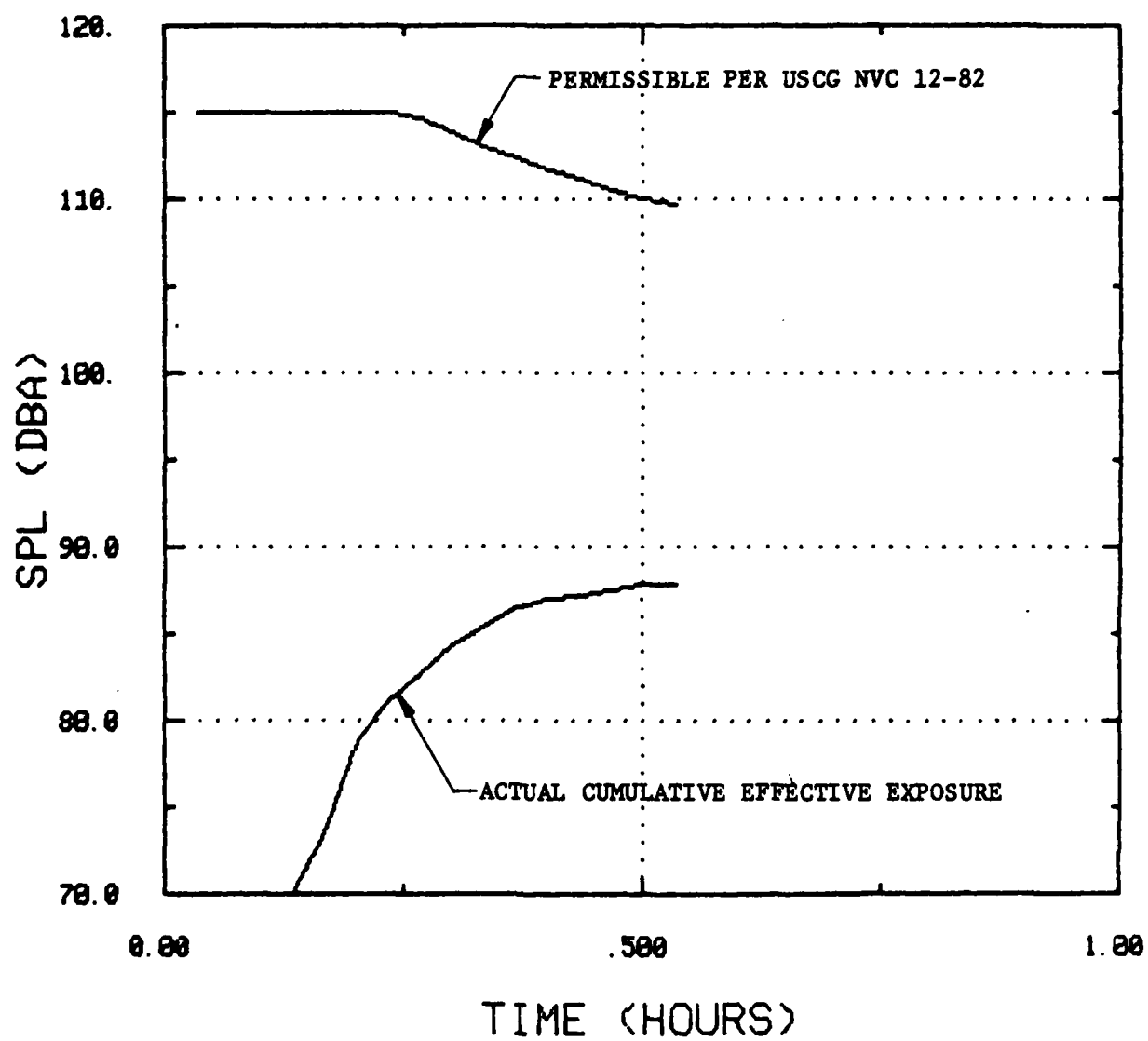


CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 25

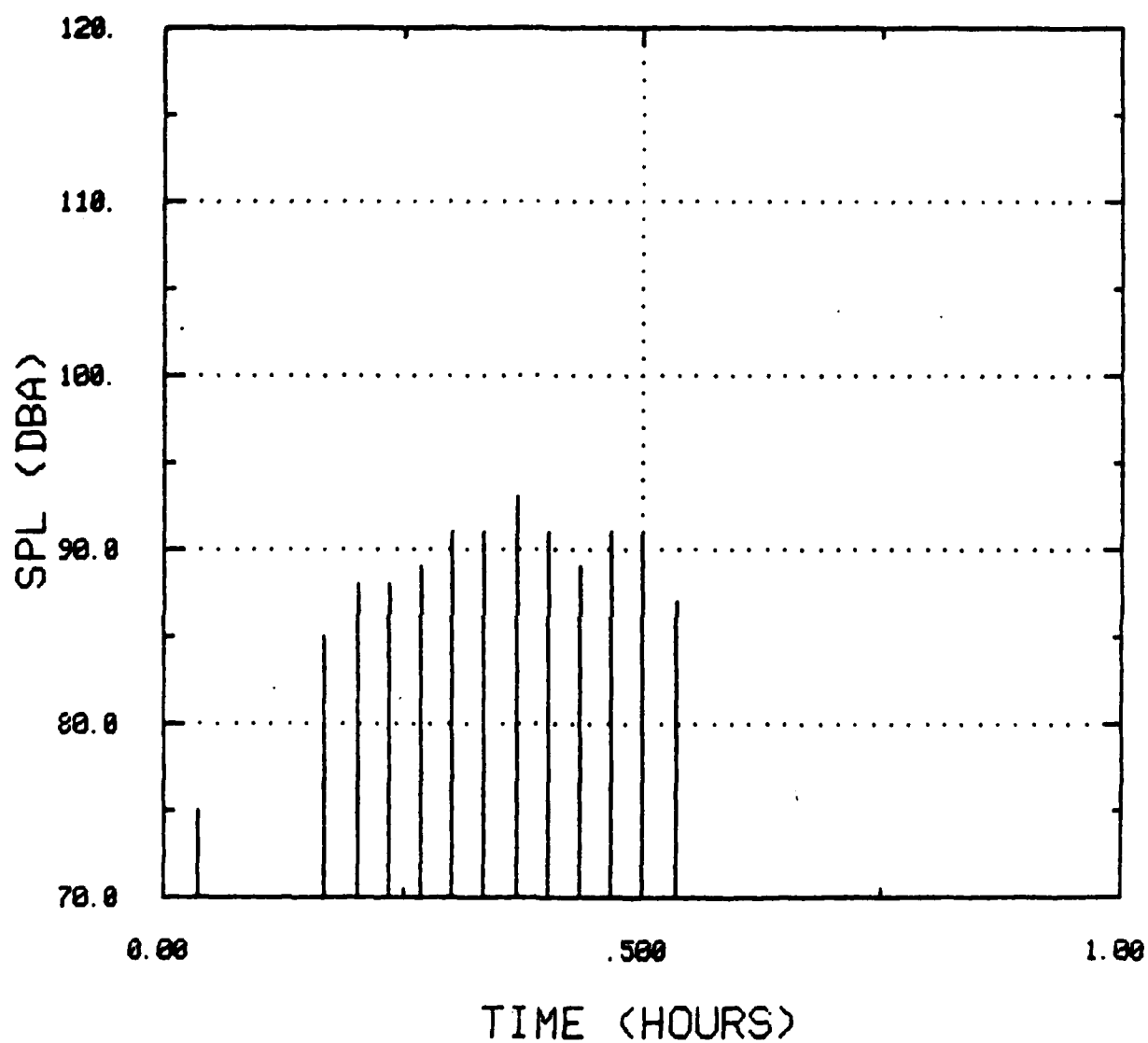


NOISE DOSIMETRY - SAMPLE 25

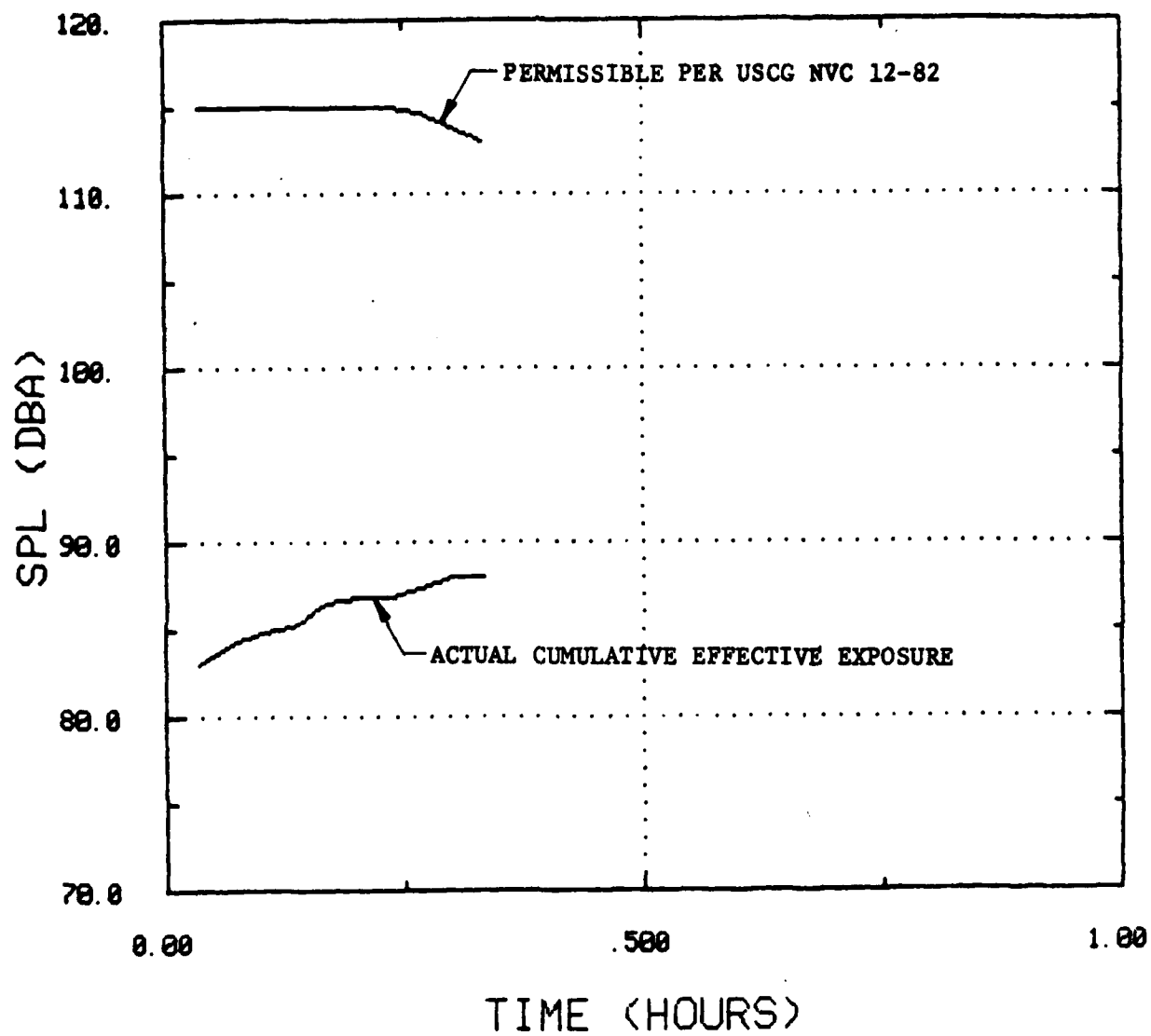




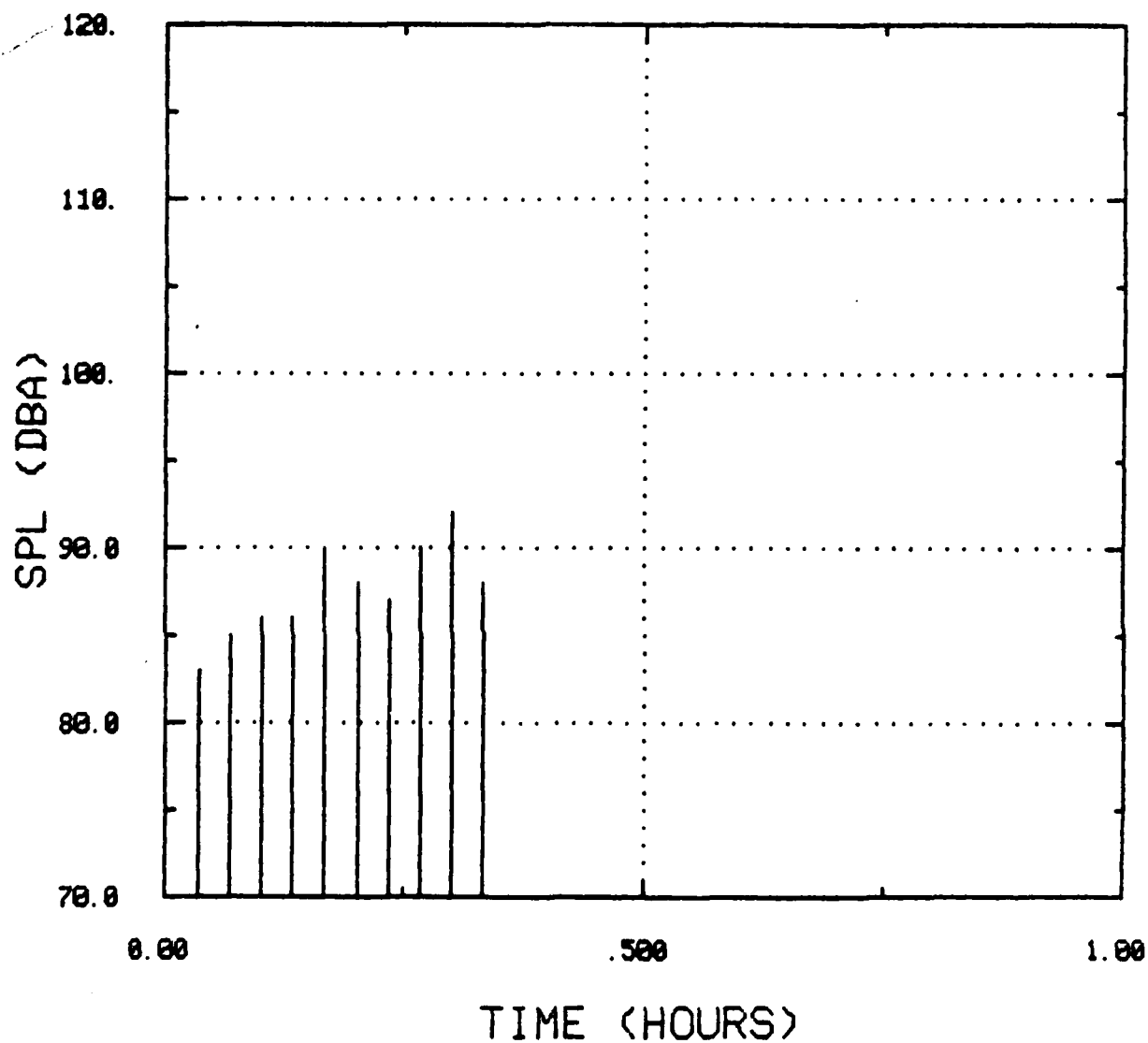
CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 23



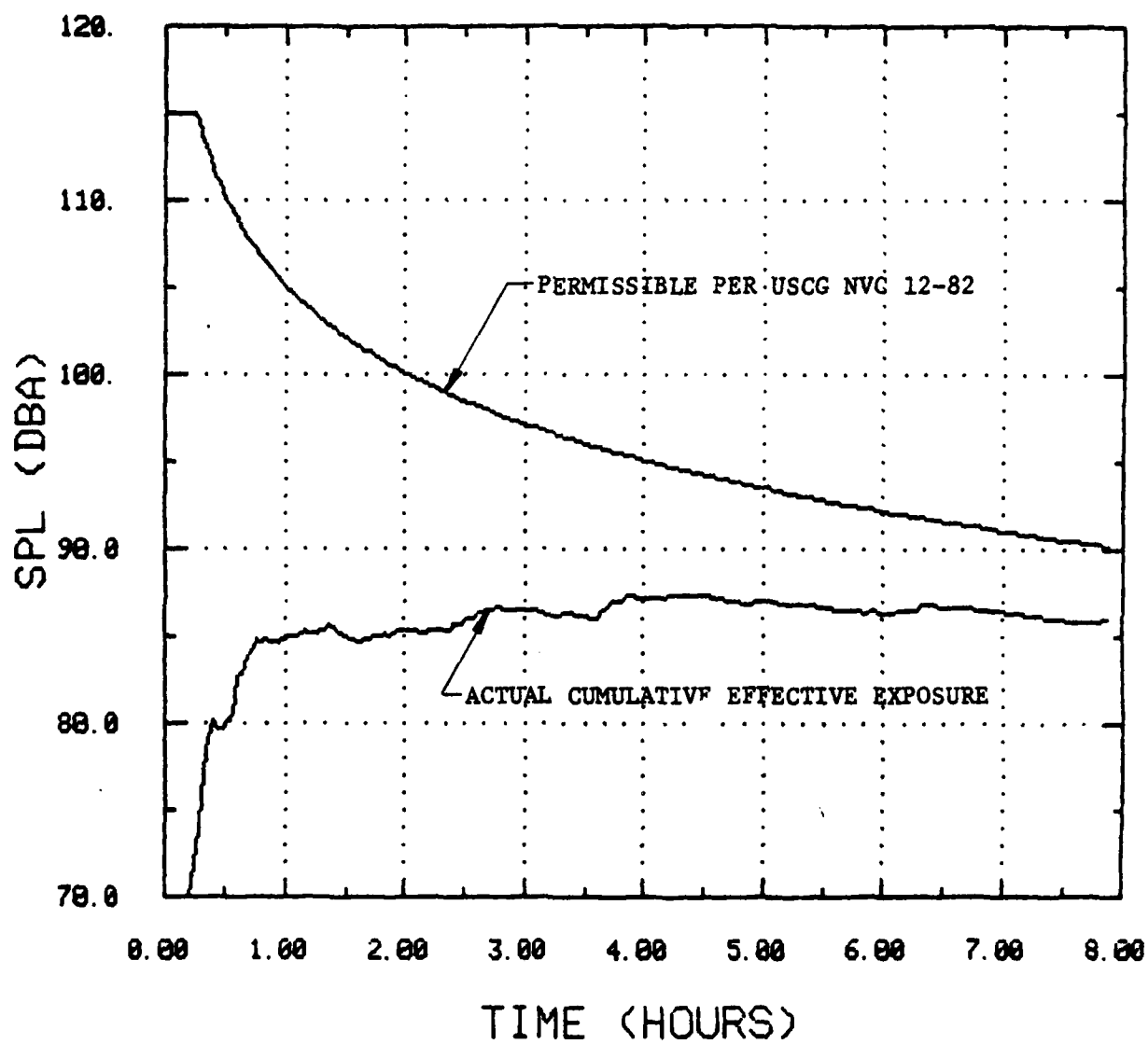
NOISE DOSIMETRY - SAMPLE 23



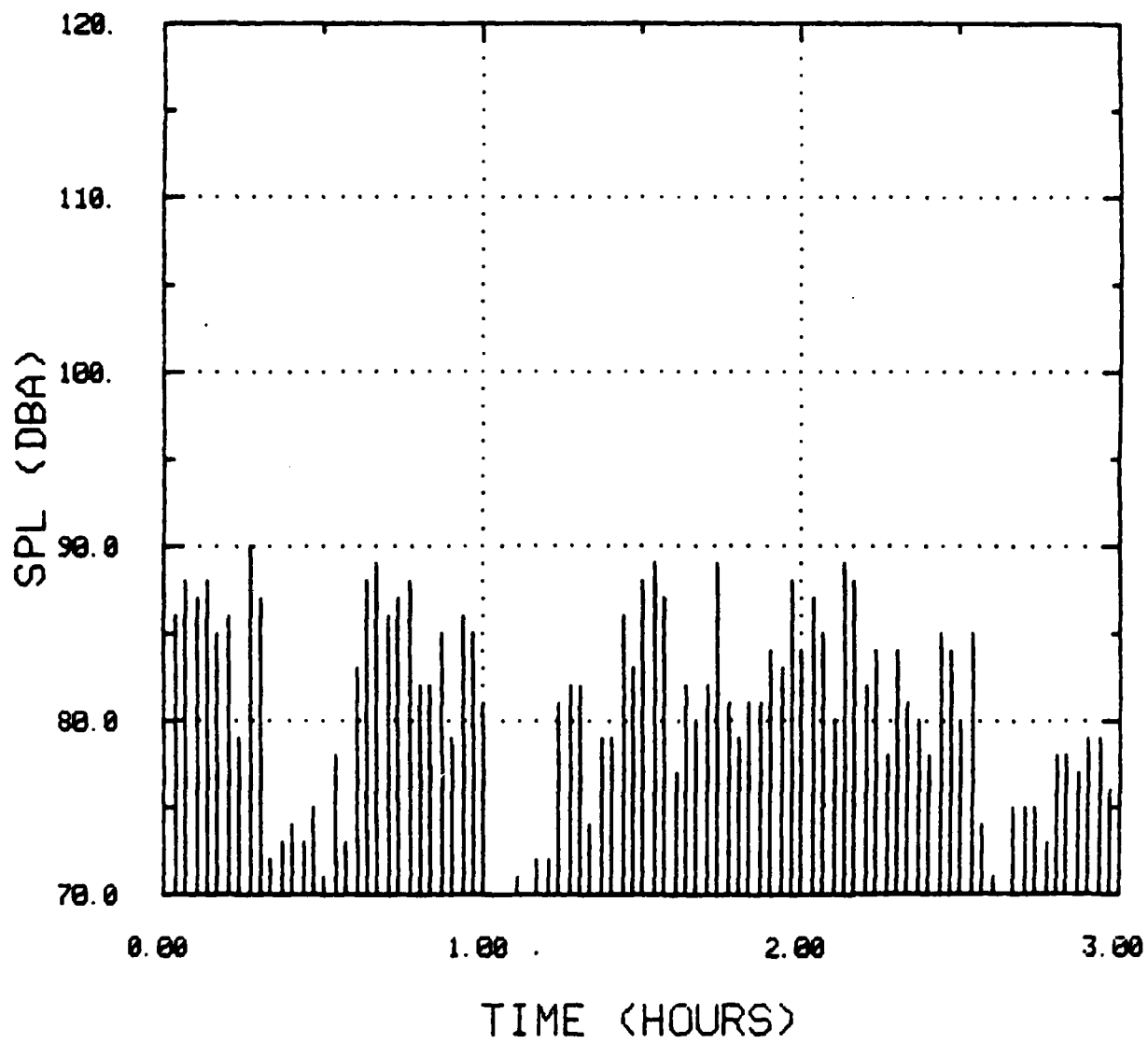
CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 22



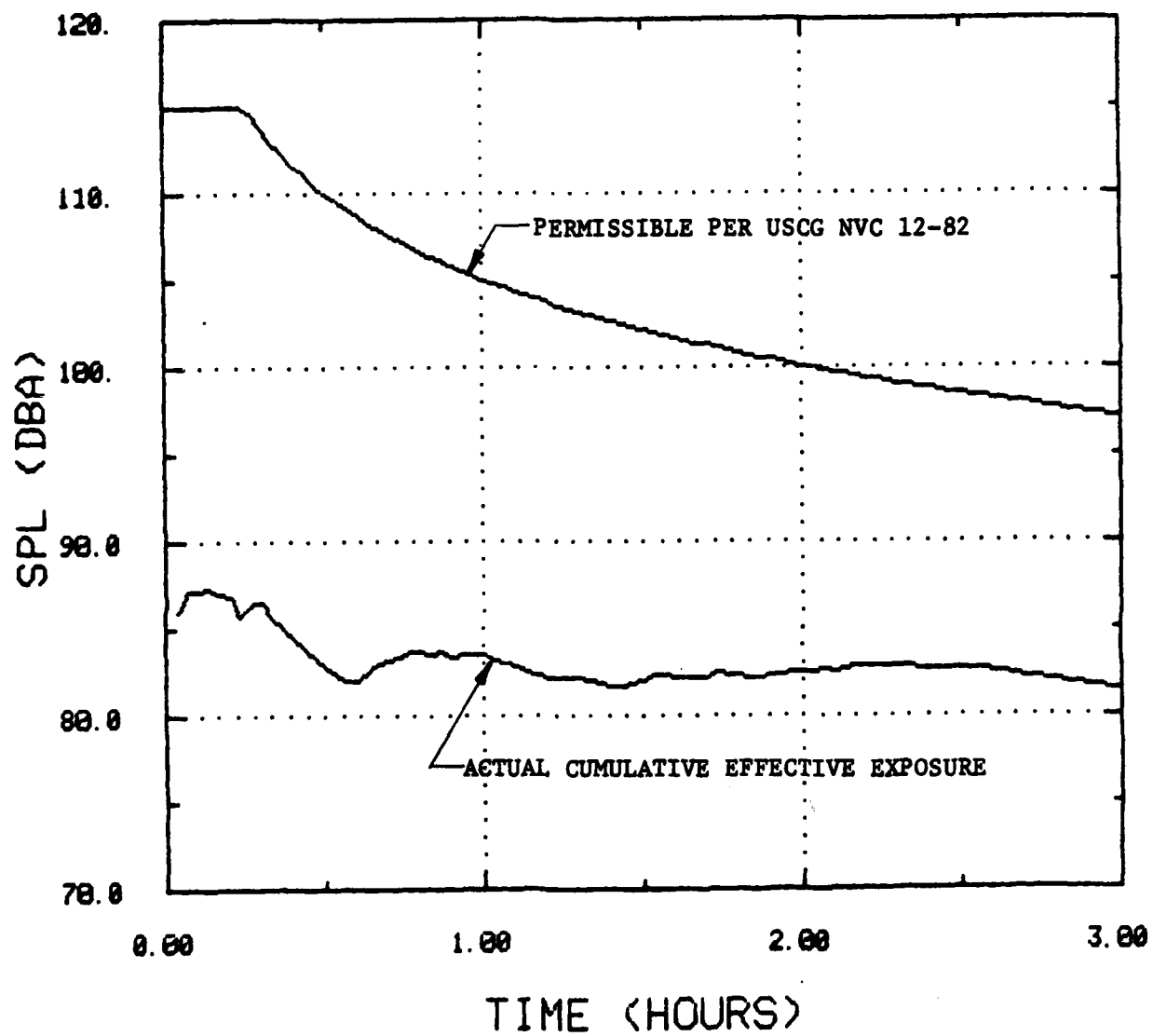
NOISE DOSIMETRY - SAMPLE 22



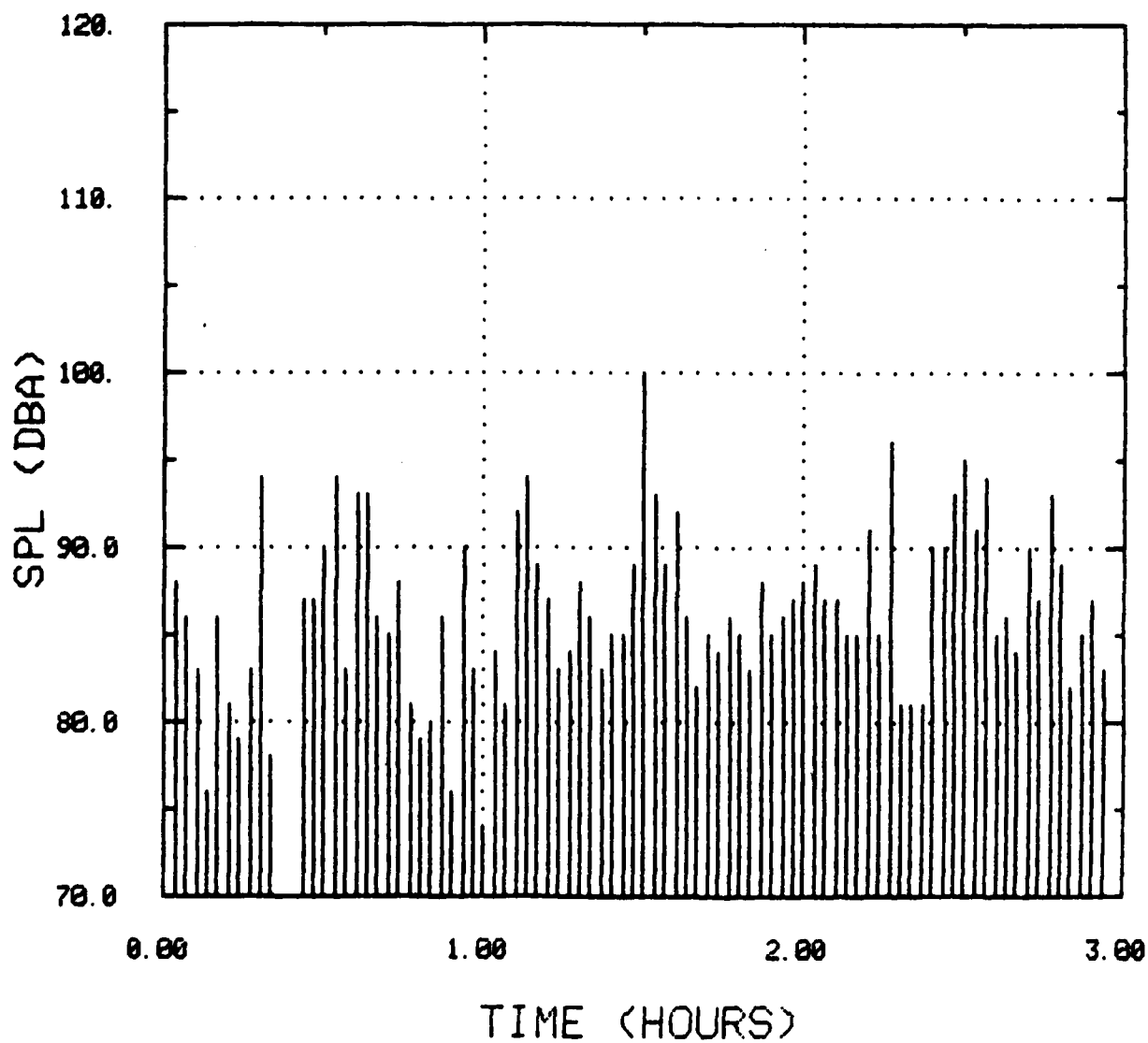
CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 28



NOISE DOSIMETRY - SAMPLE 29

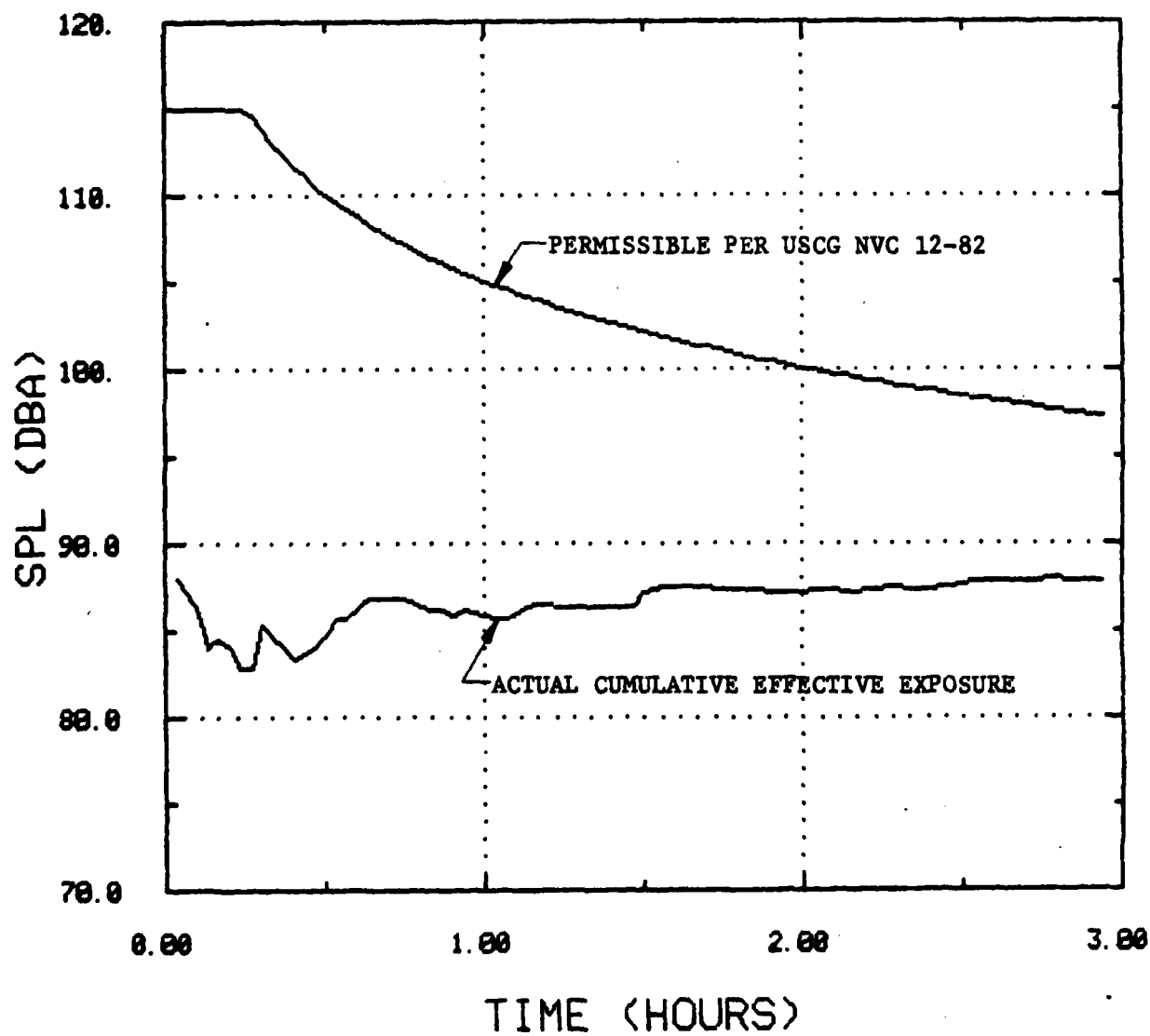


CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 29



NOISE DOSIMETRY - SAMPLE 30





CUMULATIVE EFFECTIVE EXPOSURE - SAMPLE 30

**END**

**FILMED**

**9-85**

**DTIC**