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A CREW EXPOSURE STUDY —— PHASE II
VOLUME I —— OFFSHORE

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FINAL REPORT

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16. Abstract

The objective of this project was to implement the Phase I test plan for characterizing occupational exposures of offshore facility workers to chemical substances and selected physical agents. This report documents the measurement and monitoring data that were collected during a 7-day period on drilling and production facilities. Respirable and total dust/fume exposures were monitored during mud makeup operations, welding and rust/paint chipping. Sound pressure level contour maps were generated for seven platforms and two rigs. Personal noise dosimetry data were collected during drilling and tripping, addition of drilling fluid chemicals and maintenance/repair activities. Occupational exposures to dusts and fumes were evaluated relative to ACGIH exposure limits. Noise dosimetry data were interpreted relative to the exposure guidelines in USCG Navigation and Vessel Inspection Circular (NVC 12-82).

The study concluded that exposures to the airborne substances were acceptable for the materials and operations that existed during the 7-day observation. Additional monitoring would be needed to assess other drilling muds and mud chemicals that were not observed. Noise data obtained on this study indicate the need for initiating or maintaining hearing conservation programs.

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We wish to thank Prof. James Hammond of the University of Texas School of Public Health in Houston for his valued assistance to the project team. Also, we are grateful for the assistance of Miss Donna Wauters in carrying out the data reduction and graphical presentation of the results of the noise dosimetry data. Finally, this report could not have been produced without the skill and patience of Mrs. Dorothy Endicott who typed the report manuscript and revisions.

EXECUTIVE SUMMARY

"A Crew Exposure Study - Phase I" was the title of a research project that developed a test plan and methodology for assessing the exposure of workers to potentially hazardous chemical substances in the work environment for both the [illegible] emical transport industry and the offshore drilling and produc[illegible] stry. The offshore test plan also included the methodology for [illegible] loping sound pressure level (SPL) contour maps for platforms and rigs. A trial implementation of the offshore plan was subsequently conducted in Phase I for exposures to chemical substances, which included gases, vapors, dusts and liquids.

The objectives of the offshore portion of Phase II of the Crew Exposure Study included implementation of the SPL methodology and an additional implementation of the test plan for exposure to chemical substances. The original scope of work for Phase II did not include personal noise dosimetry. Monitoring of personal exposures to this physical agent was added by Southwest Research Institute, with USCG approval, to (1) fill a void in the industrial hygiene literature and to (2) provide a mechanism for comparing SPL and noise dosimetry data.

The Phase I offshore test plan emphasized exposures to chemical substances for those activities that were directly related to drilling and production operations. Within Phase II, the definition of the chemical substances was expanded to include other substances such as welding fumes, paint chipping debris and sandblasting materials that are encountered during maintenance and repair operations on offshore facilities.

Because the offshore and merchant marine industries differ with respect to their basic operations, chemical substances, exposure potentials and work schedules, the results of Phase II are being published in two volumes.

- Volume I - Offshore
- Volume II - At Sea

This volume addresses the offshore portion of the study. This volume of the final report was prepared to assist the USCG in discharging its defined and continuously developing responsibility for the health and safety of (1) workers on Outer Continental Shelf facilities and (2) USCG personnel who conduct inspections of offshore facilities.

In Phase II, the test plan was implemented over a 7-day period on five production platforms and two platforms with both drilling rigs and production facilities. Sound pressure level contours were developed for all seven drilling and production facilities. Noise dosimetry data were collected on three production platforms and on both combination (drilling and production) facilities. Occupational exposures to dusts and fumes were monitored on two production platforms and on the drilling rigs of the

combination facilities. Since Phase I of the Crew Exposure project concluded that the hazard potential of gas and vapor exposures during normal facility operations was minimal, additional monitoring for these contaminant classes was not performed during the Phase II offshore test.

The following results and conclusions were drawn from the observations and measurements that were made during the 7-day offshore test period. Because of the wide range of equipment, facility configurations, work practices and company policies that make up the industry, the conclusions are not meant to be representative of the entire industry.

- Sound pressure levels (SPL) associated with normal drilling and production operations (non-maintenance) ranged from less than 65 dB(A) in the living quarters to 106 dB(A) in platform compressor rooms, and to 90 and 105 dB(A) at the draw works and generator room on a drill rig, respectively. Sound pressures between these extremes were measured at different locations on both production platforms and drilling rigs.

- The SPL contour maps indicate that entire portions of platforms and rigs would be exempt from hearing protection requirements for non-maintenance operations as these areas are below the 85 dB(A) action level that is recommended in USCG Navigation and Vessel Inspection Circular NVC 12-82.

- The SPL environment on production platforms is relatively constant from day to day. However, the SPL environment on drilling rigs is very dependent on what operations are taking place. For example, shale shakers and mud pumps do not operate during tripping of drill string.

- The SPL measurement technique was found to provide a rapid means of evaluating the spatial variation of noise. On production platforms, areas exceeding the 85 dB(A) criterion for hearing protection can be easily identified. The technique can also be used on drilling rigs if it is recognized that multiple surveys are necessary in order to account for the time-varying levels that result from intermittent equipment operation.

- The noise dosimetry measurements indicate that potential exposures were generally above 100 percent of the permissible dose relative to USCG Navigation and Vessel Inspection Circular NVC 12-82 criteria. All of the dosimeter records for a full 12-hour shift (14 of 16 records) indicate a potential exposure greater than an action level of 50 percent of the OSHA permissible dose. Under OSHA guidelines, a hearing conservation program would be required.

- Potential noise exposures represent the exposure to the unprotected ear. Facility workers wore varying degrees of protective devices including no protection, cotton balls, earplugs and earcups. Recent industrial hygiene literature indicates that in practice the entire array of earplug types may provide less than 50 percent of their rated protection relative to the ANSI attenuation criteria. The primary reason is improper insertion of the plug into the ear.

- Drillers and derrickmen tended not to wear hearing protection. Their noise exposures exceeded the allowable dose within four to eight hours after the beginning of the shift. Hence, the $L_{eff}(24)$ exposure level of 82 dB(A) was also exceeded. The time when cumulative dose equals allowable dose defines the exposure at which the $L_{eff}(24)$ will equal 82 dB(A) if no further exposure is received for the remainder of the 24-hour period.

- Roustabouts that chipped paint with needle guns were potentially exposed to noise levels that exceeded the allowable dose within 90 minutes of the beginning of the shift. $L_{eff}(24)$ doses were nominally 100 dB(A), assuming no exposure during the succeeding 12-hour rest period. One worker used cotton balls inserted into his ears, and the other wore the ear plugs furnished by his company for his use. No attempt was made to determine the affect of these protective devices on actual dose received.

- Noise levels below 80 dB(A) do not influence the $L_{eff}(24)$ according to NVC 12-82 procedures. Because the 12-hour rest period is spent in a sub-80 dB(A) environment, the $L_{eff}(12)$ may be a more appropriate indicator for offshore operations as it would reduce the costs associated with dosimetry without compromising the integrity of the procedure.

- Sound pressure level meter readings were compared to the real time noise dosimetry records. There is good agreement between the two recorded levels if (1) the two measurements are made side-by-side at the same time or if (2) the documentation is sufficient to establish that the measurements were made at the same location and under the same equipment operating conditions but at different times. The level of agreement is diminished if there is deviation in the space-time documentation. Hence, on drill rigs caution should be used in estimating noise exposures based on SPL meter surveys because of the time varying nature of equipment operations. On production platforms, the operating status of the equipment is more uniform; therefore, the estimation of noise exposures from SPL meter readings is more feasible.

- Occupational exposures to airborne dusts from drilling fluid makeup and paint/rust chipping were acceptable relative to the current ACGIH guidelines. For the bagged materials that were added to the drilling mud, the particulates were classed as nuisance dusts. A similar conclusion was obtained for the rust/paint chipping debris. The presence of nuisance dust was not assumed a priori, but it was verified by applying x-ray fluorescence and wet chemistry techniques to the materials in question. Where Material Safety Data Sheets and qualitative analysis indicated the presence of toxic metals, e.g. chrome and lead, in the rafter samples, quantitative analysis verified that the concentrations in the airborne dusts were below instrument detection limits.

- Fume samples were collected beneath the welder's helmet during welding and in the breathing zone during periodic weld inspection. Elemental analysis of the fume constituents was based on the parent metal and electrode classification. Concentrations of manganese, iron oxide and zinc oxide fume were below their respective exposure limits.

- Opportunities did not arise to monitor sandblasting, oil-base drilling mud operations or addition of asbestos-containing mud chemicals to the drilling fluids.

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GLOSSARY OF TERMS AND NOMENCLATURE

ACGIH - American Conference of Governmental Industial Hygienists

AIHA - American Industrial Hygiene Association

AWS - American Welding Society

dB(A) - Decibel level on A-weignted scale

Hz - Frequency in Hertz

L_{eff}( ) - Effective noise dose referenced to the exposure duration in parenthesis

MEC - Mixed Esters of Cellulose

MSDS - Material Safety Data Sheet

NIOSH - National Institute for Occupational Safety and Health

NRR - Noise Reduction Rating

NVC - Navigation and Vessel Inspection Circular

OSHA - Occupational Safety and Health Administration

P&CAM - NIOSH Physical and Chemical Analysis Method

PTS - Permanent Threshold Shift

PVC - Polyvinyl Chloride

Q - Flow rate in liters per minute

SPL - Sound Pressure Level

TLV-STEL - Threshold Limit Value - Short Term Exposure Limit

TLV-TWA - Threshold Limit Value - Time Weighted Average; used interchangeably with TLV designator

USCG - United States Coast Guard

W_c - Weight of sampled contaminant

XRF - X-Ray Fluorescence

I. INTRODUCTION

This final report presents the results of the offshore drilling and production observations performed by Southwest Research Institute as one element of the Phase II-Crew Exposure Study for the U. S. Coast Guard, Office of Research and Development. The purpose of this study is to characterize the potential for on-the-job exposures of crew personnel to chemical substances and selected physical agents during routine and non-routine work activities on offshore drilling and production facilities, and on bulk liquid tankers and barges at sea. Because both the nature of the potential hazards and the work activities of offshore workers differ greatly from those for tanker and barge crewmen, the results of this Crew Exposure Study are being published in two separate volumes. Volume I reports the results for offshore oil and gas drilling and production operations. Volume II reports the results for bulk liquid tanker and barge operations.

I.1 Background

The United States Coast Guard is responsible for the health and safety of offshore and marine transportation workers through the Ports and Waterways Safety Act as amended in 1978 and the Outer Continental Shelf Lands Act. This responsibility was clarified in a March 1983 Memorandum of Understanding between the USCG and OSHA. With respect to offshore activities, notice of proposed rule making has been issued for Workplace Safety and Health Requirements for Facilities on the Outer Continental Shelf (January 9, 1984). The Coast Guard is aware that there are potential health and safety hazards associated with the exposure of crewmen to flammable and possibly toxic materials involved in offshore drilling and production operations. Exposure to high levels of noise is another potential hazard that may be associated with either the work activities or work environment of crewmen. However, there has been very little information reported in the open literature to document the actual exposures of offshore workers to potentially hazardous materials and noise during their work activities. This information is desirable in order to determine whether additional regulation or implementation of industry standards is needed to provide for the health and safety of offshore workers. To obtain this information, the Coast Guard contracted with Southwest Research Institute to perform a research project to characterize the exposure of offshore drilling and production workers both to noise and to hazardous liquids, gases, dusts and vapors during their work activities.

Phase I of the Crew Exposure Study was completed in March 1982 and is reported in reference [1]. The Phase I project consisted of the following activities.

(1) Performing a background study to define the potential hazard sources associated with offshore operations that might bring a crewman into contact with toxic or flammable materials.

(2) Developing appropriate analytical models to simulate the effect of contaminant sources on the exposure to hazardous materials.

(3) Developing experimental measurement methods and an experimental test plan to quantify the actual levels of exposure of offshore crewmen to hazardous materials.

(4) Conducting a trial implementation of the experimental test plan for measuring exposure to hazardous material on offshore drilling and production facilities.

(5) Developing an experimental plan for determining sound pressure levels and worker exposure to sound pressure (noise) on offshore drilling rigs and production platforms.

A seven-day long observation was performed during Phase I in which the experimental test plan was implemented. Drilling and production operations were monitored on a total of four offshore facilities. All fugitive and major emission sources of dust, vapor and gas were identified and characterized. Personal exposure to respirable dust was measured for a roughneck during mud mixing operations. Levels of hydrocarbon gas and vapor concentration were measured near a shale shaker, in a fuel gas compressor room and downwind of an oil flotation cell. The results of these measurements are described in the Phase I Final Report [1].

In Phase II, the offshore portion of the Crew Exposure Study consisted of one additional implementation of the experimental test plan for measuring exposure to hazardous materials. Concurrently, the experimental test plan for sound pressure measurements and worker exposure to noise was implemented.

I.2 Objectives

The primary objective of this study was to characterize the exposure of offshore drilling and production workers to potentially hazardous materials in the form of gases, vapors, dusts and liquids, and to sound pressure (noise) encountered in their work activities. One additional offshore observation of seven days duration was arranged to supplement the exposure data collected in Phase I. The specific objectives of the Phase II observation for test plan implementation were as follows.

- Identify and measure the concentration of contaminant emissions of gases, vapors, dusts and mists as they exist on offshore drilling rigs and production platforms.

- Monitor the exposure of platform workers to these contaminants using accepted industrial hygiene procedures.

- Measure sound pressure contours and perform noise dosimetry on platforms and rigs.

- Observe and document dermal contact with drilling fluids for rig workers.

The development of the experimental program and the results of the exposure monitoring activities are described in the following sections.

I.3 U. S. Coast Guard Guidelines on Noise Exposure

In 1978, the U. S. Coast Guard Office of Research and Development sponsored a study which was conducted by the Naval Ocean Systems Center (NOSC) of the U. S. Navy under an interagency agreement. The objective of that study was to investigate various aspects of noise as it relates to occupational health and habitability on merchant ships. That study resulted in the publication of five NOSC documents.

- Technical Document 243 - Airborne Noise Levels on Merchant Ships: A Compilation of Data
- Technical Document 254 - Airborne Noise Limits for Merchant Ships: Recommended Acoustical Criteria to Insure Acceptable Functional and Habitable Environments in Crew Quarters and Work Stations
- Technical Document 257 - Noise on U. S. Merchant Ships: A Summary of the Problem With Recommended Limits and Future Work
- Technical Document 267 - Behavioral and Physiological Effects of Noise on People: A Review of the Literature
- Technical Report 405 - Noise Levels and Crew Noise Exposure Aboard U. S. Merchant Vessels

The NOSC study recommended the adoption of an equivalent 24-hour noise exposure criterion, $L_{eff}(24)$, of 80 dB(A) with a 3dB(A) exchange rate for hearing conservation purposes. A 75 dB(A) criterion level was recommended as a future goal. The 80 dB(A) criterion was derived from the 8-hour, 85 dB(A) exposure limit of the International Standards Organization (ISO). In arriving at their $L_{eff}(24)$ recommendation, the Navy also considered other domestic standards including an 82 dB(A), 24-hour equivalent exposure limit, which was derived from the OSHA 90 dB(A), 8-hour standard.

Following the NOSC study, a joint U. S. Coast Guard/Industry study group was convened for the purpose of drafting noise exposure guidelines. The resulting consensus recommendation appears in Navigation and Vessel Inspection Circular (NVC) No. 12-82, which is entitled "Recommendations on Control of Excessive Noise" and is included in its entirety as an appendix in this report. The USCG was represented on the study group by the Merchant Vessel Inspection and Merchant Marine Technical Divisions. Industry was represented by ship owners and the Offshore Marine Services Association (OMSA).

The hearing conservation recommendation in NVC 12-82 is based on an extension of the domestic OSHA standard as opposed to an international standard. Philosophically, this approach was adopted out of consideration for (1) familiarity with existing domestic standards, (2) ease of implementation and (3) general applicability.

NVC 12-82 was developed primarily for inspected merchant vessels. Because a separate guideline was not formulated for offshore facilities, the USCG has recommended that NVC 12-82 be applied to the recognition, evaluation and control of noise exposures on inspected drilling rigs and production platforms. To this end, offshore noise exposures were moitored and interpreted in accordance with NVC 12-82.

II. DEVELOPMENT OF THE EXPERIMENTAL PROGRAM

The background study and the offshore observations on drilling rigs and production platforms reported in the Phase I Final Report [1] provide the basis for the development of the experimental program. These studies indicated that sources of hydrocarbon gases, vapors and liquids may be encountered on both production platforms and drilling rigs. Sources of potentially hazardous dust or mist are more likely to be associated with drilling or workover activities. Sound pressure (noise) sources are found on both drilling and production facilities. The nature of these potential hazards, their relationship to drilling or production operations and the experimental measuring techniques are discussed below.

II.1 Sound Pressure

II.1.1 Definition of Potential Hazards

It is generally accepted that long-term exposure to excessive sound pressure levels can produce a permanent loss in hearing acuity. It is also known that this permanent threshold shift (PTS), excluding the relatively rare loss due to single massive exposures, is dependent not only on the amplitude of the sound but also several other variables. These variables include:

- o frequency,
- o exposure duration,
- o coexisting medical disorders,
- o prior exposure history,
- o altered ear response due to drugs or chemicals,
- o availability of recovery time and
- o individual susceptibility.

Unfortunately, beyond the fact that these variables influence the amount of permanent hearing loss, little correlation exists.

Medical research and testing performed by Glorig [2] and many others have indicated a statistical correlation between long term exposure to sound pressure levels above 80 dB(A) for eight hours per day, five days per week, and a permanent loss of hearing. From Table II.1 it can be seen that the 90 dB(A) standard of OSHA would assume an acceptable risk of 15.6% for a 30-year work life. However, others using this and similar data from later studies have continued to recommend a "no-risk" exposure criterion of 80 dB(A) per 8-hour exposure.

One of the most significant factors mentioned in the list of variables is individual susceptibility. In a significant research program, Dr. D. Robinson [3] started with 40,000 factory workers in an attempt to relate exposure to sound and long-term (permanent) hearing loss. During the course of his research he eliminated any subject (or single subject's ear) that had been exposed to high sound levels away from work or had suffered any medical trauma which could have resulted in a loss of hearing acuity.

TABLE II.1. RELATION BETWEEN RISK AND EQUIVALENT CONTINUOUS SOUND (Ref.[2])

Level for up to 45 Years of Habitual Exposure
(Age = 20 Years + Years of Exposure)
(% Noise = "Risk" as defined in document [2])

(All data have been corrected to a median hearing level of 0 dB for 80 dBA exposure and 25 yrs. of age.)

Age		20	25	30	35	40	45	50	55	60	65
Exp. Years (Age - 20)		0	5	10	15	20	25	30	35	40	45
Exp. Level	Total % Expected	0.7	1.0	1.3	2.0	3.1	4.9	7.7	13.5	24.0	40.0
80 dB(A)	% Due to Noise	No Increase in Risk at This Level of Exposure									
Exp. Level	Total %	0.7	2.0	3.9	6.0	8.1	11.0	14.2	21.5	32.0	46.5
85	% Noise	0.0	1.0	2.6	4.0	5.0	6.1	6.5	8.0	8.0	6.5
Exp. Level	Total %	0.7	4.0	7.9	12.0	15.0	18.3	23.3	31.0	42.0	54.5
90	% Noise	0.0	3.0	6.6	10.0	11.9	13.4	15.6	17.5	18.0	14.5
Exp. Level	Total %	0.7	6.7	13.6	20.2	24.5	29.0	34.4	41.8	52.0	64.0
95	% Noise	0.0	5.7	12.3	18.2	21.4	24.1	26.7	28.3	28.0	24.0
Exp. Level	Total %	0.7	10.0	22.0	32.0	39.0	43.0	48.5	55.0	64.0	75.0
100	% Noise	0.0	9.0	20.7	30.0	35.9	38.1	40.8	41.5	40.0	35.0
Exp. Level	Total %	0.7	14.2	33.0	46.0	53.0	59.0	65.5	71.0	78.0	84.5
105	% Noise	0.0	13.2	31.7	44.0	49.9	54.1	57.8	57.5	54.0	44.5
Exp. Level	Total %	0.7	20.0	47.5	63.0	71.5	78.0	81.5	85.0	88.0	91.5
110	% Noise	0.0	19.0	46.2	61.0	68.4	73.1	73.8	71.5	64.0	51.5
Exp. Level	Total %	0.7	27.0	62.5	81.0	87.0	91.0	92.0	93.0	94.0	95.0
115	% Noise	0.0	26.0	61.2	79.0	83.9	86.1	84.3	89.5	70.0	55.0

His screening was meticulous and resulted in a sample size of only slightly less than 600 ears. Using rather sophisticated mathematical curve fitting techniques, he developed a correlation equation which related permanent threshold shift to the exposure (level and time) with the following equation.

$$PTS = 27.5\ (1 + \mathrm{Tanh}(L_{A2} + 10\ \log(T/T_O) + U_N - \lambda i)/15) \qquad (1)$$

where

PTS = permanent noise induced threshold shift
T = exposure time (greater than 1 month)
T_O = reference time (1 month)
L_{A2} = dB(A) sound level exceeded 2% of the exposure time
U_N = constant based on individual susceptibility
λi = constant depending on the audiometric test frequency

The variables in this equation require additional clarification. The PTS was determined experimentally by determining the difference in hearing acuity for an individual at a given frequency relative to a control group which was not exposed. Robinson utilized a reference time of one month in his curve fit. This was selected based on "goodness-of-fit". L_{A2} is the sound pressure level in dB(A) which was exceeded during 2% of the individual's total exposure time. For example, an L_{A2} of 100 dB(A) means that 98% of the subject's exposure during the total exposure period was less than or equal to 100 dB(A).

Plotting this curve over the actual experimental data from his survey, Dr. Robinson found the correlation shown in Figure II.1. In this figure $E_{A2} = L_{A2} + 10\ \log\ (T/T_O)$. The most significant aspect of this figure and Dr. Robinson's work results from the observation that for any exposure level, the range of possible expected hearing acuity shifts can be over 50 dB(A). Even at a level of 130 dB(A) exceeded 2% of the time the range is 50 dB(A).

One quite logical conclusion that can be drawn from this data is that any gains that might be derived from slight (less than 10 dB(A)) changes in exposure levels are completely overshadowed by individual susceptibility. From this conclusion then it would appear that the most effective method for preventing permanent threshold shift in a significant percent of the exposed population would be to isolate "sensitive ears". Short term (every 6 months) measurements of hearing acuity could isolate workers with sensitive ears, and these workers could be moved to quieter working environments or be required to wear special hearing protection.

Another conclusion, which can be drawn from this figure, rests on reviewing the distribution about zero hearing loss in the 90 dB(A) area. At this point in the curve it is not possible to say that long term exposure to noise produces significant hearing loss. Above a level of 100 dB(A) the data supports a decline in hearing acuity "of the sensitive ears" and above 110 dB(A) there appears to be a measurable decline in

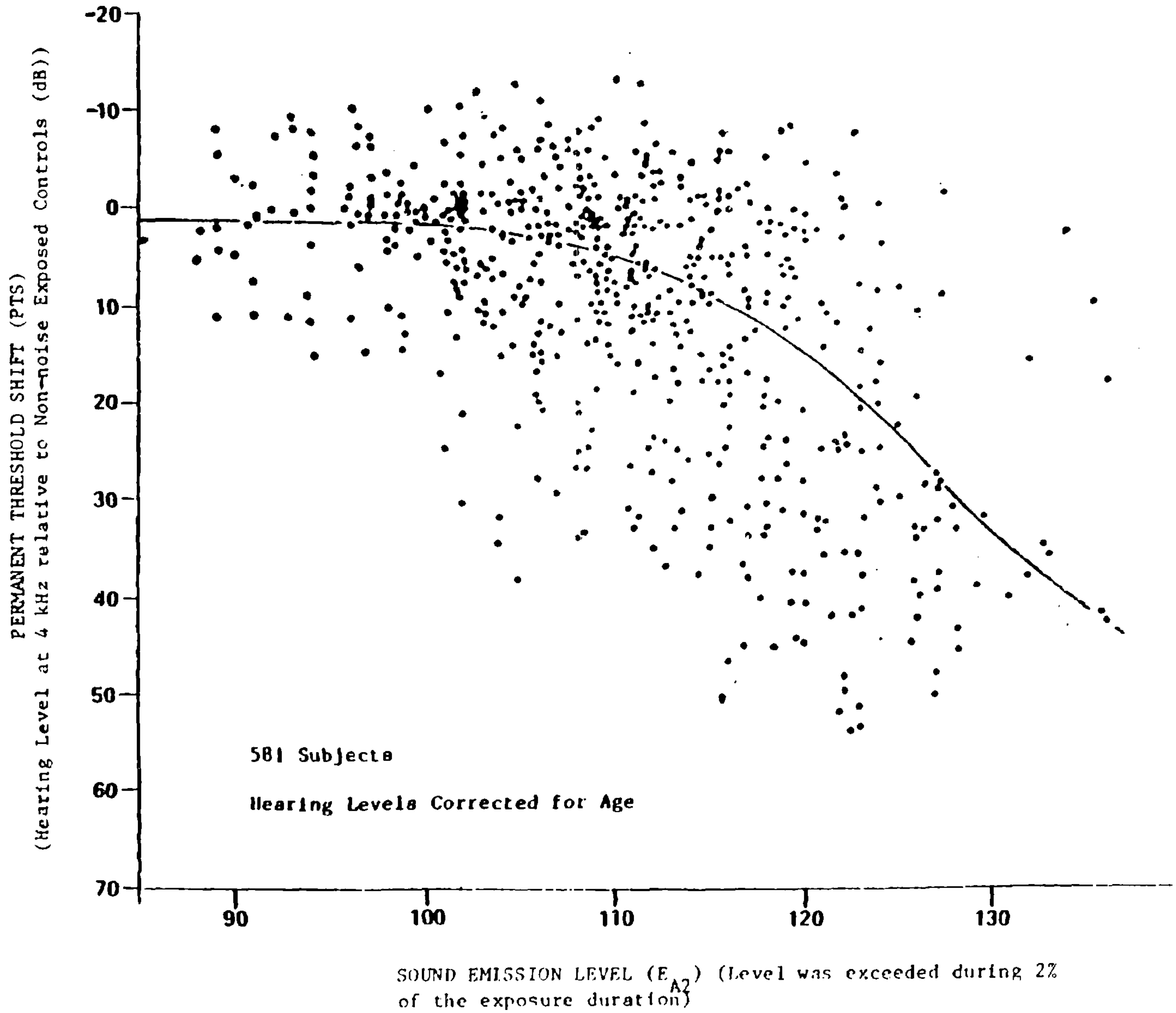


FIGURE II.1. CURVE FIT OF EXPERIMENTAL THRESHOLD DATA hearing acuity for the overall population. From this data, it would again be logical to establish a criteria similar to the existing 90 dB(A) criteria but enhanced by a mandatory procedure to isolate those with sensitive ears.

Another factor mentioned above that contributes to the uncertainty in establishing a firm relation between exposure to sound and noise induced permanent threshold shift is the natural recovery mechanism of the human ear. If continued weekly exposure to sound can cause a loss of hearing, it would seem logical that the 7-day on, 7-day off exposure patter of the offshore worker could offer significantly lower risk. Again, medical research has been unable to document the effects of such intermittent exposure to sound. Perhaps the long-term exposure histories and audiometric records being accumulated by the offshore industry will provide the necessary data for such a correlation.

Lacking an accurate model for the prediction of noise induced permanent threshold shift from exposure to sound, it is necessary to establish an interim standard which, while perhaps of unknown validity, is conservative enough to protect the majority of personnel exposed to sound above 80 dB(A) during their working days offshore. The data collected during this project represents an attempt to accumulate typical sound pressure levels on offshore facilities and typical noise exposure patterns. The following sections on sound levels will present this data.

Offshore facilities are unique facilities for sound pressure level studies in that although the same types of equipment are used in land-based installations, they are seldom seen in such close proximity to each other. This closeness can produce higher sound levels than their land-based counterparts.

The specific equipment used and the arrangement of this equipment varies widely between offshore facilities. Certain general types of equipment, however, were common to all types of installations studied. Table II.2 lists the generic noise sources found on most off-shore drilling and production facilities and the normal mode of operation of each source.

Personnel on these facilities work 12-hour shifts for seven days followed by seven days off. In addition to this longer work day, their work requires that they be exposed to these sound levels for different periods each day. This makes it important to give proper consideration to documenting the range of exposures for each job classification. Table II.3 illustrates the typical number of hours that the various individuals working in the listed job descriptions would be exposed to levels above 80 dB(A) in a normal 12-hour shift. In some cases, the individual might spend a lengthy period of time in a quiet area. As an example, an instrument repairman, during a period of limited equipment failures, may remain in a relatively quiet area for several days followed by several days where the exposure exceeds 80 dB(A) for 12 hours per day. This creates an intermittent-variable noise exposure. The exposure is intermittent because of the 7-day on/off cycle and variable due to the wide range of daily exposures.

TABLE II.2. TYPICAL NOISE SOURCES FOR OFFSHORE FACILITIES

Item	Type of Facility: Drilling Rig	Type of Facility: Production Platform	Duration: Continuous	Duration: Intermittent
Generator Sets	x	x	x	
Auxiliary Generators	x	x		x
Compressors	x	x		x
Pumps (Hyd, mud, water)	x	x		x
Crane	x	x		x
Pressure Reduction Valves	x	x		x
Drain Works	x			x
Piping Flow Noise	x	x		x
Helicopters	x	x		x
Crew Boats	x	x		x
Electric Motors	x	x		x
Pneumatic Motors	x	x		x
Horns and Loudspeakers	x	x		x
Turbine and Int. Comb. Eng. Exh. Stacks	x	x	x	
Turbine and Int. Comb. Eng. Air Intakes	x	x	x	
Cooling Fans	x	x	x	
Flares and Vents	x	x		x
Pneumatic Leaks	x	x		x

TABLE II.3. EXPOSURE BY JOB TITLE

Job Title	Type of Facility: Drilling Rig	Type of Facility: Production Platform	Typical Exposure* Time Above 80 dB(A)/12 Hr Shift
Foreman	x	x	2 - 12
Roustabout	x	x	4 - 10
Welders/Grinders	x	x	4 - 10
Crane Operator	x	x	3 - 10
Tool Pusher	x		3 - 12
Derrick Man	x		2 - 10
Deck Hands	x		6 - 12
Mud Mixer	x		6 - 10
Cook	x	x	1 - 3
Electrician	x	x	2 - 10
Mechanic	x	x	2 - 10
Instrument Repairman	x	x	2 - 10

* NOTE: These variations were obtained by observation and discussion with offshore workers.

II.1.2 Experimental Methodology

II.1.2.1 Sound Pressure Level Measurements

The original experimental plan developed in Phase I sought to document the sound pressure levels in dB(A) on from two to four offshore installations. This documentation was to include the measurement of sound pressure levels at every point that would be normally occupied by offshore workers.

The measurement equipment used during this study included:

- o GenRad Precision Sound Level Meter and Analyzer, Model 1982
- o GenRad Sound Level Calibrator, Model 1562-A
- o GenRad Type II Sound Level Meter, Model 1565-B
- o GenRad Windscreens

Upon arriving at a new facility, an initial survey of the entire platform was made in order to become familiar with the equipment layout, personnel and type of acoustic environment. After the initial survey was completed, a detailed drawing of the various levels of the facility was obtained and sound level contours were measured. The use of sound level contours in dB(A) at operator ear level has proven over the years to provide the best format for recording large volumes of acoustic data. This format also provides a basis for studying operator exposure by allowing the analyst to overlay the operator's normal work paths onto the drawings. For these measurements, variations of less than 2 dB(A) were recorded as the average for that point. Where variations exceeded this range, the range was noted as a "max/min" pair on the drawing.

During the measurement of these sound level contours, special attention was given to documenting the impact of such items as partitions, walls, screens and piping on the sound field because these items can be used to improve the efficacy of various abatement techniques.

Normal procedures were followed to insure the continued accuracy of the measurements. The equipment was calibrated at the start and end of each day as well as several times throughout the day. In addition, when the wind levels became a noticeable variable in the measurements, wind screens were installed. At no time were sound levels measured when the wind speed exceeded 10 mph.

During the conduct of the study, it was found that scaled drawings were not available for certain areas of some of the platforms. When this was the case, hand sketches were made of the areas to show the relative position of each major piece of equipment, and these drawings were then used to plot the contours.

In those highly reverberant areas where sound level contours were not possible, point sound levels were noted. On the drilling rigs, areas such as the generator and mud pump rooms were often too reverberant to allow the development of valid contours.

II.1.2.2 Octave Band Analysis

In order to give a more complete picture of the nature of the sound which made up the exposure of the various operators, octave band levels were measured near representative noise sources. By splitting the overall sound level into 10 octaves, it is possible to identify not only the portions of the spectrum that contribute most to the overall dB(A) reading but also to provide the basis for designing or selecting the most effective noise abatement approaches.

No attempt has been made to develop a comprehensive list of all sources, but rather the emphasis was on documenting selected sources which were significant on the platforms visited.

The locations where octave band test points were taken are marked on the sound level contour plots for each installation and are tabulated later in the report.

II.1.2.3 Noise Dosimetry

For many job descriptions, personnel are exposed to a wide range of sound pressure levels during a normal workday. One procedure for determining the equivalent or effective exposure level experienced during a work day is to have the worker wear a dosimeter. The effective exposure may also be obtained by manually calculating exposures based on sound pressure level measurements combined with time-motion studies of the employee. Both techniques are discussed.

Noise dosimeters are available with a large variety of features. Some can be programmed for various standards via internal switches or replaceable PROM's*. Sampling rate, dynamic range, crest factor, weighting, response time, linearity, and resolution vary among units. Some of the dosimeters can also be used as sound level meters. Many of the dosimeters have a digital display which indicates the accumulated effective exposure using the programmed criterion level, threshold level, and exchange rate. Other units require an external reader which can then provide a hard copy or dump the recorded information to a computer for storage or further processing.

SwRI utilized the Metrosonics dB-301P/652 Metrologgers and Metroreader as the primary dosimetry system in this study. 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 [7]. The units sampled four times per second, and the L_{OSHA} exposure for 480 samples (120 seconds) was stored in the unit's memory. The L_{OSHA} exposure was computed using the following equation.

---

*Programmable Read Only Memory

$$L_{OSHA} = 16.6 \text{ LOG} \left[\frac{1}{480} \sum_{i=1}^{480} 10^{L_i/16.6} \right] \qquad (2)$$

where

L_i is the 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 sampling times are used. The system has a resolution of 1 dB.

When sampling is completed, the data stored in the Metrologger is transferred to the Metroreader which provides a hard copy output displaying time history of the exposure. Figure II.2 indicates the heading information provided by the system. The first four lines of the header provides owner information followed by two lines of Metroreader identification, including the software version and the unit's serial number. The logger identification is then printed. The remainder of the printout is labelled such that it is fairly self-explanatory. We have added short descriptions in Figure II.2 of those items which may not be clear.

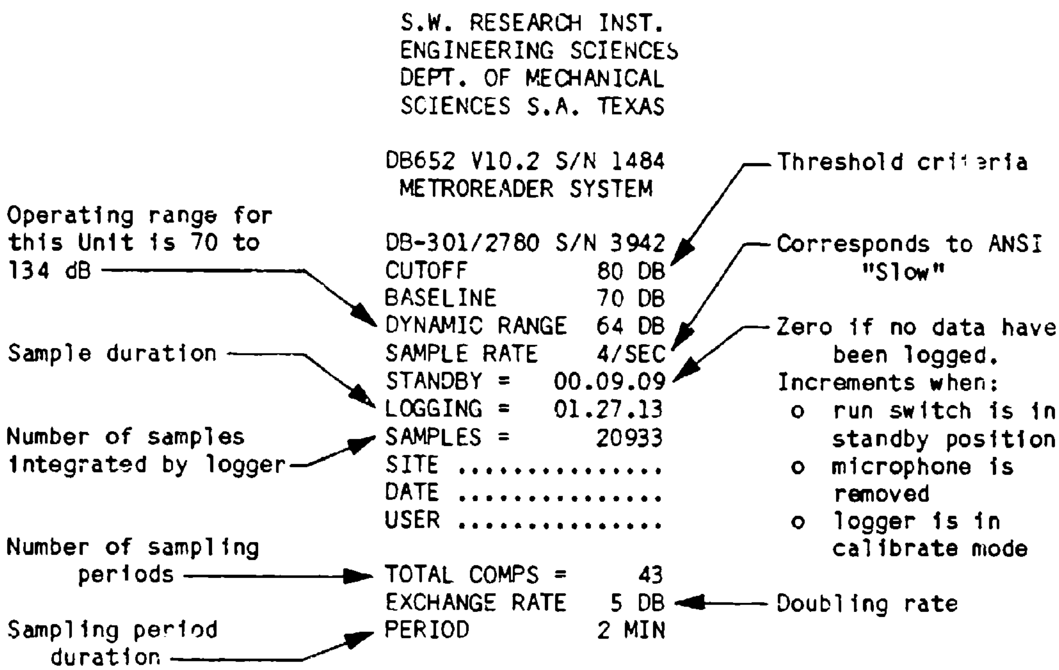


FIGURE II.2. METROREADER HEADER INFORMATION

After every Period of time the logger does a calculation and then stores the result. The number of Computations made is listed as "TOTAL COMPS = nnnn". The next line is the Exchange (Doubling) rate used. Commonly used averaging (Doubling) rates are:

L_{EQ} = 3 dB (Worldwide)
L_{OSHA} = 5 dB (U.S. and Canada)
L_{DOD} = 4 dB (U.S. Dept. of Defense)

Below, we will use the term "L_{avg}" rather than one of the specific types.

Figure II.3 shows an example of the quasi-graphical time history printed by the Metroreader.

The major portion of a time history listing is the time versus L_{avg} printout. At the beginning and end of the printout, L_{avg} annotation, in dB, are printed vertically across the paper. The baseline value is at the left and then every third column is 10 dB higher. Logging time is annotated on the far right or far left depending on the value being printed. At the top is the line "HRS . . . . HRS" or "MIN . . . . . MIN" as the Period requires. The dots are under the start of each decade (e.g. 60, 70, 80, 90, . . . dB).

The actual level is printed in an appropriate column so that visually the lower levels are on the left while increasing levels are printed more to the right side.

After this printout, several intermediate, cumulative, and current L_{avg}'s are printed. The cumulative value is from the start of the test to the end of the annotated period of time, while the current value is the L_{avg} for the specific period only.

The Metrologger/Metroreader system was selected because of its ability to provide a time history of exposures. Combined with a time-motion study of the individual's work activity, it is possible to associate high periods of exposure with proximity to specific sources of noise. This feature was deemed a valuable asset for a research study although a system which records accumulated doses might be sufficient to determine compliance with prescribed regulations. The dosimeter should also provide a storage of the peak SPL detected to verify that the prescribed maximum level is not exceeded.

The second procedure for determining personnel exposure is to map SPL contours of the facility and record the amount of time the individual spent within each level. The effective exposure level can then be calculated using Equation 3.

```
TIME HISTORY

            1   1   1   1     Graph heading columns
 7   8   9  0   1   2   3     indicate Lavg levels
 0   0   0  0   0   0   0     in dB
HRS  .   .  .   .   .HRS
72
      91
        97
       95
        98
       95
       96
        97
       96
 .   . 95  .   .   .   . <--  Dots are spaced 10 dB
       95                     horizontally and 20
       95                     minutes vertically in
       95                     this example
        99
      93
        97
       96
        97
        98
 .   . .102    .   .   . <--
       96
        97
        97
        100
        97
        97
       95
        97
       94                     Indicates one hour of
 .   . 95  .   .       1 <--  logging time
       95
       95
       95
       95
       96
       96
        98
        97
        97
 .    89.  .   .   .   .
       96
        98
        98
HRS                    HRS
            1   1   1   1
 7   8   9  0   1   2   3
 0   0   0  0   0   0   0

        LOSHA
HOUR  CURRENT  CUMUL

 1      96.3    96.3
 2      96.0    96.2

III METROSONICS, INC.
```

FIGURE II.3. EXAMPLE OF HISTOGRAM

$$L_{eff} = 16.61 \text{ LOG} \left[\frac{1}{T} \sum_{i=1}^{m} 10^{L_{Ai}/16.61} \Delta t_i \right] \quad (3)$$

where

L_{Ai} = A-weighted sound pressure level (dB(A)) during the i-th time interval, Δt_i

t_i = i-th time interval

$T = \sum_{i=1}^{m} \Delta t_i$ = total time interval (i.e. 24 hours) for L_{eff} (24)

This equation assumes a 5 dB exchange rate, and all levels below 80 dB(A) may be disregarded.

To successfully evaluate the effective exposure, SPL contours must be available for differing operations. For example, an auxiliary generator may be run periodically. The SPL contours in the vicinity of the generator will, therefore, vary depending on its operating status. The location, frequency, and magnitude of the noise source(s) will affect the contour spacing and the accuracy necessary in the time-motion study. The employee may work in an area of relatively constant SPL, requiring a minimum of accuracy in the time motion study. Alternatively, the employee may be using equipment which itself is a source of noise (i.e. welding, sandblasting, paint chipping, drill pipe makeup using pneumatic tongs, etc.) The exposure due to these operations is very much dependent on the number of times the operation is performed, as well as the workers' proximity to the source. Therefore, a much more accurate time-motion profile is required to evaluate the cumulative exposure.

Additional details regarding noise dosimetry are included in Sections III.3 and IV.1. These sections discuss collection and interpretation of dosimetry data.

II.2 Dust, Fumes and Mists

II.2.1 Definition of Potential Hazards

Mists were seldom encountered during either the Phase I or Phase II project observations. A few exceptions should be noted, however. When drilling fluid passes over the vibrating screens on a shale shaker on a drilling rig, a small amount of mist may be formed. A mist of water droplets may also be formed when the mudman washes down the shale shaker with a water hose. Neither type of mist was considered to be a hazard. A mist of airborne paint droplets was observed during routine spray painting operations on offshore drilling and production facilities. The inhalation of paint vapor and spray could constitute a health hazard depending upon the nature of chemical ingredients present in the paint and the level of worker exposure.

Dust and particle emissions were observed during several operations. Fine particle dusts were produced in the drilling mud makeup area when barite and dry drilling fluid chemicals were added to the mud through dry bulk hoppers. The amount of airborne dust produced varied with the fineness of the particles. Coursely ground nut hulls and caustic soda pellets appeared to produce very little airborne dust when handled by crewmen. On the other hand, finely ground material such as lignitic material and lignosulfonates produced a visible dust when bags were slit open and emptied into the hopper. Sandblasting was observed during the offshore familiarization visits on Phase I. Silica monitoring equipment was included on the Phase II test, but this operation did not occur during the seven day offshore test period. Airborne paint chips and rust were also observed during paint chipping (removed prior to repainting) using pneumatic air chisels. Inhalation of the paint particles may pose a potential hazard depending upon the base materials and pigments in the paint formulation.

These types of dust emissions may present a health hazard to workers. Inhalation of silica dust produced during sand blasting should be avoided because it could lead to silicosis and permanent lung damage. Inhalation of dust from drilling fluid materials and paint or rust chips may present a health hazard depending upon the nature of the chemical ingredients present and the concentration level and duration of the worker's exposure.

Information on potentially hazardous ingredients in drilling fluid materials and paint materials can be found in the Material Safety Data Sheets that are compiled by the product manufacturer. Some drilling fluid chemicals, such as sodium hydroxide, have an accepted Threshold Limit Value (TLV-TWA) or Short Term Exposure Limit value (TLV-STEL). Other chemicals which are blends of several ingredients, may contain some percentage of a potentially hazardous ingredient such as chrome or free silica. If the dust producing material does not contain potentially toxic ingredients, it may be considered to be a nuisance particulate. In this case, either a total dust concentration or a respirable fraction dust concentration may be measured and compared with the respective limit values of 10 mg/m^3 (total) or 5 mg/m^3 (respirable) for nuisance particulate substances.

Material Safety Data Sheets can be valuable guides for identifying toxic constituents for exposure assessments. These sheets are equivalent in structure to the OSHA Form 20s. One difficulty that arises in using these sheets to identify ingredients for occupational exposure sampling and analysis is the information on the bulk material that appears in Section II - Hazardous Ingredients. Two competing mud products that perform the same function would be expected to have similar chemical and trace metal assays. However, the level of detailed breakdown on composition is highly variable to the extent that one sheet may treat the product as a nuisance dust while the sheet for the competing product that performs the same function indicates trace levels of toxic ingredients. This situation could be remedied by specifying the minimum concentration in bulk above which a substance would be included in Section II. This situation was encountered, and it was resolved by consulting data sheets for other competitive mud products.

II.2.2 Experimental Methodology

II.2.2.1 Drilling Fluid Chemicals

Sampling for airborne dust is accomplished by drawing a continuous stream of air through a filter cassette for a predetermined length of time. Although it is relatively simple to collect a dust sample for a derrick man, mud engineer or roustabout when he adds drilling fluid materials to a hopper, the analysis of the sample depends upon the nature of the chemicals on the filter. In order to ensure the proper analysis of airborne dust samples collected during drilling fluid additions, the following steps were taken:

(1) A bulk sample was collected for each of the drilling fluid materials added to the hopper during the observation. These samples could be analyzed by X-ray fluoresence to determine the presence of trace metals, and to guide the analysis of personal dust samples.

(2) A record was kept of how many bags of the various drilling fluid chemicals were added to the hopper during each personal sampling period. This information was also used to guide the analysis of individual filter cassettes.

(3) Area samples of dust in the vicinity of the hopper were collected by attaching a filter cassette and pump to the lower portion of the barite bulk tank at a cassette height approximately equal to the breathing zone height of a crewman standing close to the hopper. These samples could be analyzed to determine the presence of metals and specific chemical ingredients contained in the airborne dust during solids addition through the hopper. This information could guide the analysis of the personal dust samples.

(4) A personal sample of respirable dust fraction was collected by drawing a continuous stream of air through a miniature cyclone assembly fitted with a membrane filter. The cyclone separator and membrane filter assembly was attached to the crewman's lapel. Air from the breathing zone was drawn through the cyclone assembly by a pump attached to the crewman's belt. The respirable dust sample, which was collected on PVC filters, was analyzed by weighing the individual membrane filters both before and after exposure. The average dust concentration is determined from the increase in weight, W, the volumetric flowrate of the pump, Q, and the duration of exposure.

$$C = 1000 \frac{\Delta W}{Q \Delta t} \quad (4)$$

where

C = average dust concentration, mg/m^3

ΔW = increase in weight after exposure, mg

Q = volumetric flowrate of the pump, liters/min

Δt = time of exposure to dusty environment, min.

This method of analysis is appropriate if the dust has been determined to be a nuisance particulate.

(5) A personal sample of total dust was collected by drawing a continuous stream of air through a cassette that contained an MEC (mixed ester of cellulose) filter. This sample was used for elemental analysis if it was determined that the dust contained metals or other potentially toxic ingredients. However, if the dust was determined to be a nuisance particulate, this sample could be weighed to determine the total dust concentration. All MEC filters were preconditioned and tarod for this purpose.

Each pump that was used for non-respirable sampling was adjusted and calibrated to give a nominal volumetric flowrate of 1.7 liters/minute with a representative load in-line. A separate set of pumps were used for respirable dust sampling, and they were calibrated with the cyclone/cassette assembly attached. Calibrations were performed before and after each dust sampling activity (after about six hours of continuous operation). The duration of each dust sample was approximately 100 minutes. Pulsation dampened pumps were used.

Figure II.4 shows a photograph of a roustabout wearing both a respirable and total dust sampling assembly and a noise dosimeter during barite addition to the hopper. The details of the samples collected and the method of analysis employed are discussed further in Section III.4.

II.2.2.2 <u>Welding Fumes</u>

Breathing zone samples of welding fumes were collected by a filter cassette assembly adjacent to the welder's nose and mouth. When the helmet was lowered into position, the filter cassette was pressed against the welder's cheek, placing the inlet approximately two inches from the centerline of the welder's breathing zone. When the helmet was up or was not worn, the cassette remained within nine inches of the welder's nose [5]. Fume particles collected on the filter are generally submicron sized solid particulate matter generated by the welding process. Several factors can affect the fume concentration in the welder's breathing zone. These factors include:

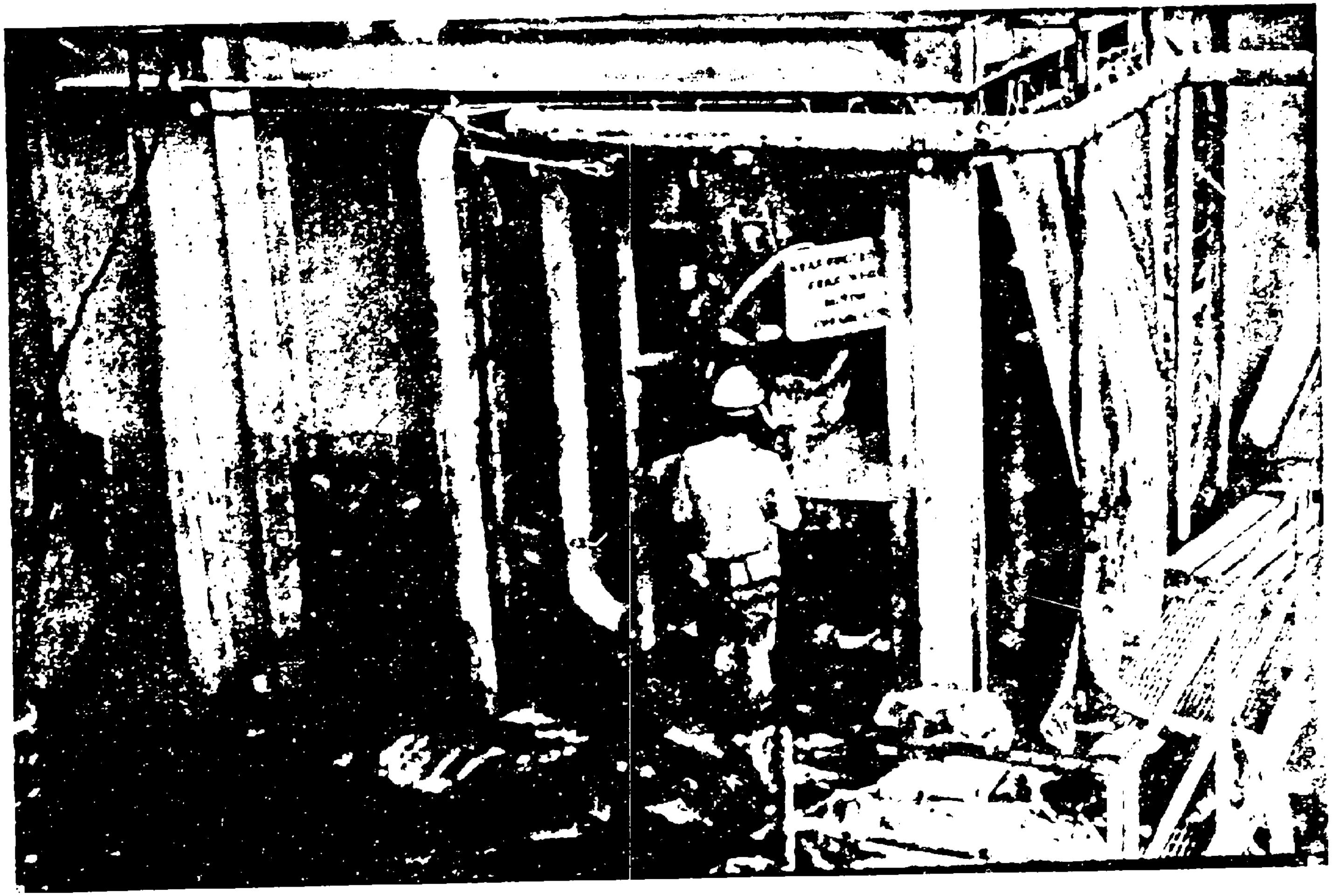


FIGURE II.4. ROUSTABOUT WEARING SAMPLE PUMPS FOR DUST SAMPLE COLLECTION AND NOISE DOSIMETER WHILE ADDING BARITE TO DRILLING FLUID

- Environmental Conditions;
- Type and brand of welding consumables;
- Welding parameters;
- Base metal;
- Surface coatings or contaminants;
- Design of welding helmet.

These factors are discussed in more detail below.

Environmental conditions which affect fume concentrations and the individual's exposure level should be recorded. These include items such as room size, ceiling height and the ventilation conditions of the environment. The use of a general or local exhaust system should be recorded. If available, actual room air flow rates, air changes per hour, and their direction with respect to the weld zone should be recorded. The position of the welder's helmet with respect to the weld zone and plume, and adjoining operations should also be recorded.

The type and manufacturer's brand of welding consumable should be recorded. The AWS electrode or rod classification, diameter and any gas shielding conditions and composition should be recorded as these items can be used to identify substances for chemical analysis.

Welding parameters can have a pronounced influence on fume generation rate. Of particular importance are welding current, polarity and arc length (arc voltage). Other welding parameters such as travel speed, electrode feed speed and electrode extension, if applicable, and arc time can be equally important and should also be recorded.

Fume concentration and composition can also be influenced by base metal alloy and surface coatings or contaminants. Notation that surfaces contain paint, oil, scale, metal plating, etc., should be recorded as well as the base metal alloy.

The design of the helmet can influence the total fume level entering the breathing zone. Helmet brand name and design type should be recorded. Because the design of the helmet can influence the exposure, it is desirable to attach the filter cassette to the welder's personal helmet rather than instrument a "standard" test helmet. A means of attaching the cassette to goggles or a face shield should also be provided so the sample may continue to be collected when the helmet is not being worn. This can be achieved by clipping the tubing that holds the cassette to the helmet, face shield hinge point or the band on the goggles. Figures II.5 and II.6 show the position of a cassette fastened in this manner.

Sampling of the welding fumes requires a calibrated system which includes a pump, filter cassette, and connecting tubing. The system is calibrated to obtain a constant sampling rate of 1.5 to 1.7 liters per minute, $\pm$ 5 percent. Pre-test calibration is accomplished by attaching a "calibration cassette" to the tubing and a bubble meter. The cassette is used with the face closed and the plug removed. The pump is adjusted to the desired flow rate and the time to draw a known volume (i.e. 1000 cc) through the bubble meter and cassette is recorded. The check is run a

FIGURE II.5. FILTER CASSETTE ATTACHED TO WELDING HELMET

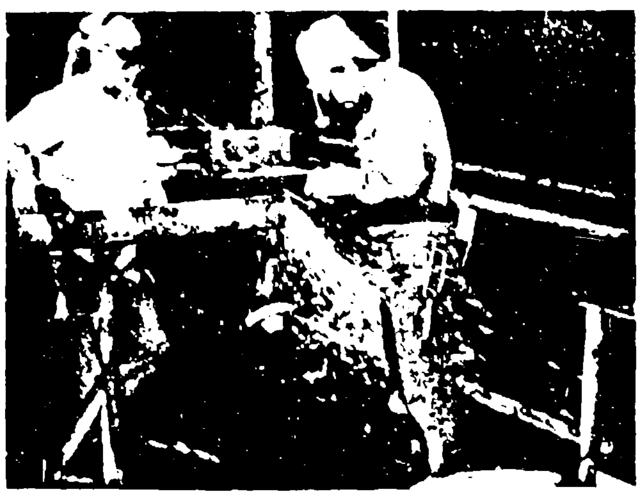


FIGURE II.6. FILTER CASSETTE SUSPENDED FROM GOGGLES total of five times to provide a base for calculating the average flow rate. The flow rate check is repeated five times following completion of the sampling to obtain the post-test calibration.

The sampling procedure employed utilizes a three-piece cassette containing a 37 mm diamter, 0.8 pore size, mixed cellulose acetate membrane filter and backup pad. The filter may be conditioned and weighed before and after sampling to determine the weight of total particulates deposited, if desired. In addition to calculating the total weight of the particulates, the elemental composition is determined using X-ray fluorescence analysis. Detailed procedures are available in NIOSH Manual of Analytical Methods - Volume 7, August 1981, under P & CAM Method No. 345 [6].

II.2.2.3 Rust and Paint Chipping

Sampling for particulate material produced during paint chipping is accomplished in a manner similar to sampling for drilling fluid dust. In this case, three steps were taken as follows:

(1) Bulk samples of paint chip particles were collected from the area where the work was performed (rafter sample). These samples were analyzed by X-ray fluoresence to determine the presence of trace metals and to guide the analysis of the personal dust samples.

(2) A record was kept of the duration of paint chipping, the posture of the roustabout (proximity of his breathing zone to the airborne debris) and the nature of the chips produced (fine or coarse).

(3) A personal sample of the total dust fraction was collected by drawing a continuous stream of air through a filter cassette attached to the roustabout's lapel. This sample was subjected to a chemical analysis of individual particulate concentration as described in Section III.4. Each sample pump was calibrated to a volumetric flowrate of about 1.7 liters/minute.

Figure II.7 shows a photograph of a roustabout wearing a total dust sampling assembly and a noise dosimeter during paint chipping.

II.2.2.4 Silica from Sandblasting

Personal sampling for free silica resulting from sandblasting operations requires a sample to be drawn through a cyclone assembly and onto the filter media of a filter cassette. A continuous stream of air is drawn through the miniature cyclone attached to the worker's lapel to obtain a breathing zone sample. A pump is calibrated with a 10 mm nylon cyclone holding a cassette with a 37 mm diameter, 5.0 pore size PVC (polyvinyl chloride) filter. The system is calibrated to draw 1.7 liters per minute using a bubble meter calibration fixture.

FIGURE II.7. ROUSTABOUT WEARING SAMPLE PUMP AND FILTER CASSETTE FOR DUST SAMPLE COLLECTION WHILE CHIPPING PAINT WITH AN AIR CHISEL

The personal samples and a bulk or rafter sample are analyzed by X-ray diffraction to determine the presence of free silica polymorphs. The analytes include quartz, cristobalite, and tridymite. The sampling and analysis procedure is given in NIOSH P&CAM 259.

II.3 Gases and Vapors

II.3.1 Definition of Potential Hazard

Phase I of the Crew Exposure project [1] paid particular attention to sources of gas and vapor on offshore facilities. Gases and vapors from down hole are sometimes found in the flow of drilling fluid that transports rock cuttings to the surface for removal at the shale shaker. These formation gases, including hydrocarbon vapors and inorganic gases such as hydrogen sulfide, carbon dioxide, helium and nitrogen, may break out of solution from the drilling fluid at the shale shaker. Hydrogen sulfide is a gas of particular hazard, but it was outside the Scope of Work of this project. The hydrocarbon vapors range from simple asphyxiants, such as methane, ethane and propane, to substances with established Threshold Limit Values (TLV) and Short Term Exposure Limits (STEL), such as butane, pentane, hexane and benzene. Whether or not the presence of these gases in the workplace constitutes a hazard depends upon their concentration in the air. The concentration level of gas near the shale shaker will depend upon the concentration of gas in the mud, the mud circulation rate and the fresh air ventilation arrangements near the shale shaker.

The drilling fluid may also emit a vapor into work areas near the mud pits and mud cleaning equipment. In the case of a water base mud, the vapor is mostly water vapor. An oil base mud with diesel fuel as the oil phase can emit a "diesel fuel" vapor (actually a mixture of several hydrocarbon vapors) that may be irritating to the eyes or respiratory system.

On production platforms fugitive emissions of natural gas and crude oil vapors may be found in the wellhead area, around oil/water/gas and oil/water separators, from atmospheric vents or sumps, around gas compressors and near gas engines that are used as a power source for pumps and compressors. Natural gas emissions may also be discovered from instrumentation and flow controllers that use natural gas as an instrument air supply. Fugitive vapor emissions may also be released from drums of specialty chemicals (corrosion inhibitors, cleaning detergents, bactericides, anti-freeze additives) that are vented to the atmosphere.

II.3.2 Experimental Methodology

The experimental methodology for locating and characterizing emission sources of gases and vapors was unchanged from Phase I [1]. The Phase I study showed that most of the emissions on production platforms are organic hydrocarbons. Emission sources of organic vapors and gases can be located quickly with an instrument like the Century Systems Organic Vapor Analyzer (now manufactured by Foxboro). It can be operated in either a total hydrocarbon or gas chromatograph mode, and it is certified for use in Class 1, Division 1, Groups A, B, C, and D hazardous areas. In the "total hydrocarbon" mode, it gives a continuous, direct readout of total organic vapor concentration for area surveys. This feature is particularly useful for walk-through area surveys in tracking an organic contaminant gas or vapor cloud back to its source.

Once a contaminant emission source is identified, it is necessary to characaterize the source constituents and concentration distribution. For this purpose, the source gas or vapor sample can be drawn through a sampling pump and collected in an inert collection bag. The contents of the collection bag are then analyzed by a gas chromatograph. As discussed in [1], the emission sources on offshore oil and gas drilling and production facilities are expected to consist mainly of natural gas and crude oil vapors. To separate these constituents, an appropriate column must be used with the chromatograph.

For flame-ionization chromatographs, the contents of a source sample collection bag may be too concentrated and may cause a flameout of the flame ionization detector. If a flameout does occur, a secondary diluted sample can be prepared by mixing gas from the source collection bag with ambient air in another inert bag.

Area sampling for gases and vapors is performed in a similar manner as source sampling. An inert collection bag is attached to a sampling pump and a gas sample is collected in the bag for a period of 10 minutes. Area samples should be collected at man breathing height, or about 1.68 m, by mounting the sampling pump and collection bag on a tripod. The contents of the sample collection bag are analyzed with a gas chromatograph.

Personal sampling for gases and vapors is usually accomplished by drawing air samples from the worker's breathing zone through charcoal sampling tubes for a fixed period of time. Organic vapors present in the airstream may be adsorbed onto the charcoal. After exposure, the charcoal tube is returned to the laboratory, and any chemicals present are desorbed from the charcoal and analyzed to determine a time weighted average concentration. Unfortunately, it is not possible to use charcoal tubes to collect many of the gases and vapors (in particular, methane, ethane, propane and butane) that are known to be present in contaminant emission sources on offshore oil/gas drilling and production facilities. If the area sampling results indicate that crew workers are likely to be breathing air containing significant concentrations of these gases, then another procedure can be implemented. Short duration (approximately 10 minutes) samples of the air in a worker's breathing zone (drawn through a pump and collected in an inert sample collection bag) should then be analyzed by a gas chromatograph. These personal sample results can then be related to the results of the source and area gas and vapor sampling activities. If the GC traces from source and area samples indicate the presence of a chemical vapor other than methane through butane, then charcoal tubes should be used for personal sampling.

The Phase I study thoroughly characterized the gas and vapor emission sources on offshore facilities; therefore, it was not intended to repeat this extensive effort in the Phase II observation.

II.4 Liquids

II.4.1 Definition of Potential Hazard

Some hazardous materials in liquid form have been observed on both drilling rigs and production platforms. For example, biocides containing acrolein are used to control the growth of micro-organisms in oil field water systems, and methanol may be used to prevent freezing in fuel gas lines on production facilities. On drilling rigs, caustic soda (sodium hydroxide) may be added as a liquid to the drilling fluid. However, the addition of caustic soda in dry pellet form was observed most frequently by project team members.

Liquids that come into contact with the skin may present a hazard as discussed in Appendix I, Dermatological Effects of Drilling Fluids, in the Phase I Final Report [1]. Some liquids can produce skin sensitization and irritation, while others may affect health if absorbed through the skin. Roughnecks working on the drilling rig floor often come into contact with the drilling fluid when adding or removing joints of drill pipe. Whether or not skin contact with the drilling fluid produces a health hazard depends upon (1) the nature and the amount of chemicals present in the mud that could produce dermatological effects, (2) the extent of skin contact (area covered) and (3) the duration of exposure. For example, a derrickman working in the mud pit area may get drilling fluid on his hands and arms when he takes samples for periodic measurements of drilling fluid properties. However, he usually is able to wash the fluid from his skin promptly so that the duration of exposure is short.

II.4.2 Experimental Methodology

The Phase I test plan called for the characterization of any occurrence of extensive dermal (skin) exposure to drilling fluids or potentially hazardous liquids. The characterization should provide information concerning

- the identity of the liquid in contact with the skin and possible irritants contained in the liquid.
- the location and approximate area of skin or clothing in contact with the liquid.
- the duration of contact, and,
- personal hygiene and protective equipment.

Where possible, documentation should also include photographs.

III. IMPLEMENTATION OF EXPERIMENTAL PLAN

III.1 Description of Facilities and Operations

During the period from April 25 to May 2, 1983, four engineers from SwRI and the USCG Project Technical Monitor took part in an observation of offshore drilling and production operations. The project team visited a total of seven fixed platform structures and two drilling rigs as shown in Table III.1. During the seven-day observation a combination of (1) sound pressure level measurements, (2) noise dosimetry measurements, and (3) dust and particulate sampling activities were carried out. These activities are summarized below.

- Sound Pressure Level Contours

  Measurements of sound pressure were made and recorded on each level of every platform and drilling rig listed in Table III.1. The point-by-point measurements of sound pressure were used to develop contour maps of sound pressure level over the platform surface. When possible, sound pressure level values were recorded with different pieces of equipment in operation. Also, sound pressure measurements on Drilling Rig No. 1 were recorded during both tripping and drilling operations.

- Personal Noise Dosimetry

  Table III.2 summarizes the noise dosimetry measurement activities of the SwRI project team. Our activities focused on determining the 12-hour noise dosage for platform and rig workers who worked in proximity to sound producing equipment.

- Particulate Sampling Activities

  Table III.3 summarizes the particulate sampling activities performed during the offshore observation. Air samples from the breathing zone were collected for three classes of workers, (1) welders and assistants, (2) roustabouts adding chemicals to the drilling fluid, and (3) roustabouts performing paint and rust chipping. For the roustabouts, samples of the particle residue (rafter samples) were collected for analysis to determine the presence of trace metals, coating materials, etc.

  The detailed results of these activities are presented in the sections that follow.

III.2 Sound Pressure Levels

During the one week of field testing, SwRI personnel conducted Sound Pressure Level (SPL) surveys on seven production platforms and two drilling rigs. This section of the report describes the measurements that were made and the format for presenting the data. The bulk of the actual data is presented in Appendix A.

TABLE III.1. LIST OF OFFSHORE STRUCTURES AND PROJECT ACTIVITIES

Structure	Operations	Project Activities
Platform 1	Oil/gas production Sales compressor Welder's work area	Sound pressure contours Noise dosimetry Sampling for welding fumes and particulates
Platform 2	Oil/gas production	Sound pressure contours Noise dosimetry
Platform 3	Oil/gas production Gas lift compressor Welder's (temporary) work area	Sound pressure contours Noise dosimetry Sampling for welding fumes and particulates
Platform 4	Oil/gas production Well work-over rig	Sound pressure contours
Platform 5	Oil/gas production	Sound pressure contours
Platform 6 and	Oil/gas production	Sound pressure contours
Drilling Rig 1	Drilling and Tripping	Sound pressure contours Noise dosimetry Sampling for drilling fluid particulates
Platform 7 and	Oil/gas production	Sound pressure contours
Drilling Rig 2	Well completion activities Rig maintenance (chipping paint and rust, spray painting)	Sound pressure contours Noise dosimetry Sampling for rust and paint particulates

TABLE III.2. SUMMARY OF NOISE DOSIMETRY ACTIVITIES

Job Title	Location	Activity	Exposure Cumulative Noise dB(A)	Logging Hours
Roustabout	Rig No. 2	Chipping paint, rust and spray painting	106.7	11.5
Roustabout	Rig No. 2	Chipping paint, rust and spray painting	102.6	11.4
Driller	Rig No. 1	Operating controls at driller's console during tripping	91.4	11.8
Driller	Rig No. 1	Operating controls at driller's console during drilling	90.8	12.0
Derrickman	Rig No. 1	Racking stands of drillpipe in derrick during tripping	85.9	12.0
Derrickman	Rig No. 1	Test drilling fluid, add chemicals to drilling fluid, service the mud pumps	95.4	11.8
Roustabout	Rig No. 1	Add chemicals to drilling fluid	91.6	5.5
Roustabout	Rig No. 1	Add chemicals to drilling fluid	90.2	1.5
Assistant Operator	Platform 1	Collect operation data on gas compressor. Perform routine maintenance and assistance	88.9	12.0
Roustabout	Platform 1	Collect operation data on turbine maintenance and assistance	88.2	12.0
Welder	Platform 1	Welding and grinding	90.3	10.7
Electrician	Platforms 1 and 2	Maintenance and repair	84.7	11.0
Welder	Platforms 1 and 3	Job setup, welding and grinding	85.1	12.0
Welder's Assistant	Platforms 1 and 3	Job setup, welding and grinding	87.3	12.0

TABLE III.3. SUMMARY OF PARTICULATE SAMPLING ACTIVITIES

Job Title	Location	Activity	Sample	Type of Sample	Duration	Analyze For
Welder	Platform 1	Welding and grinding	M101	personal, total dust	103	trace metal concentration
			M103	personal, total dust	138	traco metal concentration
Welder's Assistant	Platform 1	Grinding	M102	personal, total dust	119	trace metal concentration
Roustabout	Rig 1	Adding chemicals to drilling fluid	P1	personal, respirable dust	119	respirable dust concentrtion
			M107	area sample	120	trace metal concentration
			M1	personal, total dust	123	total dust or metal concentration
Roustabout	Rig 1	Adding chemicals to drilling fluid	P2	personal, respirable dust	113	respirable dust concentration
			M108	area sample	110	trace metal concentration
			M2	personal, total dust	112	total dust or metal concentration
Roustabout	Rig 1	Adding chemicals to drilling fluid	P3	personal, respirable dust	40	respirable dust concentration
			M109	area sample	107	trce metal concentration
			M3	personal, total dust	41	total dust or metal concentration
Roustabout	Rig 1	/ Jding chemicals to drilling fluid	P4	personal, respirable dust	94	respirable dust concentration
			M110	area sample	102	trace metal concentration
			M4	personal, total dust	94	total dust or metal concentration
Roustabout	Rig 2	Chipping rust ano paint with air chisel	M27	personal, total dust	100	total dust or metal concentration
			M38	personal, total dust	100	total dust or metal concentration
			M35	personal, total dust	104	total dust or metal concentration
			M34	personal, total dust	100	total dust or metal concentration
			M40	personal, total dust	100	total dust or metal concentration
			M37	personal, total dust	68	total dust or motal concentration
Roustabout	Rig 2	Chipping rust and paint with air chisel	M29	personal, total dust	100	total dust or metal concentration
			M32	personal, total dust	100	total dust or motal concentration
			M28	personal, total dust	99	total dust or metal concentration
			M30	personal, total dust	100	total dust or metal concentration
			M31	personal, total dust	100	total dust or metal concontration
			M36	personal, total dust	39	total dust or metal concentration
Welder	Platform 3	Welding and grinding	M126	personal, total dust	103	trace metal concentration
			M128	personal, total dust	109	trace metal concentration
Welder's Assistant	Platform 3	Grinding	M127	personal, total dust	101	trace metal concentration
			M129	personal, total dust	108	trace metal concentration

To measure the SPL's, SwRI used the GENRAD Type 1, Precision Sound Level Meters described in Section II.1.2. In accordance with NVC 12-82 and applicable ANSI procedures, these instruments were calibrated at the beginning and end of each day. In addition, they were periodically checked during the day to ensure that they were in calibration.

Where possible, SwRI utilized platform drawings provided by the participating company. SPL measurements were indicated on the drawings and operating conditions were documented. One person collected SPL data while a second individual recorded the discrete points, drew in contours, and documented the operating conditions. Development of the contours was facilitated by moving the SPL meter along an isobar between two discrete points. This procedure enabled a two-man team to rapidly characterize the SPL contours on a platform. In a few cases, engineering drawings were not available or they were not current. In these cases, SwRI personnel made a sketch of the facility for recording data.

Figure III.1 is an example of the data presented in Appendix A. The bold contours broken by numbers are the SPL's during "normal" operations. Normal here indicates the conditions most likely to be present. The broken lines with numbers show the shift in SPL's due to a change in operating conditions. There is also a cross hatched area enclosing an asterisk. This represents an area of SPL's which were compared to noise dosimetry data. More detail on this comparison can be found in Section IV.1.3. Finally, there are triangles with enclosed numbers, which indicate the points where octave band analyses were conducted.

An octave band analysis is generally performed to characterize a noise source. The procedure involves using a bandpass filter to pass a selected frequency within an octave band. The center frequencies for octave bands considered are: 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16,000 Hz. Note that a doubling of the frequency occurs for each octave step. SwRI personnel collected octave band data on selected noise sources as indicated in Tables III.4 and III.5. The tables provide a summary of C-weighted (flat) SPL's by octave band. They also indicate the overall SPL resulting from the combination of octave band levels. Two values of overall SPL are reported. The "Flat" overall level is based on C-weighting, and the dB(A) level is based on A-weighting.

The manner in which the decibel is defined requires the use of a special formula to calculate the overall SPL's. For C-weighting, the resultant SPL is calculated from:

$$SPL_{RES} = 10\ LOG_{10} \left[\sum_{I=1}^{N} 10^{SPL(I)/10} \right] \qquad (5)$$

where

SPL(I) is the sound pressure level in the I-th octave band, and
SPL_{RES} is the resultant sound pressure level.

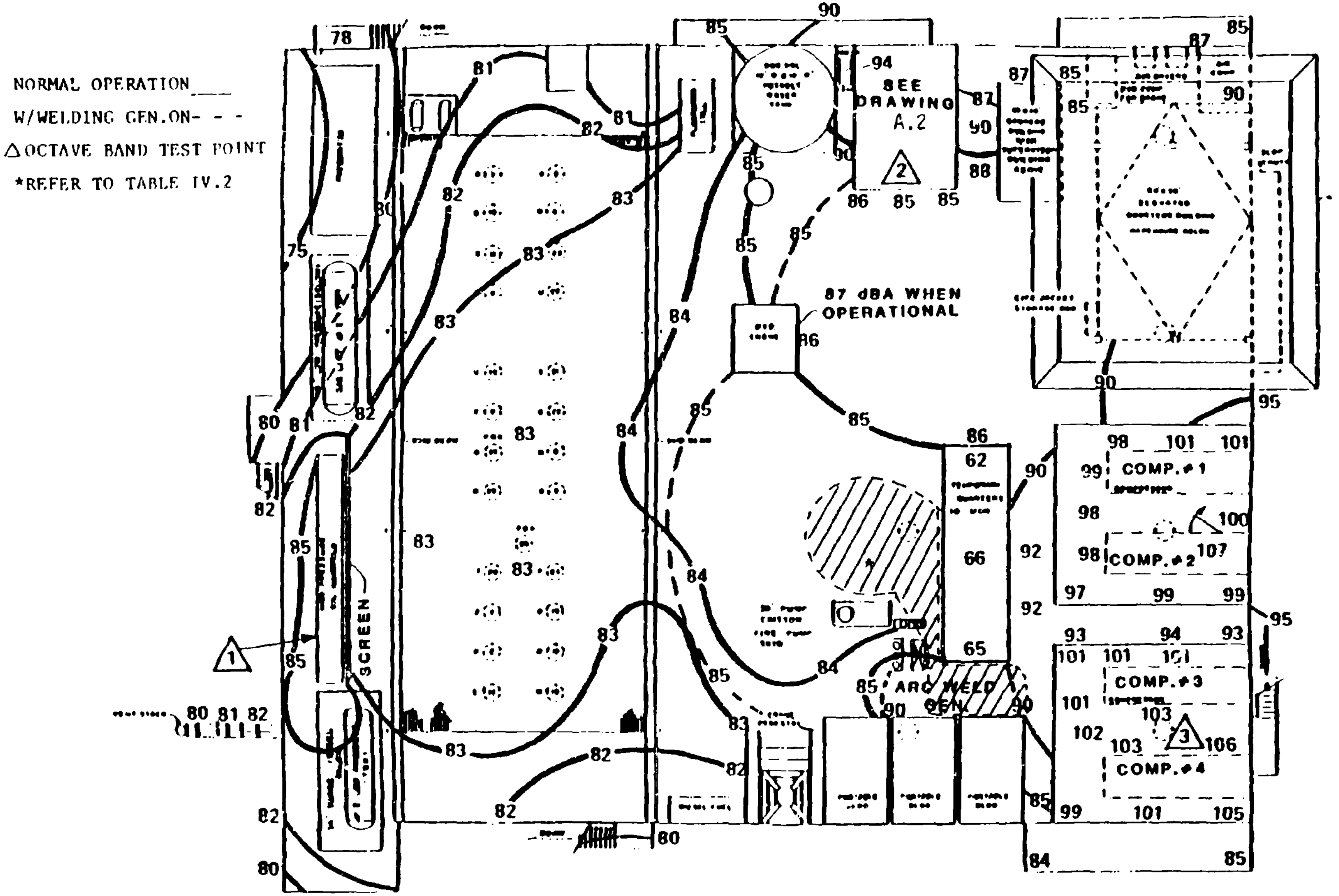


FIGURE III.1. UPPER LEVEL - PLATFORM NO. 1 - SOUND PRESSURE LEVEL CONTOURS IN dB(A)

TABLE III.4. OCTAVE BAND ANALYSIS OF SELECTIVE SOURCES

	Δ1	Δ2	Δ3	Δ4	Δ5
Platform:	No.1	No.1	No.1	No.1	No.1
Area:	Manifold	Generator Room	Compressor Room	Air Intake	Fan
Dwg. No.:	A.1	A.2	A.1	A.3	A.5
Date:	4-26-83	4-26-83	4-26-83	4-26-83	4-26-83
Time:	6:46 AM	7:37 AM	9:18 AM	12:22 PM	12:25 PM
RESULTANT SOUND PRESSURE LEVELS					
Flat:	90	105	107	105	104
dB(A):	85	103	105	105	97
OCTAVE BAND SOUND LEVELS (FLAT)					
Octave Band Center Freq.					
31.5	77	92	82	88	90
63	76	86	86	91	95
125	78	91	97	92	100
250	77	95	98	92	96
500	76	96	96	94	92
1-K	74	94	94	92	90
2-K	80	92	90	93	86
4-K	8[illegible]	94	91	89	82
8-K	78	97	102	104	94
16-K	71	98	84-92	92	78

NOTES 1. Drawing number refers to corresponding figure in Appendix A.
2. Flat designates C-weighting
3. dB(A) designates A-weighting
4. Δ - Location of octave band analysis in indicated drawing number

TABLE III.5. OCTAVE BAND ANALYSIS OF SELECTIVE SOURCES

	6	7	8	9	10
Platform:	No.2	No.2	No.2	No.2	No.4
Area:	Well Deck	Air Intake	Exhaust	No.2 Deck	Exhaust
Dwg. No.:	A.5	A.5	A.5	A.7	A.10
Date: Time:	4-25-83 6:25 PM	4-25-83 6:54 PM	4-25-83 6:57 PM	4-25-83 7:20 PM	4-26-83 4:30 PM
RESULTANT SOUND PRESSURE LEVELS					
Flat:	85	105	97	90	109
dB(A):	81	102	94	91	107
OCTAVE BAND SOUND LEVELS (FLAT)					
Octave Band Center Freq.					
31.5	72	88	80	63	86
63	72	90	82	68	99
125	75	90	86	70	99
250	76	94	91	70	104
500	80	93	88	72	102
1-K	77	94	86	71	101
2-K	72	88	87	71	100
4-K	66	83	85	87	101
8-K	72	95	90	84	89
16-K	64	89	82	75	72

NOTE: Drawing number refers to corresponding figures in Appendix A.

To determine the A-weighted overall SPL, the octave band measurements must be adjusted to their A-weighted values before inserting into Equation (5). The A-weighting values given in NVC 12-82 for Octave Bands 31.5 to 8000 Hz are:

Frequency (Hz)	31.5	63	125	250	500	1000	2000	4000	8000
A-weighting (dB)	-39	-26	-16	-8	-3	0	+1	+1	-1

In accordance with NVC 12-82, the SPL measurements were read to the nearest decibel. The SPL meter automatically calculated both the C-weighted and A-weighted overall levels. Since this process utilizes more precision than the recorded octave band levels, it is not generally possible to calculate the precisely same overall value from the recorded data. Additionally, the octave band analysis is recorded over a period of time during which levels may vary.

SwRI personnel also documented the noise environment on several field boats and helicopters. The SPL in the cabins of field boats generally varied from 75 dB(A) to 83 dB(A). The level outside the cabin often was much higher, although it varied considerably. Official company policy required personnel to remain in the cabin during transit. However, workers often remained on the deck. The occasional helicopter rides produced SPL's of 87 to 95 dB(A) in the passenger compartment.

Measurements of sound pressure levels on the helipads during helicopter take-off and landing were not possible due to company policies on personal safety. Measurements made on the stairways to the pads were not representative of actual take-off and landing levels due to the proximity of other noise sources, reverberation and excessive wind noise across the microphones caused by blade-induced air turbulence. These sound levels were not, however, considered essential due to their very short and infrequent nature and the companies' policy prohibiting personnel on the pads.

III.3 Noise Dosimetry

Noise dosimetry data collected offshore is discussed in this section. 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 workers collar, as close to the ear as possible. The worker was observed throughout the workday, and a time-motion record of his/her activities was compiled. The data obtained during this phase of the testing 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. The time-motion study was reviewed to determine the associated job activity. This information can be obtained using the legend accompanying each histogram.

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.

$$L_{eff}(i) = 16.61 \text{ LOG} \left[\frac{1}{\sum_{i=1}^{m} \Delta t_i} \sum_{i=1}^{m} 10^{L_{A_i}/16.61} \Delta t_i \right] \quad (6)$$

where

L_{A_i} = SPL measured during the i-th sample interval

Δt_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

$$SPL_{PER}(i) = 5 \frac{\text{LOG } (8/T)}{\text{LOG } 2} + 90 \quad (7)$$

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 NVC 12-82. Assuming no hearing protection, the permissible exposure was exceeded if the two curves cross. The 12-hour and 24-hour effective exosures 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 were 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.

Details regarding interpretation of the dosimetry data is presented in Section IV.1.

Figure III.2 is a record of the SPL's measured on one of the SwRI team. These data were collected on the first day offshore as the SwRI team toured the field. Table III.6 identifies the activities corresponding to the legend on the top margin of Figure III.2.

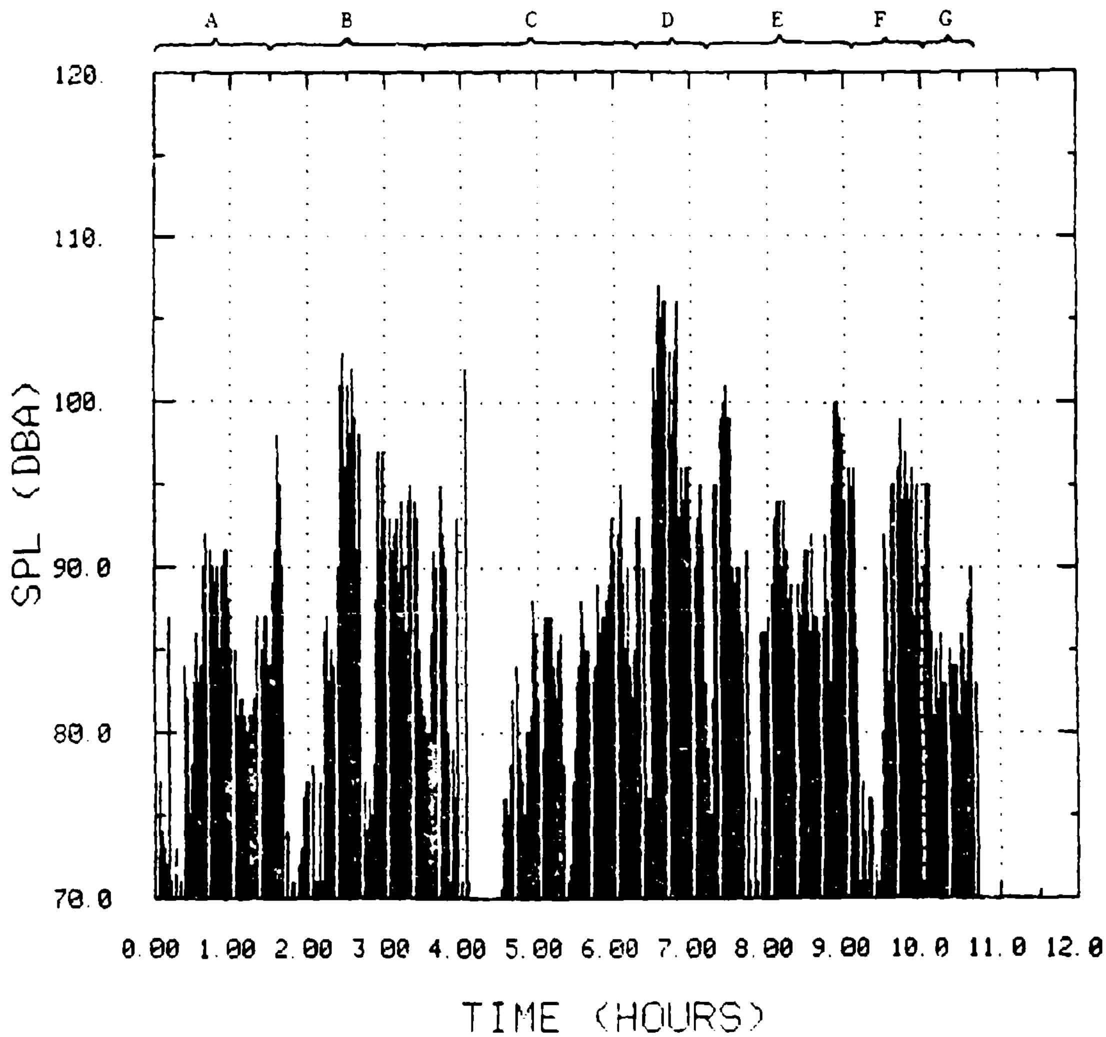


FIGURE III.2. NOISE DOSIMETRY ON SwRI EMPLOYEE TOURING THE FIELD. (IDENTIFICATION NUMBER ND 1)

TABLE III.6. SPL TIME-HISTORY ON SwRI PERSONNEL

Interval	Activity
A	Inside crewboat traveling to field
B	Touring Platform 1
C	Touring Platform 2
D	Touring Platform 3
E	Touring Platform 4
F	Touring Drilling Rig (Jack-up)
G	Fieldboat to Platform 2

Figure III.3 depicts the cumulative effective exposure based on the data from Figure III.2. This figure was not adjusted to account for hearing protection, which was worn in high noise areas. The figure indicates that the permissible cumulative exposure was exceeded at approximately 7.5 hours into the survey assuming that no hearing protection was used to attenuate sound pressure levels.

Figure III.4 shows the cumulative dose using the same time-history data. This plot also reveals that the permissible level was exceeded assuming no hearing protection. The peak indicates that this individual was exposed to approximately 146% of the allowable dose.

Figures III.2, III.3, and III.4 serve as examples of the dosimetry data collected offshore. A total of 16 dosimetry records were obtained during the offshore observations. Table III.7 is a summary of the dosimetry data collected. In all cases except ND 10 and ND 11, the sample duration was between 10.7 and 12 hours, and the range of dosages varied from 69% to 1450% of the permissible dose. In eleven cases the received dose was greater than or equal to the permissible limit. The data collected on these 16 dosimetry observations is presented in Appendix B.

III.4. Dosimetry for Airborne Contaminants

Table III.3 in Section III.1 lists the airborne dust and particulate samples collected during the offshore observation. In addition to these samples collected on cassette filters, six bulk or rafter samples were gathered. These samples were analyzed qualitatively by X-ray flouresence (XRF) for elemental composition. The results of the XRF scans are presented in Table III.8.

The elemental XRF analyses for bulk sample S-4 indicated a large fraction of Fe (rust) and only small or trace amounts of other metals. Therefore, the following personal monitoring samples for rust and paint chipping that correspond to rafter sample S-4 were analyzed gravimetrically for total nuisance particulate. The results of these analyses for Samples M29 through M36 are shown at the top of Page 45.

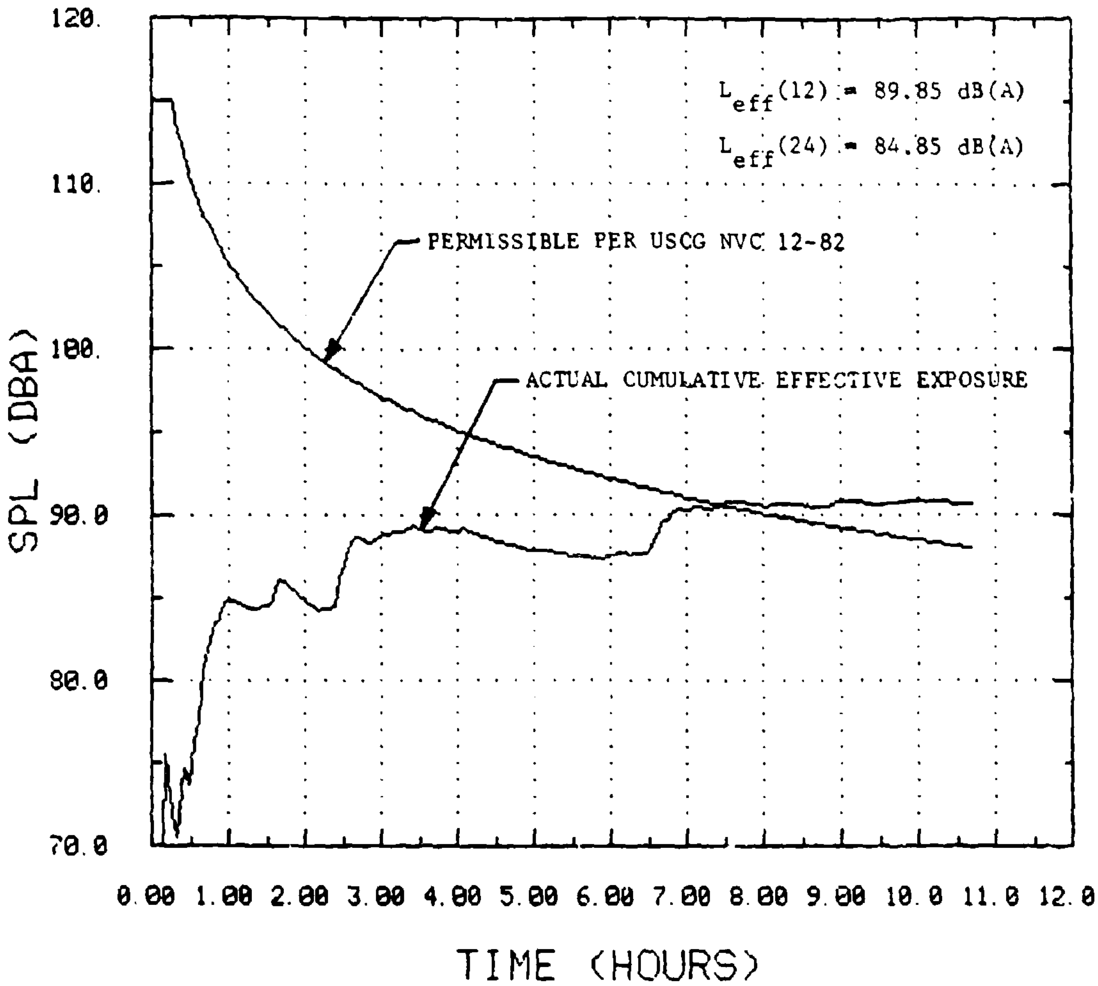


FIGURE III.3. CUMULATIVE EFFECTIVE EXPOSURE ON SwRI EMPLOYEE (IDENTIFICATION NUMBER ND 1)

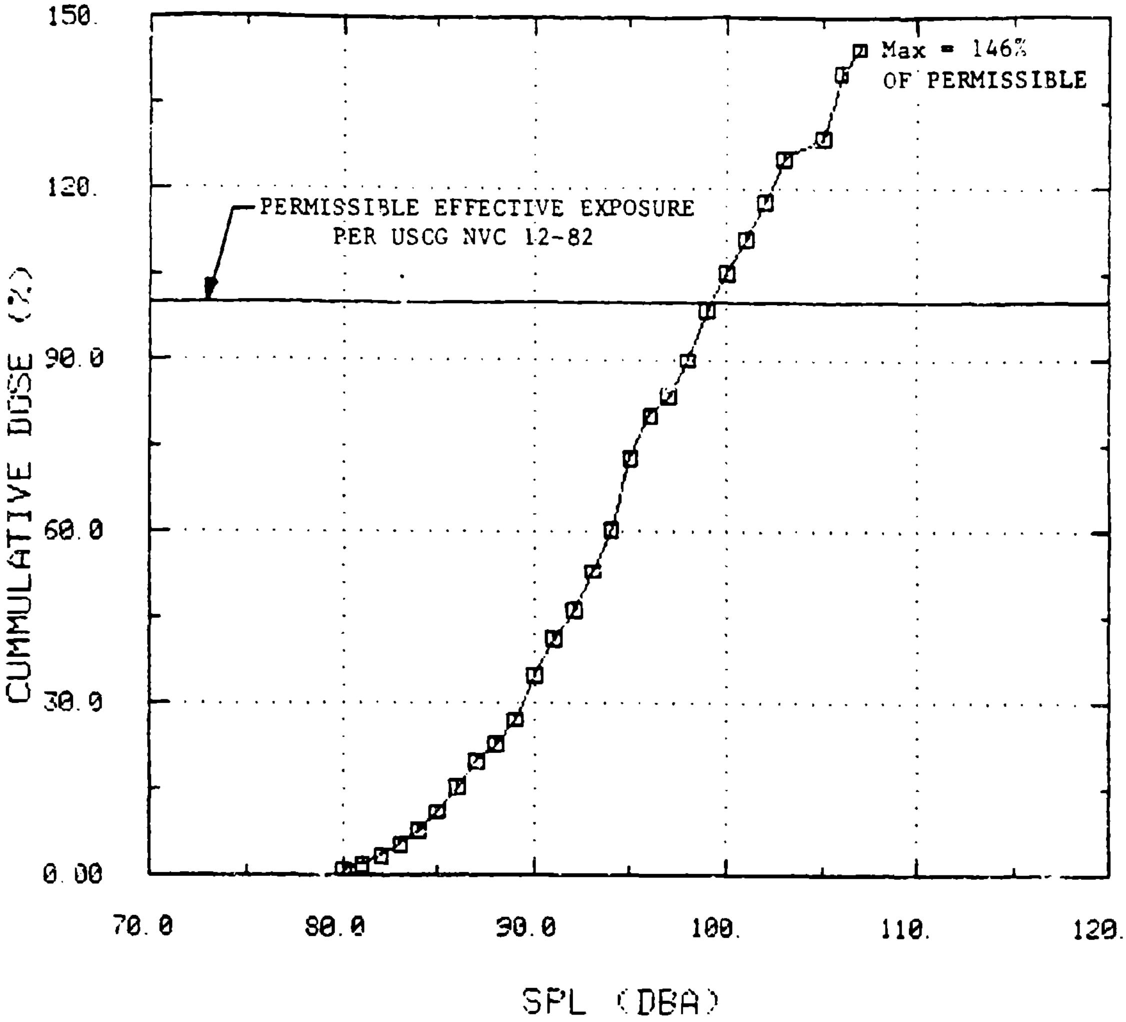


FIGURE III.4. CUMULATIVE DOSE RECORDED ON SwRI EMPLOYEE (IDENTIFICATION NUMBER ND 1)

TABLE III.7. DOSIMETRY DATA COLLECTED OFFSHORE

Dosimetry ID Number	Job or Title	Sample Duration	Time When Exceeded Allowable	Hearing Protection	Max Dose	$L_{eff}(12)$ dB(A)	$L_{eff}(24)$ dB(A)
ND 1	SwRI	10.7 hrs	7.5 Hrs	Y	146%	89.85	84.85
ND 2	USCG	10.7 hrs	7.5 hrs	Y	134%	89.40	84.40
ND 3	Day Pumper	12 hrs	8.3 hrs	Y	121%	88.84	83.84
ND 4	Day Roustabout	12 hrs	8.3 hrs	Y	110%	88.18	83.18
ND 5	Welder	10.7 hrs	10.5 hrs	N	103%	87.35	82.35
ND 6	Driller	11.8 hrs	8.3 hrs	N	176%	91.36	86.36
ND 7	Derrick Man	12 hrs	*	N	78%	85.85	80.85
ND 8	Driller	12 hrs	8 hrs	N	167%	90.78	85.78
ND 9	Derrick Man	11.8 hrs	3.7 hrs	N	318%	95.42	90.42
ND 10	Roustabout	5.5 hrs	*	N	86%	85.97	80.97
ND 11	Roustabout	1.5 hrs	*	N	19%	75.20	70.20
ND 12	Electrician	11 hrs	*	Y	58%	84.05	79.05
ND 13	Roustabout	11.5 hrs	.8 hrs	Y	1450%	106.31	101.31
ND 14	Roustabout	11.4 hrs	1.5 hrs	Y	820%	102.21	97.21
ND 15	Welder's Assistant	12 hrs	12 hrs	N	100%	87.28	82.28
ND 16	Welder	12 hrs	*	N	69%	85.10	80.10

*Allowable level was not exceeded during the sample.
Y = Hearing protection worn in designated areas.
N = No hearing protection was worn during the day.

TABLE III.8. RELATIVE ELEMENTAL COMPOSITION OF BULK SAMPLES

(Parts Per 10 Parts Total Detected Elements)
Method: X-Ray Fluorescence

Element	S-2	S-3	S-4	S-5	S-6	S-7
		Bulk Sample Identification				
Al	0.5	0.2	-	t*	-	-
Si	0.2	5	t	t	-	1
S	9	0.1	t	0.5	4.5	0.5
Cl	-	t	1	-	-	0.5
K	-	-	-	8	-	t
Ca	0.1	0.4	t	t	0.5	1
Ti	0.1	0.1	0.5	t	-	1.5
Cr	-	-	-	1	4.5	-
Mn	-	0.1	t	**	**	t
Fe	0.1	4	8	0.5	0.5	3
Zn	-	-	0.5	-	-	1.5
Pb	-	-	-	-	-	1
Ta	-	t	-	-	-	-
Sr	-	t	t	t	-	t

* t = trace
** Mn = not detectable due to strength of Cr line

Key:
S-2 = Mud Chemical
S-3 = Mud Chemical
S-4 = Rust and Paint Chipping Debris (fine)
S-5 = Mud Chemical
S-6 = Mud Chemical
S-7 = Rust and Paint Chipping Debris (rough)

Sample Number	Q(Lpm)	t(min)	W_c(μg)	C(mg/m^3)
M29	1.662	100	300	1.80
M32	1.662	100	490	2.95
M28	1.662	99	678	4.12
M30	1.686	100	515	3.05
M31	1.686	100	520	3.08
M36	1.686	39	199	3.02

These measured concentrations are less than the TLV-TWA of 10 mg/m^3 for total nuisance particulate. The measured contaminant weights reflect filter conditioning to prescribed temperature and relative humidity prior to and following sample collection.

Bulk samples S-7 corresponds to rust and paint chipping personal sample numbers M27, M34, M35, M37, M38 and M40. The indication of lead in the bulk sample, possibly from a paint primer, eliminated a gravimetric analysis for these occupational exposure samples. These samples were quantitatively analyzed by atomic absorption for Pb, Zn, Fe and Cr. Lead is of primary concern. The latter three elements were included to verify the XRF scans. The absence of Cr in both paint chipping bulk samples suggests that non-chromated paints were used. The analysis results for these six samples are summarized below. In all cases, the filter blank did not contain any of the four metals above the detection limit.

		Weight of Analyte (μg)			
Sample No.	V(L)	Fe	Zn	Pb	Cr
M-27	169.2	180	14	<4.5	<6
M-34	171.0	60	30	<4.5	<6
M-35	176.0	8	13	<4.5	<6
M-37	116.3	17	3.8	<4.5	<6
M-38	169.2	98	10	<4.5	<6
M-40	171.0	10	39	<4.5	<6

	Airborne Concentration (mg/m^3)			
Sample No.	Fe_2O_3	ZnO	Pb	Cr
M-27	1.5	0.10	<0.026	<0.035
M-34	0.5	0.22	<0.026	<0.035
M-35	0.03	0.92	<0.026	<0.034
M-37	0.02	0.41	<0.039	<0.052
M-38	0.83	0.07	<0.026	<0.035
M-40	0.08	0.28	<0.026	<0.035

The concentration of iron oxide was calculated by multiplying the iron concentration by the ratio of the molecular weight of the oxide to the molecular weight of bivalent iron. An analogous calculation was used to obtain the concentration of zinc oxide. In the case of lead and total chrome, concentrations were calculated at the detection limit.

Sample numbers M101 through M103 and M126 through M129 were collected during welding and grinding. All filters were scanned using XRF, and Fe, Mn and Zn were identified. The American Welding Society publication, Fumes and Gases in the Welding Environment (publication number FWG, 1979), indicates that Fe and Mn are the dominant fume components for the E7018 and E6010 welding electrodes that were used on the platform. All three elements were quantified by XRF (NIOSH P&CAM 345) without removing the filters from the cassettes. The elemental concentrations of Fe and Zn were converted to Fe_2O_3 and ZnO equivalents for later comparison with the appropriate TLV. The concentration of elemental Mn fume was also calculated. Fume concentrations under the welder's helmet are summarized below.

	Concentration (mg/m^3)		
Sample Number	Mn	Fe_2O_3	ZnO
M101	0.046	0.643	<0.025
M102	0.028	0.249	0.170
M103	<0.015	0.070	<0.018
M126	<0.019	0.120	<0.024
M127	<0.024	0.093	<0.030
M128	0.018	0.035	0.030
M129	<0.023	0.142	0.124

The XRF detection limit is 3μg for each element. For elements not detected, concentrations were calculated at the detection limit.

The last series of personal samples were collected during addition of dry chemicals to the drilling fluid. Sample numbers P1 through P4 were set up to collect respirable dust samples on PVC filters, i.e. the method for nuisance dusts. The results of gravimetric analysis of these samples is summarized below; concentrations are reported as respirable nuisance dust. All of these values are less than the TLV-TWA value of 5 mg/m^3 for respirable nuisance particulate even without calculating an 8-hour time weighted average concentration.

Sample Number	Q(Lpm)	t(min)	W_c(μg)	C(mg/m^3)
P1	1.381	119	71	0.43
P2	1.381	113	39	0.25
P3	1.381	40	27	0.49
P4	1.381	94	76	0.58

All gravimetric analyses include filter dessication before tare weighing and final weighing.

Material Safety Data Sheets were obtained from the manufacturer of the dry chemicals corresponding to bulk samples S-2, S-3, S-5 and S-6. Decisions regarding the type of analysis for samples M1 through M4 and M107 through M110 were guided in part by those MSDS sheets. Sample numbers M1, M2, M3, and M4 represent personal total dust exposure during addition of dry, bagged chemicals to the drilling fluid. The samples were collected on 0.8 mixed esters of cellulose (MEC) filters. X-ray fluorescence scans of the bulk materials indicated the presence of chrome in two of the four dry chemicals that were handled, but the valency of the chrome is not indicated by X-ray. The filter media was appropriate for sampling and analysis of certain chrome compounds (NIOSH P&CAM S323 and S352) but not for chrome VI which uses a PVC filter (NIOSH P&CAM 319). The Material Safety Data Sheets for one of the two chrome-bearing chemicals indicated the presence of water soluble chrome VI (sodium dichromate). Given the potential for chrome VI on the MEC filters, the following analysis procedure was devised in consultation with an AIHA accredited laboratory.

- Water extract filters to remove soluble dichromates (chrome VI) and soluble chrome II and III.
- Conduct two analyses on the water extract.
  - AAS for total soluble chrome.
  - Colorimetric analysis for soluble chrome VI per P&CAM 319.
- Calculate by difference the amount of soluble chrome II and III.
- Analyze by AAS the insoluble fraction (residue of extract) for total insoluble chrome II and III per P&CAM S323.

This procedure was selected to maximize the information from the samples; the limitations of the procedure are recognized. The results of the analysis are summarized below.

Sample No.	Total Soluble Cr VI (μg)	Total Soluble Chrome, (μg)	Insoluble Chrome, II,III, (μg)	Sample Vol (L)	Sample Time (min)
M1	<0.5	<8.0	<3.0	180	123
M2	<0.5	<8.0	<3.0	164	112
M3	<0.5	<8.0	<3.0	60	41
M4	<0.5	<8.0	<3.0	138	94

A blank filter was submitted for analysis and produced the same results. Chrome in any form was not detected above the indicated detection limits. Soluble chrome II and III is at most of the order of 7.5μg. Concentrations were calculated at the detection limit and are summarized below.

Sample No.	Total Soluble Chrome VI (mg/m^3)	Total Soluble Chrome (II,III,VI) (mg/m^3)	Insoluble Chrome II,III (mg/m^3)
M1	<0.003	<0.044	<0.017
M2	<0.003	<0.049	<0.018
M3	<0.008	<0.133	<0.05
M4	<0.004	<0.058	<0.022

These results indicate that all exposures were less than 0.05 mg/m^3 for soluble chrome VI and 0.5 mg/m^3 for soluble or insoluble chrome II and III.

Table III.3 indicates that four area samples (M107 through M110) were collected during addition of dry, bagged chemicals to the drilling fluid. Analysis of these four samples was not justified because

- o physical constraints and air current patterns around the mud makeup hopper were not conducive to collecting a representative airborne sample, and
- o the results of the personal exposure samples were extremely low.

IV. INTERPRETATION OF RESULTS

IV.1. Sound Pressure Levels and Dosimetry

IV.1.1 Measured Sound Levels

In this section, the results of the SPL surveys have been interpreted relative to NVC 12-82 guidelines. NVC 12-82 makes recommendations regarding both cumulative exposures and peak exposures. The document recommends that current "vessels should ensure an $L_{eff}(24)$ less than or equal to 82 dB(A). It further recommends that non-impulse noise levels over 115 dB(A) and impulse noise levels over 140 dB(A) be avoided. The circular further recommends that exposures between 105 dB(A) and 115 dB(A) be comprised of intermittent exposures "such that each exposure duration is one-seventh of the total allowable exposure at that noise level" [NVC 12-82]. Finally, it is recommended that personnel wear hearing protective devices in area with levels over 85 dB(A).

The Coast Guard and the International Maritime Organization (IMO) recognize the problems associated with reducing noise levels on relatively small vessels and facilities. For this reason, a noise standard published by IMO in November 1981 is applicable only to vessels over 1600 tons. Since NVC 12-82 represents the USCG's implementation of the IMO code, it, too, is aimed at ocean-going vessels over 1600 tons. The tight conditions on smaller vessels lead to a great deal of structure-borne noise which may be excessively costly to adequately attenuate using engineering controls. Therefore, the circular suggests that both engineering and administrative controls be implemented to ensure that the exposure criteria are met.

A review of the SPL contours developed during the field study indicates that a majority of the noise levels generally ranged from the 70's to approximately 100 dB(A), although levels were detected as high as 117 dB(A) and as low as 41 dB(A). The results of the survey can be readily compared to NVC 12-82 by considering two ranges of SPL's. Levels below 85 dB(A) do not require action according to NVC 12-82. NVC 12-82 considers 85 dBV(A) an action level. Warning notices are recommended in areas exceeding 85 dB(A). Further, it recommends that

> "Unless the $L_{eff}(24)$ computed or measured for a crewmember accounts for and allows such an exposure, crewmembers should be required to wear hearing protective devices whenever entering spaces with noise levels greater than 85 dB(A)." [NVC 12-82]

The distribution of SPL's as shown on the contour plots in Appendix A indicates that entire portions of each offshore facility can be identified as normally falling above or below the 85 dB(A) action level. If company policies require hearing protection in all areas where the SPL exceeds 85 dB(A), the costs associated with computing or measuring a specific employee's exposure will be minimized. Alternatively, companies could consider requiring ear protection everywhere outside of the crew quarters.

An exception occurs if the worker engages in an activity which produces a high SPL. Chipping paint with a needle gun is a prime example of this situation. The work may be performed
in an area with a normal SPL contour of 70 or 80 dB(A), well below the action level. However, the activity may produce SPLs at the worker's ear level in excess of 110 dB(A).

IV.1.2 Noise Dosimetry

SwRI has interpreted the results of the noise dosimetry records based on the recommendations outlined in USCG NVC 12-82 [7]. This is a general interpretation of the recorded levels. No attempt was made to determine the actual exposure received by an individual. The decision to avoid assessing a specific exposure was based on several items. First, in most cases, it was impossible to determine the NRR (Noise Reduction Rating) of protective plugs or muffs. Generally, no model number or NRR could be located on the devices. In addition, the adequacy of the fit was not known. Therefore, SwRI has made no attempt to determine compliance levels. The records in Appendix B indicate the exposures received if no hearing protection is used.

Figure IV.1 shows the cumulative effective exposure during the course of sampling on a roustabout. During the sample period, the worker was primarily involved in chipping paint with an air-driven needle gun. The $L_{eff}(24)$ for an unprotected worker was calculated to be 101.31 dB(A), presenting 1450% of the permissible exposure. The level of exceedance is based on a calculation of the permissible dose using an extension of the procedures given in NVC 12-82.

The permissible dose was defined as the length of time that an individual may be exposed to a particular SPL. For example, an exposure of 90 db(A) for 480 minutes is 100% of the permissible. Likewise, an exposure of 90 db(A) for 240 minutes is 50% of the allowable level. For non-impulse noise, NVC 12-82 indicates the range of SPL's which should be considered is 80 dB(A) to 115 dB(A). For each level in this range, SwRI calculated the length of time required to reach 100% of the permissible exposure. The actual length of time that the individual was exposed to a particular SPL was determined from the noise dosimetry record. The ratio of the actual time to permissible time represents the dose at a given SPL. Finally, the cumulative dose may be calculated by summing over the range 80 to 115 dB(A). The function is shown as

$$\%\ \text{Cumulative Dose} = \sum_{SPL=80}^{115} \frac{t_{A(SPL)}}{t_{p(SPL)}} \times 100 \qquad (8)$$

where $t_{A(SPL)}$ = time the worker was exposed to a specified SPL

$t_{P(SPL)}$ = time to reach maximum permissible level when exposed to a given SPL. This assumes no other levels are present.

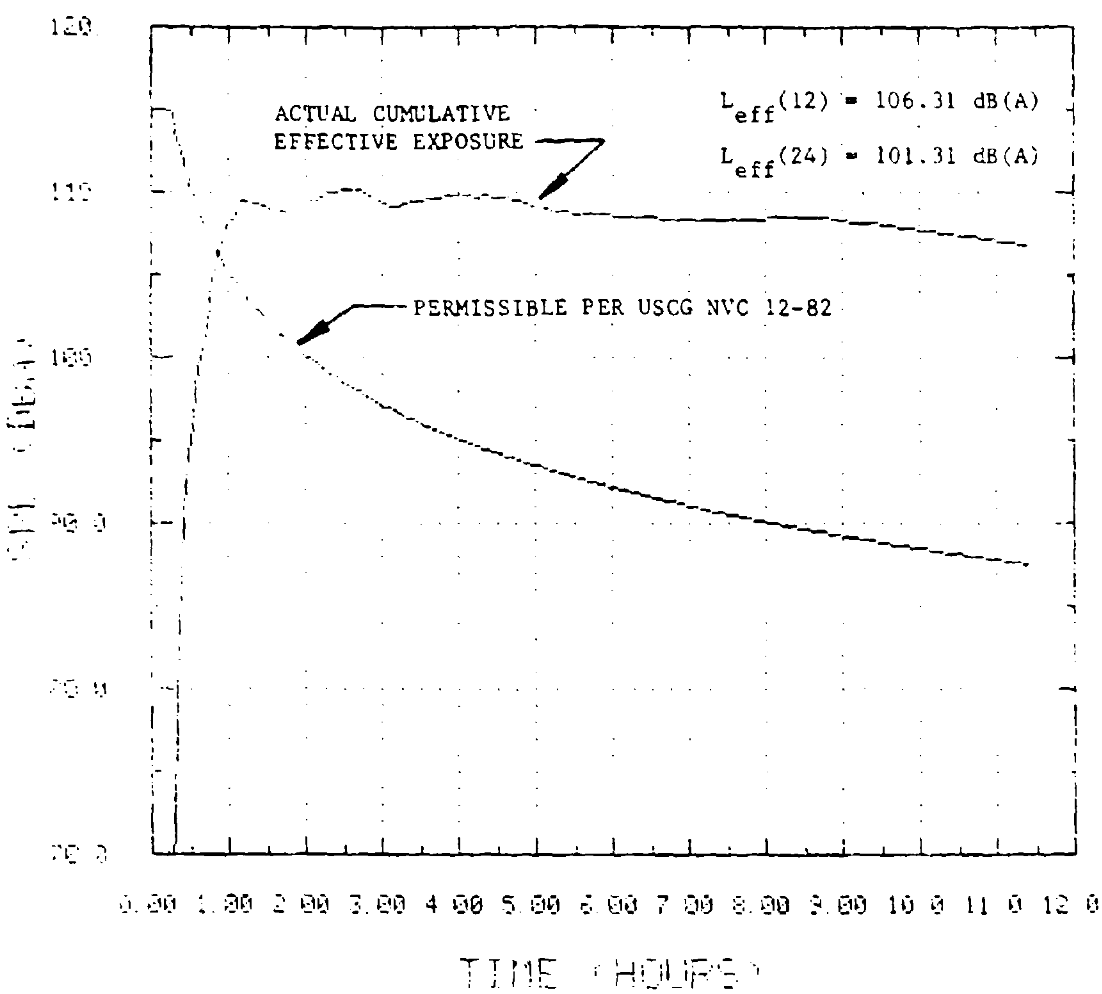


FIGURE IV.1. CUMULATIVE EFFECTIVE EXPOSURE ON ROUSTABOUT (Identification Number ND13)

The result of this procedure may be plotted as shown in Figure IV.2(a). This type of plot appears to be particularly useful in assessing the severity of an overexposure and in estimating the effects of implementing a program to reduce exposures. For example, it is relatively simple to estimate the reduction in the overall dose due to applying an attenuation to all exposures greater than some action level. Figure IV.2(b) and (c) show two examples of attenuating levels greater than or equal to 85 dB(A). Note that 85 dB(A) was chosen as the action level based on NVC 12-82. Figure IV.2(b) shows the result of applying 10 dB(A) attenuation. Figure IV.2(c) is the result of applying 20 dB(A). For 10 dB(A) attenuation, the original 90 dB(A) exposure durations were added to the 80 dB(A) exposures. The contribution to the overall dose was calculated by dividing the new sum by the permissible duration at 80 dB(A). The same procedure was followed for all levels >90 dB(A). Note that 85 through 89 dB(A) can be ignored because 10 dB(A) attenuation reduces them below the 80 dB(A) cutoff recommended by NVC 12-82. The same type of process was used to apply 20 dB attenuation in Figure IV.2.(c). This analysis indicates that at least 20 dB attenuation was required to reduce the worker's exposure to a level below the permissible exposure.

SwRI personnel did not attempt to evaluate the noise reduction provided by the various hearing protective devices used by offshore personnel. In this study, it was our intention to evaluate the noise environment, not the personal devices used to attenuate the SPL. Therefore, we only noted that personnel did or did not use some form of protection. Devices observed in use included cotton balls, fitted plugs, foam plugs, and earmuffs.

The Occupational Safety and Health Administration (OSHA) issued an amendment to its noise standard (29CFR1910.95) [8] on March 8, 1983. This new amendment emphasizes the use of noise dosimetry to determine worker exposure. The National Institute of Occupational Safety and Health (NIOSH) has established practices for determining compliance [8]. The procedure is based on the calculation of an overall dose. The maximum dose shown in Figure IV.2(a)(b)(c) and similar figures in Appendix B represents this overall dose. Noise exposures are then classified by dose as shown in Table IV.1 [8]. The second column on Table IV.1 indicates the number of SwRI dosimetry samples which reuslted in a dose within the indicated range. Based on these data, it appears that a hearing conservation program is required for offshore workers.

IV.1.3 Comparison of SPL and Dosimetry

As previously described, SwRI utilized precision sound pressure level (SPL) meters and personal dosimeters to measure potential noise exposures. In several cases, both techniques were used concurrently. In other cases, it was possible to identify locations that were sampled using both types of instruments at different points in time. Documentation accompanying the dosimetry records was reviewed and several cases which may be compared to the SPL survey data were identified.

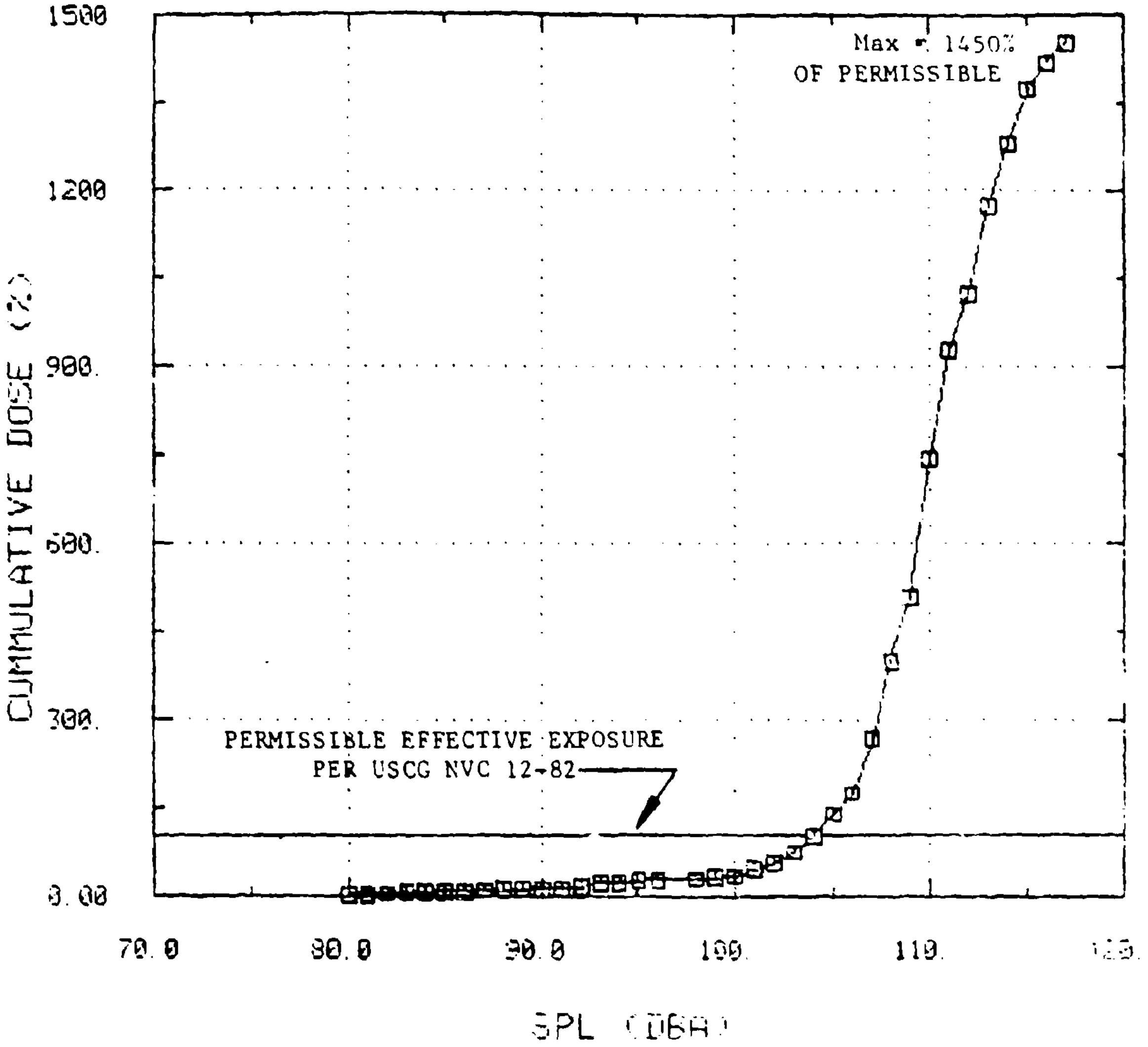


FIGURE IV.2(a). CUMULATIVE DOSE RECORDED ON ROUSTABOUT (Identification Number ND13)

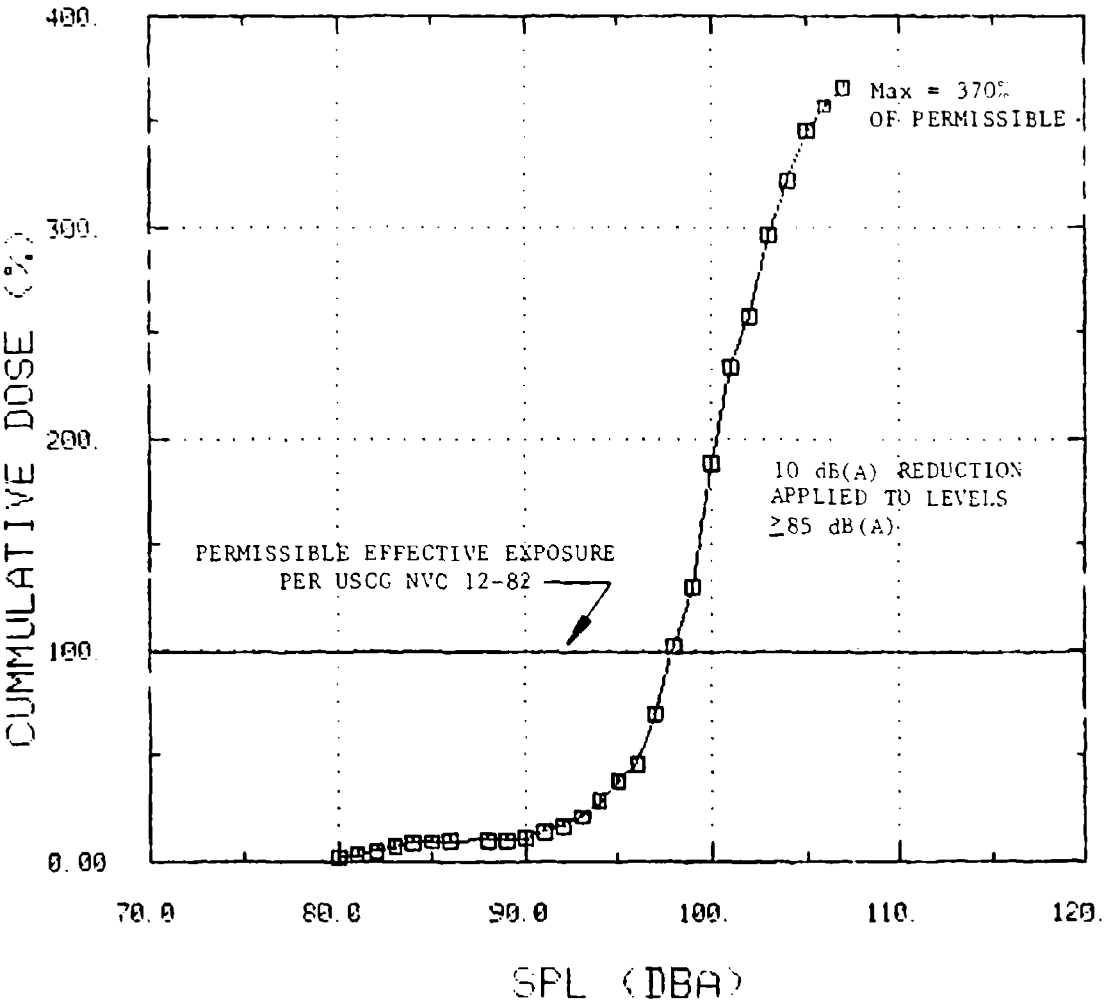


FIGURE IV.2(b). CUMULATIVE DOSE RECORDED ON ROUSTABOUT (Identification Number ND13; 10 dB(A) attenuation applied to levels ≥85 dB(A))

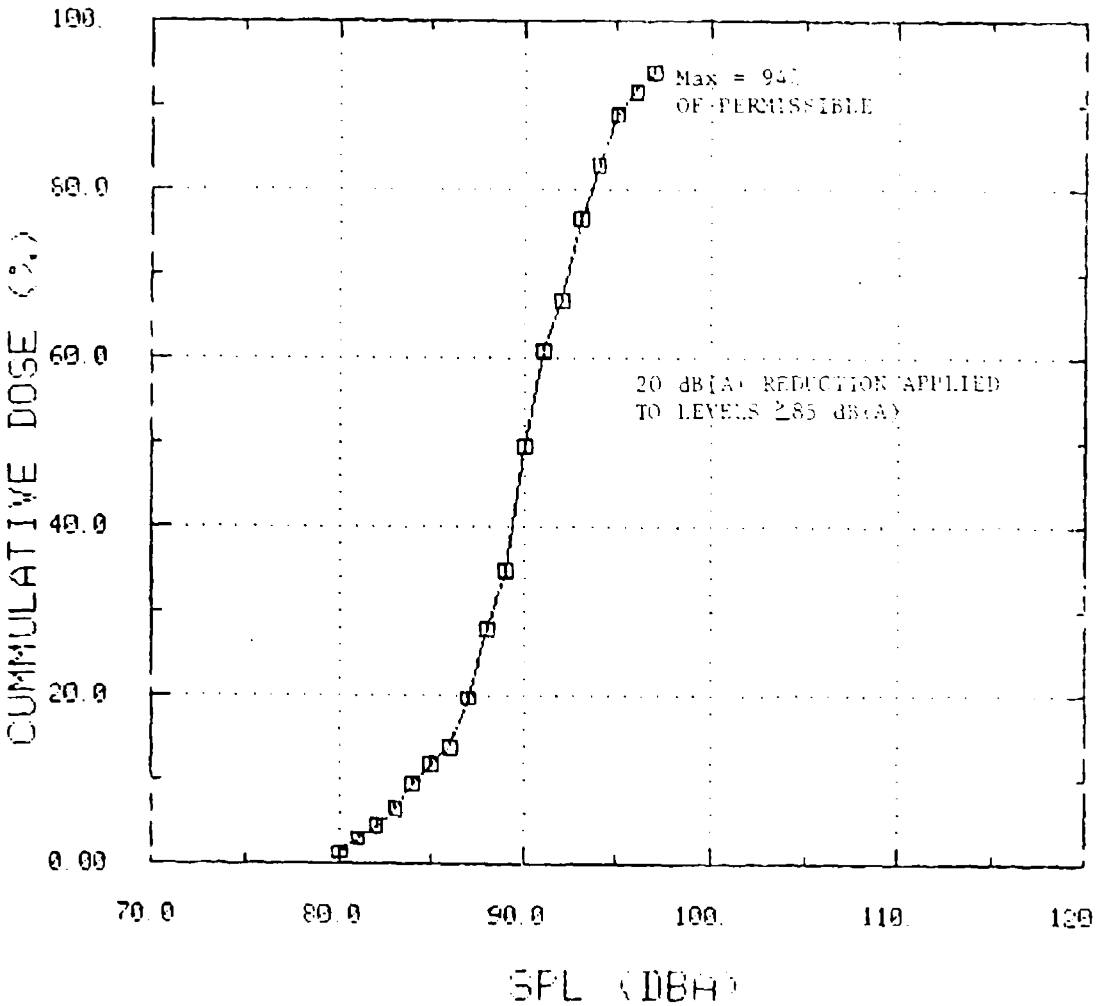


FIGURE IV.2(c). CUMULATIVE DOSE RECORDED ON ROUSTABOUT (Identification Number ND13; 20 dB(A) attenuation applied to levels ≥85 dB(A))

TABLE IV.1. CLASSIFICATION OF NOISE EXPOSURES

Dosimeter Reading+ (%)	Number of SwRI Samples In Indicated Range	OSHA Compliance Classification+	Potential Regulatory Action+
0-38%	1*	Compliance documented	No action taken unless other portions of noise standard are exceeded.
38-64%	1	Possible exposure above action level (50%).	Further sampling recommended, hearing conservation program optional.
64-75%	1	Exposure above action level documented.	Agency may cite for failure to implement hearing conservation program.
75-131%	6	Possible exposure above 90 dB(A) standard (100%).	Further sampling recommended, engineering controls optional, hearing conservation program required.
132% or above	7	Noncompliance documented. Program required.	Citation probable, engineering controls required if feasible, hearing conservation.

*Sample duration was 1.5 hours

+Extracted from Reference [8]

Note: Dosimeter reading equals percent permissible dose. This is indicated as "Cumulative Dose" on Figures IV.2(a), (b), (c), and similar figures in Appendix A.

The criteria that were used in selecting items for comparison included location, duration, and activity. The location is important because it determines what value on the SPL survey should be used in the comparison. The resolution required in defining this location is dependent on the spatial variation of SPL in the area. For example, if a worker is standing near a noise source (i.e. generator, crane, etc.), the SPL will decay rapidly with distance. Therefore, it is important to know if he was two feet from the source or five feet from the source. Alternatively, an entire deck may have a nearly constant SPL. In this case, it is only necessary to know the worker was on the deck.

Duration is important due to the sampling procedure used in the noise dosimeters. These units record 480 intervals. The duration of these intervals is programmable. During this observation, all units sampled for two minutes before storing a value. The SPL meters provide essentially a real-time representation of the SPL field. Truly valid comparisons between the two instruments can only be made if the source remained constant during an entire 2-minute sampling interval. This requirement implies both a constant worker location and a constant activity during the sample.

Activity is used to denote a job function or operating condition. Job functions might include welding, paint-chipping, or any other work. Operating conditions include tripping a string, crane operation, or any other condition which might affect the SPL environment. It is impossible to compare the dosimetry levels recorded on an individual using a needle gun in a specific location of the platform to the SPL's recorded at that location when no paint-chipping was being conducted.

Several of the cases that were identified for comparison have been included in this section. Table IV.2 provides a cross reference between figures depicting SPL survey and dosimeter results. It also provides a brief description of the worker's activity. Several entries are described in greater detail in the remainder of this section.

Item No. 1 is a very important comparison. In this particular case, the SPL survey was conducted while a driller was wearing a noise dosimeter. In the documentation for this dosimetry sample, the SPL levels detected over a period of approximately 15 minutes were also recorded. As shown in Table IV.2 the levels recorded by both methods were very close. Unfortunately, the range of levels makes it very difficult to estimate potential exposures based on the 15-minute sampling. This is characteristic of locations where changing activities produce a wide range of SPL's. The SPL recorded near the driller varied almost constantly during the 15 minutes that the SPL's could be correlated to documented activities. Application of the brakes resulted in short duration excursions as high as 107 dB(A) at the driller's ear. A level of 84 dB(A) was produced when either the drawworks motor or the rotary table were in operation.

TABLE IV.2. COMPARISON OF SPL AND DOSIMETRY

Item Number	SPL Figure No.	Survey Area Designator	Noise Dosimetry		Activity During Dosimetry	Measured Levels		Comments
			Figure No.	Interval Designator		SPL Survey dB(A)	Noise Dosimetry dB(A)	
1	IV.2	*	IV.3	*	Drilling/Operating Control Panel	87-100	85-100	SPL and dosimetry conducted simultaneously
2	IV.4	*	IV.3	A,B,C,E	Drilling	82-84	92	Same equipment not operating during SPL survey
3	A.1	Unit No. 2	B.34	C	Turbines running	101-103	101	Same operating conditions during SPL and dosimetry
4	A.3	*	B.34	J	Fans operating; loudspeaker nearby	95	91-98	Same operating conditions during SPL and dosimetry
5	A.1	Unit No. 1	B.34	D,F,H	Maintenance on Unit No. 1	98-100	72-100	Units operated intermittently during dosimetry
6	A.5	Quarters Building	B.34	P,R	Maintenance in office	54-61	<70-84	Higher noise levels during dosimetry due to television, conversation
7	A.6	*	B.34	Q	Pick up tools in generator building	97	96	Same operating conditions during SPL and dosimetry
8	A.1	*	B.43	A	Preparing to transfer equipment to field boat	84-90	83-91	Same operating conditions during SPL and dosimetry
9	A.8	Quarters Building	B.43	D,I,L	Inside quarters	58-62	75	Same operating conditions during SPL and dosimetry
10	A.8	Mechanic Shop	B.43	F	Inside mechanic shop	69-72	73-84	Same operating conditions during SPL and dosimetry
11	A.1	*	B.46	A	Preparing to transfer equipment to field boat	84-90	84-93	Same operating conditions during SPL and dosimetry
12	A.8	*	B.46	K,C,D	Setting up welding equipment	88-96	84-99	Same operating conditions during SPL and dosimetry
13	A.8	Quarters Building	B.46	G,J,M	Inside quarters	58-62	70-87	Same operating conditions during SPL and dosimetry

*Appears in shaded region on the indicated figure

This observation indicates that, when SPL meters are used, an accurate assessment of potential exposures to levels exceeding NVC 12-82 requires measurements for every operating condition and an estimate of the duration of each condition during an individual's shift. For repetitive activities such as tripping a string, it may be possible to describe a duty cycle at a specific location. This requires that SPL measurements be correlated to activities and operating conditions over a period of the cycle. The potential exposure can then be estimated based on the number of cycles which occur during the worker's shift. Figure IV.3 illustrates the time-varying nature of the SPL at the driller's position. The record does appear to be somewhat cyclic. However, it is not obvious what period would be appropriate for measurement. Figure IV.4 shows the area of the platform where comparative samples were gathered. The SPL survey documentation indicates that the noise level varied from 87 to 100 dB(A) near the driller depending on the activity. However, the existence and details of any cyclic pattern were not determined. In this type of situation, it appears that dosimetry is the most accurate, cost effective means of interpreting exposures relative to NVC 12-82.

Item No. 2 is a good example of a relatively constant dosimetry measurement that disagrees with the SPL survey due to different equipment operating conditions. Figure IV.5 shows the noise dosimetry records. The roustabout was in the area indicated on Figure IV.6 during intervals A,B,C and E. In this case, the SPL survey was conducted during a shift when much of the equipment in the area was not operating. During the dosimetry observation, mud pumps and other pieces of equipment were operating. The consistency of the levels recorded by the dosimeter indicates that simply surveying the area during similar operating conditions would probably have been sufficient to estimate potential exposures. However, it also shows that it is not acceptable to assume that SPL's measured at one time are valid during all operations.

The remaining items in Table IV.2 refer to SPL survey figures in Appendix A and noise dosimetry figures in Appendix B. For the SPL contours, the area of interest is identified by the symbol or label indicated in Table IV.2. The span of time during which the noise dosimetry was conducted in the same area is designated by the intervals at the top of each dosimetry plot. In Table IV.2, the range of sound levels indicated for SPL and noise dosimetry are estimates based on documentation. As discussed previously, spatial and temporal resolution affect the accuracy of these comparisons. Items 9, 10, and 13 show discrepancies between the SPL survey and the dosimetry records although the facility was believed to be operating under the same conditions. The differences are believed to be due to conversations, televisions, radios, and other miscellaneous sources. The contribution of these sources were not documented. However, the dosimetry samples generally occurred during lunch, coffee break, and at shift changes when a relatively large number of people were present. The SPL surveys were conducted at times when a small number of people were present. This ensured that measurements were representative of the SPL's due to platform operations.

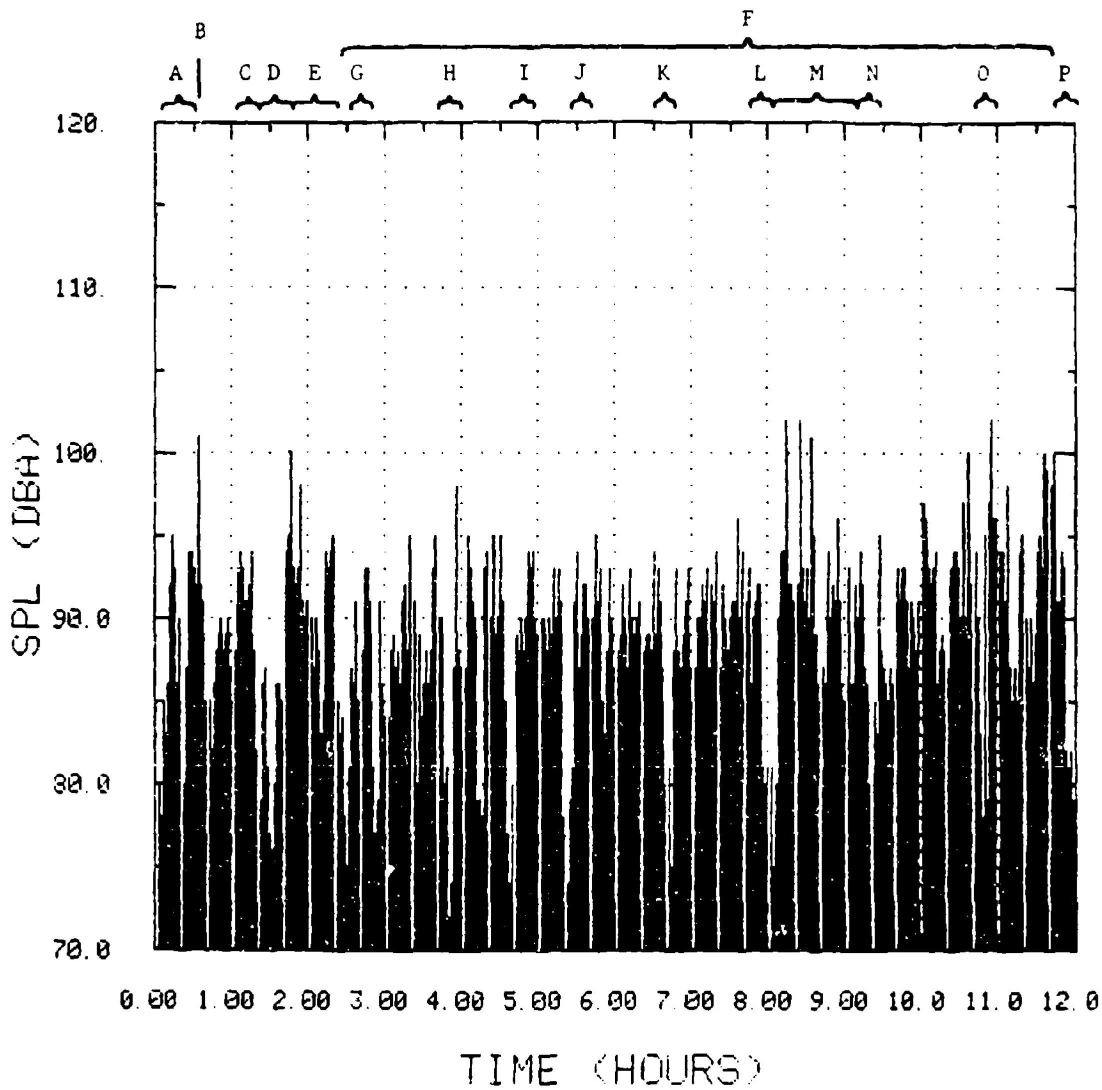


FIGURE IV.3. NOISE DOSIMETRY ON DRILLER
(Identification Number ND8)

NOTE: #/# REPRESENTS SOUND LEVEL MEASUREMENTS RECORDED DURING VARIOUS ACTIVITIES TAKING PLACE ON SEVERAL ADJACENT LEVELS

*Area where comparative samples were collected

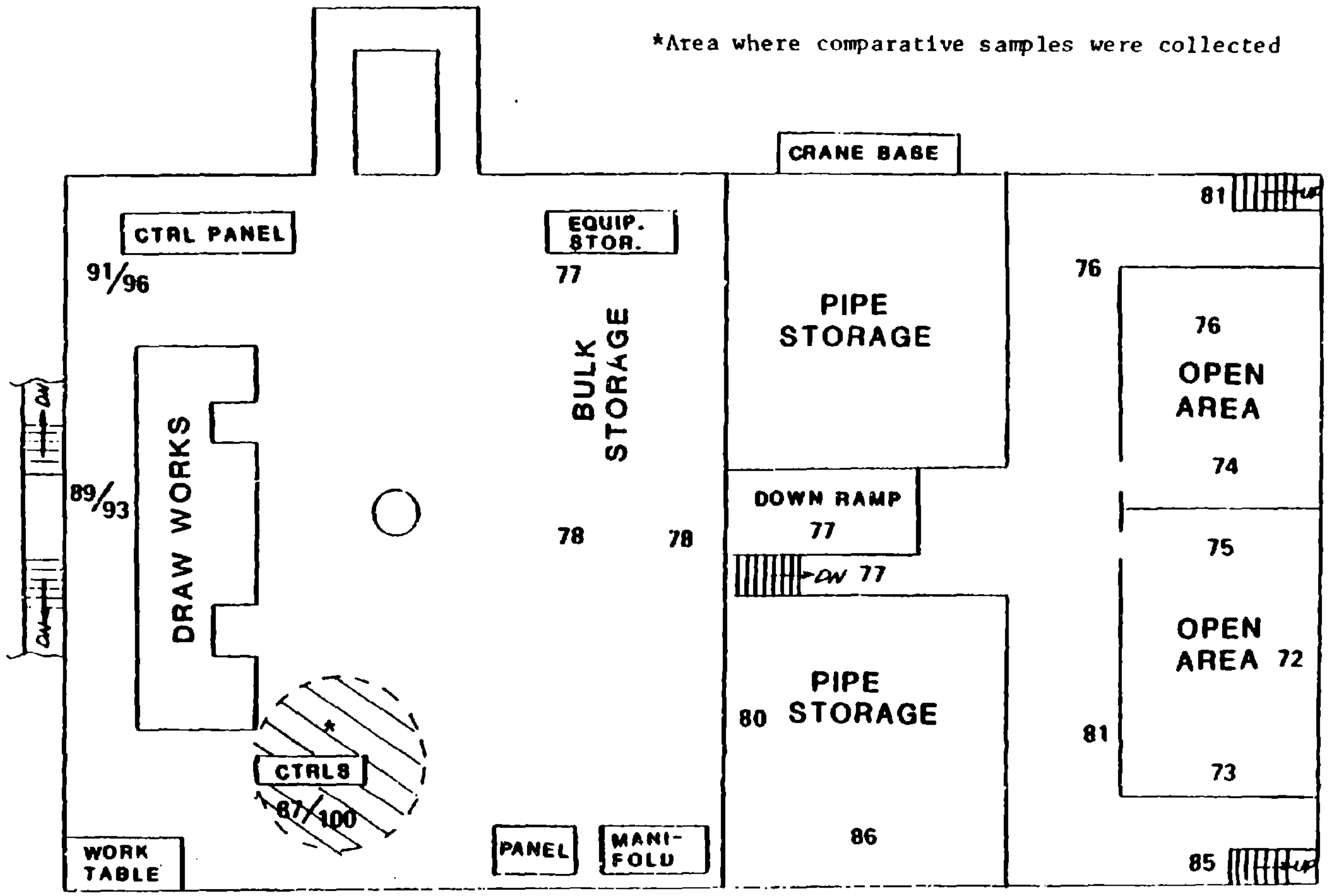


FIGURE IV.4. DRILLING LEVEL, DRILL RIG NO. 1
SOUND PRESSURE LEVELS IN dB(A)

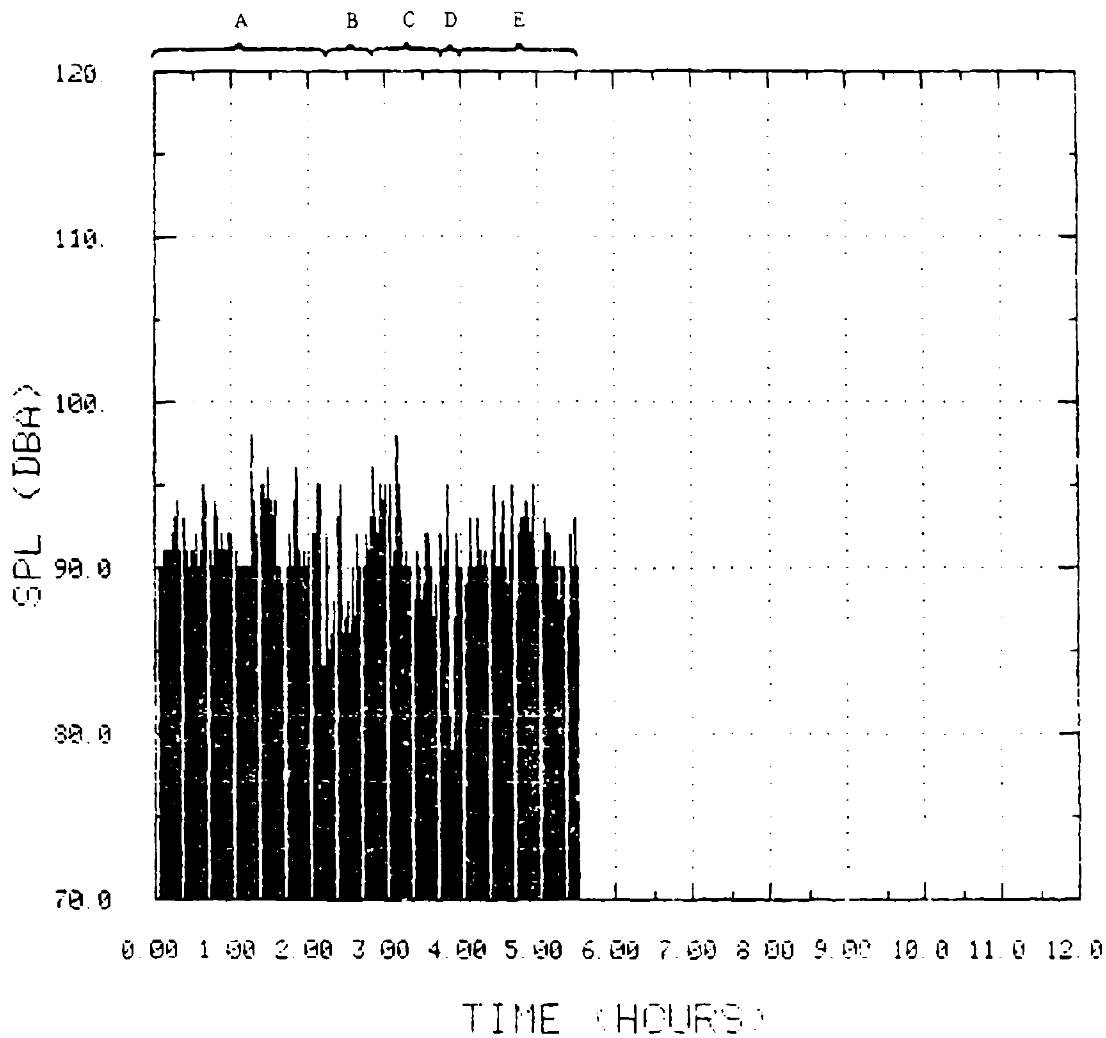
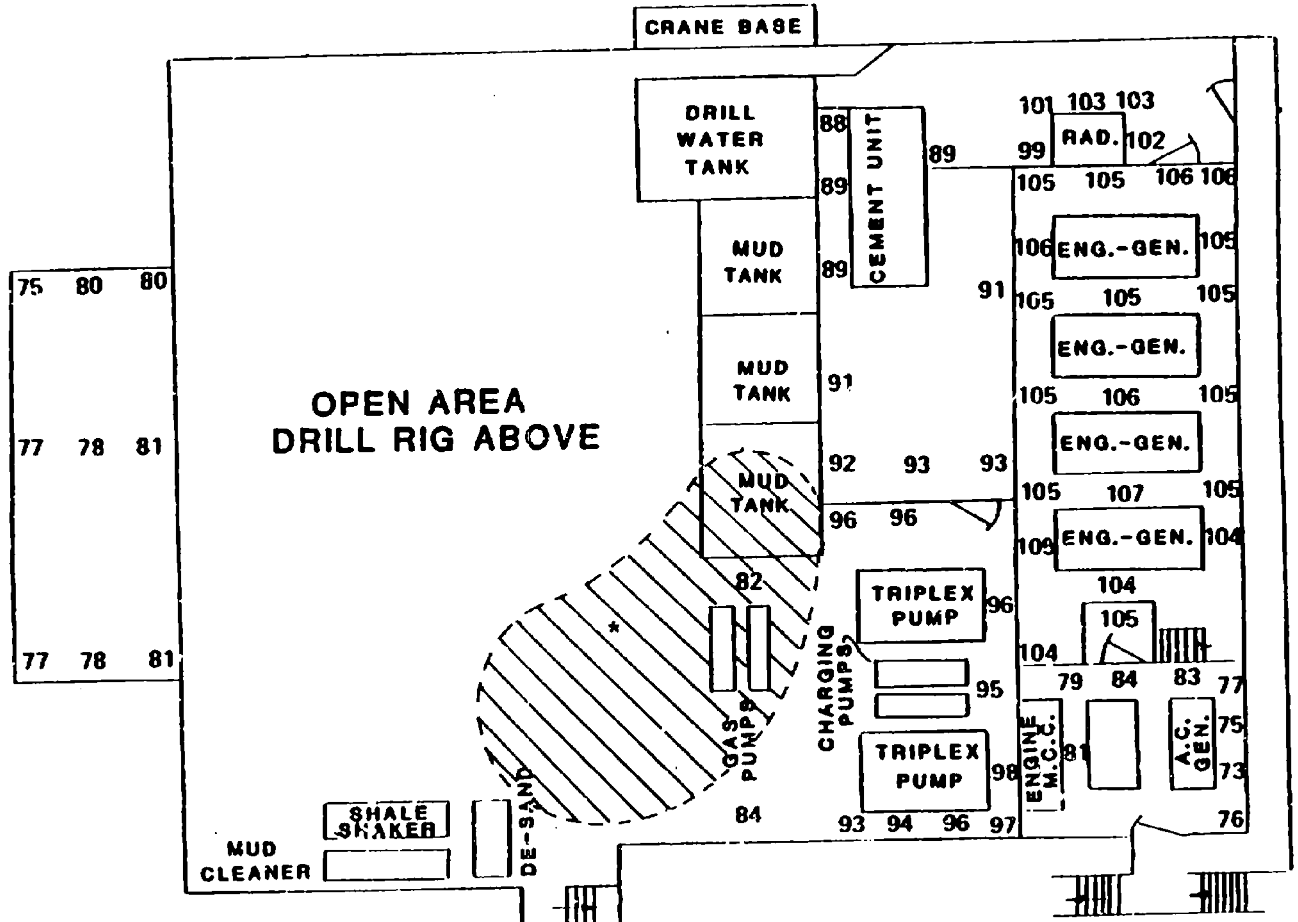


FIGURE IV.5. NOISE DOSIMETRY ON ROUSTABOUT
(Identification Number ND10)



*Area where comparative samples were collected

FIGURE IV.6. EQUIPMENT DECK, DRILL RIG NO. 1 SOUND PRESSURE LEVELS IN dB(A)

IV.2 Airborne Contaminants

Sample Nos. M29, M32, M28, M30, M31 and M36 were collected sequentially on one worker who was performing rust and paint chipping. Based on XRF scans of the chipping debris, it was concluded that the airborne substance could be classed as a total nuisance particulate. Accordingly, the samples were analyzed gravimetrically. All individual sample concentrations were less than half of the ACGIH total nuisance particulate TLV-TWA of 10 mg/m^3. The time-weighted average exposure during the 538-minute chipping operation was calculated to be 3.0 mg/m^3. The individual sample concentrations represent integrated levels over the sampling durations. Significant excursions above these levels would not be expected because the chipping operation was conducted nearly continuously without interruption. These measured dust levels for this scenario suggest that the respiratory comfort of the paint chipper may have benefited from the use of a disposable nuisance dust respirator.

Sample Nos. M27, M38, M34, M35, M40 and M37 were collected on a second individual who was also performing rust and paint chipping operations but in another area of the platform. The possible presence of lead in the chipping debris as determined by qualitative XRF scans of the debris indicated that an elemental analysis, not a nuisance dust approach, was in order. The analysis revealed that lead levels were below the detection limit. At the detection limit, lead concentrations were well below the TLV-TWA of 0.15 mg/m^3. The absence of chrome in the bulk samples was substantiated by quantitative analysis of the filter deposits. Hence, the zinc was not chromated but most probably was present as an oxide for pigmentation. Concentrations of Z_nO were well below their total nuisance dust limit of 10 mg/m^3. In the final analysis, this set of samples could also have been analyzed gravimetrically for nuisance dust. However, this scenario demonstrates an important point. Analysis of samples must be guided by a thorough knowledge of the history of the materials that are involved in an operation. Lead and chromated paints may have been used at some point in time on this portion of the platform. In the absence of this historical knowledge, the conservative approach is to make analysis procedure decisions based on a qualitative evaluation of the paint debris.

The welding fume samples M101 through M103 and M126 through M129 were collected in accordance with AWSF1.1-76. These samples reflect concentrations under the hood when welding was in progress and in the breathing zone when the welding helmet was raised for weld inspection. Based on the electrode classifications and the base material (uncoated mild steel), x-ray fluorescense analyses of the filters indicated that

- manganese fume concentrations were roughly one-thirtieth of the 1.0 mg/m^3 TLV-TWA, and
- zinc oxide and iron oxide fume concentrations were substantially below the TLV-TWA of 5 mg/m^3.

Two series of samples were collected sequentially during addition of dry chemicals to the mud makeup hopper. One series consisted of respirable nuisance dust samples (P1 through P4). Each sampled concentration was nominally one order of magnitude below the respirable nuisance dust TLV-TWA of 5 mg/m^3. The TWA exposure relative to an 8-hour day was 0.32 mg/m^3. The second series of samples, M1 through M4, was analyzed quantitatively for chrome because the presence of this element was indicated by (1) qualitative XRF scans of the bulk material and (2) information on Material Safety Data Sheets for competitive mud products that perform the same function as the bagged materials that were used on the drill rig. The analysis indicated that

- o soluble chrome VI levels were below the detection limit. At the detection limit, all chrome VI concentrations were less than 0.008 mg/m^3 relative to a TLV-TWA of 0.05 mg/m^3,
- o soluble chrome II and III were also below the detection limit. At the detection limit, calculated concentrations were well below the chrome II and III TLV-TWA of 0.5 mg/m^3, and
- o similar results were obtained for insoluble chrome II and III.

In the final analysis, these samples could also have been analyzed gravimetrically for total dust concentration. However, the caveat that was associated with the rust and paint chipping operation is appropriate to this scenario also.

V. CONCLUSIONS AND RECOMMENDATIONS

V.1 Noise

The conclusions presented here are based on the documentation and measurement activities conducted during this project. The operating conditions and worker activities depicted in this report may not always be typical of the offshore industry. Therefore, unless otherwise indicated, these conclusions should not be generalized.

- The SPL environment on offshore production platforms is relatively constant over time. Local variations do occur when welders, cranes, portable generators, and other equipment are operated. However, the operating conditions appear to stay reasonably stable from day to day.

- The SPL environment on drilling rigs is much more time dependent than on production platforms. Operating conditions may change on a somewhat random basis depending on the type of bit, formation structure, drilling depth and many other variables. For example, the mud pumps and shale shakers may not be noise sources during tripping operations. However, the time required to conduct the tripping operation, and the time between tripping operations are both variable, making exposure estimates from SPL surveys very difficult.

- Dosimetry measurements provide the most accurate method of evaluating potential noise exposures incurred by an individual, but the dosimetry does not isolate major noise sources unless simultaneous time-motion data are recorded.

- SPL survey techniques provide a rapid means of evaluating the spatial distribution of SPLs. Temporal variations require additional surveys if the data is to be used in estimating a worker's exposure. The temporal and spatial resolution of both the SPL environment and the worker's activity should be considered to assess the validity of exposure estimates.

- SPL surveys are well suited to finding areas which exceed the recommended action level of 85 dB(A) for hearing conservation programs. The company may then elect to determine or calculate exposures for specific individuals. Alternatively, company policy might require hearing protection in all areas where the SPL exceeds 85 dB(A).

- Dosimeters capable of "dumping" time-dependent raw data provide an excellent means of assessing exposure problem areas. This type of instrument should be considered when evaluating the SPL environment on a facility.

- Dosimeters which provide a "bottom line" assessment of exposures are probably adequate to ensure compliance with standards. This type of instrument may provide a calculation of the cumulative effective exposure, L_{eff}; the dose as a percent of the permissible; and the maximum SPL recorded. Features and options vary from model to model.

- Recent studies [9] indicate that 50% of industrial workers tested in-situ "....were receiving less than one-half the potential attenuation of the earplugs". The reason was improper application of the protective device. The tests considered preformed, acoustic wool, custom molded, and acoustic foam earplugs. These findings should be considered when (1) selecting protective devices based on an assessment of the required attenuation and (2) implementing a training program.

- Measurements obtained during this study indicate that potential noise exposures are generally above 100% of the permissible exposure level. All samples collected for a full shift indicated a potential exposure greater than 50% of the OSHA permissible dose. Therefore, hearing conservation programs should be employed.

- Confined areas such as compressor buildings and generator rooms had warning signs and hearing protective devices were provided at the entrances. However, the SPL contours around the outside of these sources may also exceed the 85 dB(A) action level recommended in NVC 12-82. The exceedance may be due to either the source within the confined space or that source combined with other noise sources exterior to the enclosure. The circular advises employers to determine actual exposures or require hearing protection in these surrounding areas to ensure an $L_{eff}(24) \leq 82$ dB(A).

- The use of the word "spaces" in NVC 12-82 regarding the posting of warning notices should be interpreted as both open spaces and confined space.

- The current recommended $L_{eff}(24)$ of 82 dB(A) can be achieved through a combination of engineering, protective equipment and administrative controls. The $L_{eff}(24)$ of 77 dB(A) proposed for "vessels" constructed after 1985 will require more stringent administrative controls. Engineering controls will be prohibitively costly.

- NVC 12-82 presently recommends SPLs ≤ 75 dB(A) in living quarters. Future "vessels" should have SPLs ≤ 70 dB(A). In many cases, the SPL measured in living quarters was less than 70 dB(A). Exceptions tended to result from a gathering of people, television, maintenance, and testing equipment for short periods.

- o Workers generally spent 12 hours per day inside the living quarters. Therefore, an $L_{eff}(12)$ may be more appropriate than an $L_{eff}(24)$ for offshore operations. The evaluation of a worker's exposure over a 12-hour period will probably reduce the costs associated with making the necessary measurements.

- o NVC 12-82 is a recommended guideline that applies strictly to inspected commercial vessels excluding Mobile Offshore Drilling Units. The USCG recommends that, in the absence separate guidelines, NVC 12-82 also be applied to offshore rigs and platforms. This situation accounts for varying degrees of awareness of the NVC. Workers were not aware of its existence. Some facility owners are aware of the NVC, others are not.

- o NVC 12-82 appears to be applicable to operations on offshore facilities. As applied to offshore work schedules, an $L_{eff}(24)$ of 82 dB(A) and a 5dB(A) exchange rate is equivalent to 12 hours at 87 db(A) followed by 12 hours below an 80 dB(A) threshold. Consistent with the Coast Guard philosophy of an action level, hearing protective devices should be worn in areas that exceed 85 dB(A). The applicability is directed toward individuals with normal hearing. Noise sensitive individuals would benefit from a screening program that would identify these individuals and treat them accordingly--possibly with a recommendation for continuous protection everywhere outside of the crew quarters.

V.2 Airborne Contaminants

The conclusions that follow are based on a 7-day observation of offshore drilling and production operations. During this 7-day period, it was possible to observe and monitor only a small portion of the drilling fluid chemicals and additives that are used in drilling operations. Similarly, not all maintenance activities occurred during this period, e.g. sandblasting. Consequently, the conclusions are specific to the observation period and the materials/ operations that were involved; extrapolation or generalization to other situations is not justified.

- o The debris from rust and paint chipping resulted in exposures to total nuisance dusts at levels that were less than half of the TLV-TWA of 10 mg/m^3. In general, rafter samples of the chipping debris should be analyzed first for the absence of lead, chrome and other toxic trace metals in order to justify the nuisance dust assumption.

- o Welding on mild, uncoated steel resulted in breathing zone fume concentrations of manganese, zinc oxide and iron oxide that were substantially below their respective TLVs.

- o Addition of dry, bagged chemicals into the mud makeup hopper produced respirable nuisance dust exposure concentrations that were roughly one-tenth of the 5 mg/m^3 TLV-TWA. However, care should be taken to consult manufacturers' Material Safety Data

Sheets to determine whether the drilling fluid chemicals contain toxic metal compounds, such as sodium dichromate, which may nullify the nuisance dust assumption.

Opportunities did not arise to observe the following operations or materials

- o sandblasting,
- o spray painting,
- o confined space entries involving, dust or vapor atmospheres,
- o addition of asbestos-containing mud chemicals, and
- o oil-base drilling muds.
- o skin contact with well completion fluids

Based on Phase I of this study, it was concluded that the potential for vapor or gas exposure was minimal during normal rig operations. There are sources of high concentrations of fugitive emissions. However, the size of the sources and the release rates are such that meaningful concentrations do not develop in the workplace.

During the 7-day test, opportunities did not arise to monitor occupational exposures to silica from sandblasting. Despite this situation, sandblasting is a fairly routine operation on Outer Continental Shelf facilities. The hazards associated with respiratory exposure to free silica are well recognized. For improperly protected workers, chronic fatal silicosis may occur after 10 years of exposure [10,11]. Acute fatal sandblaster's silicosis may occur after intense exposures over three to four years [10,11]. The hazards of exposure are not limited to the sandblasters. Samimi's research [11] revealed that workers who were not directly involved in the blasting operation were exposed on the average to free silica concentrations up to 2.7 times the TLV. Free silica dust from an adjacent blasting operation was transported by the ambient wind to where the unprotected employees were working. That study also revealed that sandblaster's exposures were excessive and resulted principally from the use of nonair-supplied hoods, worn-out hoods, defective air-supplied hoods and careless procedures. Based on this discussion, it is recommended that future industrial hygiene surveys be conducted to identify the frequency and duration of blasting operations, the corresponding occupational exposures of blasters and support workers, and the level, extent and condition of respiratory protective equipment.

In addition to sandblasting, an opportunity to observe the handling of well completion fluids did not arise during the 7-day test. Saturated brine solutions such as sodium, potassium and calcium chloride or bromide are used to displace the drilling mud from the well bore prior to perforating. The Phase I report (Ref. (1), Appendices K and L) summarized discussions with drilling crew members that showed an awareness of the potential for skin irritation due to contact with saturated brine solutions. One drilling contractor posted a notice in the crew's quarters warning the crew of the irritation hazard of saturated brine solutions, and advising the use of a skin barrier cream to avoid contact. Crew members were also advised to rinse their hands for 15 minutes under running water (with hand washing) to avoid irritation and infection from skin contact with saturated brine solutions.

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2. Glorig, A., et al, "Third Draft Secretariat Proposal for Assessment of Noise Exposure During Work for Hearing Conservation Purposes", ISO/TC, 43/SC-1, "Noise".

3. Robinson, D. W., "The Relationship Between Hearing Loss and Noise Exposure", NPL AERO Report Ac 32, July 1968, United Kingdom.

4. Robinson, D. W., and Cook, J. P., "The Quantification of Noise Exposure", NPL AERO Report Ac 31, June 1968, United Kingdom.

5. "Method for Sampling Airborne Particulates Generated by Welding and Allied Processes", Prepared by AWS Project Committee on Fumes and Gases, American Welding Society Document AWS F1.1-76, July 1, 1976.

6. NIOSH Manual of Analytical Methods - Volume 1, August 1981.

7. USCG Navigation and Vessel Inspection Circular No. 12-82, June 2, 1982.

8. Coleman, Sheldon R., "A Practical Approach to Noise Measurement", Occupational Health and Safety, July 1983.

9. Lempert, B. L. and R. G. Edwards, "Field Investigations of Noise Reduction Afforded by Insert-type Hearing Protectors", American Industrial Hygiene Association Journal, Vol. 14, No. 12, Dec. 1983, pp 894-902.

10. Ziskind, Morton, et al, "Silicosis in Shipyard Sandblasters," Environmental Research, Vol. 11, 1976.

11. Samimi, Behzad, et al, "The Efficiency of Protective Hoods Used by Sandblasters to Reduce Silica Dust Exposures," American Industrial Hygiene Association Journal, February 1975.

APPENDIX A

SOUND PRESSURE CONTOUR DATA

NORMAL OPERATION ___
W/WELDING GEN.ON- - -
△OCTAVE BAND TEST POINT
*REFER TO TABLE IV.2

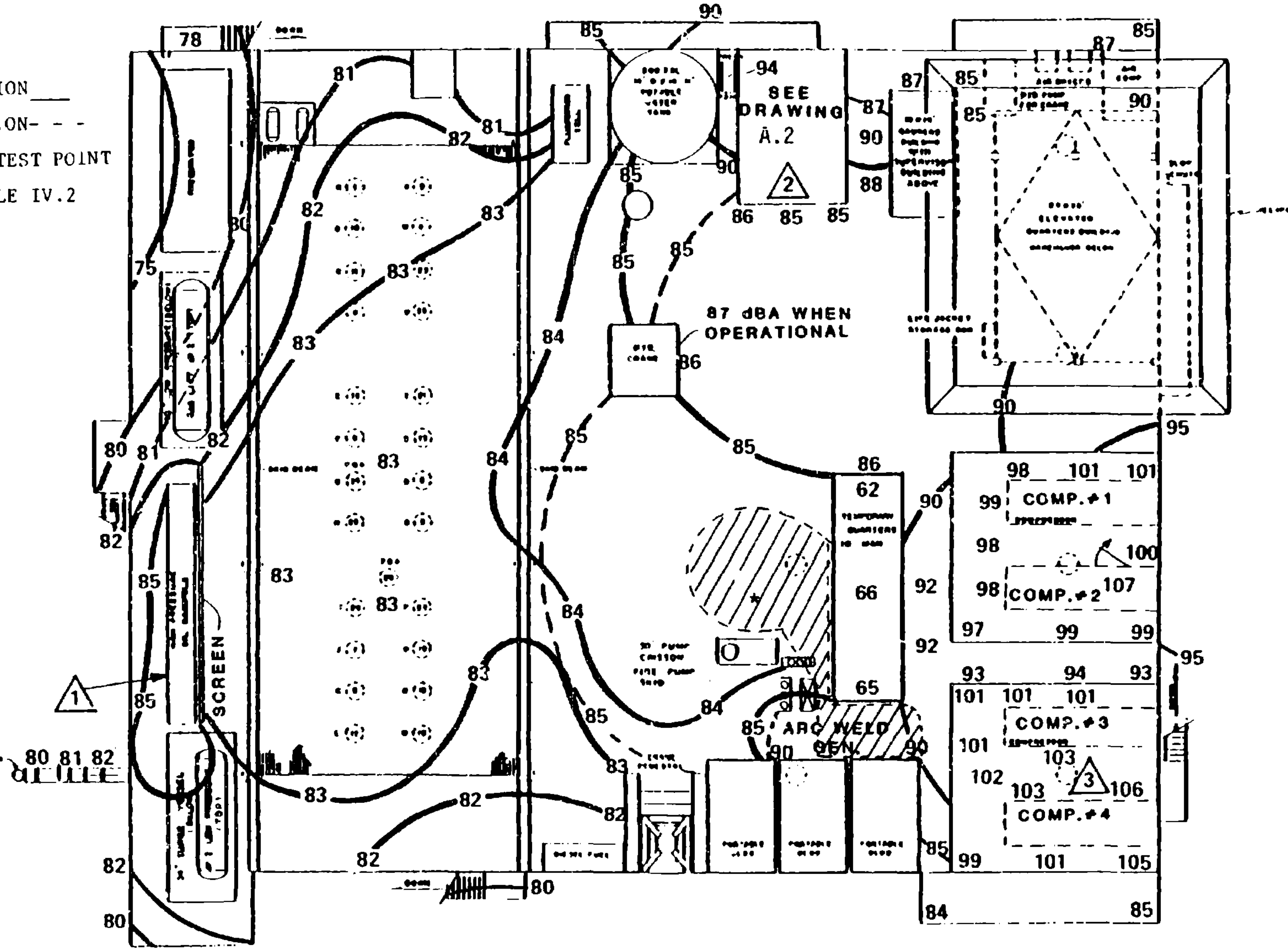


FIGURE A.1. UPPER LEVEL - PLATFORM NO. 1 - SOUND PRESSURE LEVEL CONTOURS IN dB(A)

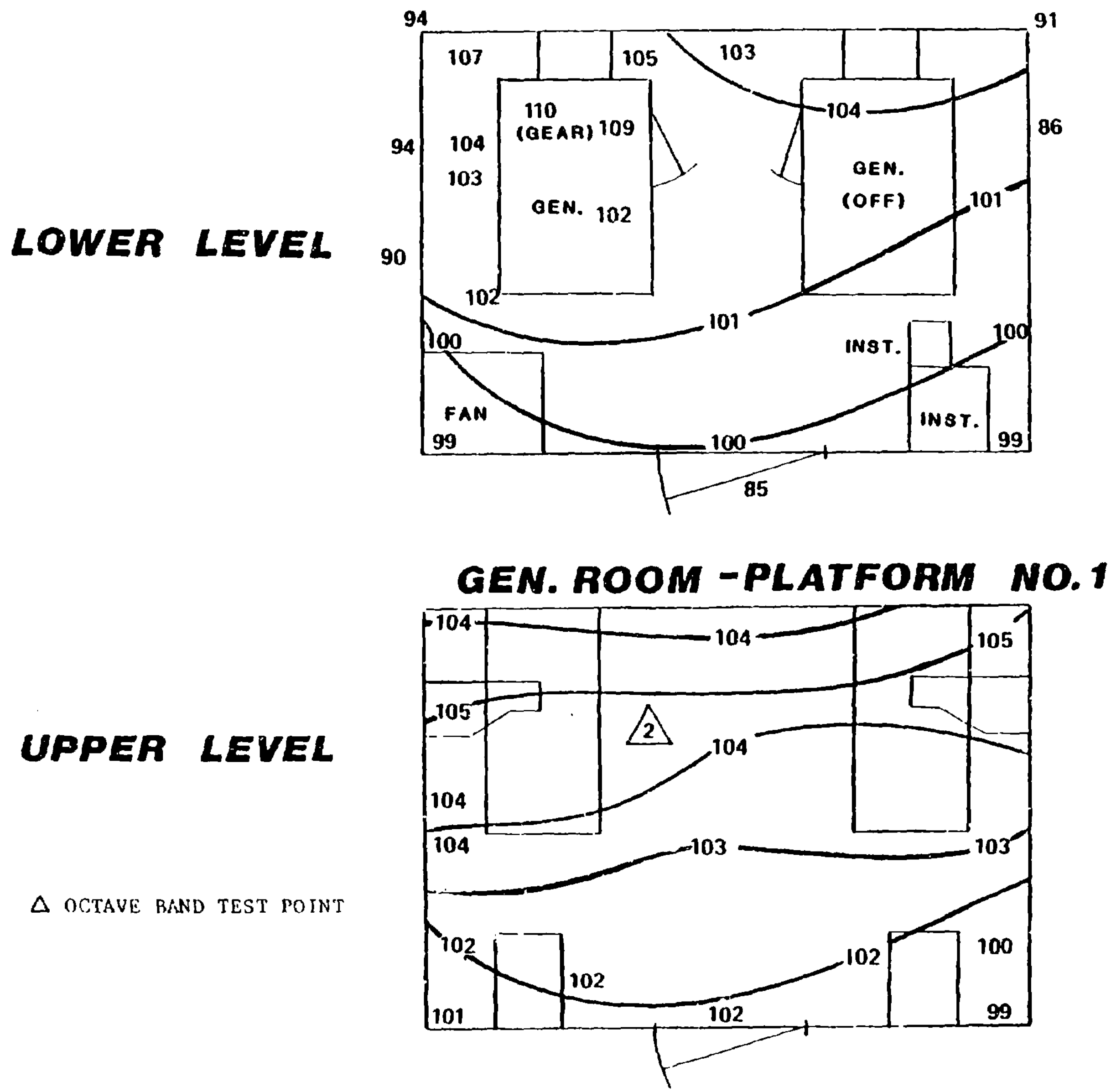


FIGURE A.2. GEN. ROOM - PLATFORM NO. 1 - SOUND PRESSURE LEVEL CONTOURS IN dB(A)

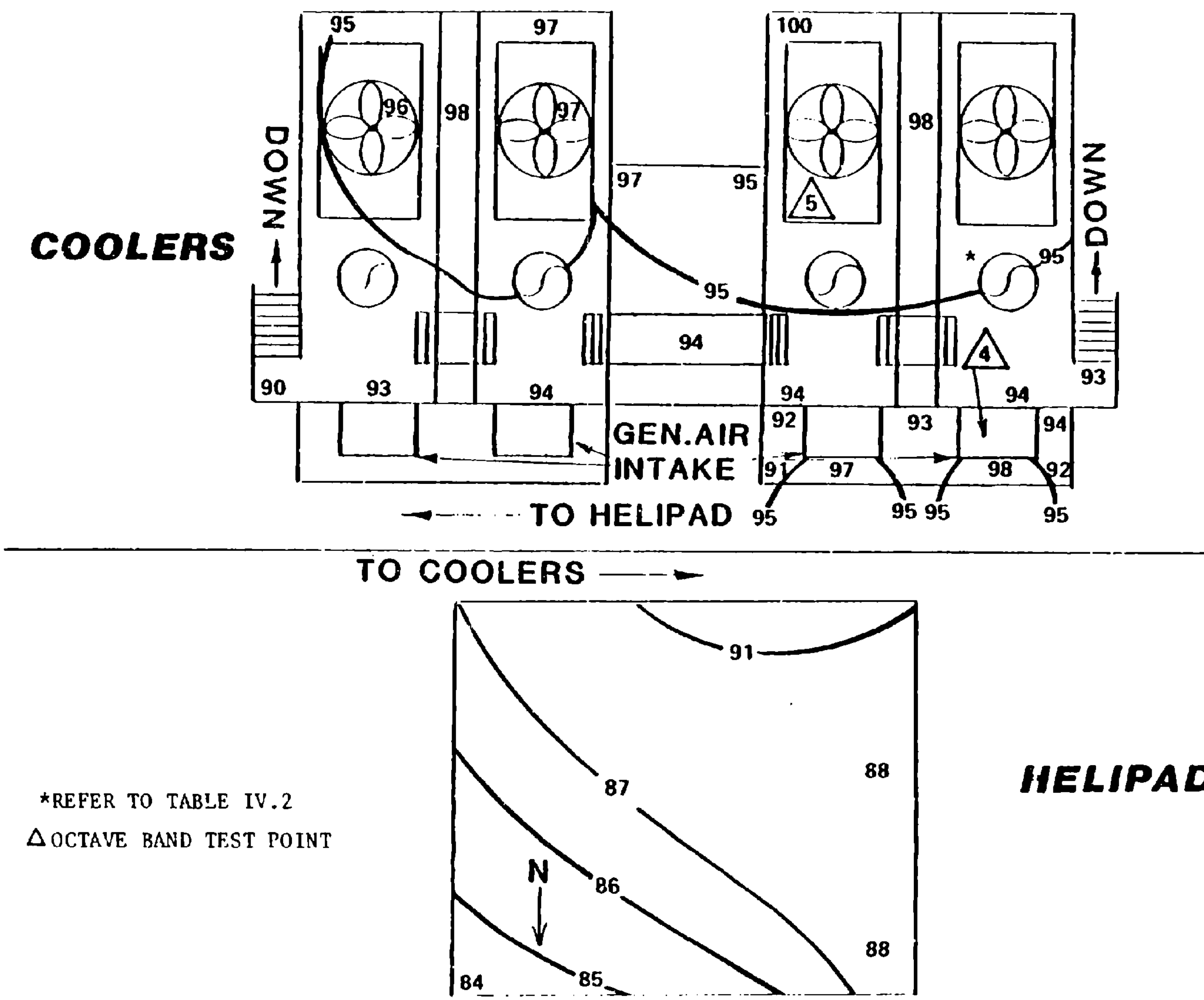
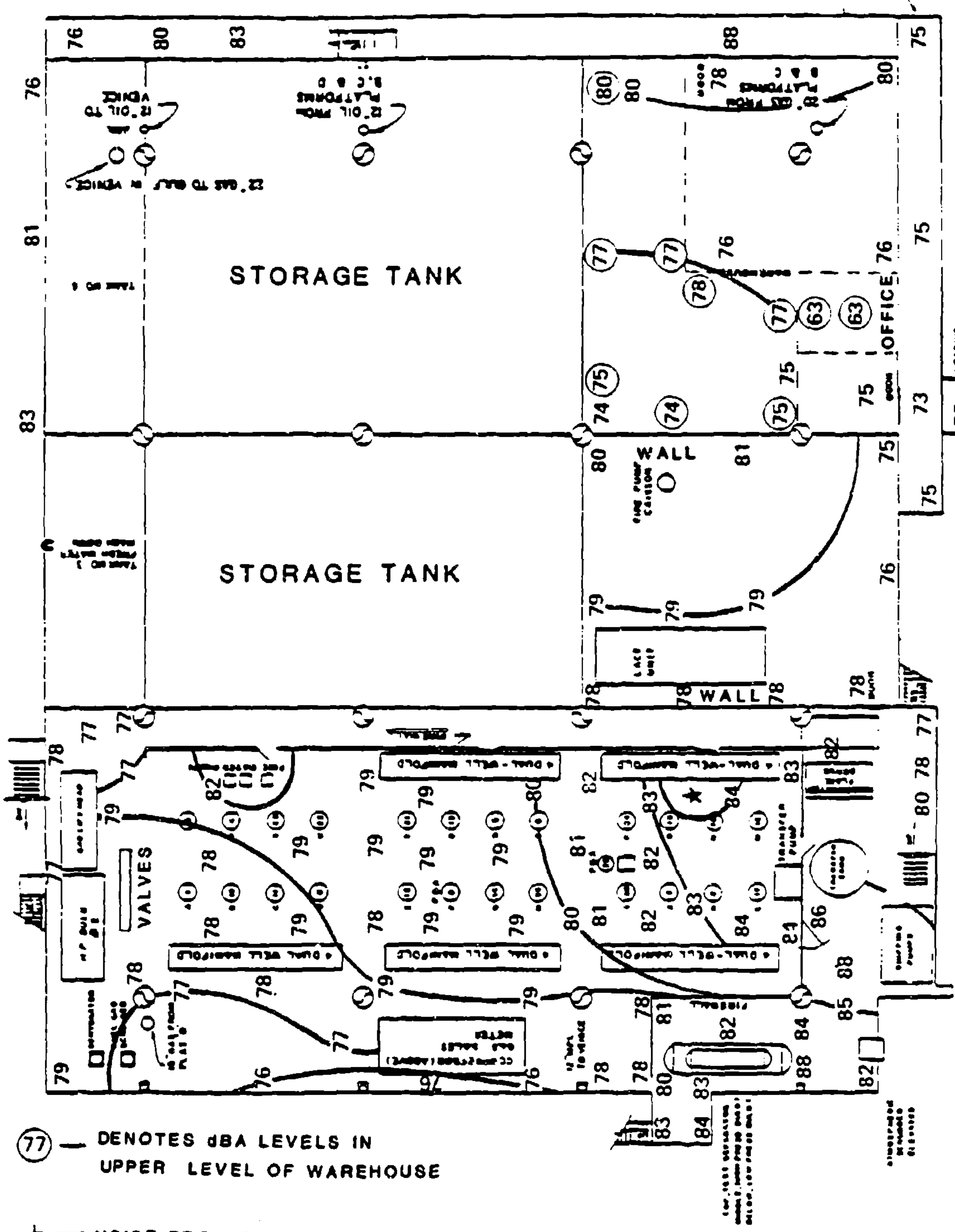


FIGURE A.3. TOP LEVEL - PLATFORM NO. 1 - SOUND PRESSURE LEVEL CONTOURS IN dB(A)



(77) — DENOTES dBA LEVELS IN UPPER LEVEL OF WAREHOUSE

★ — NOISE FROM BELOW DECK PIPING RUN

FIGURE A.4. LOWER LEVEL - PLATFORM NO. 1
SOUND PRESSURE LEVEL CONTOURS IN dB(A)

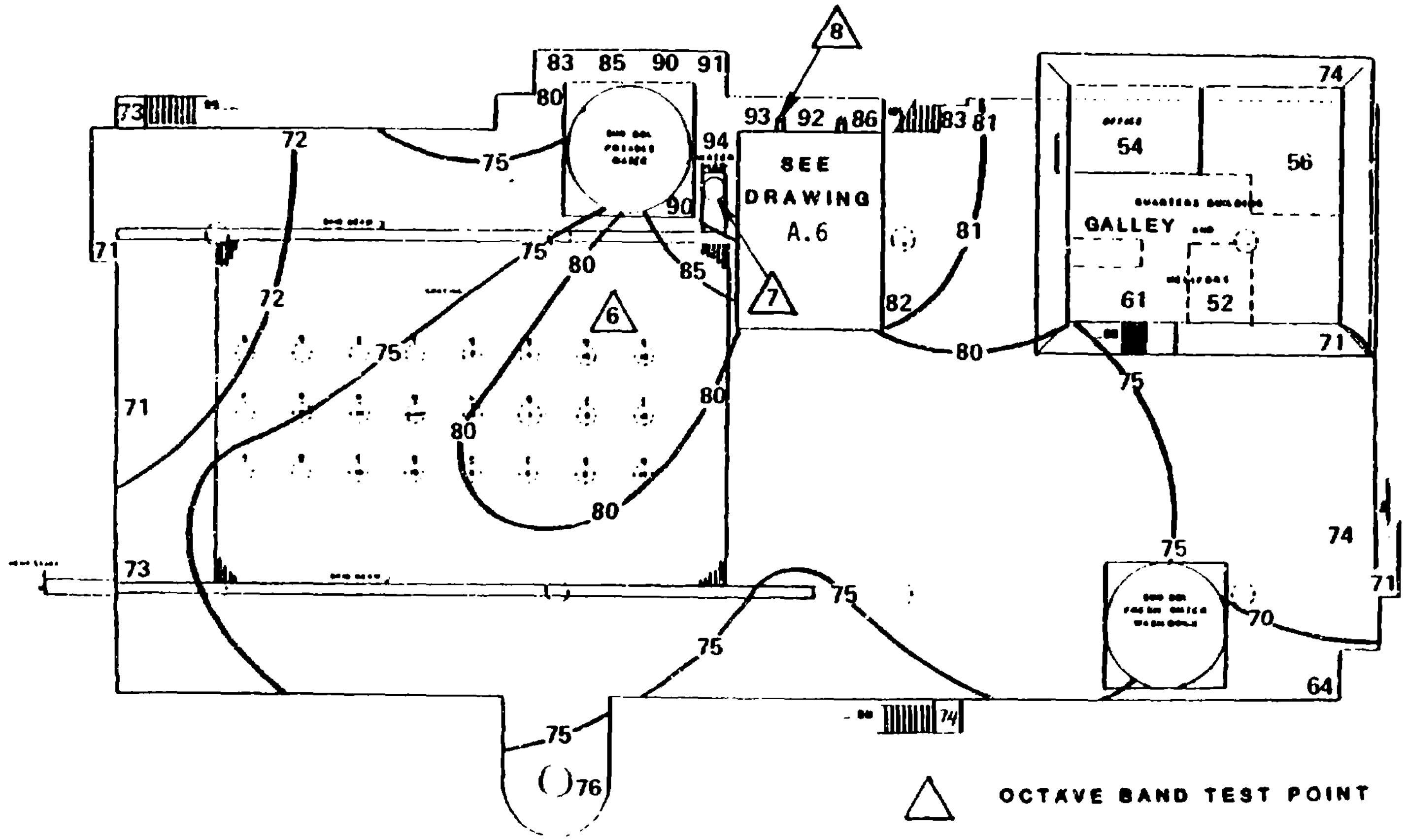


FIGURE A.5. UPPER LEVEL - PLATFORM NO. 2 - SOUND PRESSURE LEVEL CONTOURS IN dB(A)

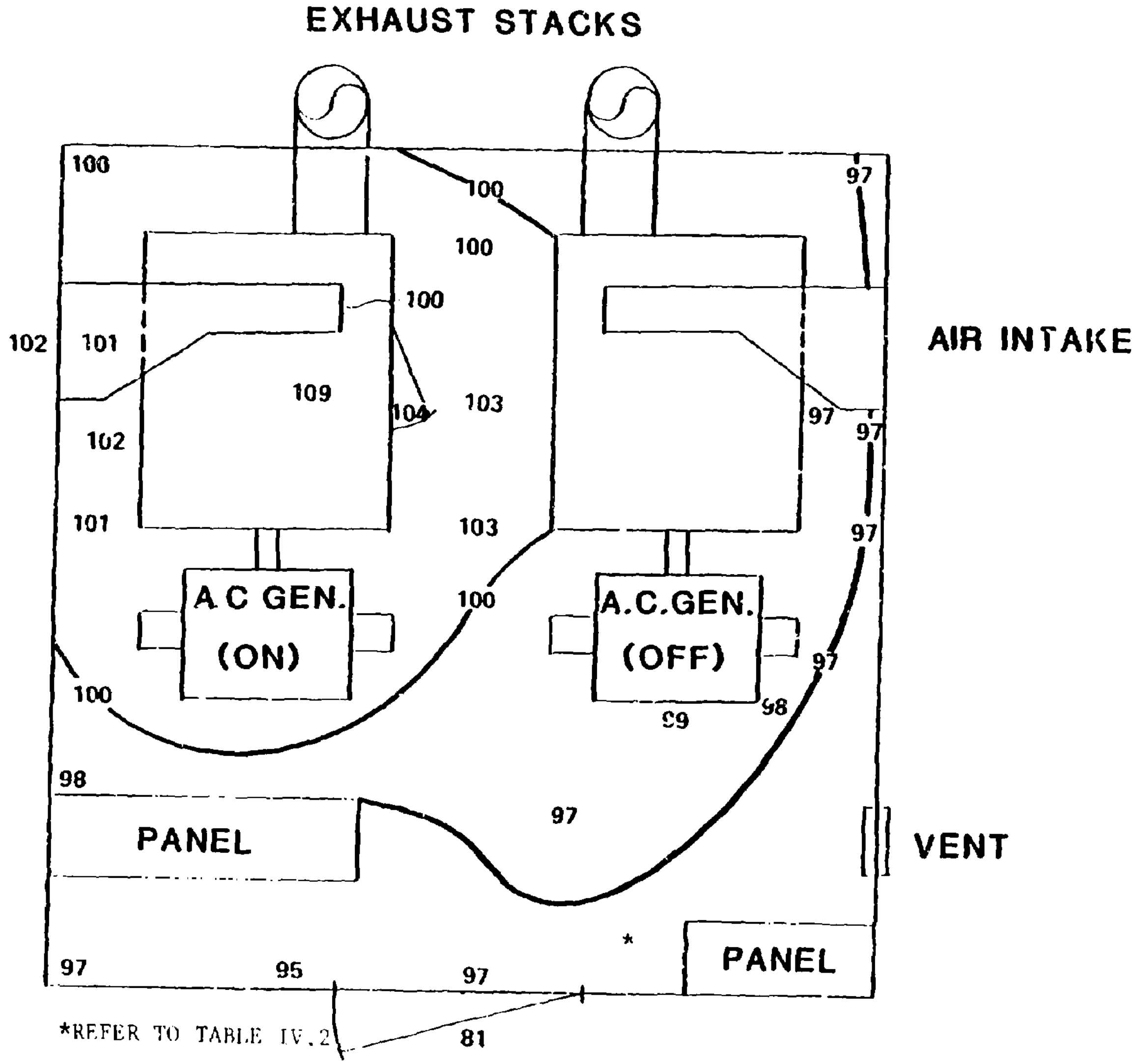


FIGURE A.6. GEN. ROOM - PLATFORM NO. 2 - SOUND PRESSURE LEVEL CONTOURS IN dB(A)

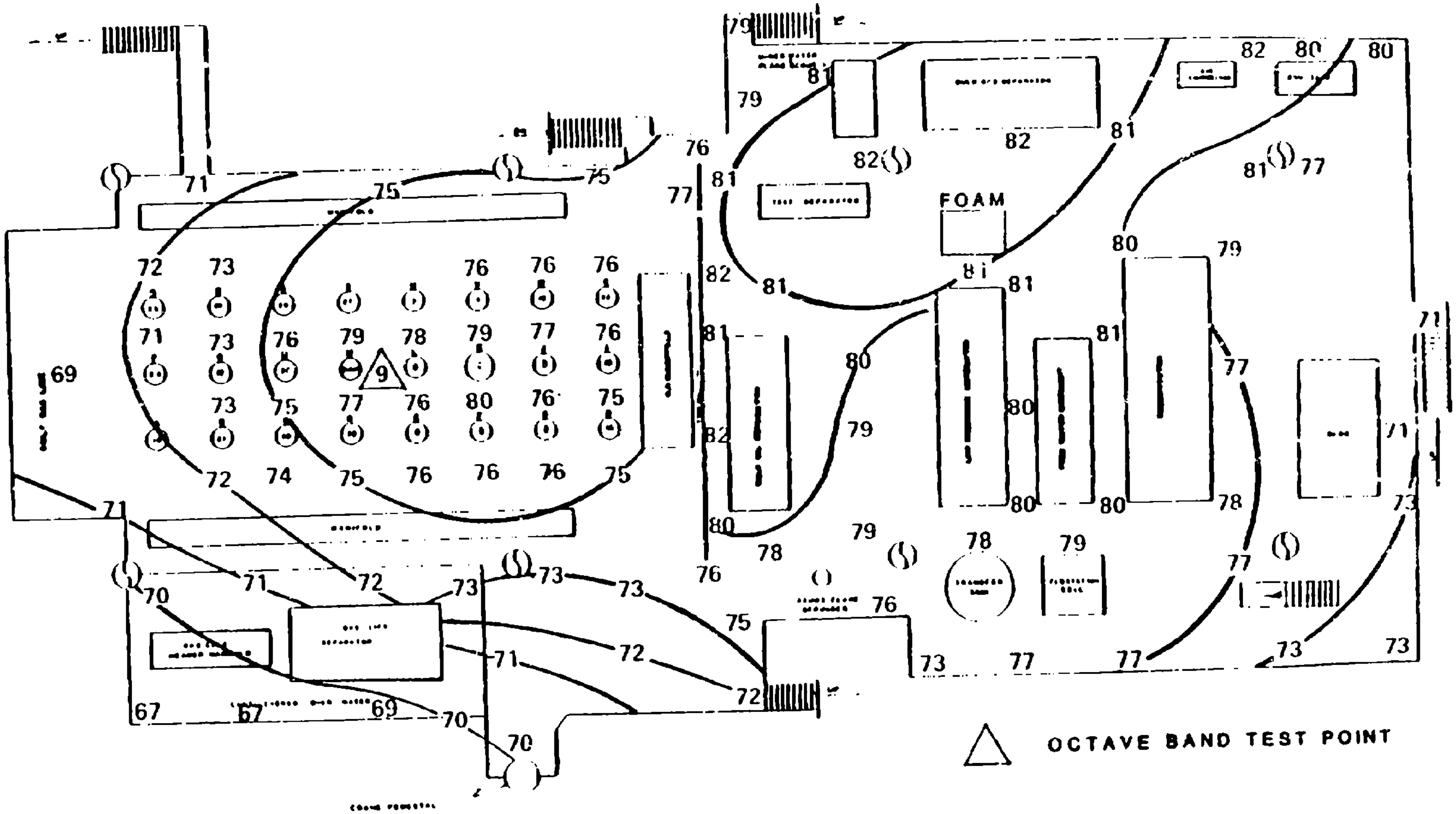
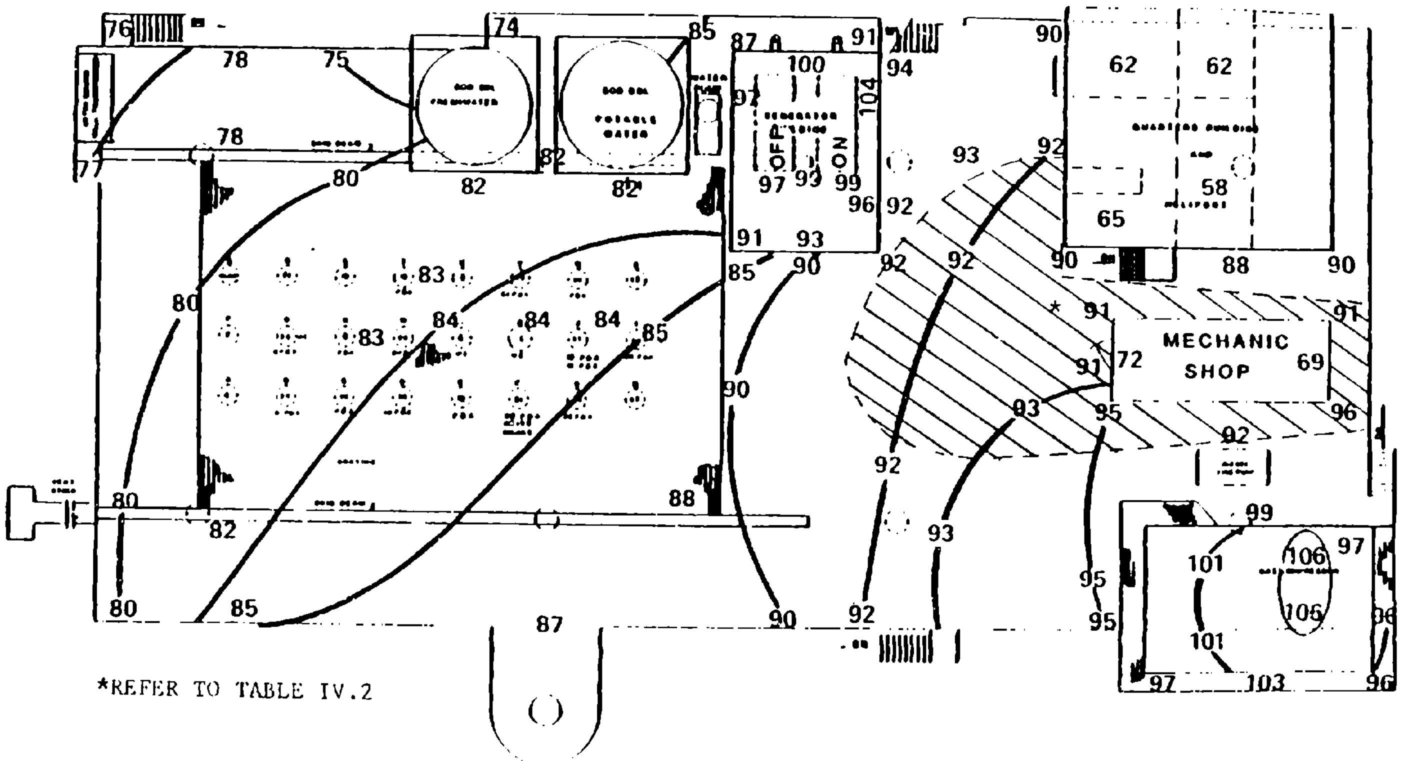
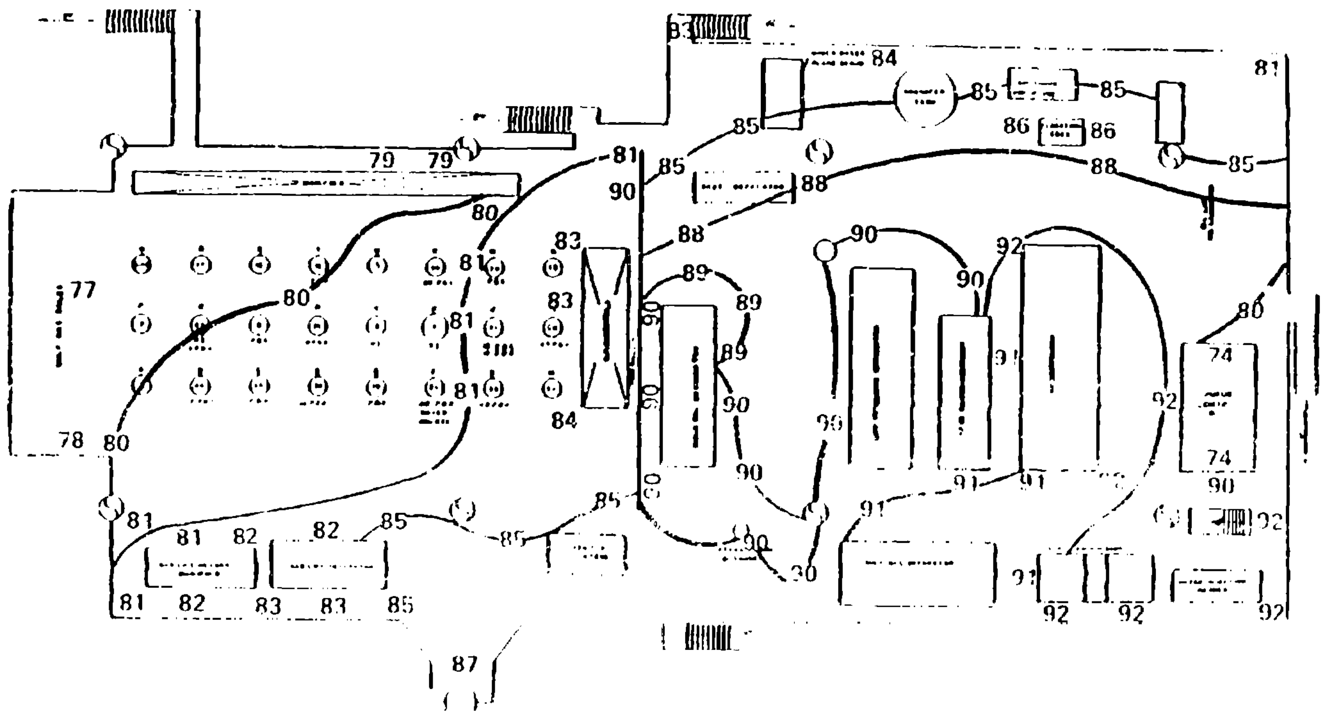


FIGURE A.7. LOWER LEVEL - PLATFORM NO. 2 - SOUND PRESSURE LEVEL CONTOURS IN dB(A)



*REFER TO TABLE IV.2

FIGURE A.8. UPPER LEVEL - PLATFORM NO. 3 - SOUND PRESSURE LEVEL CONTOURS IN dB(A)


77
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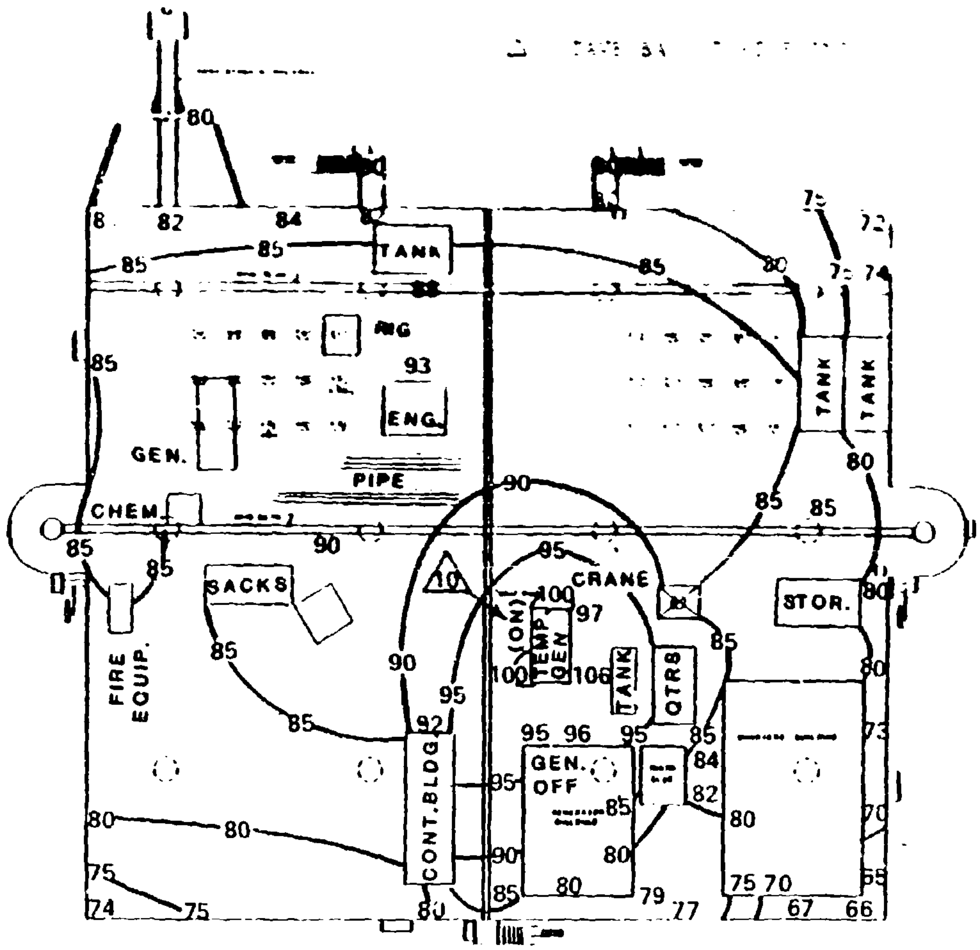
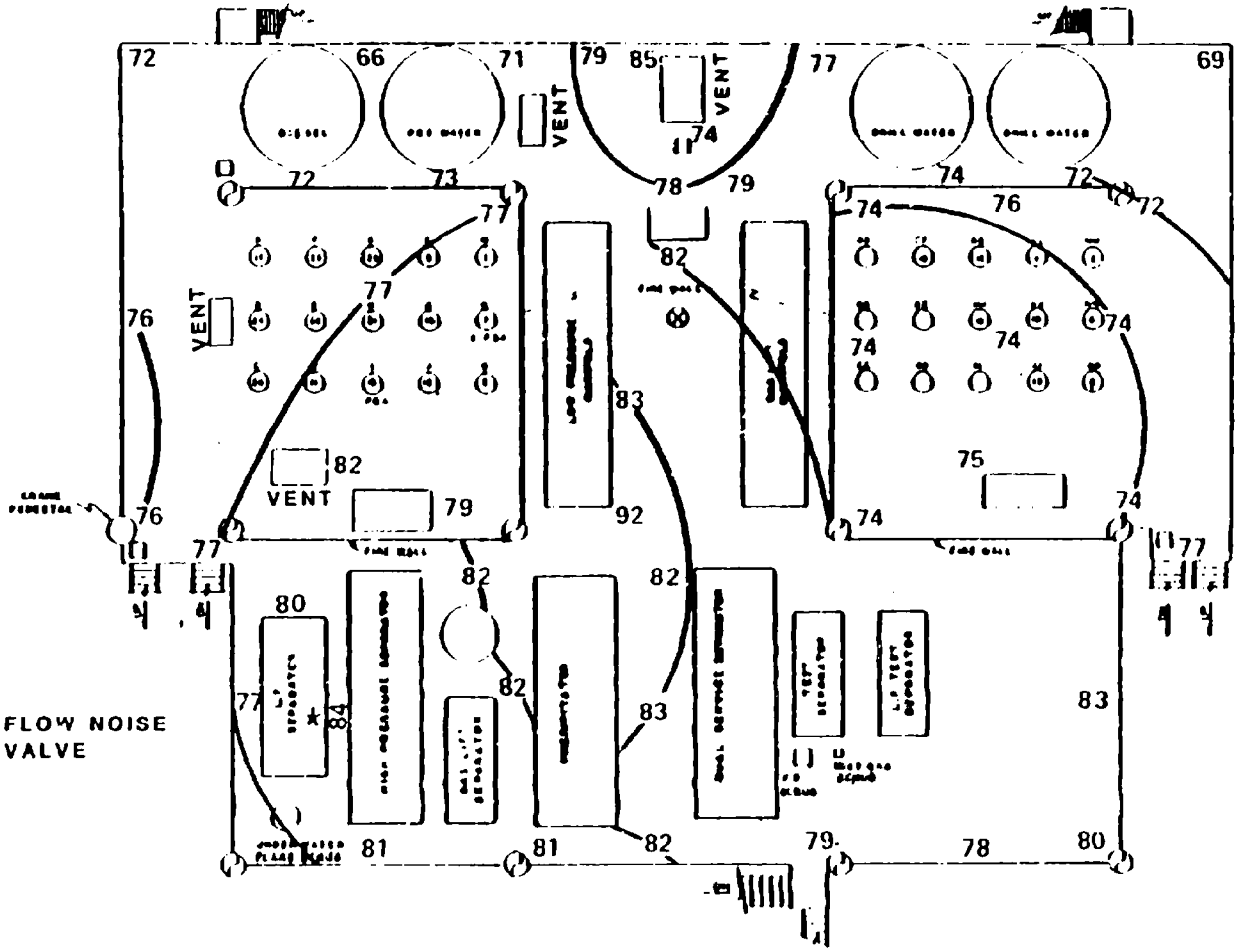


FIGURE A.10. UPPER LEVEL - PLATFORM NO. 4
SOUND PRESSURE LEVEL CONTOURS IN dB(A)



★ DENOTES FLOW NOISE THROUGH VALVE

FIGURE A.11. LOWER LEVEL - PLATFORM NO. 4 - SOUND PRESSURE LEVEL CONTOURS IN dB(A)

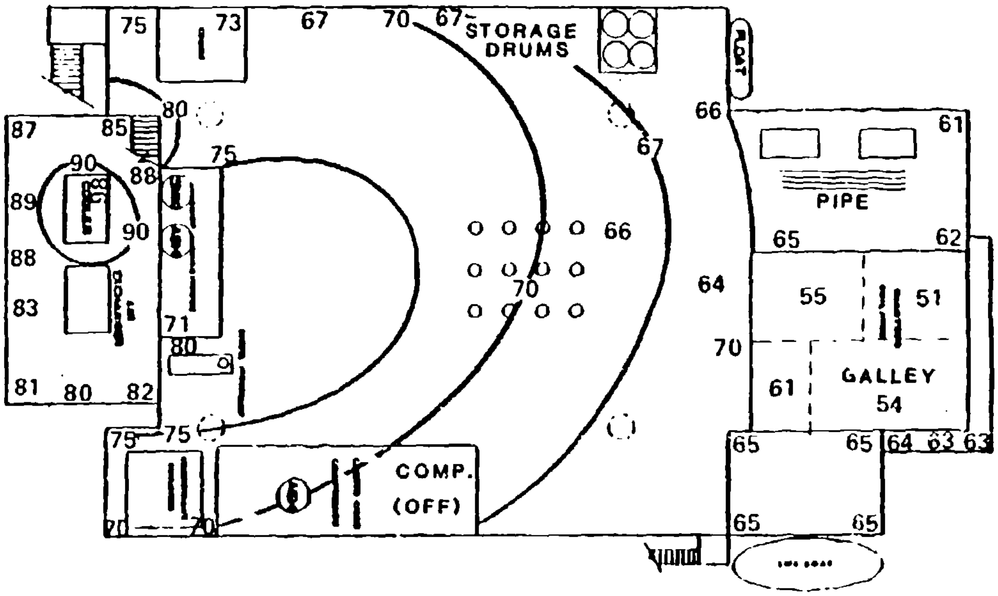


FIGURE A.12. UPPER LEVEL - PLATFORM NO. 5
SOUND PRESSURE LEVEL CONTOURS IN dB(A)

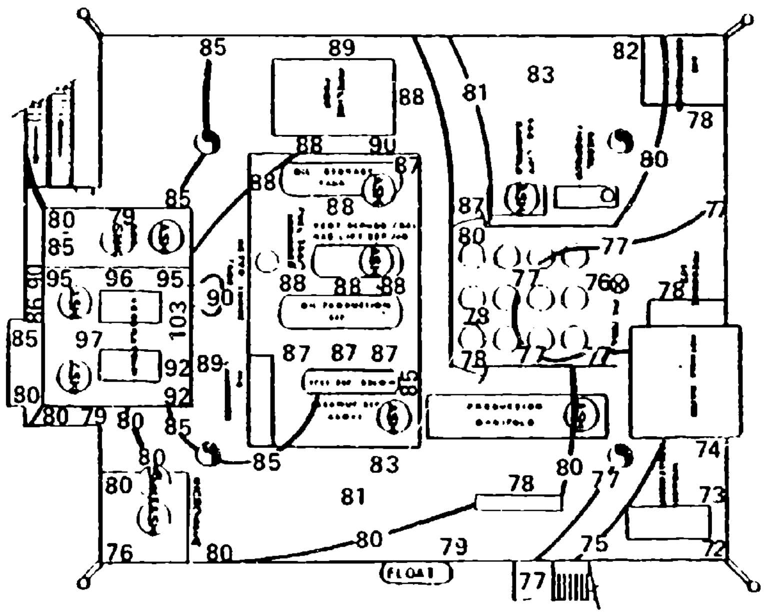
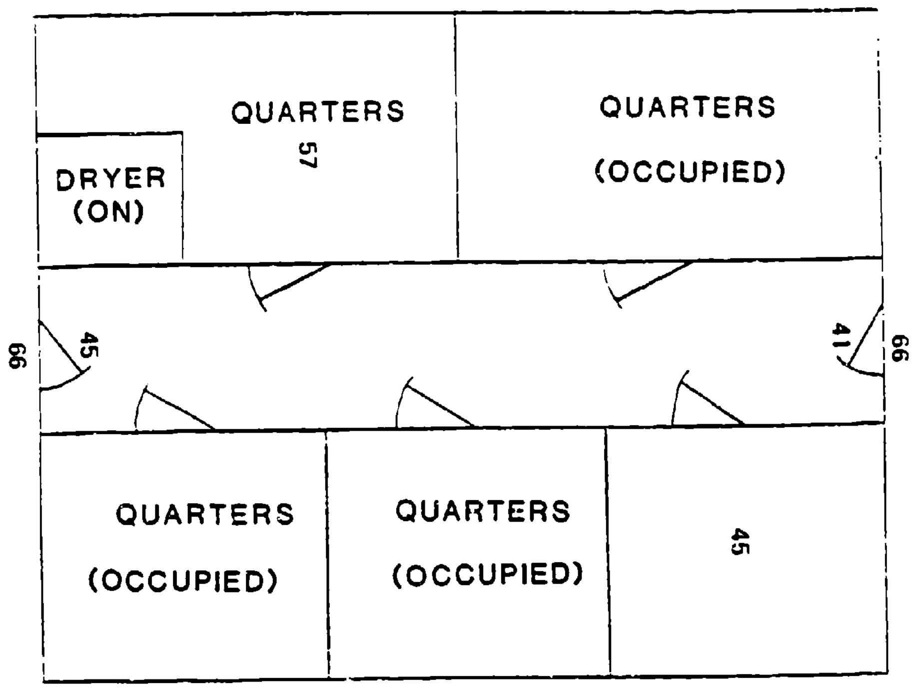


FIGURE A.13. LOWER LEVEL - PLATFORM NO. 5
SOUND PRESSURE LEVEL CONTOURS IN dB(A)



NOTE:

QUARTERS MARKED "OCCUPIED" WERE NOT AVAILABLE FOR SOUND LEVEL MEASUREMENTS

FIGURE A.14. PRODUCTION QUARTERS - PLATFORM NO. 5
SOUND PRESSURE LEVEL IN dB(A)

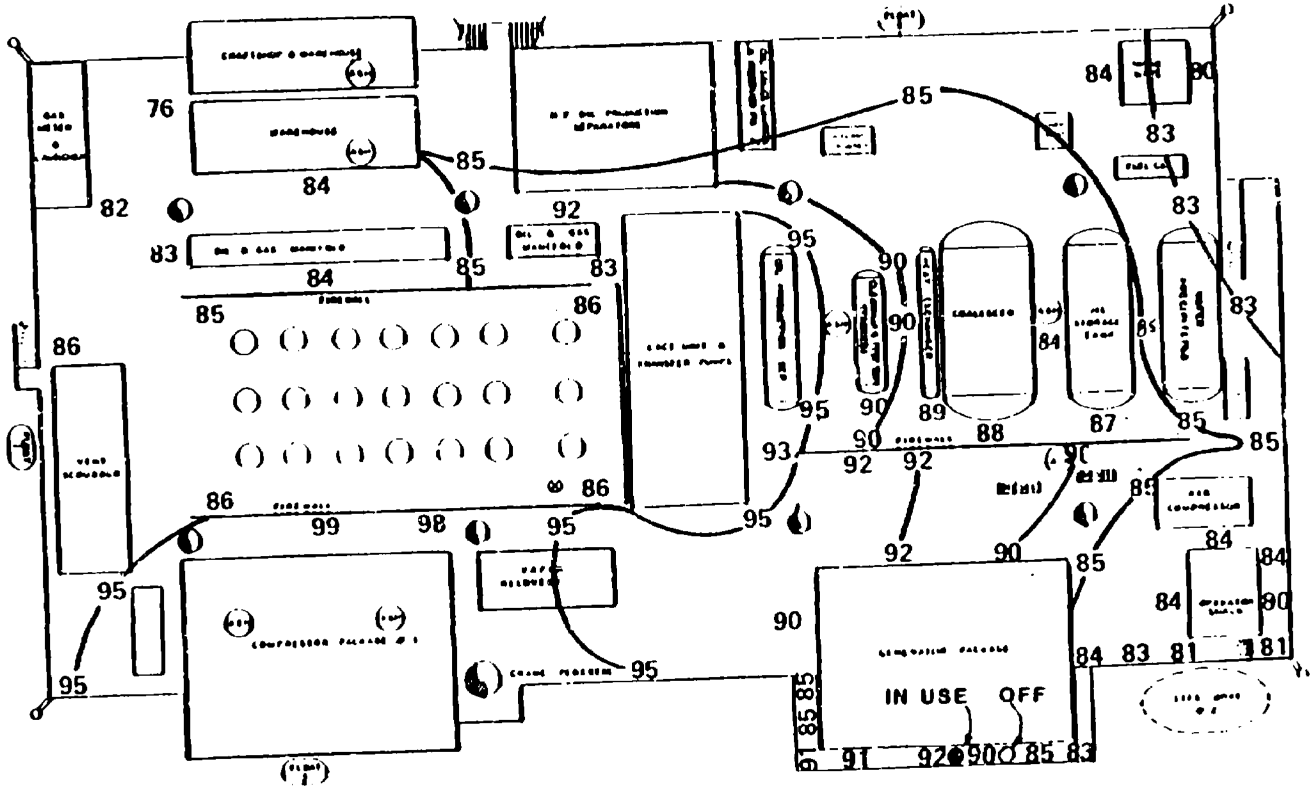
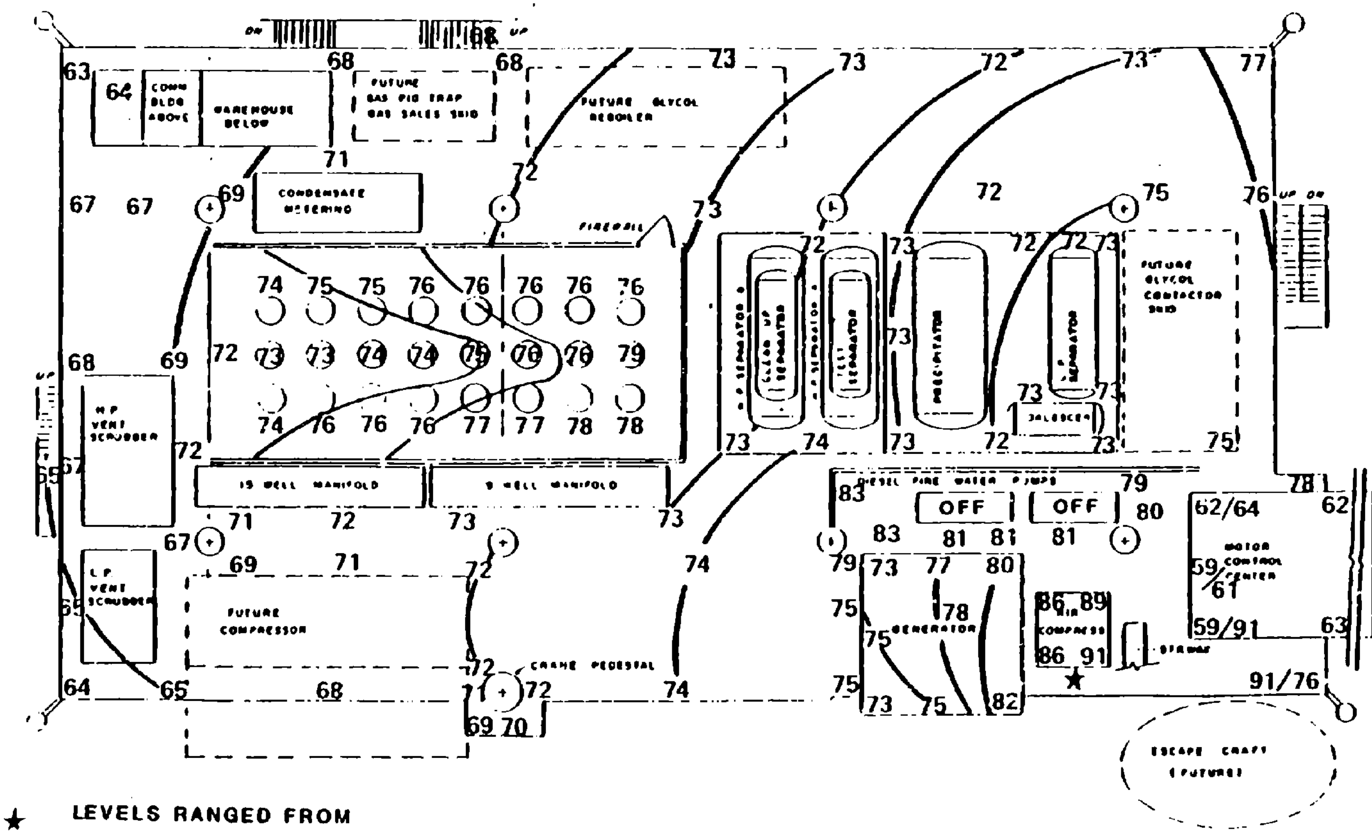


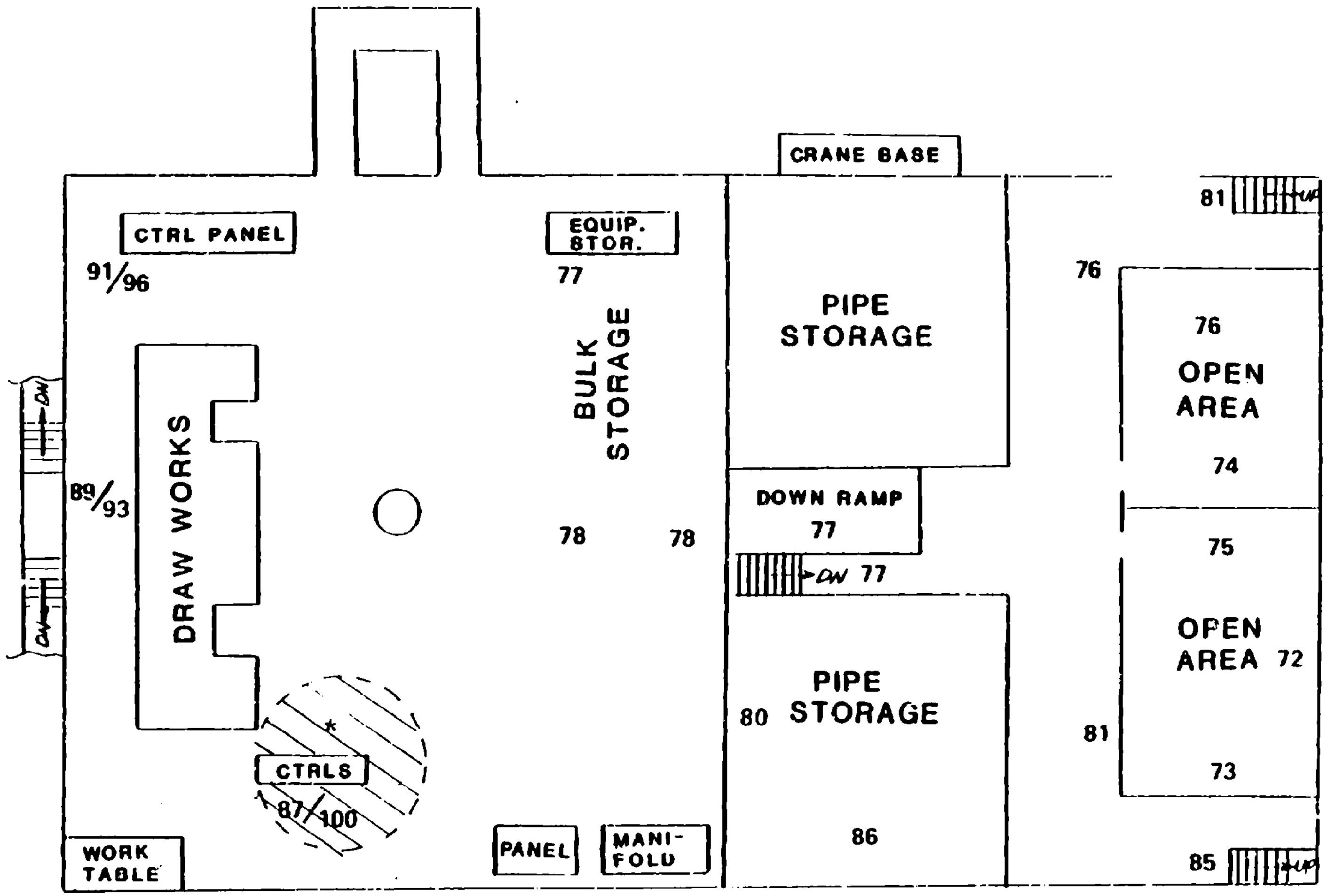
FIGURE A.15. PRODUCTION DECK - PLATFORM NO. 6 - SOUND PRESSURE LEVEL CONTOURS IN dB(A)



★ LEVELS RANGED FROM 76-95 dBA WHEN AIR COMPRESSOR WAS ON.

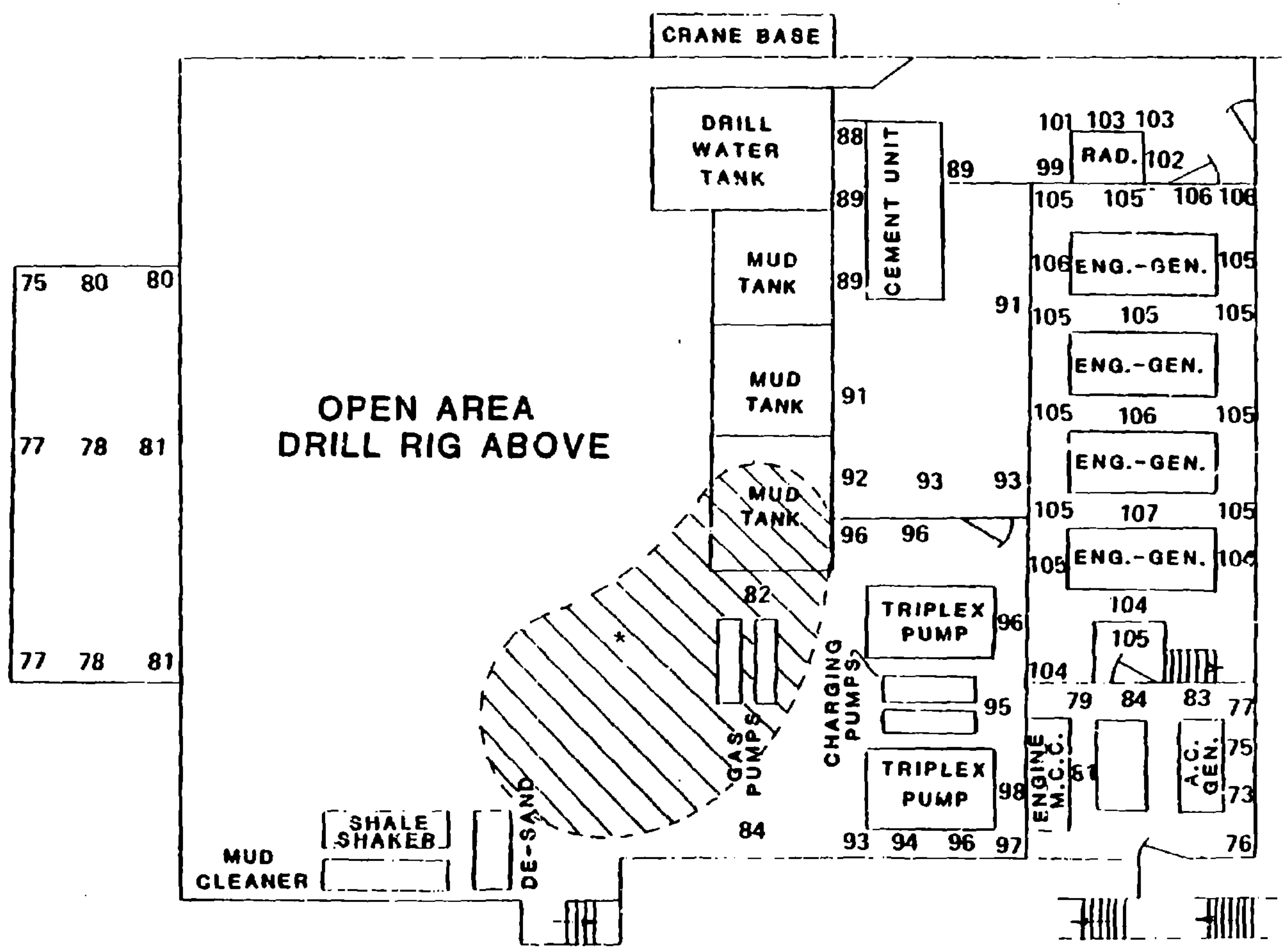
FIGURE A.16. PRODUCTION DECK - PLATFORM NO. 7 - SOUND PRESSURE LEVEL CONTOURS IN dB(A)

NOTE: #/# REPRESENTS SOUND LEVEL MEASUREMENTS RECORDED DURING VARIOUS ACTIVITIES TAKING PLACE ON SEVERAL ADJACENT LEVELS



*REFER TO TABLE IV.2

FIGURE A.17. DRILLING LEVEL - DRILL RIG NO. 1 - SOUND PRESSURE LEVELS IN dB(A)



*REFER TO TABLE IV.2

FIGURE A.18. EQUIPMENT DECK - DRILL RIG NO. 1 - SOUND PRESSURE LEVELS IN dB(A)

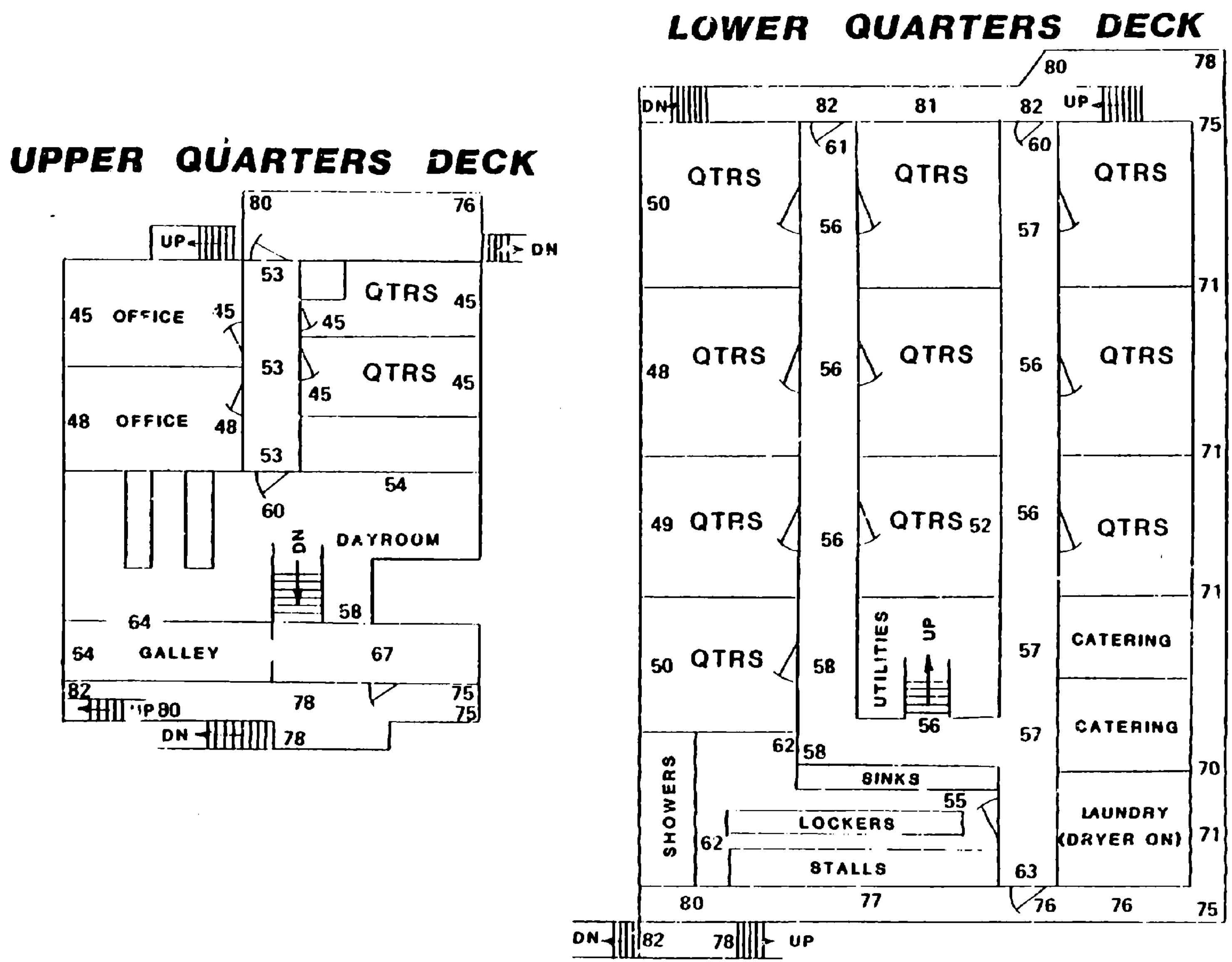


FIGURE A.19. DRILL RIG NO. 1 - DRILLING QUARTERS - SOUND PRESSURE LEVELS IN dB(A)

NOTE: QUARTERS MARKED OCCUPIED WERE NOT AVAILABLE FOR SOUND LEVEL MEASUREMENTS.

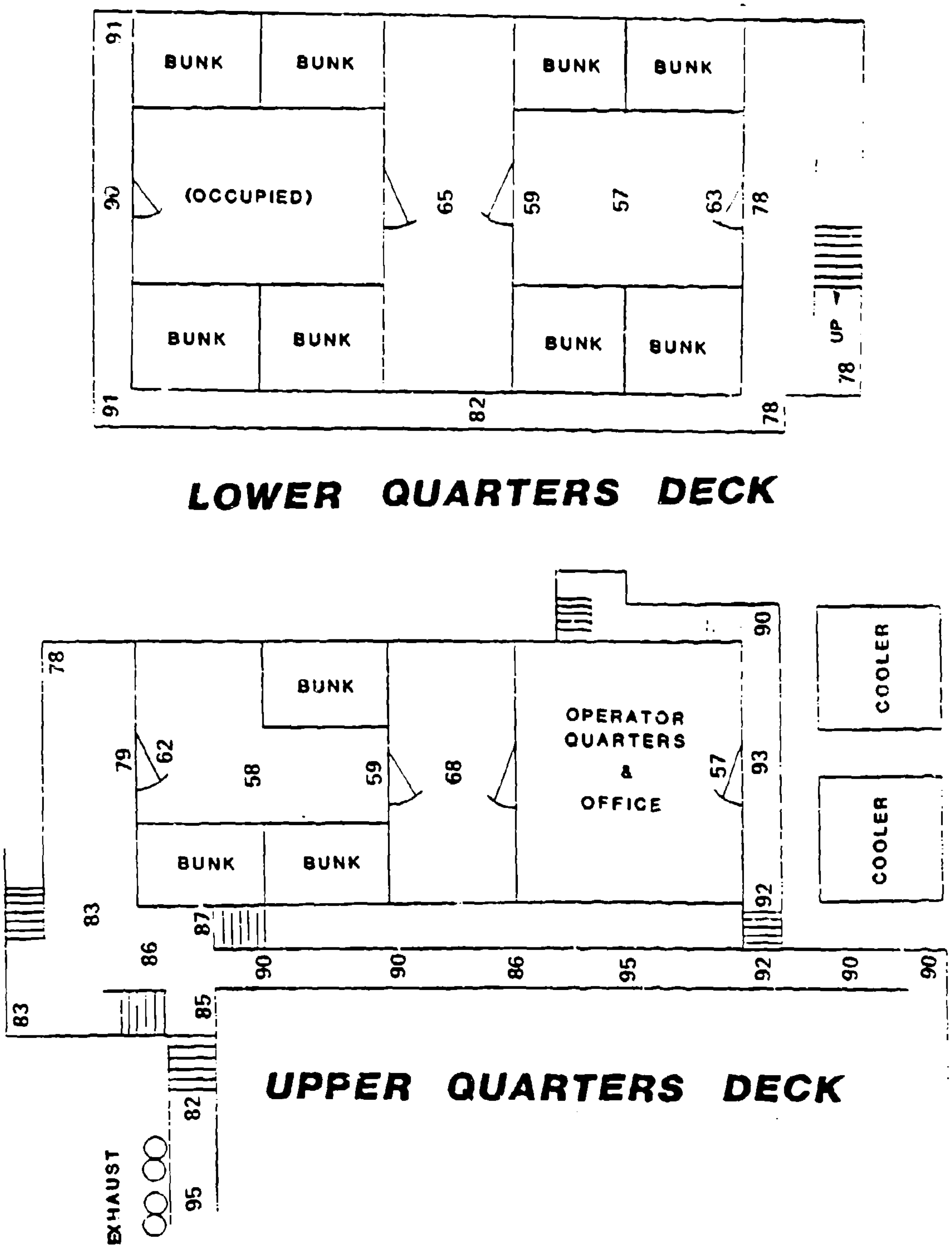


FIGURE A.20. PRODUCTION QUARTERS - DRILL RIG NO. 1
SOUND PRESSURE LEVELS IN dB(A)

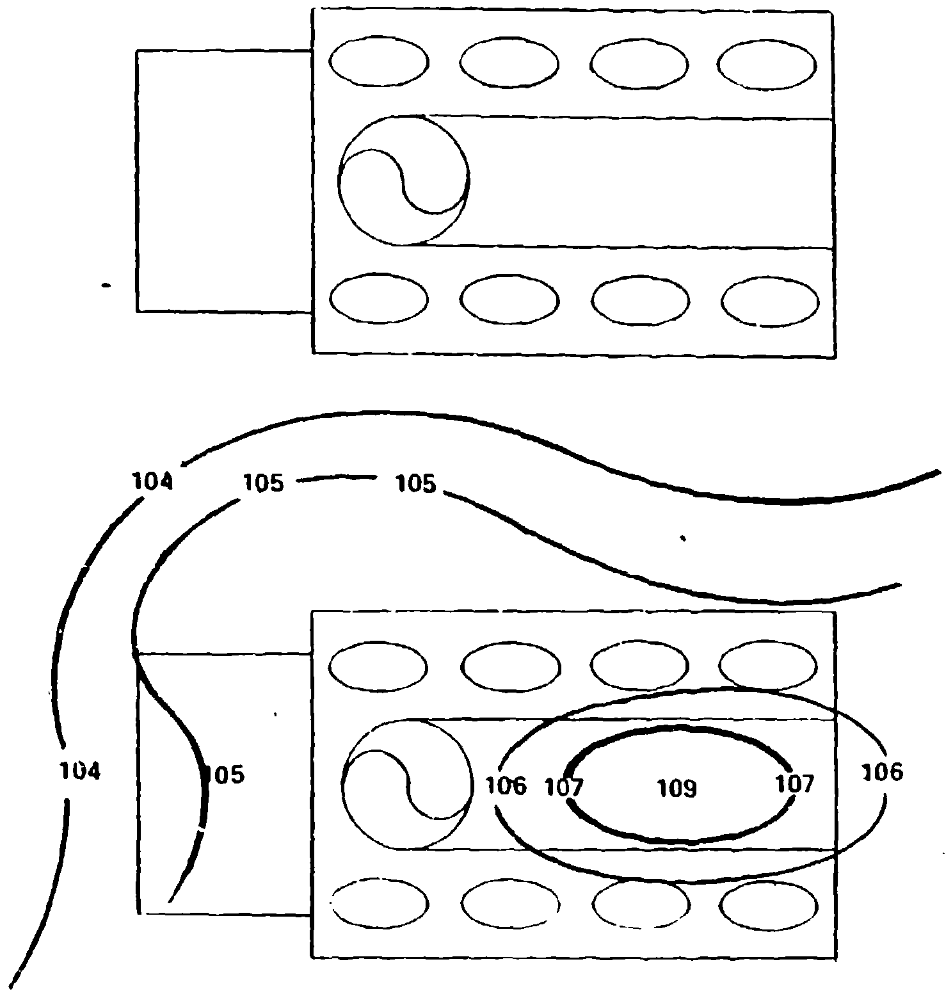
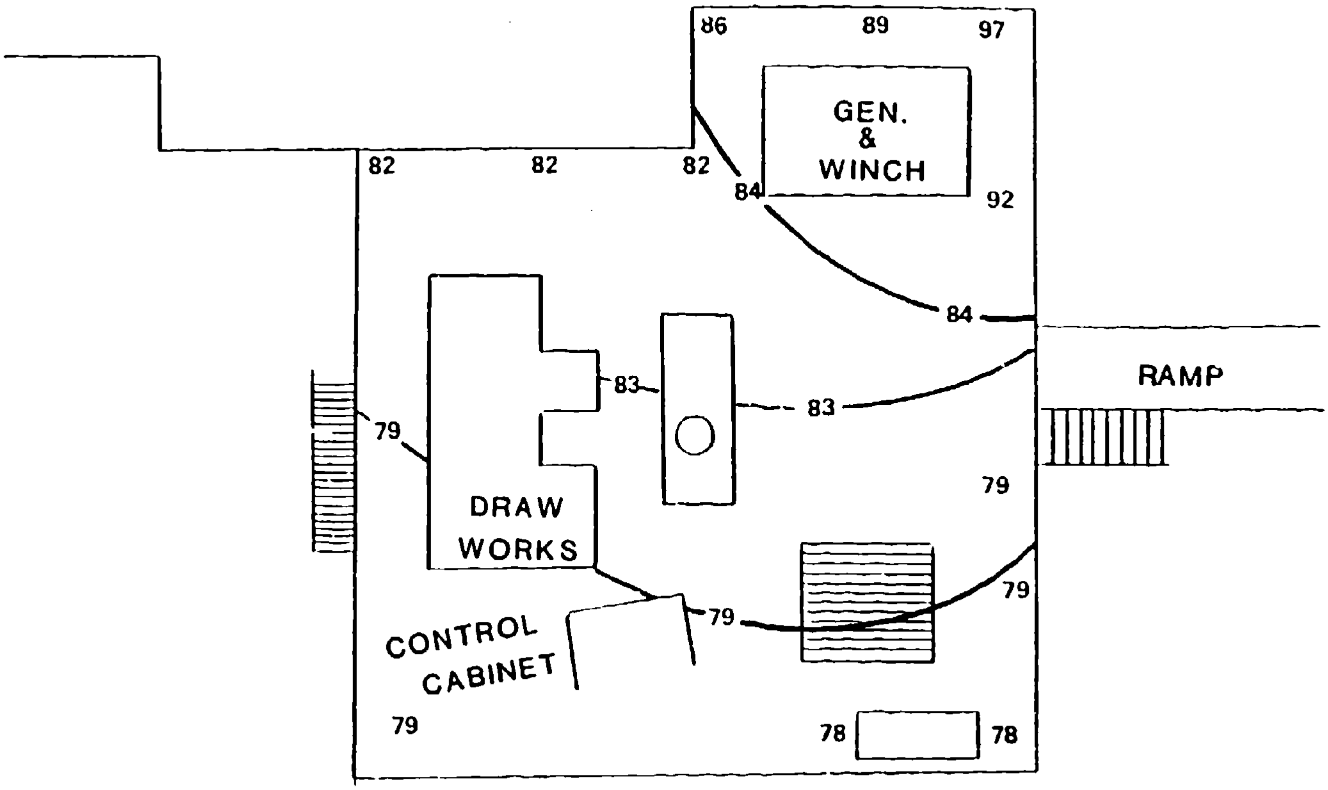


FIGURE A.21. ENGINE-GENERATOR DECK - DRILL RIG NO. 1
SOUND PRESSURE LEVEL CONTOURS IN dB(A)



NOTE:

LEVELS SHOWN
ARE NOT CONSTANT
AND VARY WITH
DRILLING ACTIVITY

FIGURE A.22. DRILLING LEVEL - DRILL RIG NO. 2
SOUND PRESSURE LEVEL CONTOURS IN dB(A)

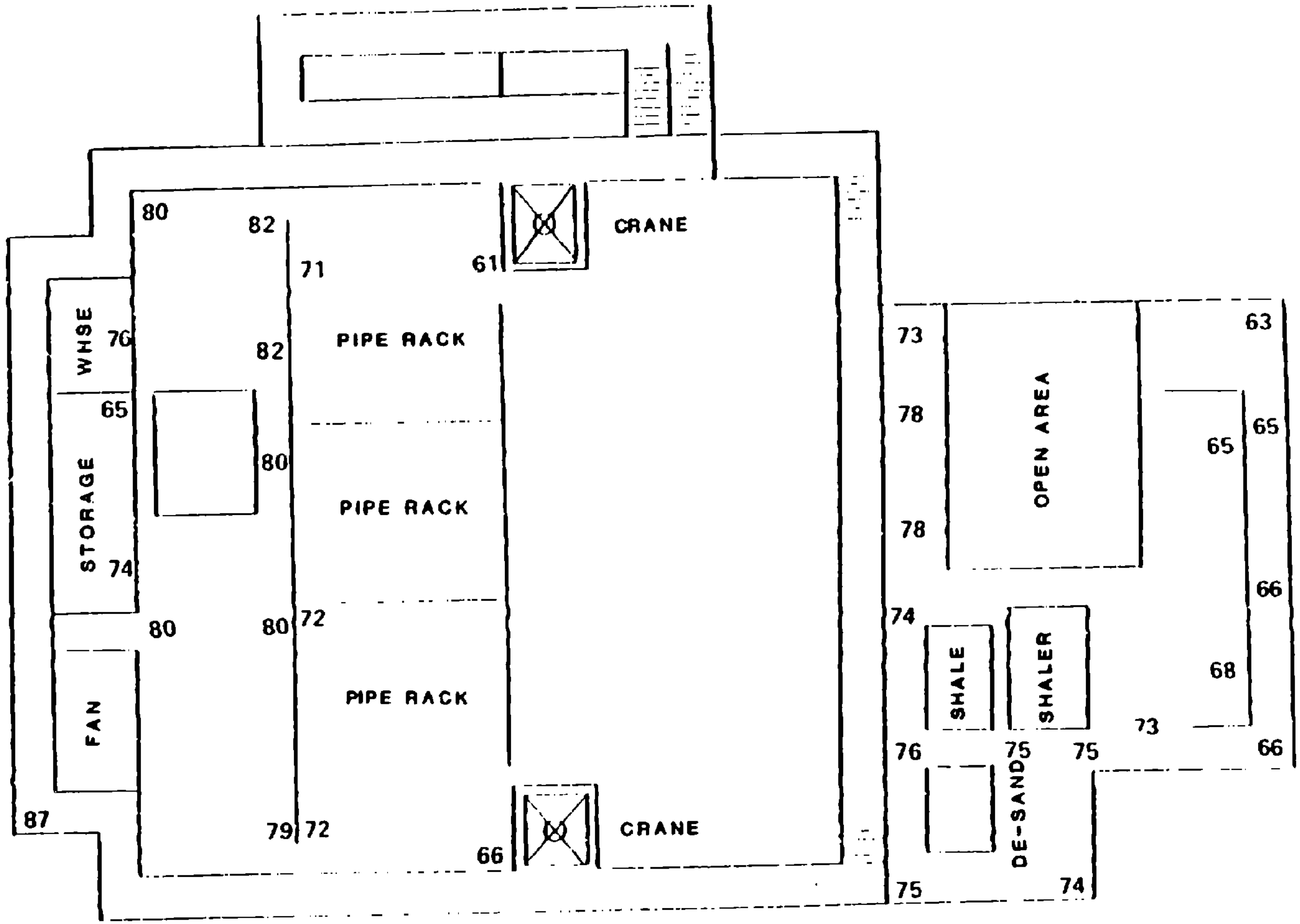
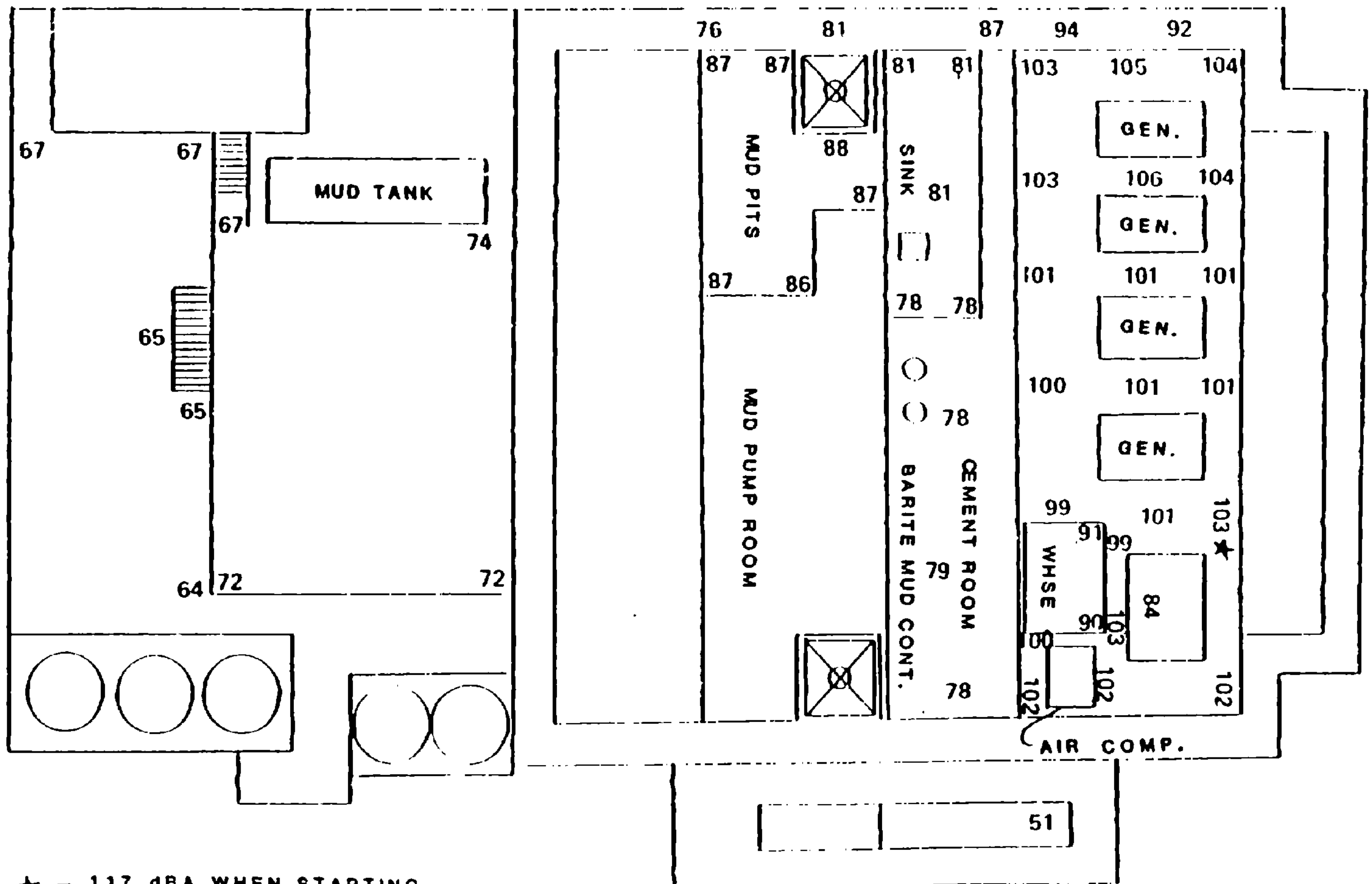


FIGURE A.23. UPPER LEVEL - DRILL RIG NO. 2 - SOUND PRESSURE LEVELS IN dB(A)



★ – 117 dBA WHEN STARTING DIESEL-ELEC.GEN.

FIGURE A.24. LOWER LEVEL - DRILL RIG NO. 2 - SOUND PRESSURE LEVEL CONTOURS IN dB(A)

APPENDIX B

NOISE DOSIMETRY DATA

During the period April 25, 1983 through May 1, 1983 two SwRI employees and the USCG technical monitor collected noise dosimetry data on selected individuals. The selection was made primarily on the basis of job title or description. We intentionally selected the worker's believed to have the highest probability of exceeding the permissible exposure levels during a normal work-day, assuming no hearing protection was worn.

A total of sixteen dosimetry records were obtained during the offshore observation period. Fourteen of the surveys had sample durations in excess of 10.5 hours. Of these fourteen observations, eleven indicated the worker would have received more than 100% of the allowable exposure without hearing protection. Table B.I summarizes the noise dosimetry observations. This table indicates the identification number under which SwRI has stored the data; the worker's job or title; the sample duration; the elapsed time to reach 100% of the allowable exposure; whether or not hearing protection was worn; and the projected 12 hour and 24 hour effective exposures assuming no additional exposure >80 dB(A). Although most of this data can be readily interpreted, the hearing protection column requires an explanation.

During the offshore observation, workers inserted ear plugs or donned muffs prior to entering a structure which required hearing protection. Therefore, the use of hearing protection indicates that the worker was required to enter a compressor room, generator room, or other high noise area. The only exceptions were surveys ND 13 and ND 14. The two roustabouts worked outside in an area which was quiet when they were not working. Therefore, no signs were posted requiring hearing protection in the general area. However, due to the high noise level of the work, both roustabouts wore plugs, which appeared to be cotton balls.

The remainder of this appendix contains the data obtained for each case listed in Table B.1. Three figures are presented for each case as described in Section III.3. A table is presented with each of the sixteen histograms to indicate what activities were conducted during the intervals marked on the histograms.

TABLE B.1. DOSIMETRY DATA COLLECTED OFFSHORE

Noise Dosimetry ID No.	Worker Job or Title	Sample Duration (Hours)	Time When Exposure Exceeded Allowable (Hours)	Hearing Protection	Max* Dose	$L_{eff}(12)$ dB(A)	$L_{eff}(24)$ dB(A)
ND 1	SwRI	10.7	7.5	Y	146%	89.85	84.85
ND 2	USCG	10.7	7.5	Y	134%	89.40	84.40
ND 3	Day Pumper	12.0	8.3	Y	121%	88.84	83.84
ND 4	Day Roust-about	12.0	8.3	Y	110%	88.18	83.18
ND 5	Welder	10.7	10.5	N	103%	87.35	82.35
ND 6	Driller	11.8	8.3	N	176%	91.36	86.36
ND 7	Derrick Man	12.0	**	N	78%	85.85	80.85
ND 8	Driller	12.0	8.0	N	167%	90.78	85.78
ND 9	Derrick Man	11.8	3.7	N	318%	95.42	90.42
ND 10	Roustabout	5.5	**	N	86%	85.97	80.97
ND 11	Roustabout	1.5	**	N	19%	75.20	70.20
ND 12	Electrician	11.0	**	Y	58%	84.05	79.05
ND 13	Roustabout	11.5	.8	Y	1450%	106.31	101.31
ND 14	Roustabout	11.4	1.5	Y	820%	102.21	97.21
ND 15	Welder's Assistant	12.0	12.0	N	100%	87.28	82.28
ND 16	Welder	12.0	**	N	69%	85.10	80.10

* = Maximum dose is calculated based on USCG NVC 12-82 acceptable effective exposures.

** = Allowable level was not exceeded during the sample.

Y = Hearing protection worn in designated areas.

N = No hearing protection was worn during the day.

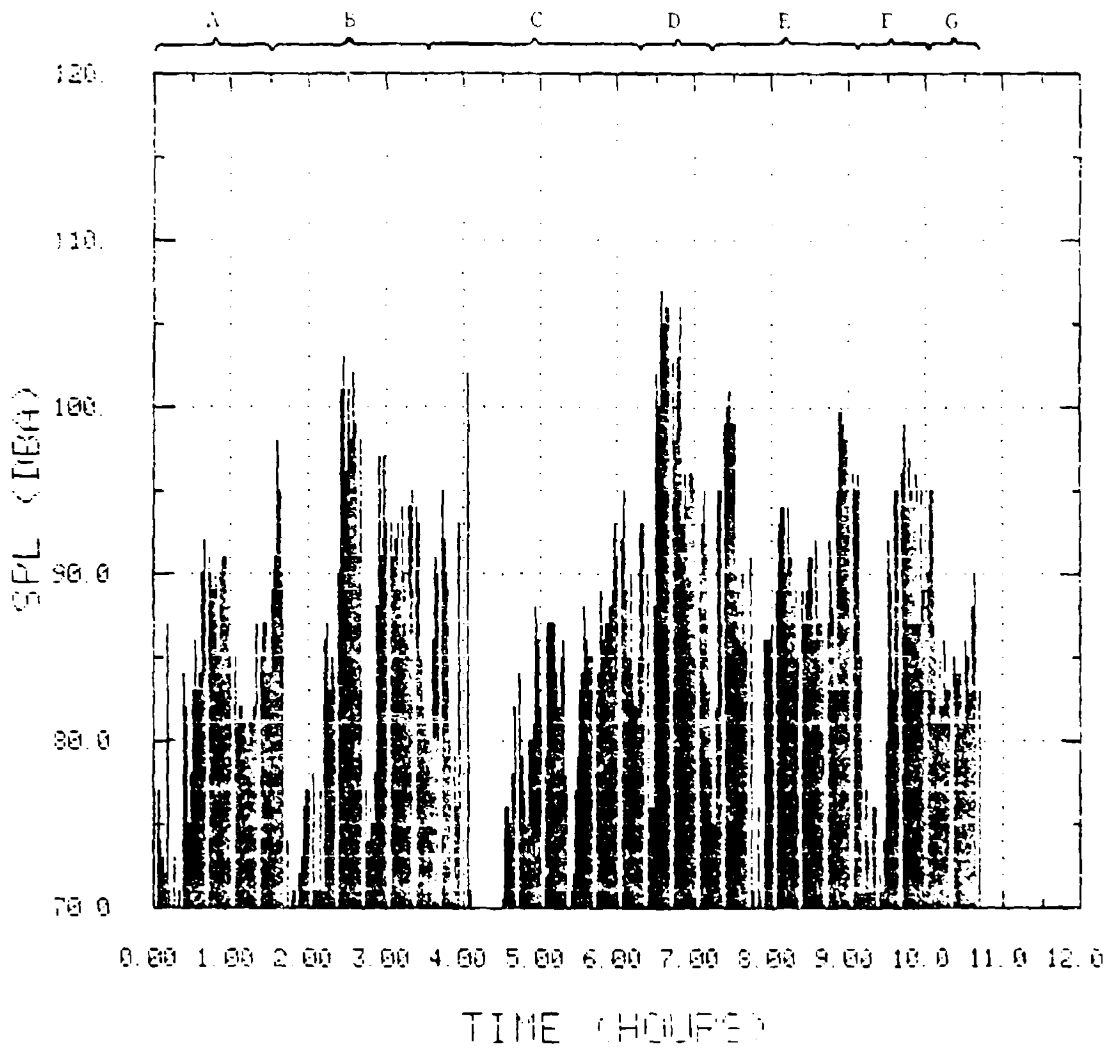


FIGURE B.1. NOISE DOSIMETRY ON SwRI EMPLOYEE TOURING THE FIELD (Identification Number ND1)

TABLE B.II. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.1

Interval	Activity
A	Inside crewboat traveling to field
B	Touring Platform 1
C	Touring Platform 2
D	Touring Platform 3
E	Touring Platform 4
F	Touring Drilling Rig
G	Fieldboat to Platform 2

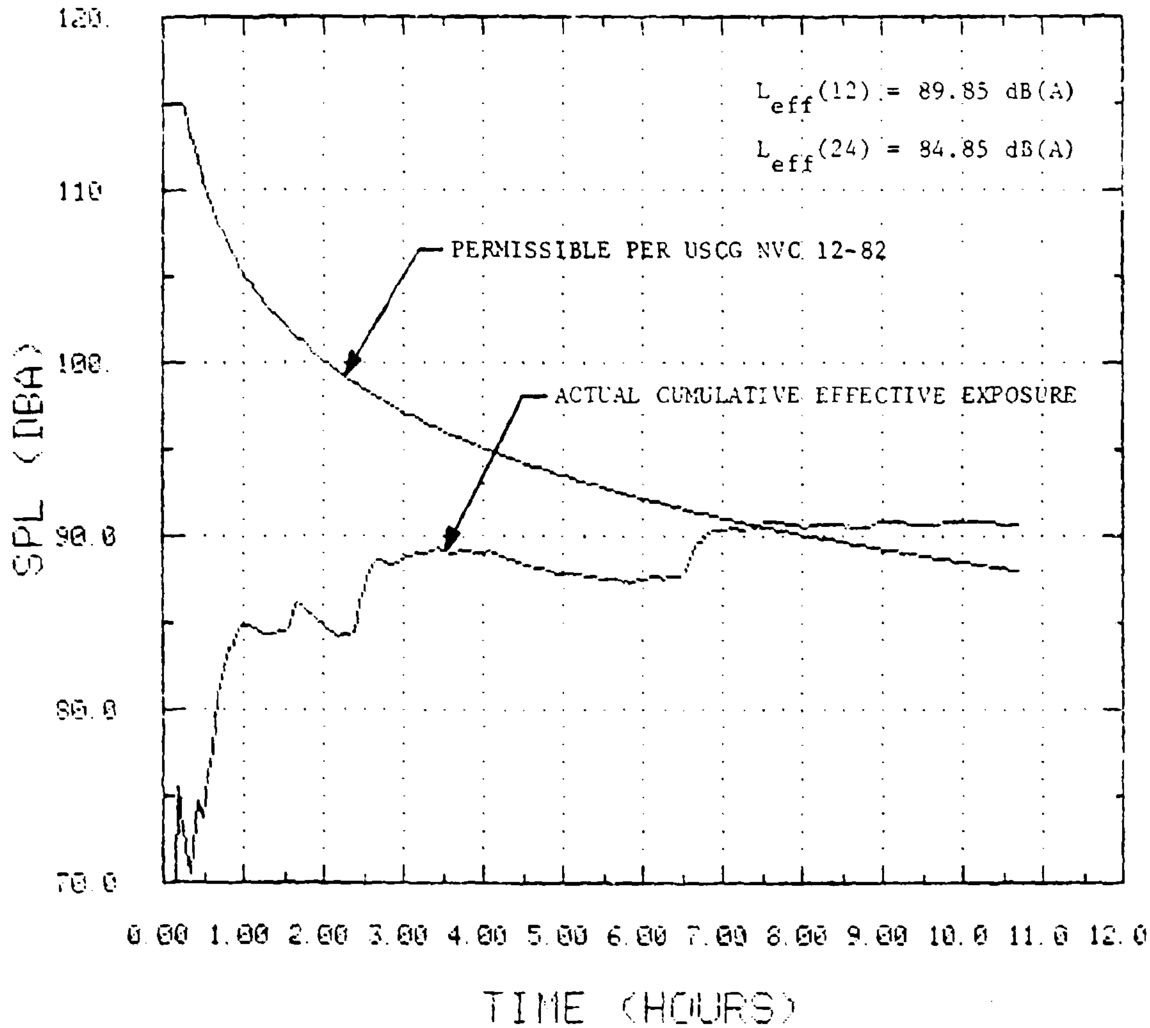


FIGURE B.2. CUMULATIVE EFFECTIVE EXPOSURE ON SwRI EMPLOYEE (Identification Number ND1)

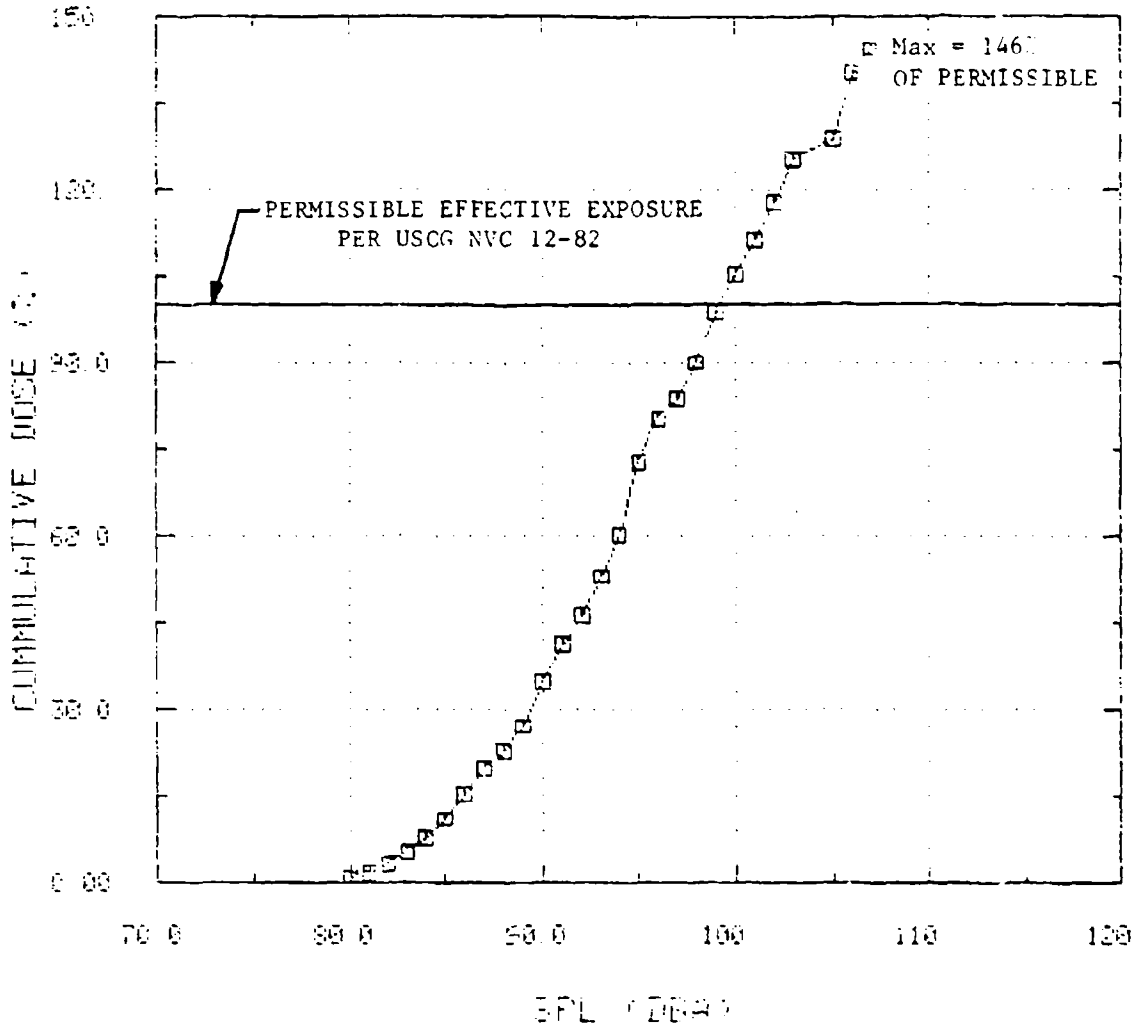


FIGURE B.3. CUMULATIVE DOSE RECORDED ON SwRI EMPLOYEE
(Identification Number ND1)

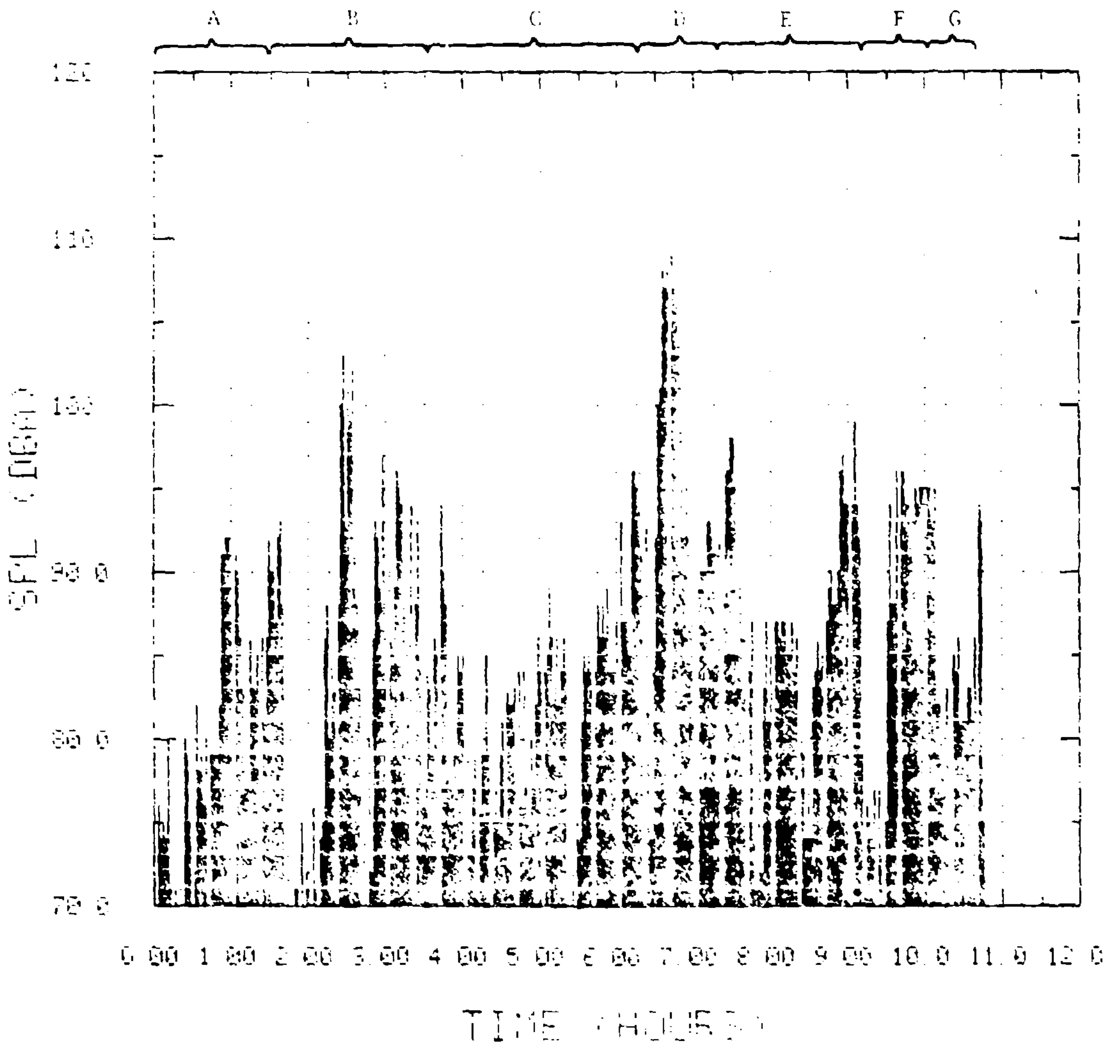


FIGURE B.4. NOISE DOSIMETRY ON USCG TECHNICAL MONITOR TOURING THE FIELD (Identification Number ND2)

TABLE B.III. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.4

Interval	Activity
A	Inside crewboat traveling to field
B	Touring Platform 1
C	Touring Platform 2
D	Touring Platform 3
E	Touring Platform 4
F	Touring Drilling Rig
G	Fieldboat to Platform 2

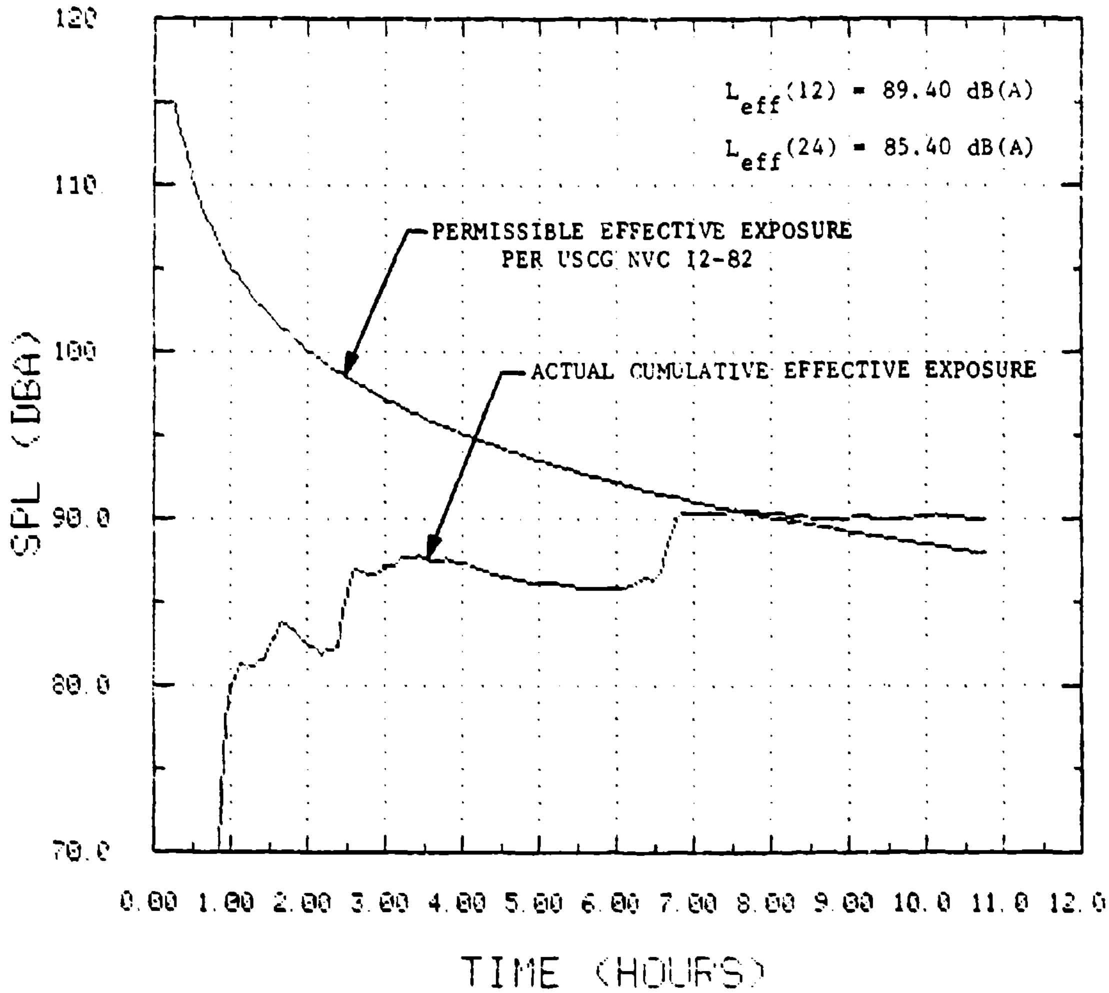


FIGURE B.5. CUMULATIVE EFFECTIVE EXPOSURE ON USCG TECHNICAL MONITOR (Identification Number ND2)

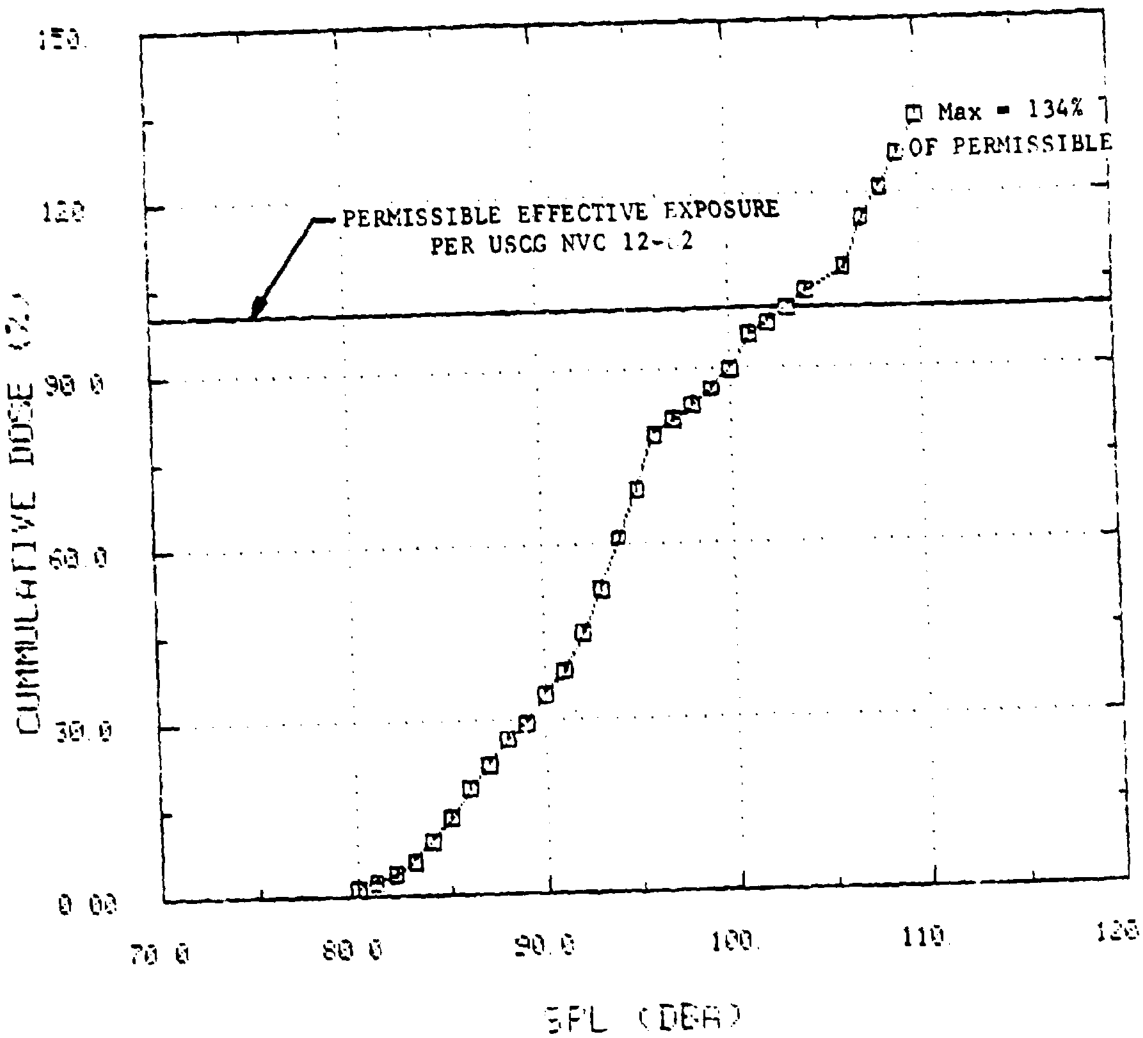


FIGURE B.6. CUMULATIVE DOSE DETERMINED FOR USCG TECHNICAL MONITOR (Identification Number ND2)

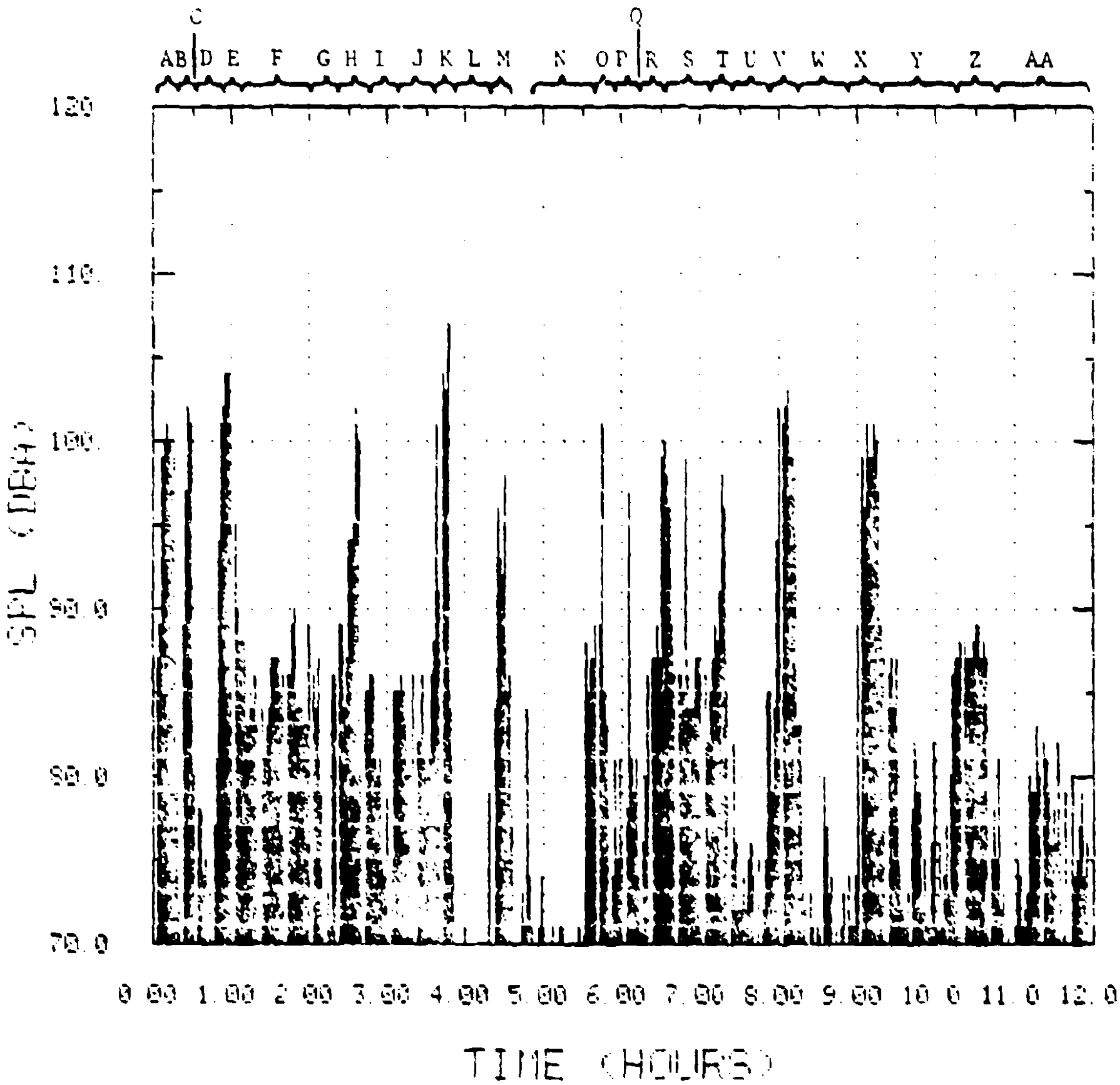


FIGURE B.7. NOISE DOSIMETRY ON DAY PUMPER
(Identification Number ND3)

TABLE B.IV. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.7

Interval	Activity
A	Inside compressor buildings.
B	Inside control room.
C	Operated crane.
D	Inside office.
E	Inside compressor building.
F	Worked on 10 foot level and wellhead level.
G	Inside quarters.
H	Inside compressor building. Neither unit running initially while repairs were being made.
I	Checked wellhead area.
J	Worked near wellhead area.
K	Operated crane, checked generator room.
L	Inside quarters.
M	Operated crane.
N	Inside quarters.
O	Operated crane.
P	Inside office.
Q	Inside compressor building.
R	Inside warehouse 10 minutes and then lubricated crane.
S	Worked primarily in wellhead area lubricating valves; also operated crane.
T	Operated crane.
U	Inside operator's shack.
V	Inside compressor building collecting data.
W	Inside office.
X	Operated crane and read instruments on top of compressor building. Hearing protection was worn 17 minutes.
Y	Worked near separators 6 minutes and worked in mechanic's shop.
Z	Unloaded equipment basket on main deck.
AA	Inside quarters.

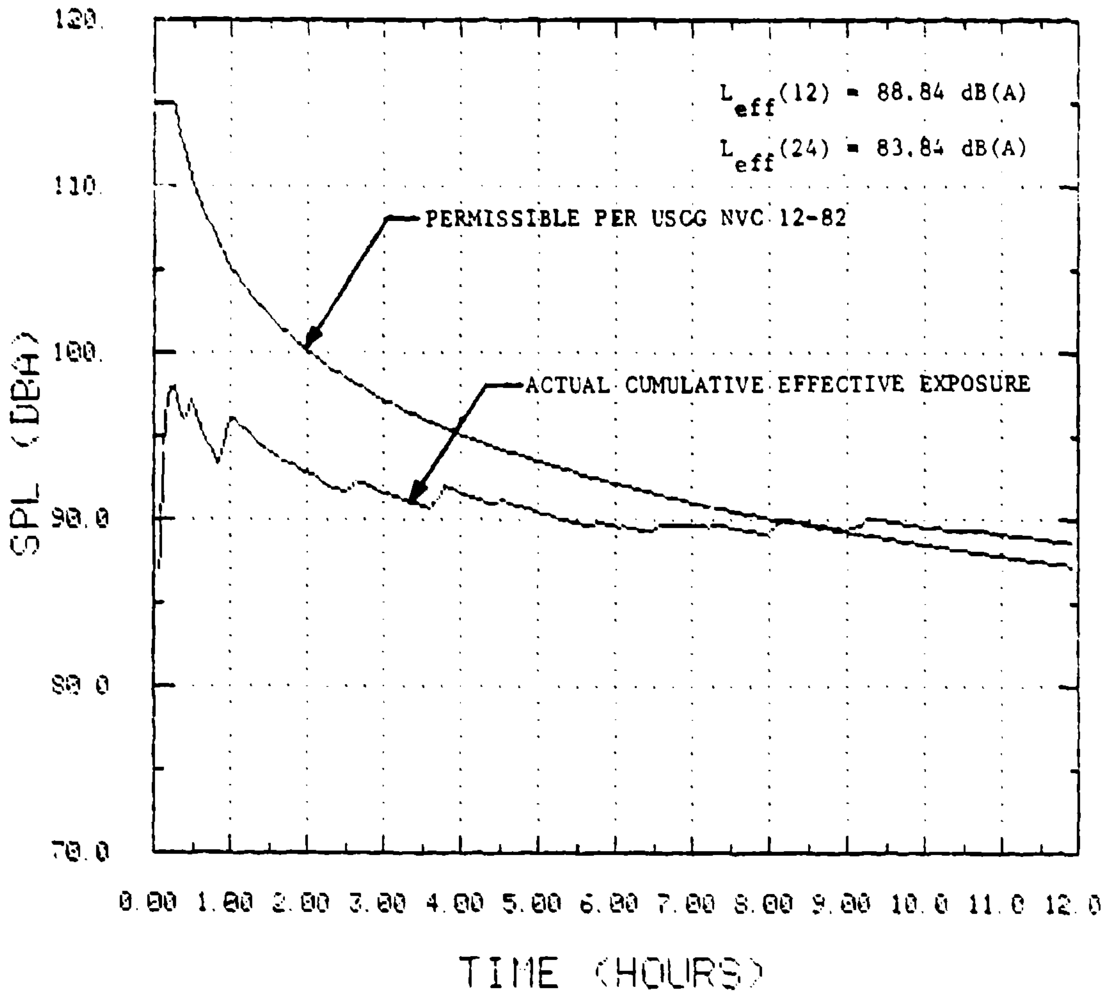


FIGURE B.8. CUMULATIVE EFFECTIVE EXPOSURE ON DAY PUMPER (Identification Number ND3)

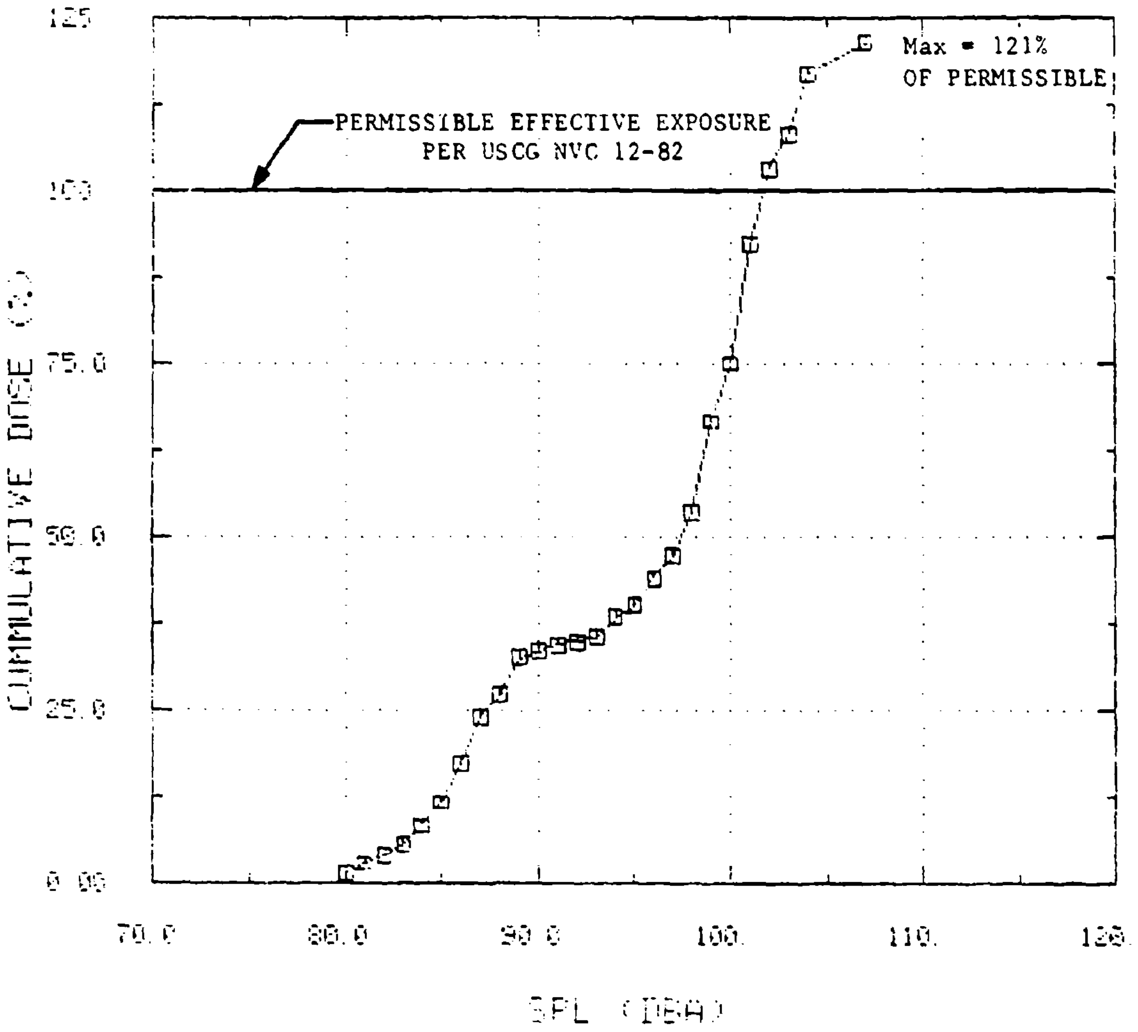


FIGURE B.9. CUMULATIVE DOSE RECORDED ON DAY PUMPER
(Identification Number ND3)

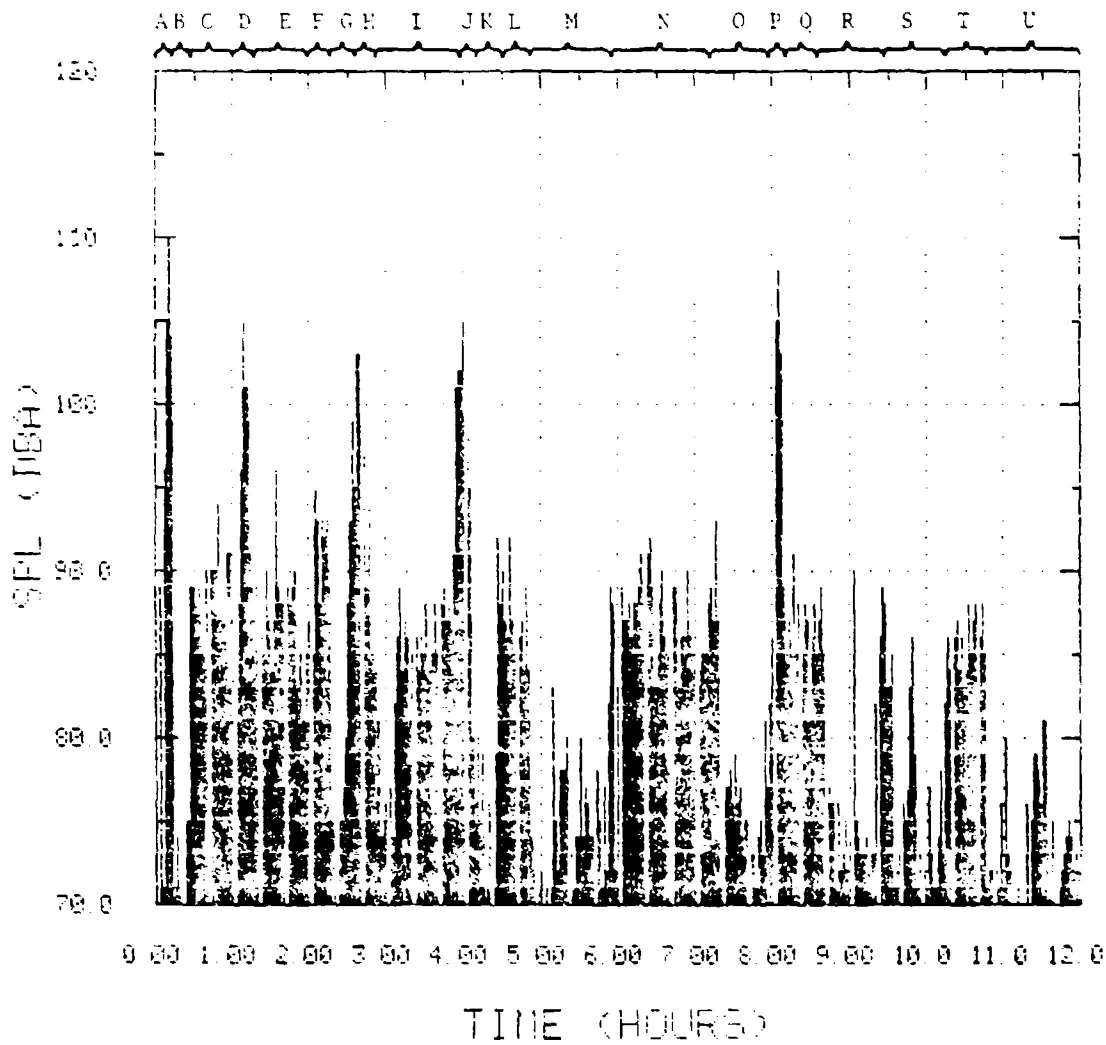


FIGURE B.10. NOISE DOSIMETRY ON DAY ROUSTABOUT
(Identification Number ND4)

TABLE B.V. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.10

Interval	Activity
A	Performed rounds to take readings on equipment, including generators. Wore ear muffs.
B	Inside office.
C	Tended cargo basket, went down to lower level of platform.
D	Operating crane.
E	Worked on 10 foot level and wellhead area.
F	Wellhead area.
G	Inside for break.
H	Worked on compressor room.
I	Wellhead area 27 minutes, main deck 22 minutes during this interval.
J	Taking readings on generators.
K	Inside office.
L	Well bay area.
M	Inside for lunch.
N	Worked in well bay area primarily.
O	Operated crane.
P	Taking readings on generators.
Q	Working in wellhead area.
R	Inside office.
S	Working inside mechanic's shop.
T	Working on main deck 20 minutes and 7 minutes in well bay area.
U	Inside quarters.

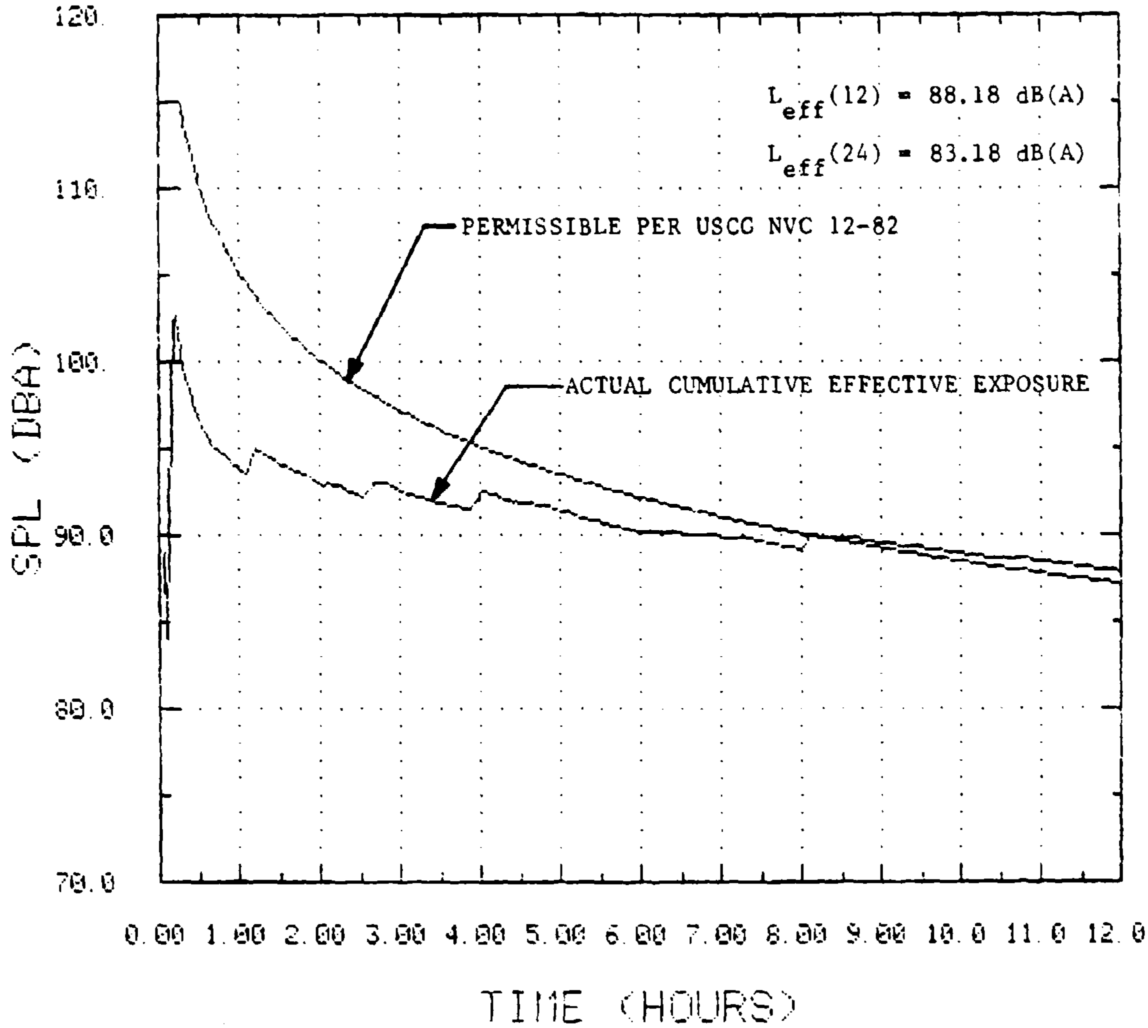


FIGURE B.11. CUMULATIVE EFFECTIVE EXPOSURE ON DAY ROUSTABOUT (Identification Number ND4)

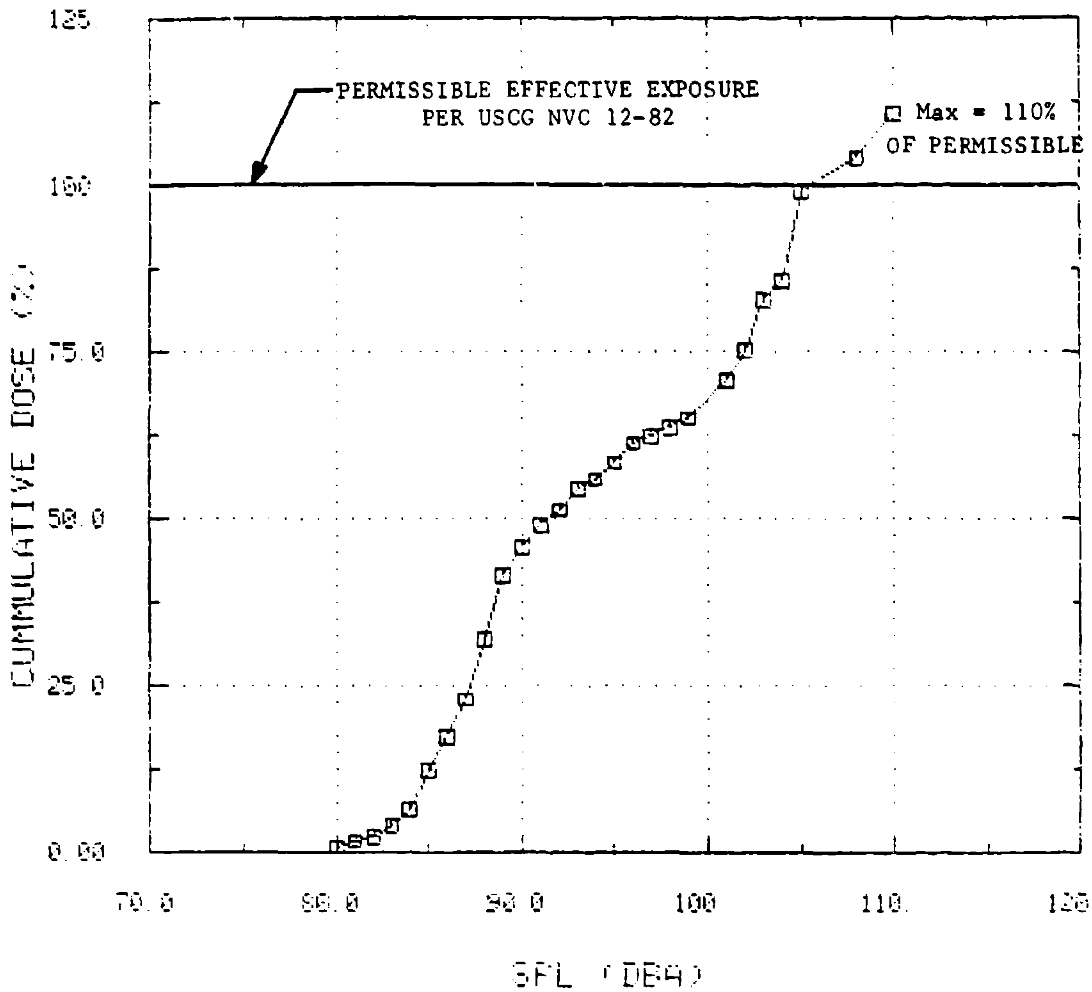


FIGURE B.12. CUMULATIVE DOSE RECORDED ON DAY ROUSTABOUT (Identification Number ND4)

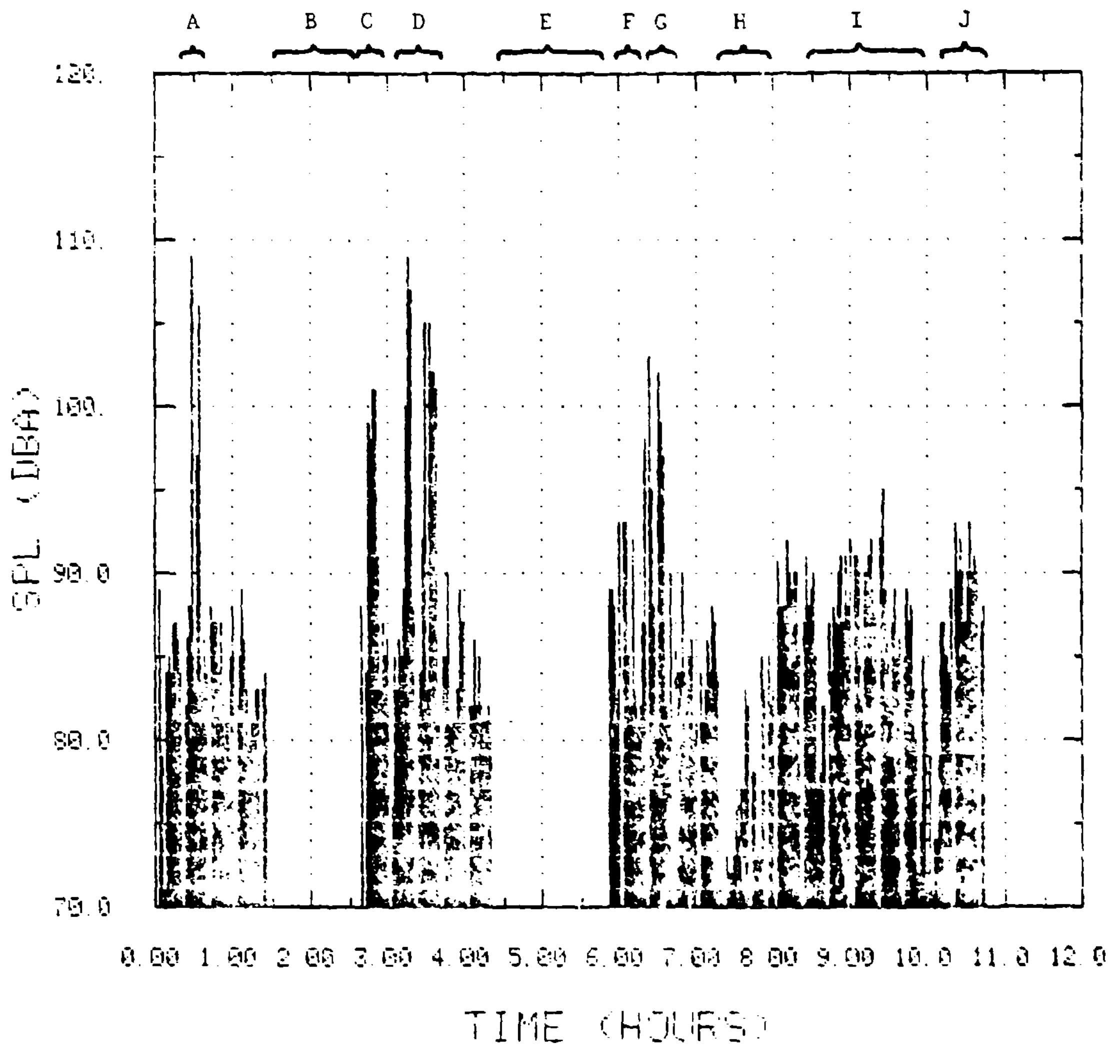


FIGURE B.13. NOISE DOSIMETRY ON CONTRACT WELDER
(Identification Number ND5)

TABLE B.VI. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.13

Interval	Activity
A	Grinding and welding on Platform 1.
B	Inside quarters while gas was flared. (Dosimeter was in standby position.
C	Grinding and welding.
D	Welding, cutting pipe, and grinding.
E	Inside quarters. (Dosimeter was in standby position)
F	Cutting pipe and grinding.
G	Grinding and welding.
H	Inside quarters.
I	Installing a new hoist in welding area.
J	Transferring finished pices to top deck.

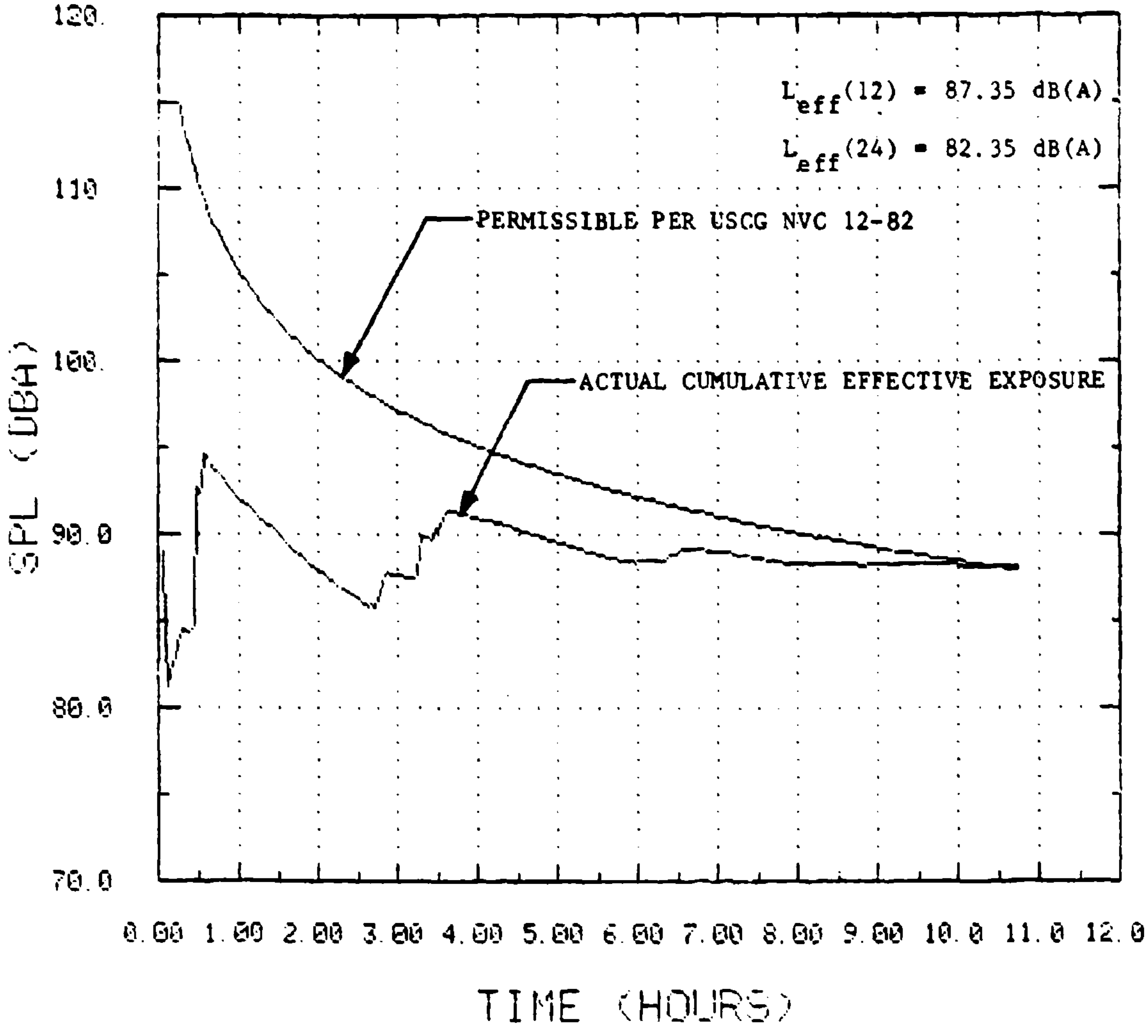


FIGURE B.14. CUMULATIVE EFFECTIVE EXPOSURE ON CONTRACT WELDER (Identification Number ND5)

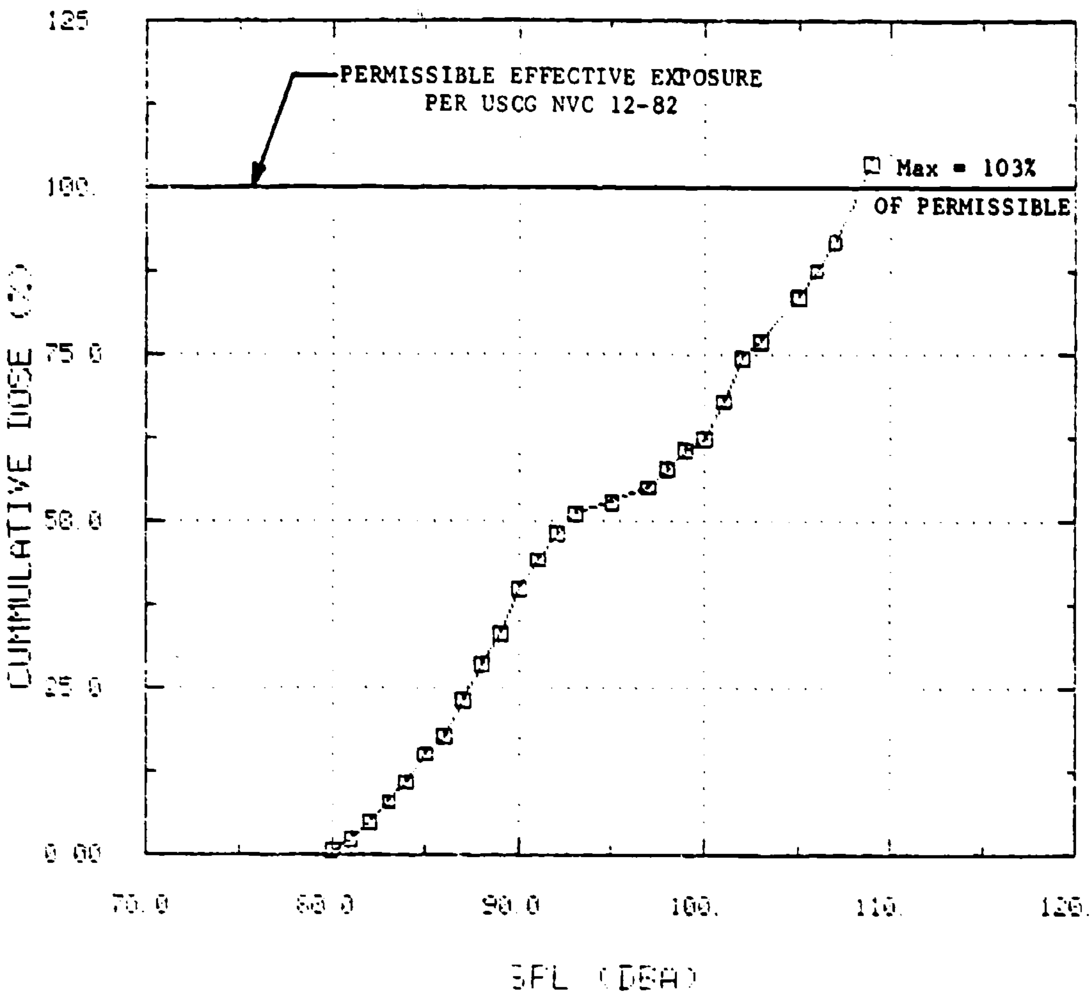


FIGURE B.15. CUMULATIVE DOSE RECORDED ON CONTRACT WELDER (Identification Number ND5)

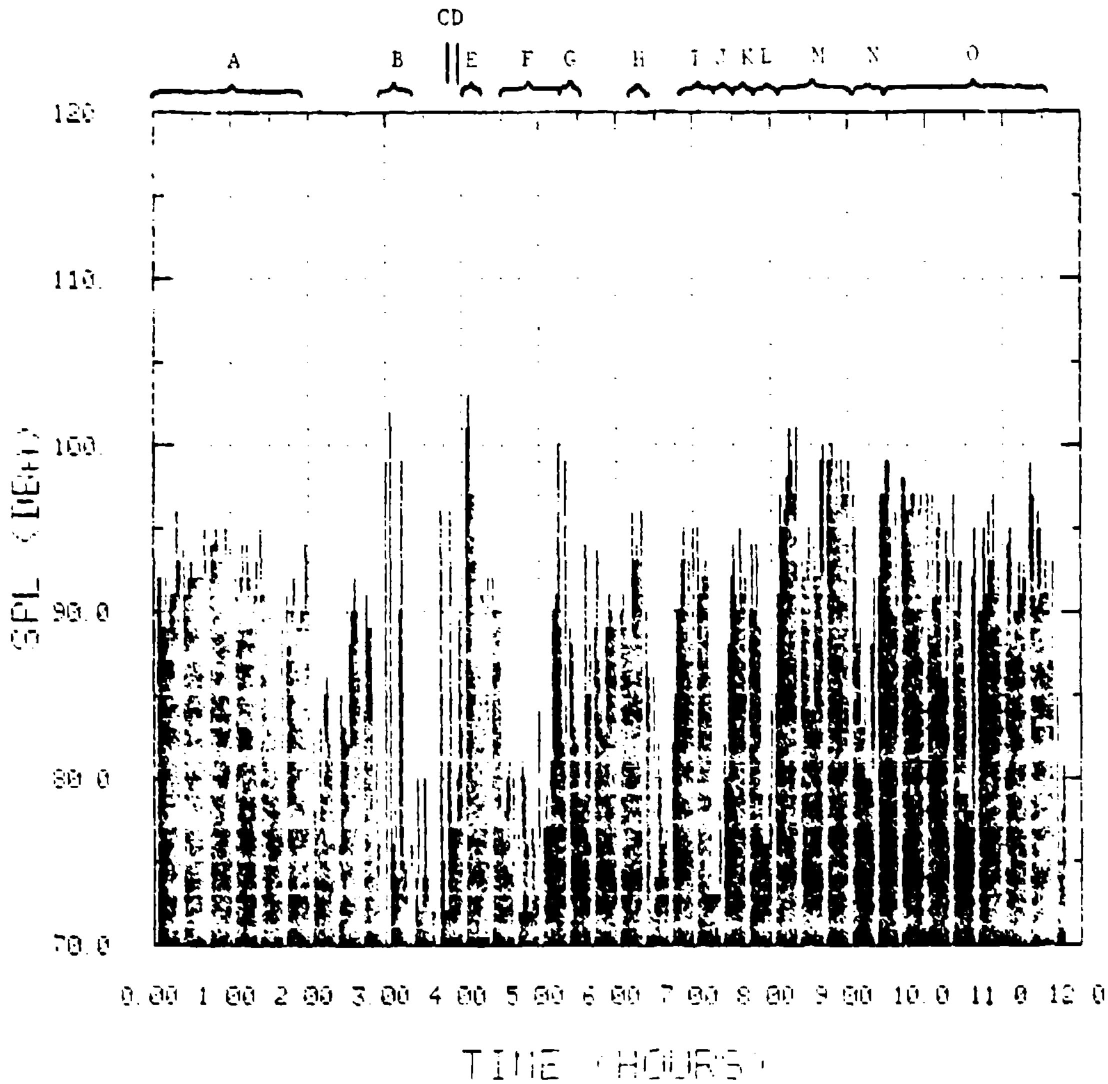


FIGURE B.16. NOISE DOSIMETRY ON DRILLER
(Identification Number ND6)

TABLE B.VII. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.16

Interval	Activity
A	Tripping pipe. Drawworks were shutdown for 4 minutes after 1 hour, 34 minutes.
B	Accumulator operated intermittently for a total of 4 minutes, 15 seconds.
C	Accumulator operated 68 seconds.
D	Accumulator operated 79 seconds.
E	Accumulator operated 4 minutes, 16 seconds.
F	Equipment shutdown 39 minutes.
G	Drawworks operating, accumulator operated 30 seconds.
H	Testing MWD system.
I	Going back into hole.
J	Testing MWD.
K	Going back into hole.
L	Testing MWD
M	Going back into hole.
N	Filling drill pipe with mud.
O	Finish going back into hole.

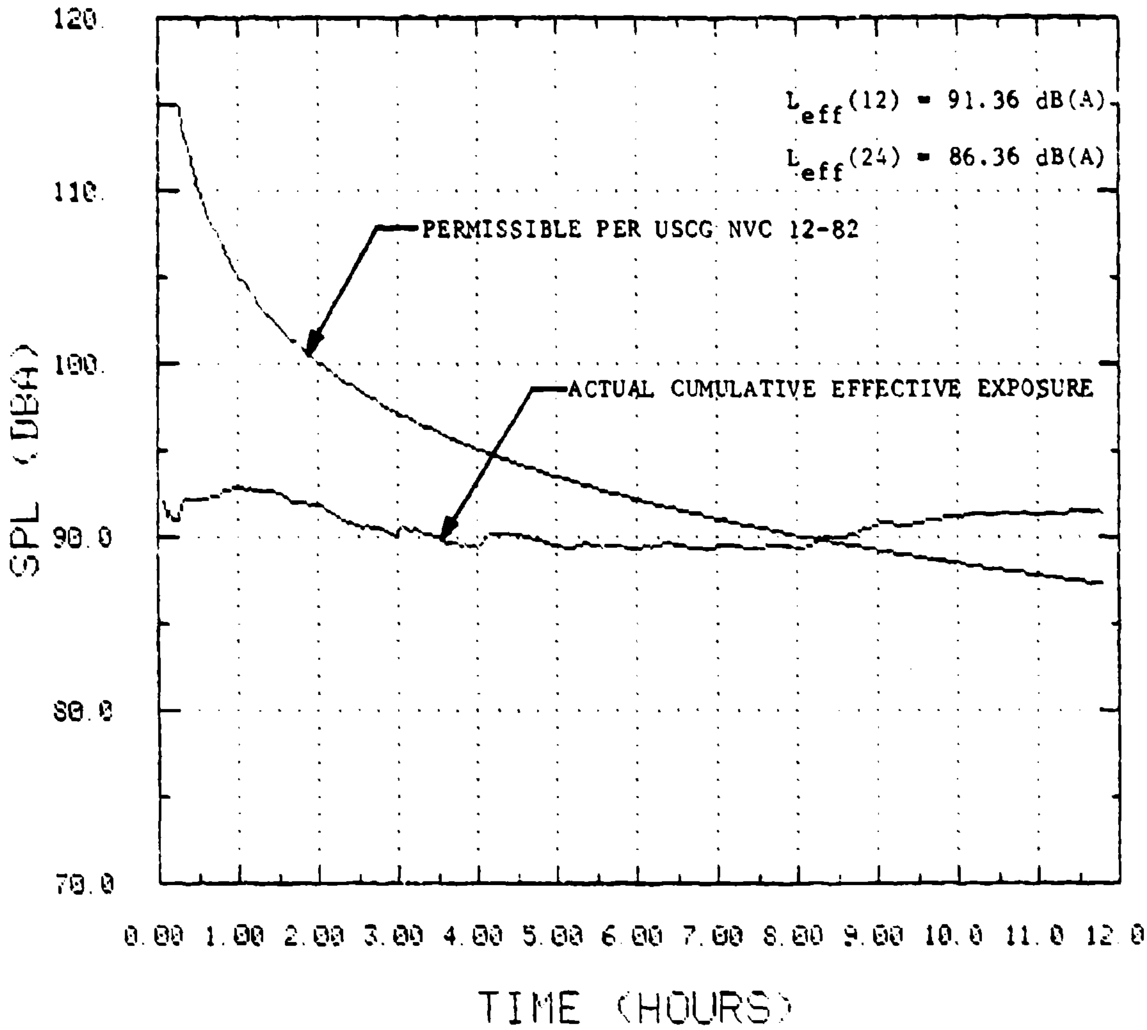


FIGURE B.17. CUMULATIVE EFFECTIVE EXPOSURE ON DRILLER
(Identification Number ND6)

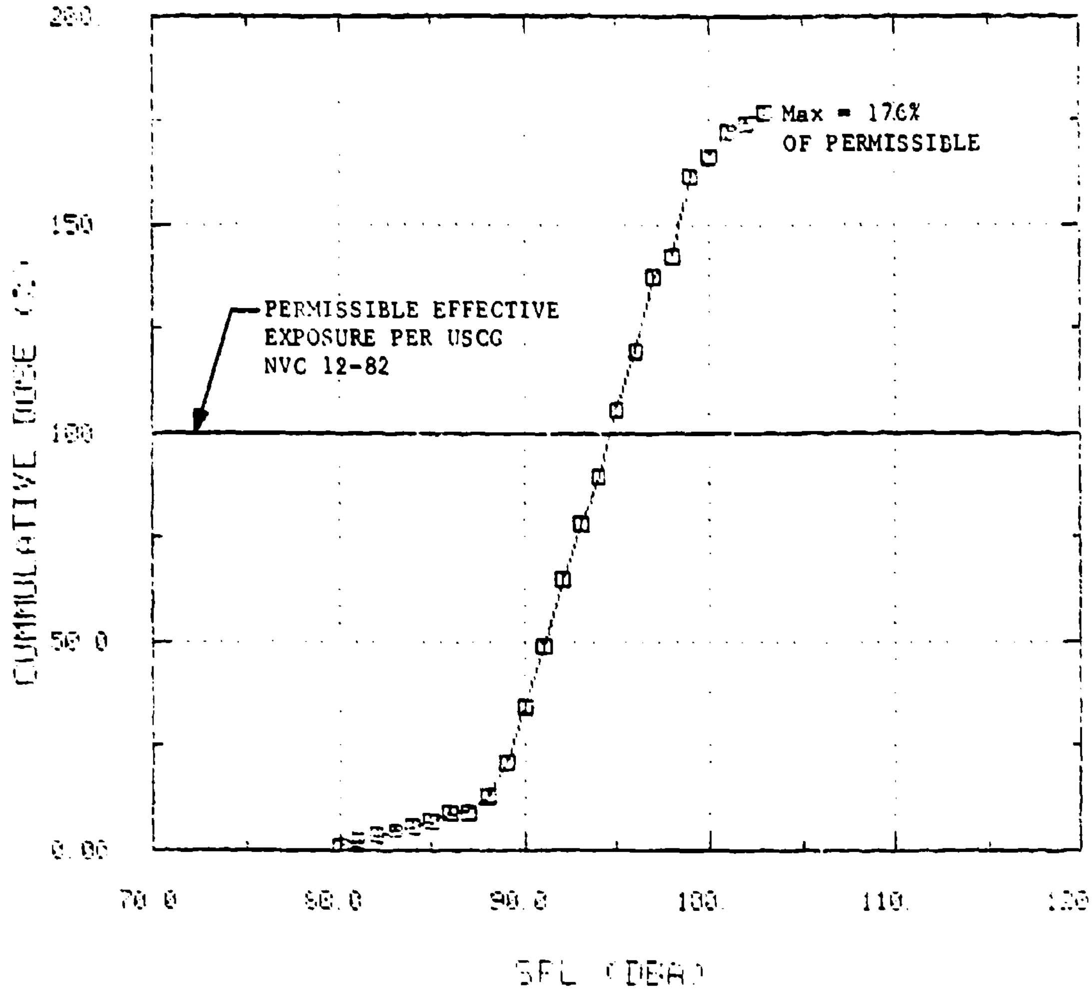


FIGURE B.18. CUMULATIVE DOSE RECORDED ON DRILLER
(Identification Number ND6)

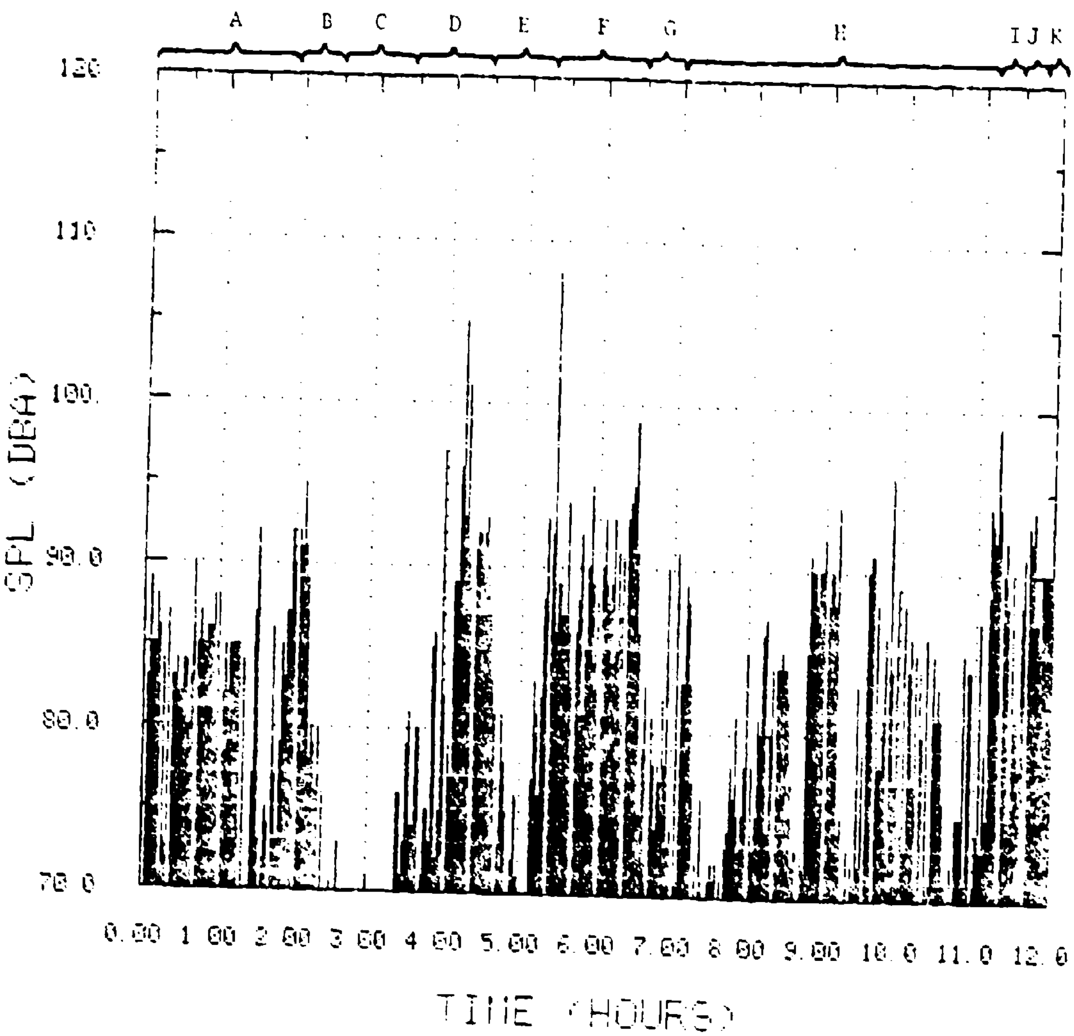


FIGURE B.19. NOISE DOSIMETRY ON DERRICKMAN
(Identification Number ND7)

TABLE B.VIII. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.19

Interval	Activity
A	Worked on monkey board stacking pipe.
B	Worked on drill floor.
C	Worked on drill floor and pipe storage area cleaning equipment and preparing to test BOP.
D	Worked on drili floor. Accumulator was periodically charged during this time. Derrickman occasionally stood within 3 feet of the accumulator during charging.
E	Inside quarters for dinner.
F	Worked on drill floor. Accumulator drawworks and crane operated during this time.
G	Worked on monkey board adding pipe.
H	Came down to rig floor for 5 minutes; went to mud pump room for 1 minute and remained in mud makeup area 7 minutes.
I	Returned to monkey board.
J	Came down to mud makeup area for 15 minutes.

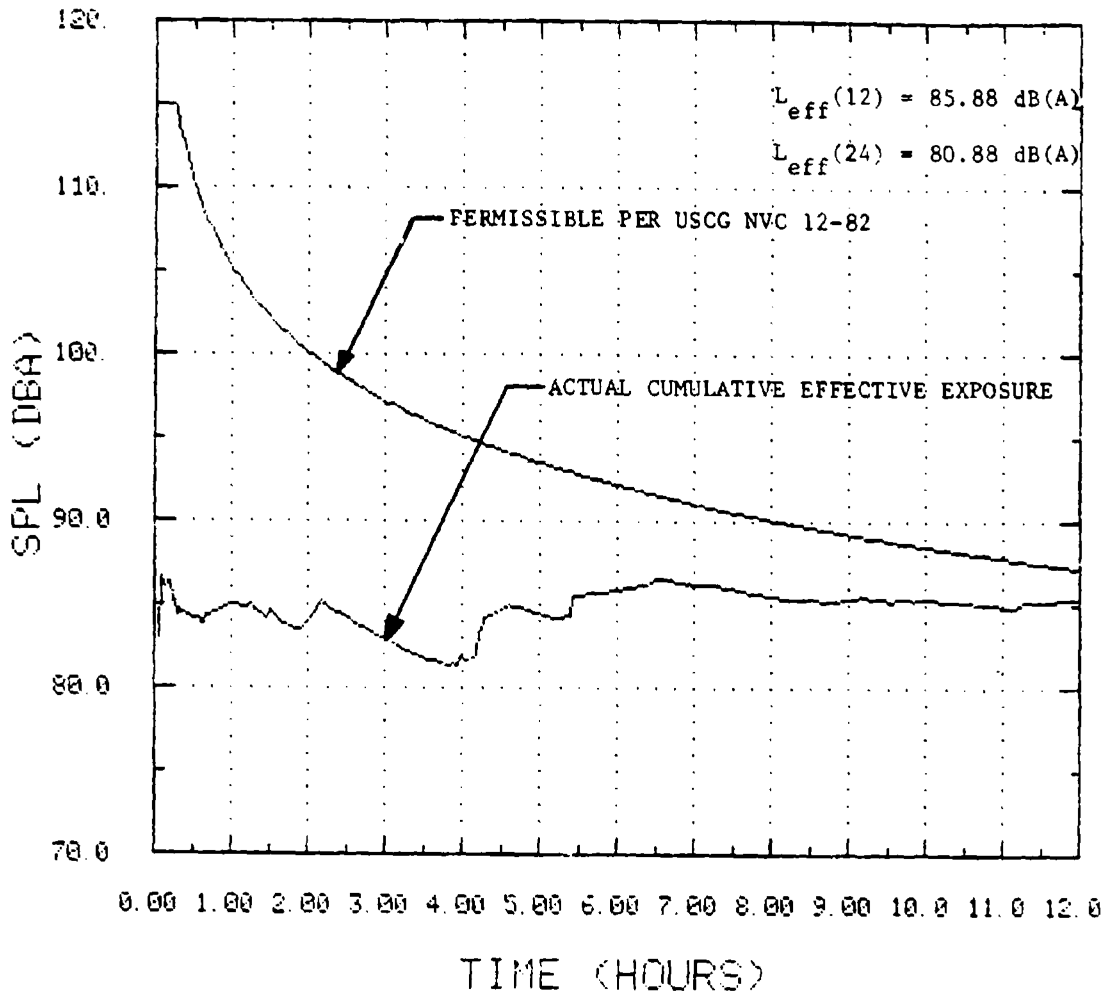


FIGURE B.20. CUMULATIVE EFFECTIVE EXPOSURE ON DERRICKMAN (Identification Number ND7)

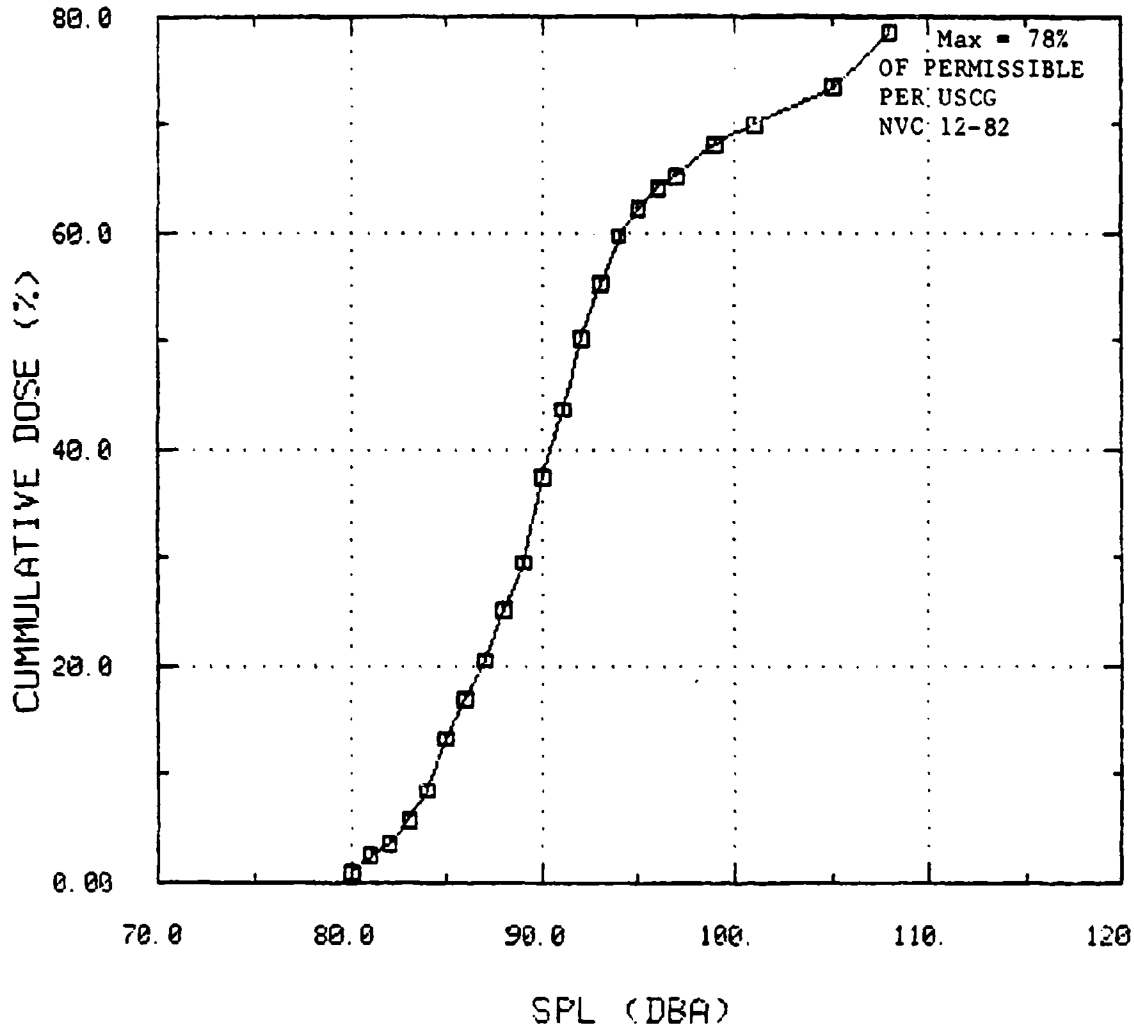


FIGURE B.21. CUMULATIVE DOSE RECORDED ON DERRICKMAN (Identification Number ND7)

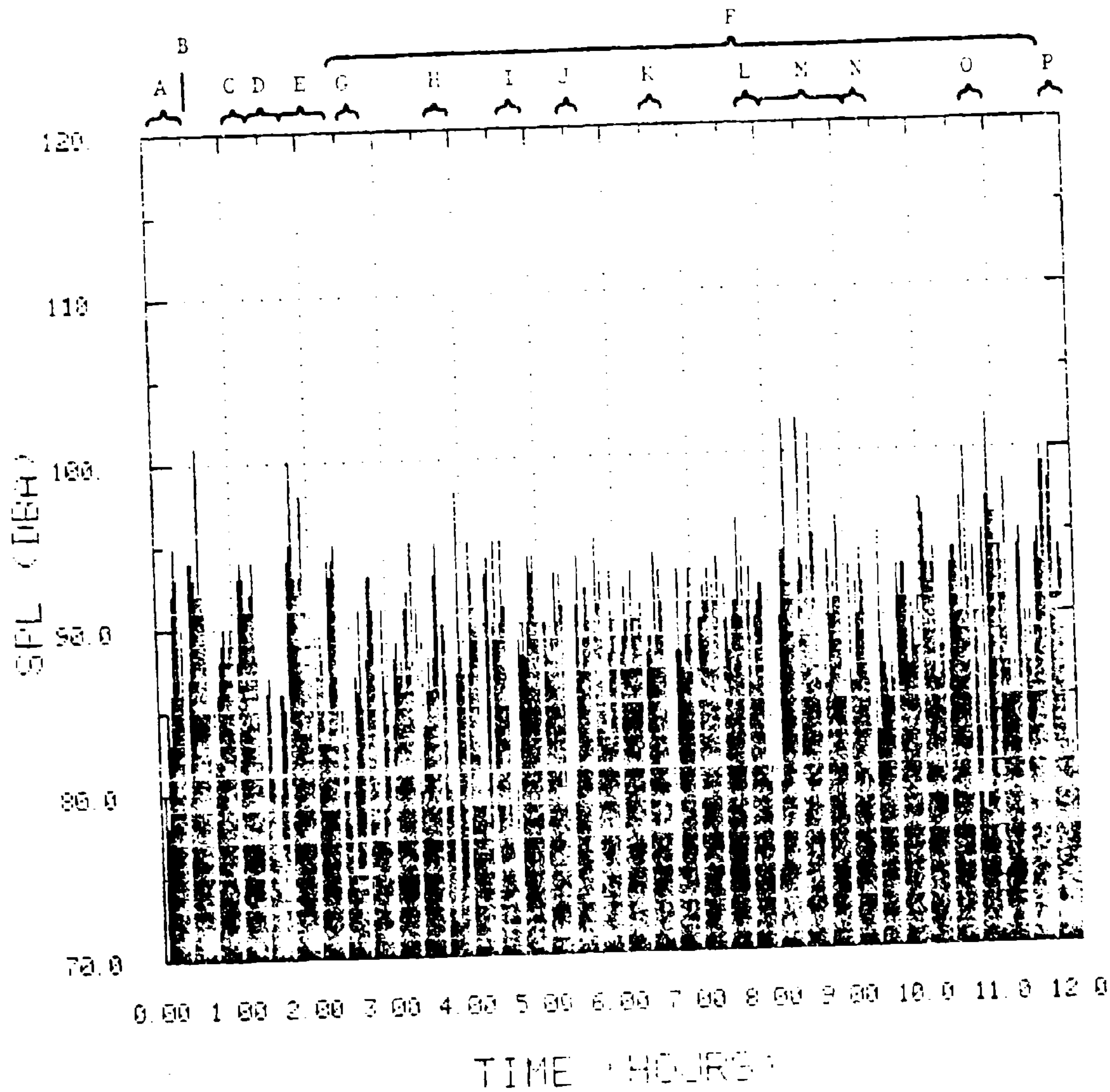


FIGURE B.22. NOISE DOSIMETRY ON DRILLER
(Identification Number ND8)

TABLE B.IX. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.22

Interval	Activity
A	Drilling.
B	Drawworks brake applied 28 times in 60 seconds.
C	Brake applied 75 times.
D	Equipment shutdown, driller placed a telephone call.
E	Breaking in new bit through "tight" formation.
F	Drilling for 5.5 hours.
G	MWD survey.
H	MWD survey.
I	MWD survey.
J	Driller moved away from the drill floor to eat breakfast.
K	MWD survey.
L	MWD survey.
M	Drilling.
N	MWD survey.
O	MWD survey.
P	MWD survey.

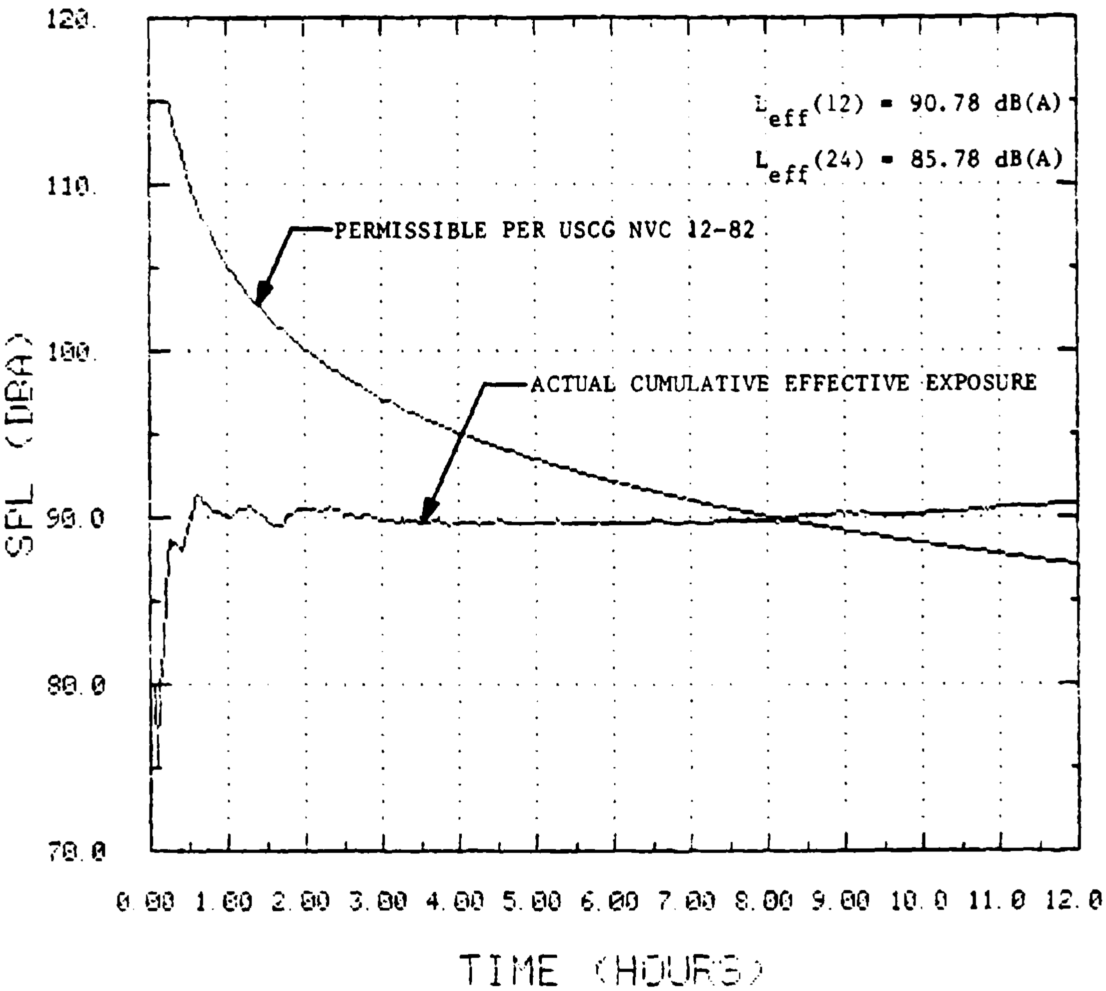


FIGURE B.23. CUMULATIVE EFFECTIVE EXPOSURE ON DRILLER (Identification Number ND8)

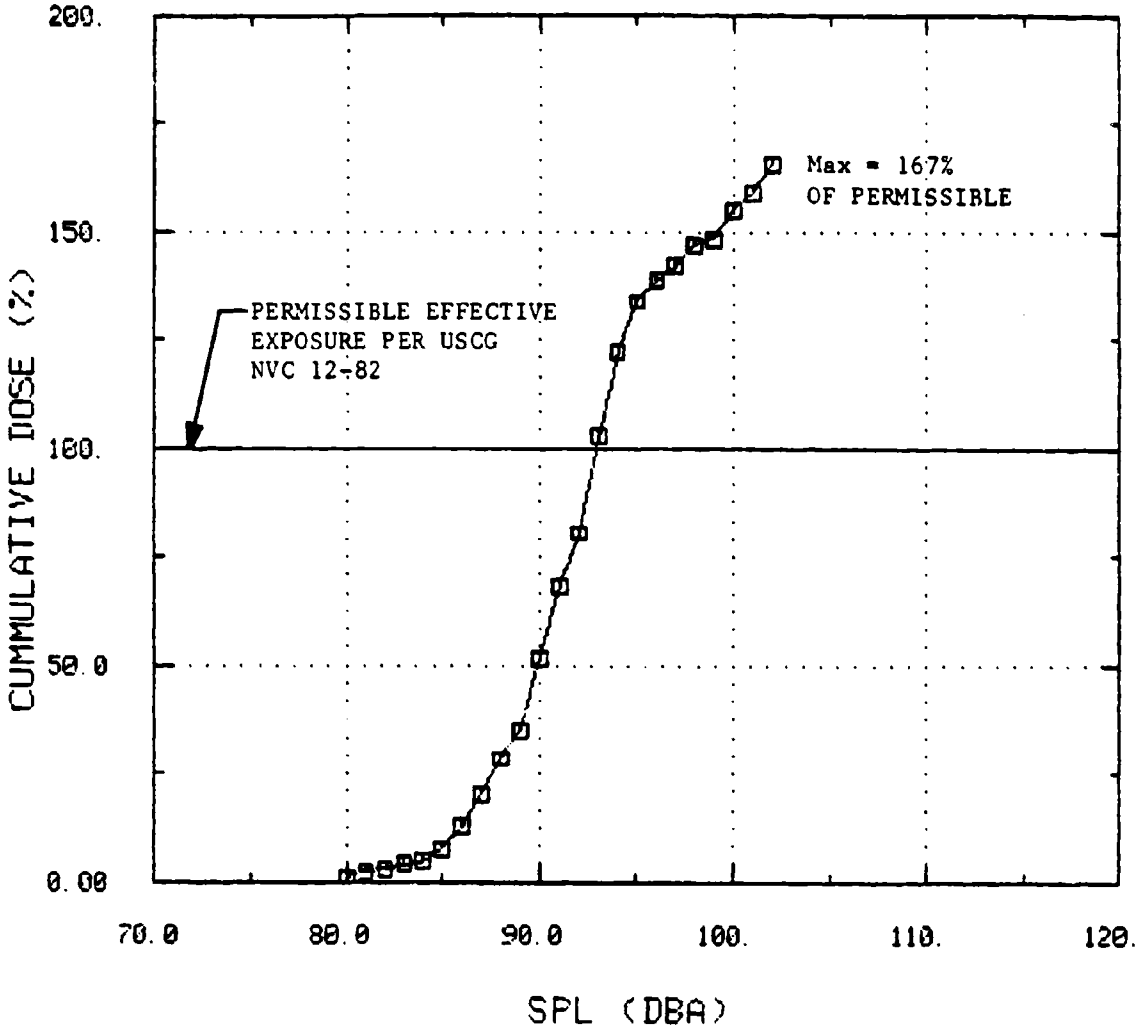


FIGURE B.24. CUMULATIVE DOSE RECORDED ON DRILLER
(Identification Number ND8)

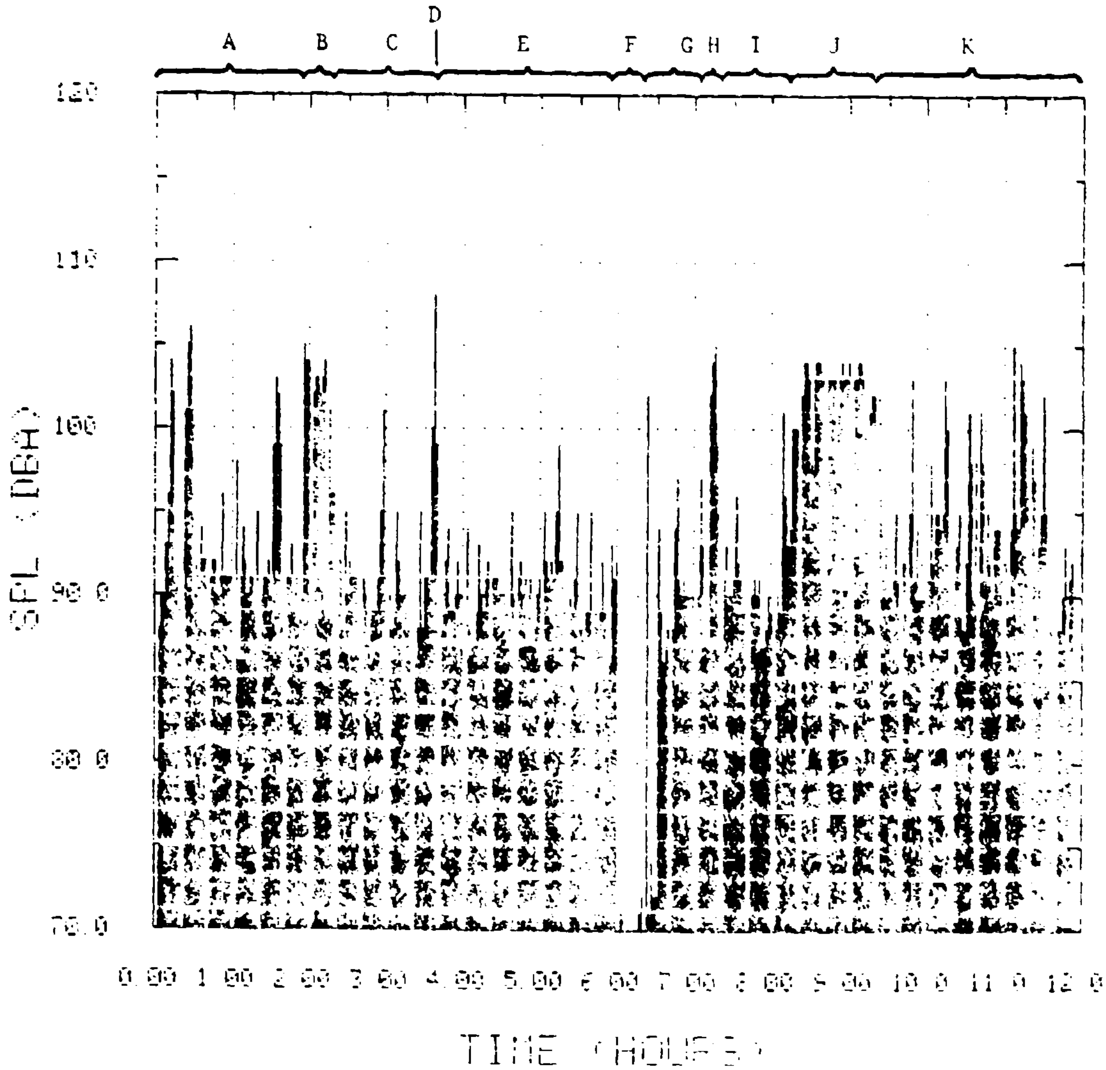


FIGURE B.25. NOISE DOSIMETRY ON DERRICKMAN
(Identification Number ND9)

TABLE B.X. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.25

Interval	Activity
A	Worked in mud makeup area and pump room. (SPL peaks occurred while he was in the pump room)
B	Inside pump room.
C	Worked primarily in mud makeup area. Entered pump room for short periods of time.
D	Inside pump room.
E	Worked primarily in mud makeup area. Entered pump room twice for a total of 75 seconds.
F	Inside quarters to eat.
G	Worked in mud makeup area. Entered pump room for short periods.
H	Worked in pump room.
I	Worked in mud makeup area.
J	Worked in pump room.
K	Worked primarily in mud makeup area. Also worked in pump room and cementing room a total of 20 minutes.

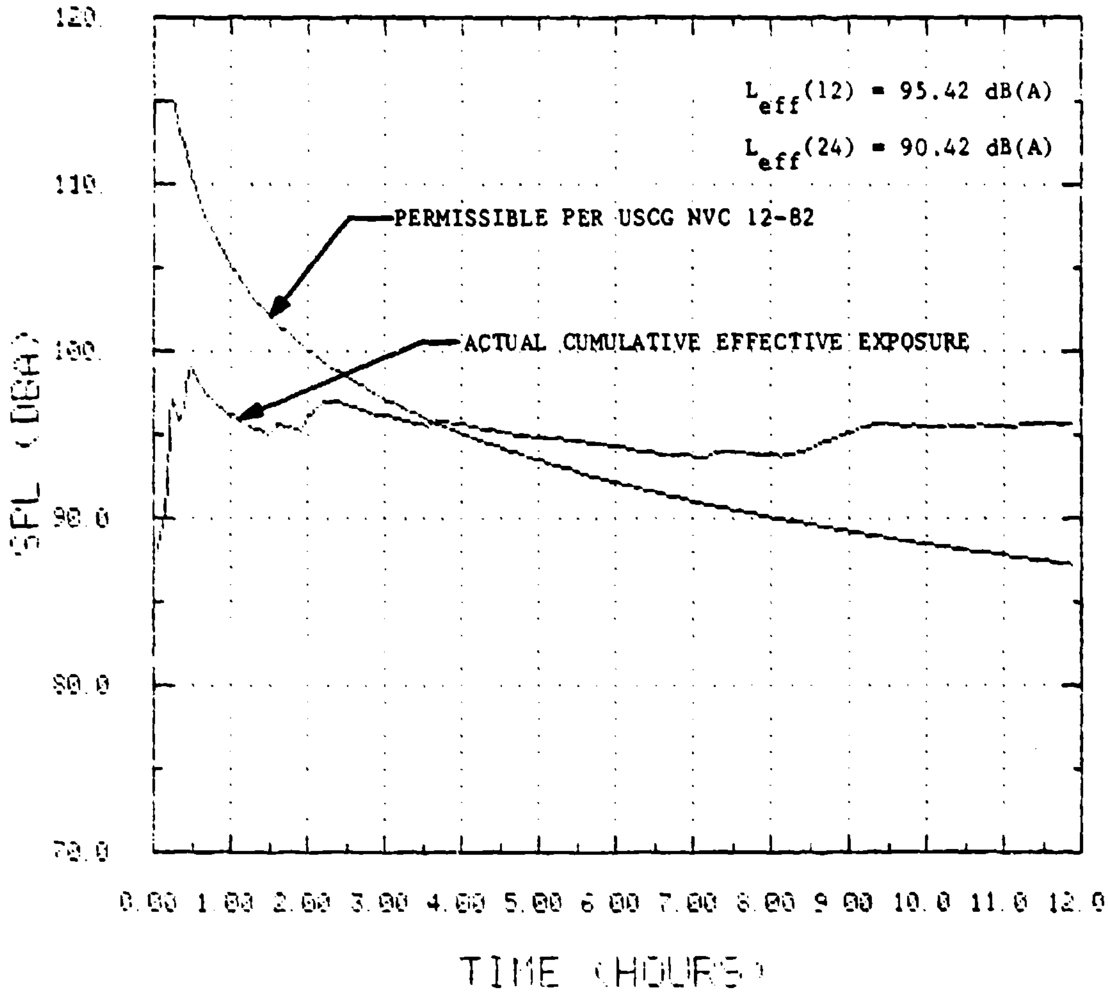


FIGURE B.26. CUMULATIVE EFFECTIVE EXPOSURE ON DERRICKMAN (Identification Number ND9)

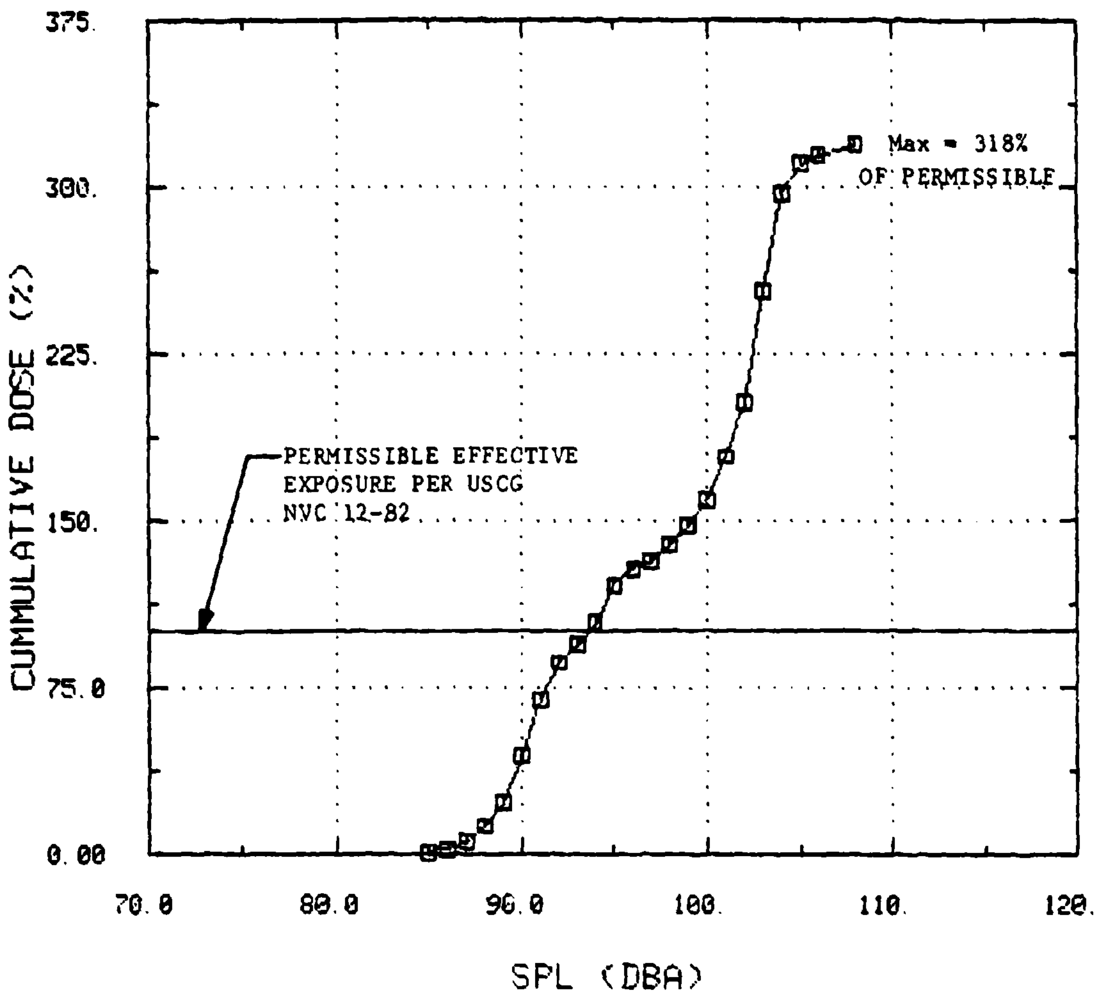


FIGURE B.27. CUMULATIVE DOSE RECORDED ON DERRICKMAN
(Identification Number ND9)

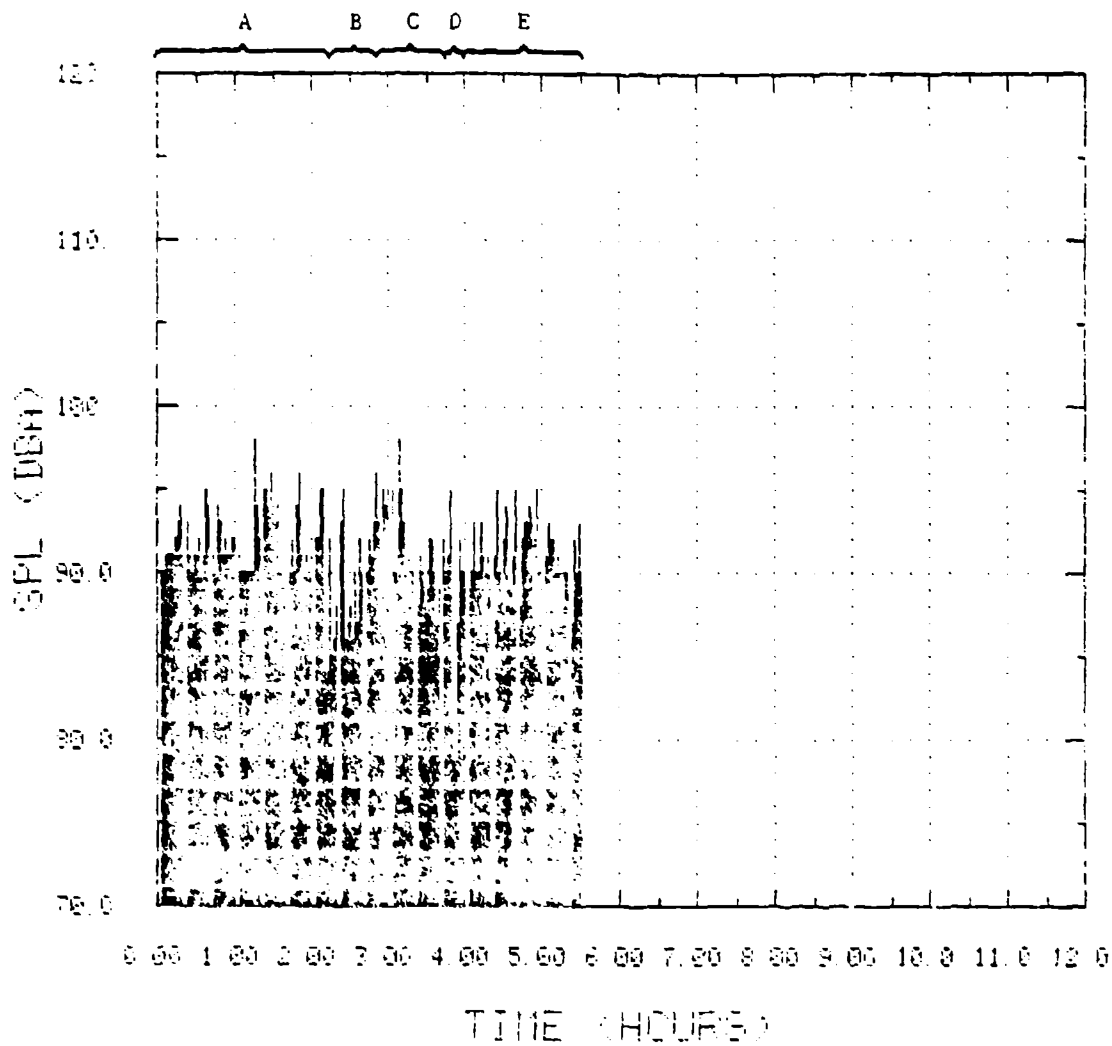


FIGURE B.28. NOISE DOSIMETRY ON ROUSTABOUT
(Identification Number ND10)

TABLE B.XI. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.28

Interval	Activity
A	Working in mud pit area adding Barite; cleaning up area.
B	Inside for break.
C	Working in mut pit area.
D	Left mud pit area.
E	Working in mud pit area.

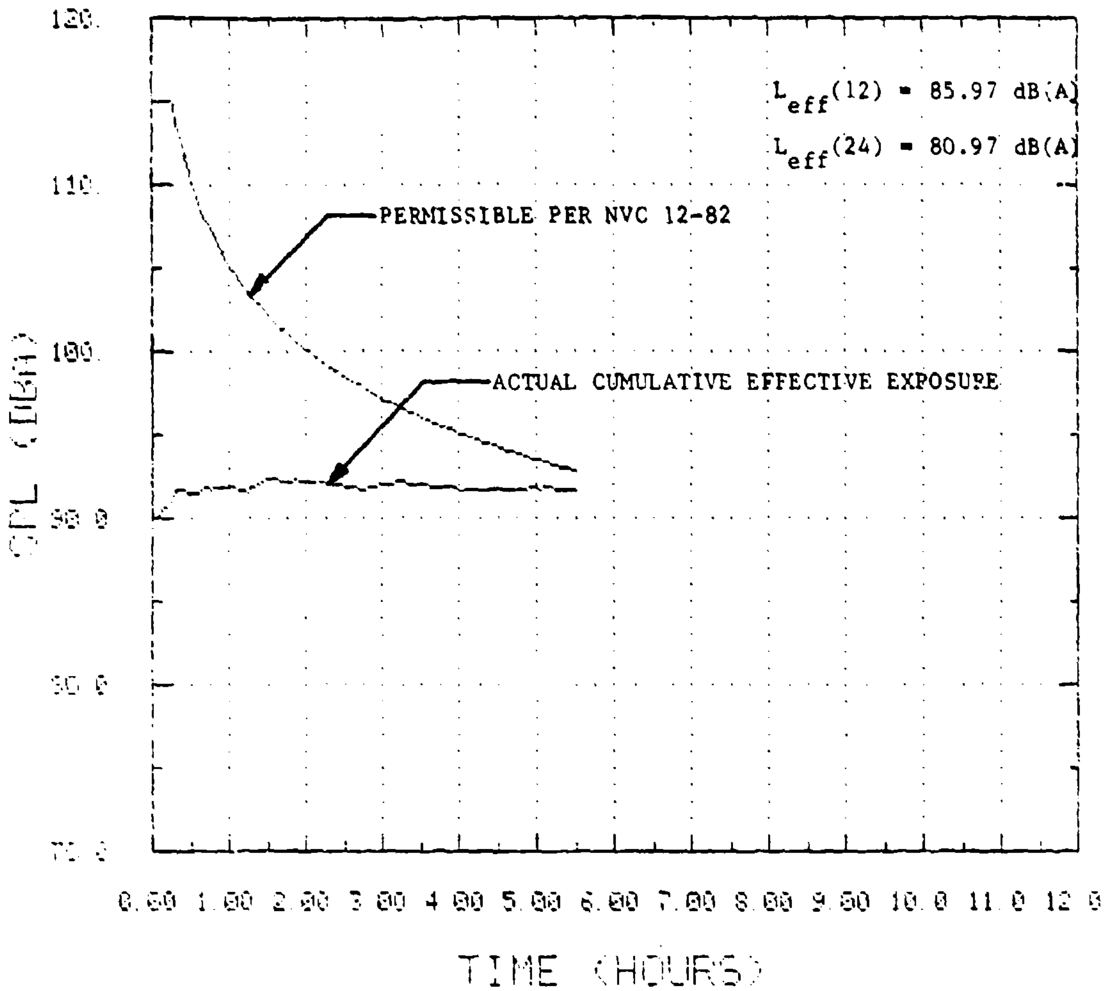


FIGURE B.29. CUMULATIVE EFFECTIVE EXPOSURE ON ROUSTABOUT
(Identification Number ND10)

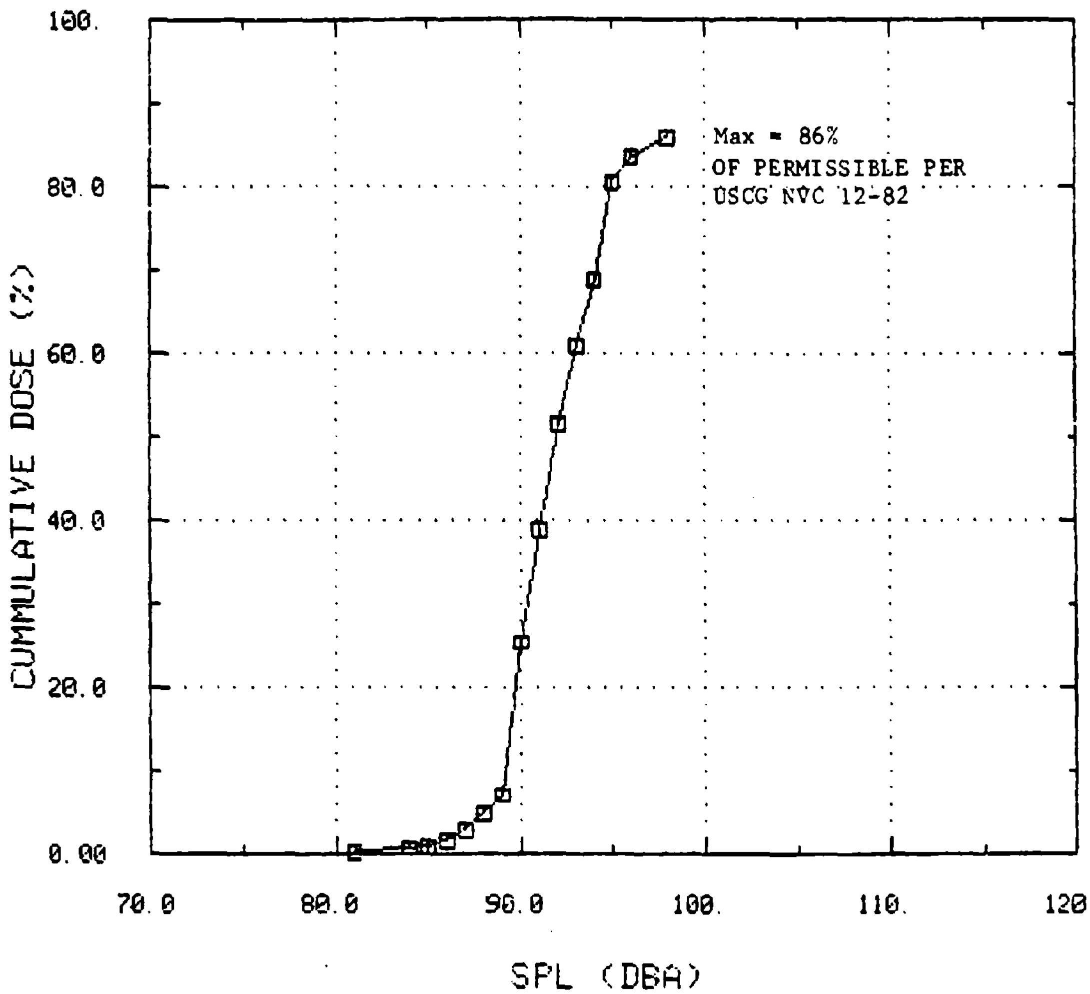


FIGURE B.30. CUMULATIVE DOSE RECORDED ON ROUSTABOUT (Identification Number ND10)

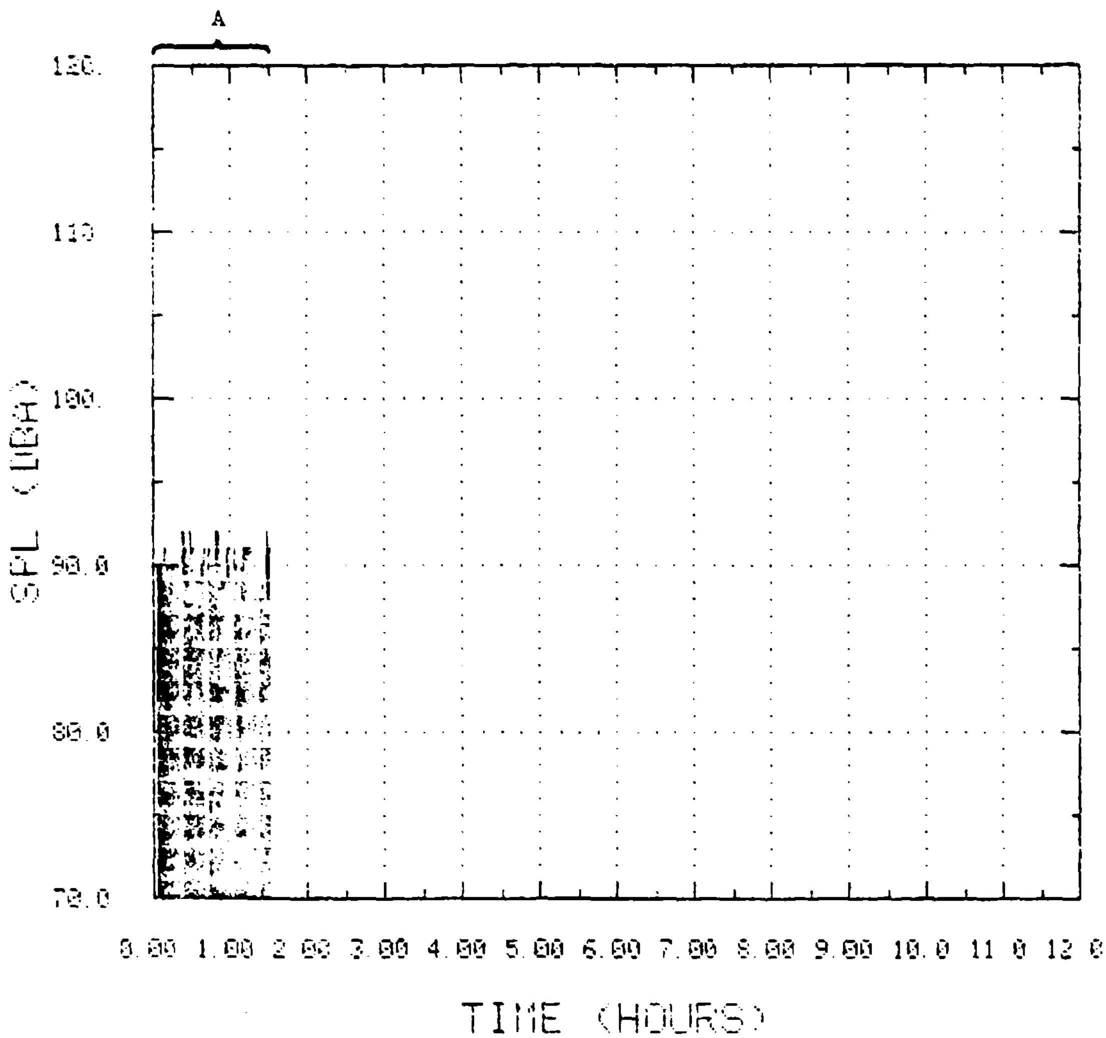


FIGURE B.31. NOISE DOSIMETRY ON ROUSTABOUT
(Identification Number ND11)

TABLE B.XII. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.31

Interval	Activity
A	Worked in immediate vicinity of Barite hopper for the duration of the survey. He had been directed to go work on another area of the rig when the dosimeter was removed.

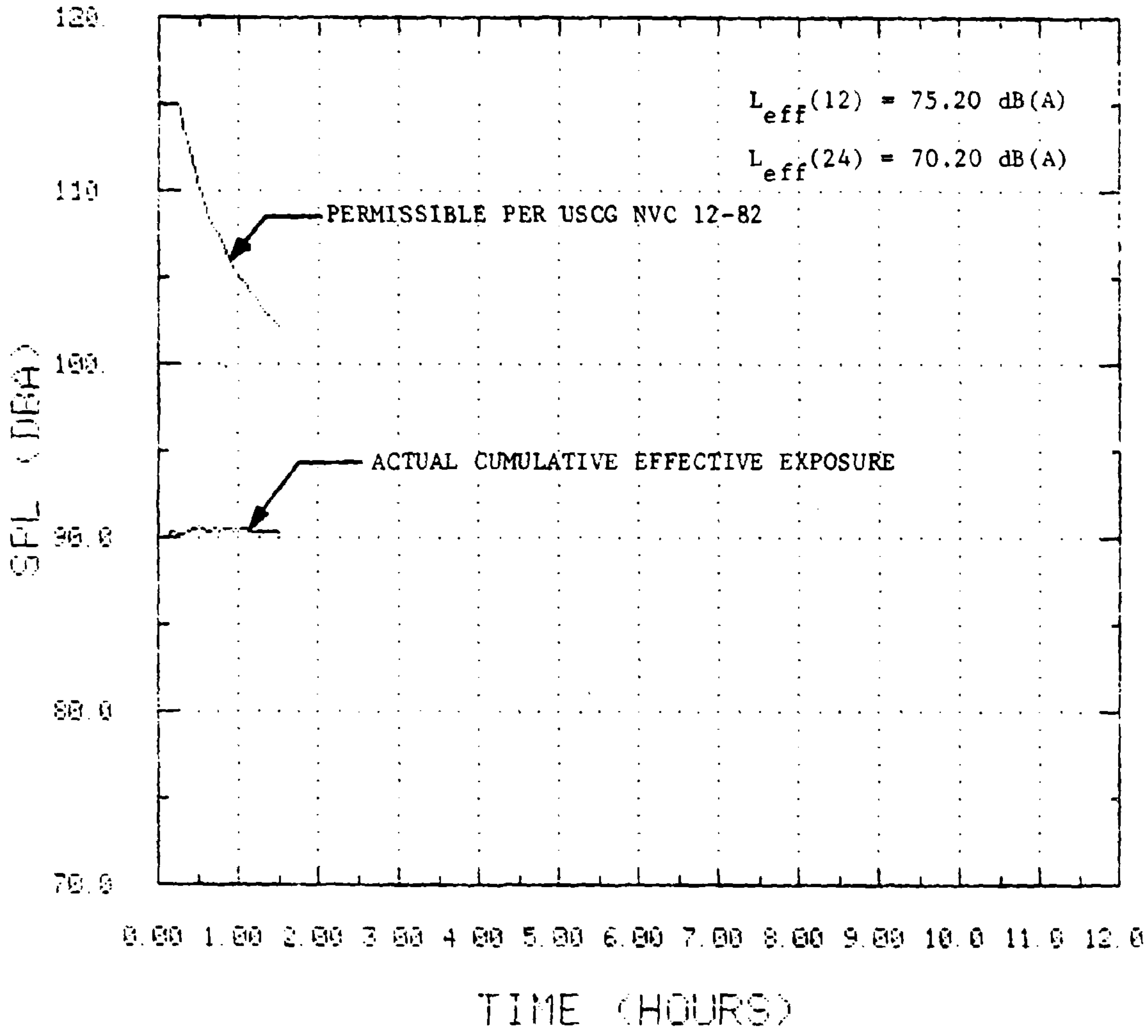


FIGURE B.32. CUMULATIVE EFFECTIVE EXPOSURE ON ROUSTABOUT (Identification Number ND11)

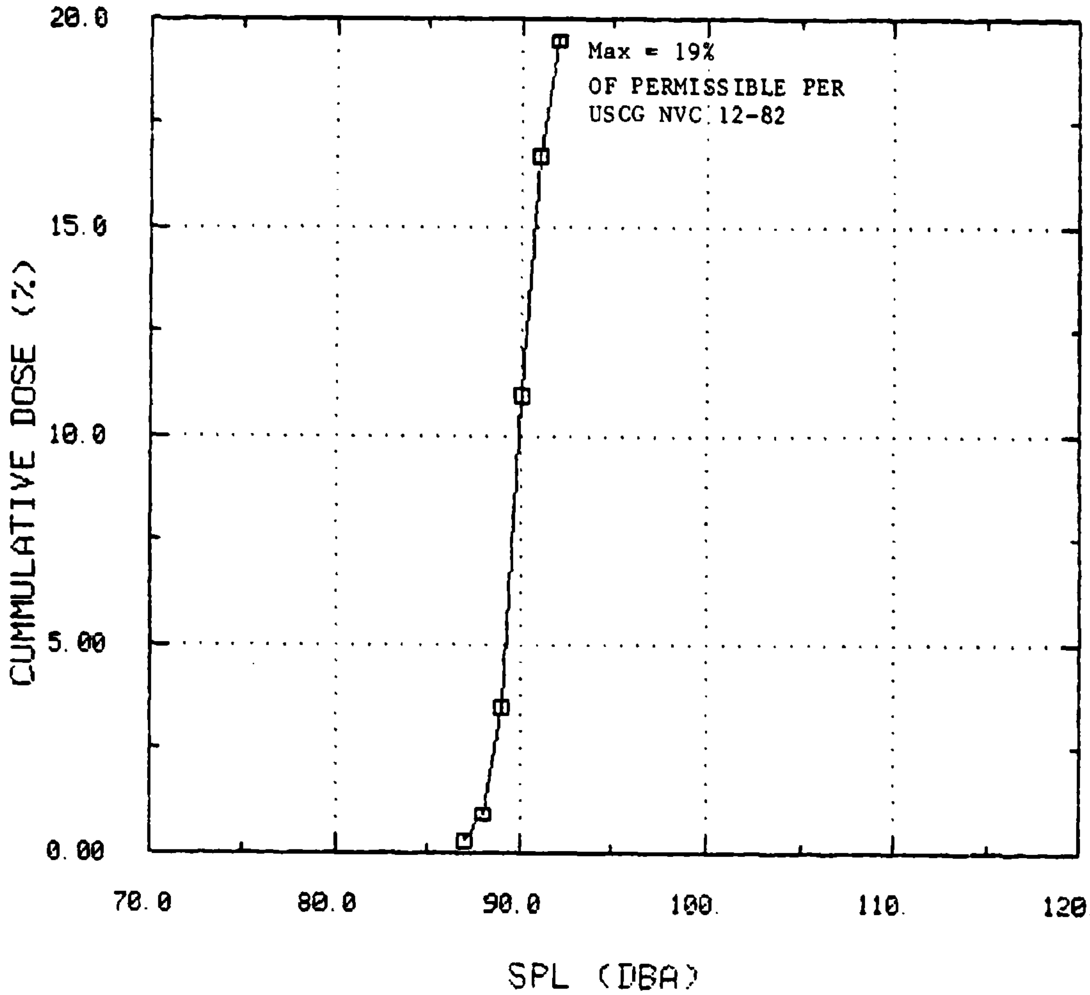


FIGURE B.33. CUMULATIVE DOSE RECORDED ON ROUSTABOUT (Identification Number ND11)

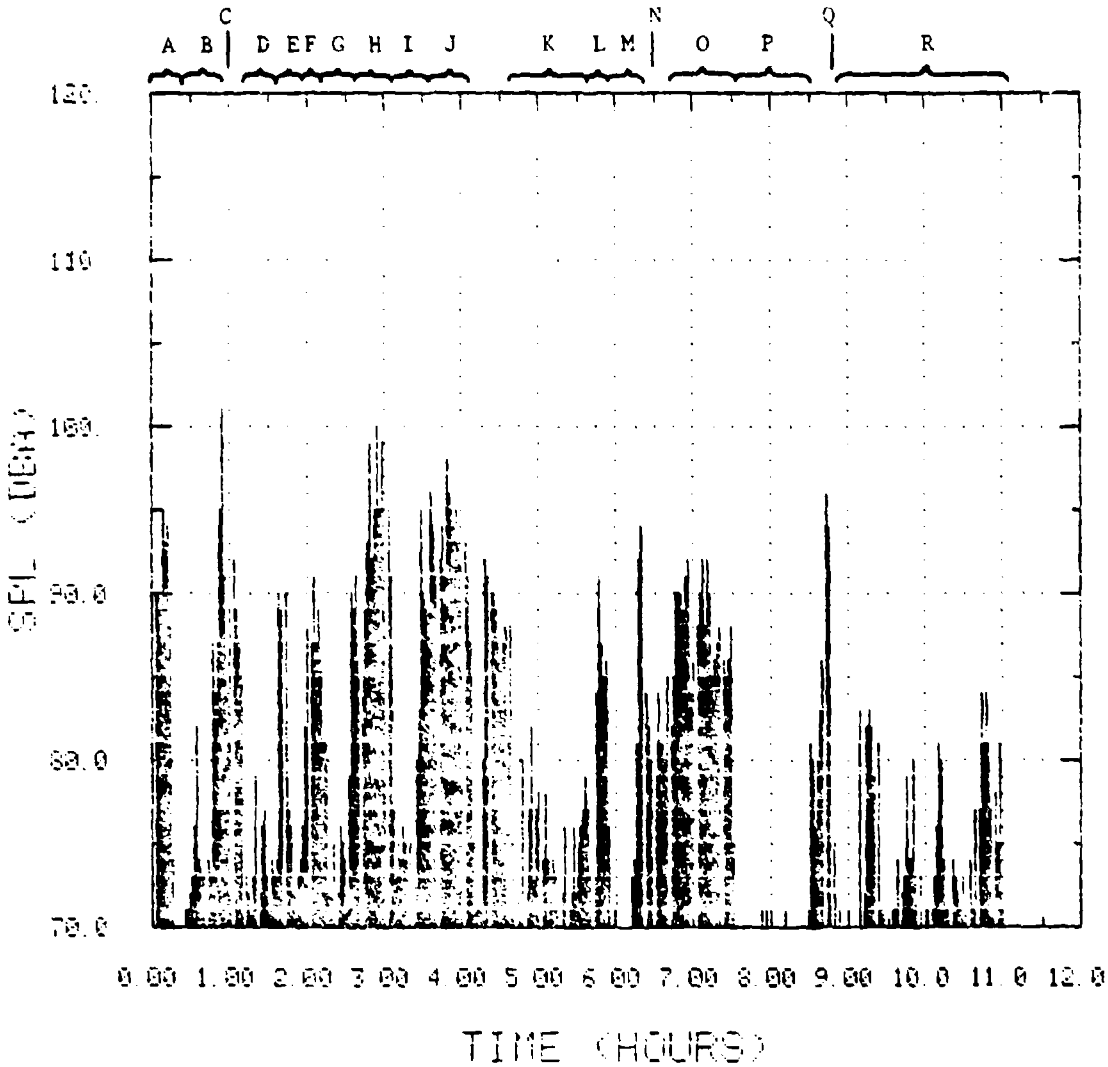


FIGURE B.34. NOISE DOSIMETRY ON ELECTRICIAN
(Identification Number ND12)

TABLE B.XIII. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.34

Interval	Activity
A	Field boat to Platform 1.
B	Inside living quarters and welder's shed.
C	Inside compressor building No. 2 - two units running. Wore earplugs.
D	Inside compressor building No. 1 - no units running. Did not wear plugs.
E	Inside quarters.
F	Inside compressor building No. 1.
G	Inside mechanic's shop.
H	Inside compressor building No. 1 (one unit was run for 5 minutes).
I	Inside quarters.
J	Working on roof of compressor building No. 1. Did not wear ear plugs. (A P.A. speaker on the roof was being used almost continuously. The SPL due to the speaker was 95-100 dB(A)).
K	Inside quarters for lunch.
L	Inside compressor building No. 1.
M	Inside electrical shop.
N	Inside compressor building No. 1.
O	Field boat to Platform 2.
P	Inside quarters to repair ice maker.
Q	Inside generator room 3 minutes to get SwRI soldering iron to use on ice maker.
R	Inside quarters to finish repairs, eat dinner, and wait for field boat.

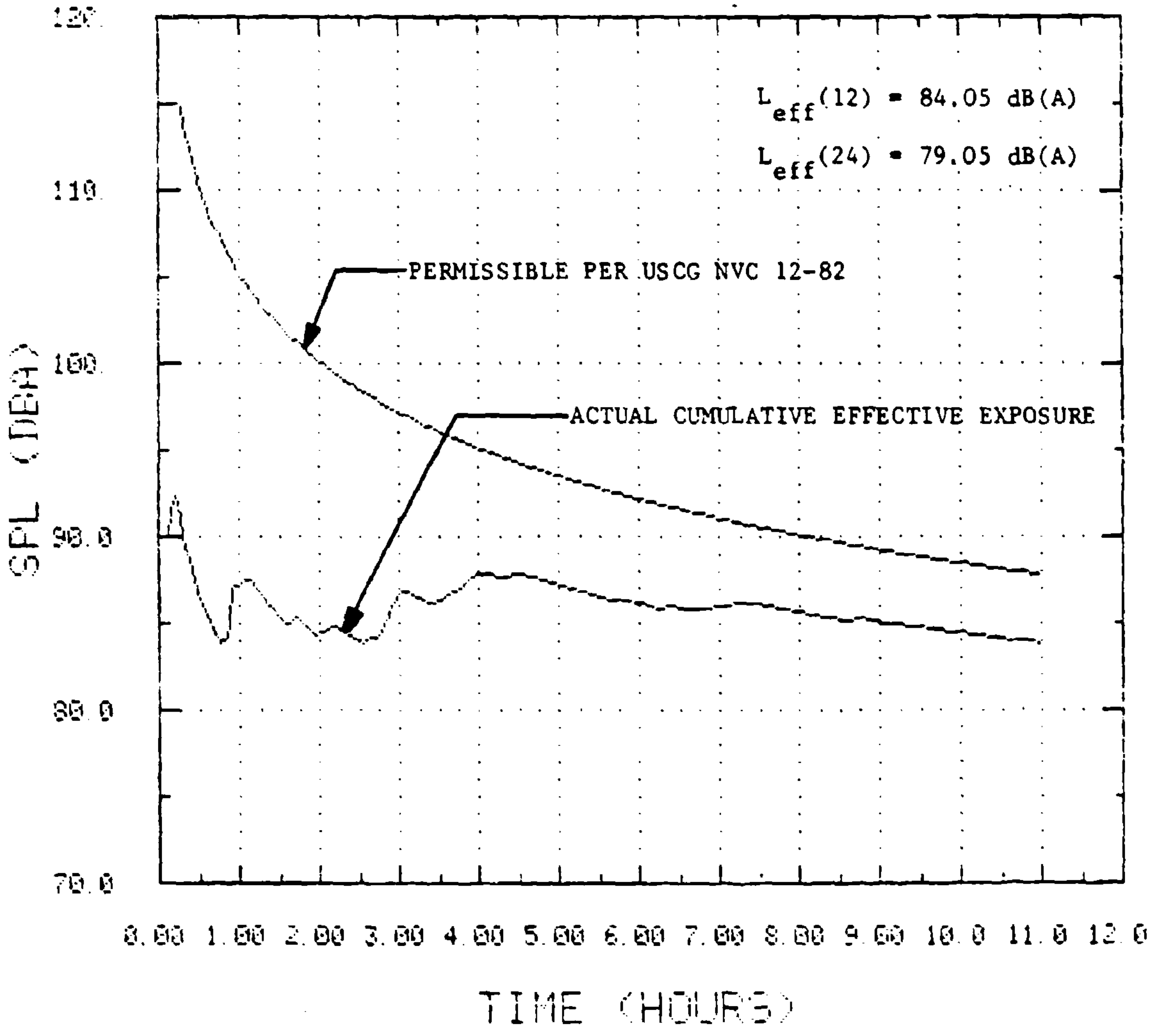


FIGURE B.35. CUMULATIVE EFFECTIVE EXPOSURE ON ELECTRICIAN (Identification Number ND12)

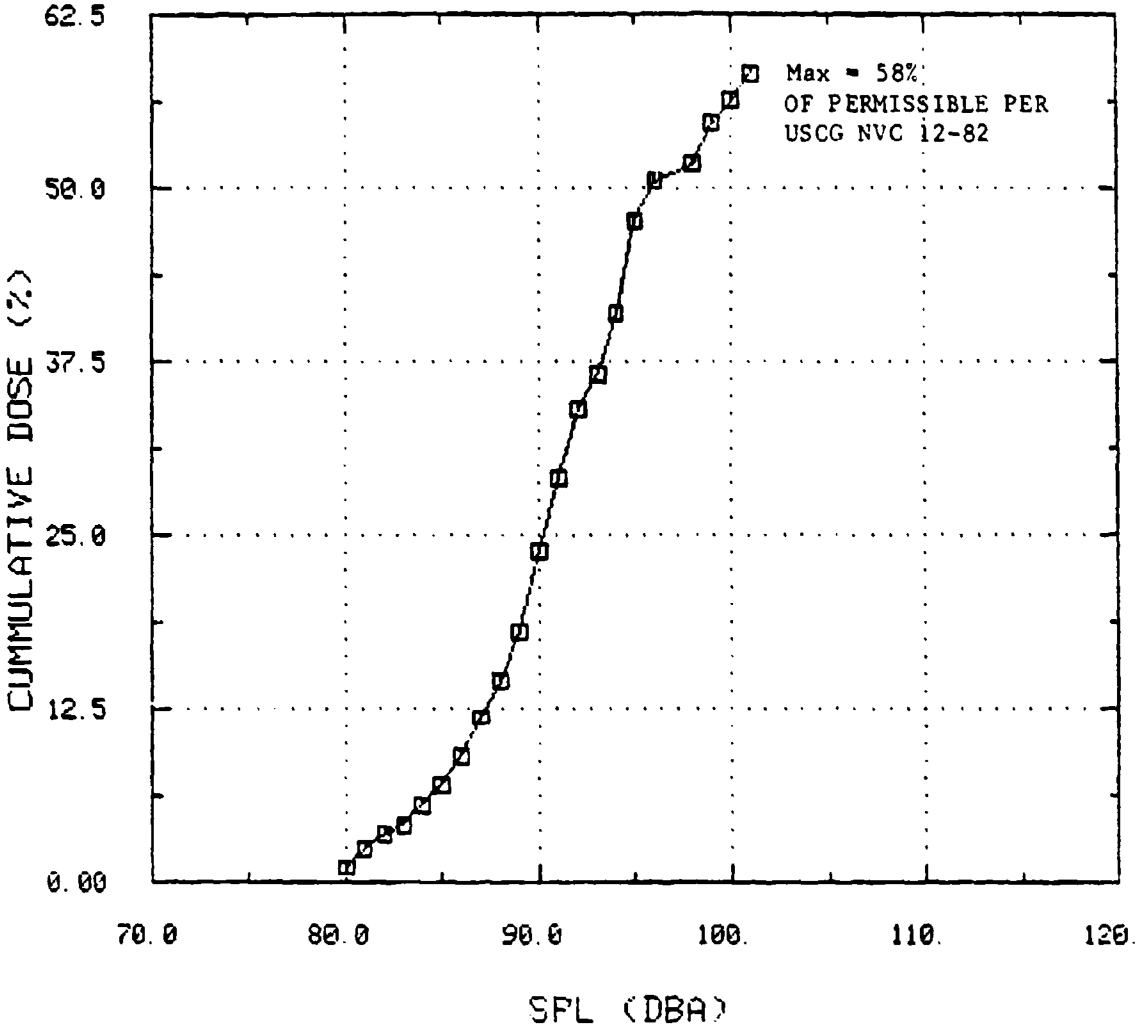


FIGURE B.36. CUMULATIVE DOSE RECORDED ON ELECTRICIAN (Identification Number ND12)

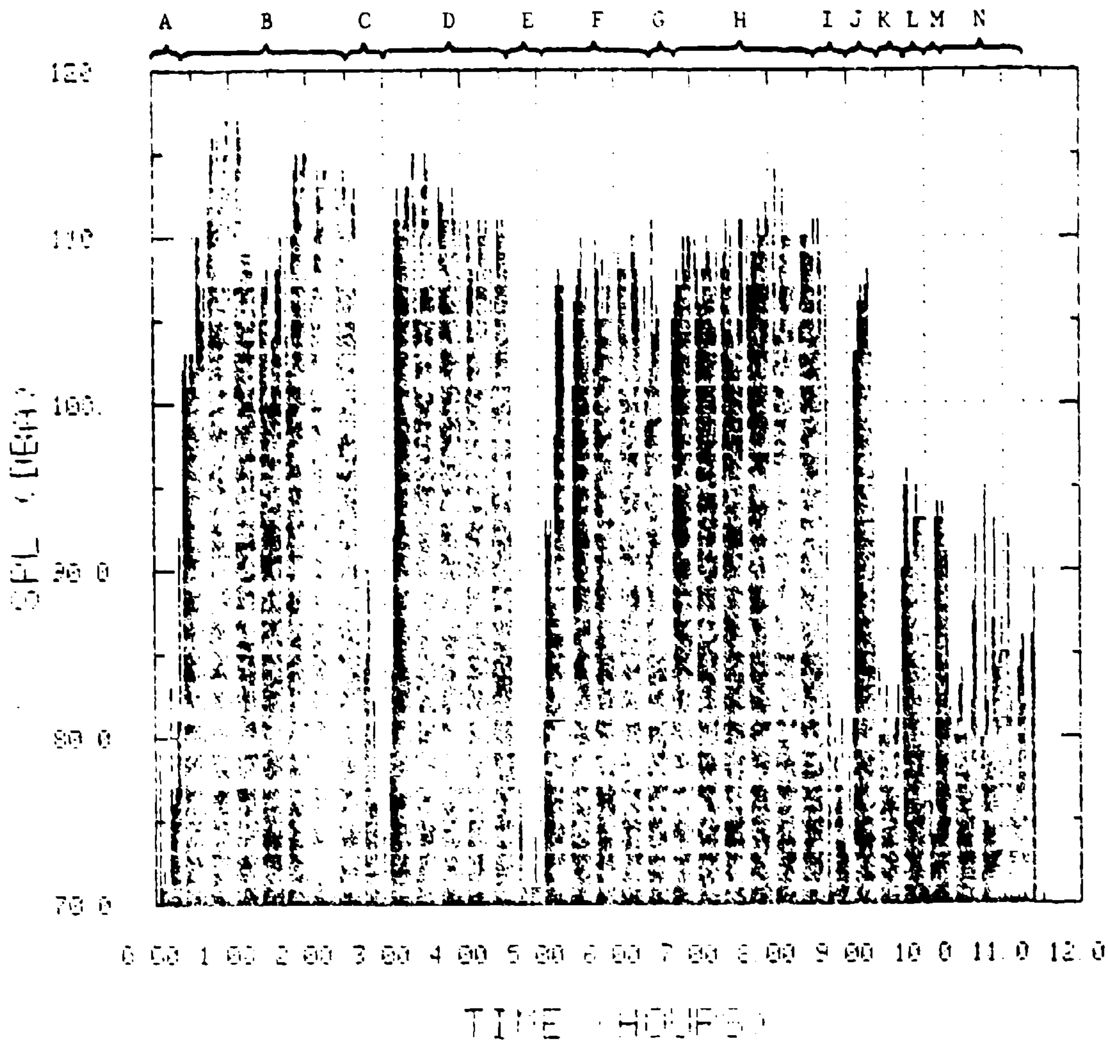


FIGURE B.37. NOISE DOSIMETRY ON ROUSTABOUT
(Identification Number ND13)

TABLE B.XIV. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.37

Interval	Activity
A	Inside office.
B	Chipping paint.
C	Inside for break.
D	Chipping paint.
E	Inside for lunch.
F	Chipping paint.
G	Assisting crane operator.
H	Chipping paint.
I	Inside for break.
J	Chipping paint.
K	Handling air hose for other roustabout.
L	Sprain painting.
M	Inside office.
N	Spray painting.

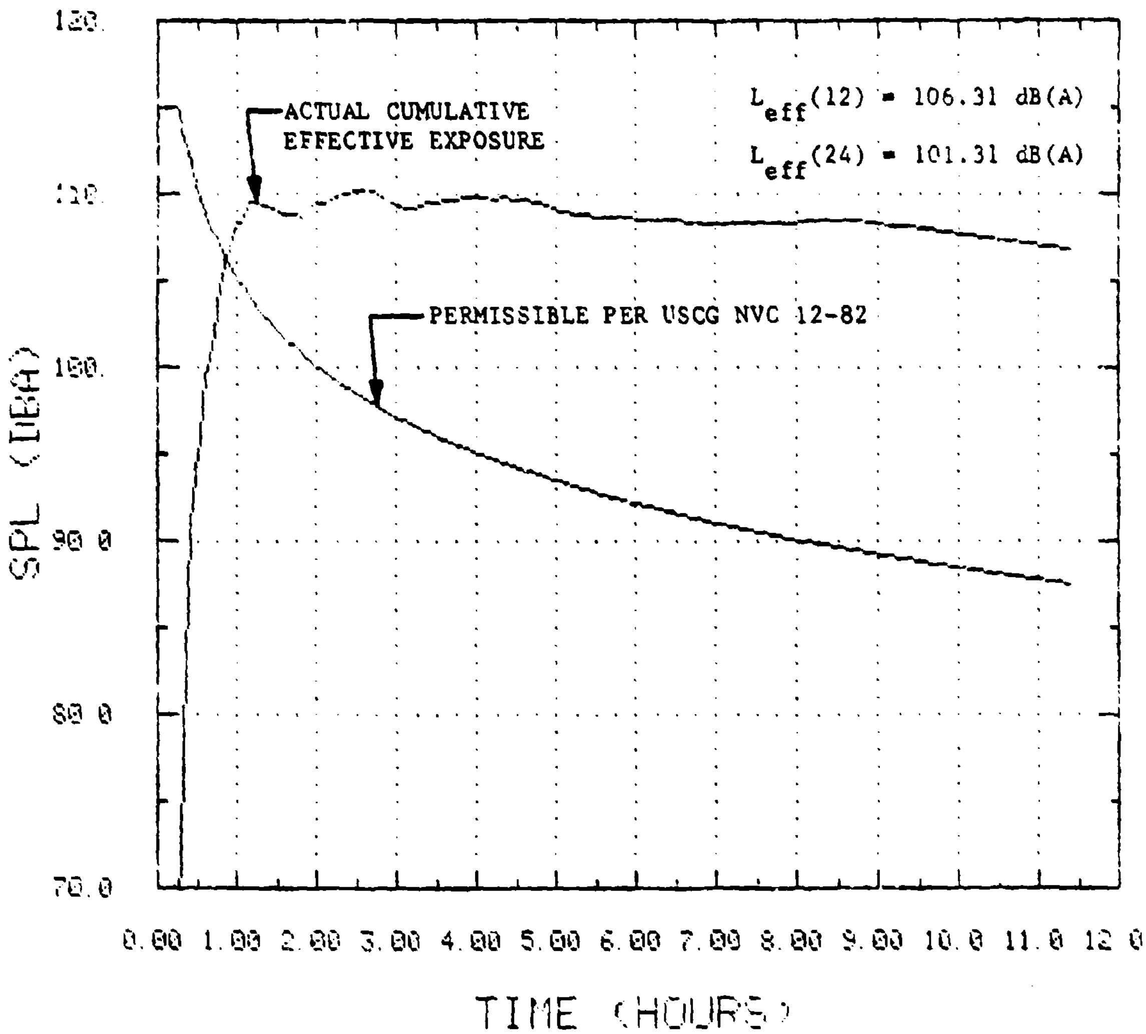


FIGURE B.38. CUMULATIVE EFFECTIVE EXPOSURE ON ROUSTABOUT (Identification Number ND13)

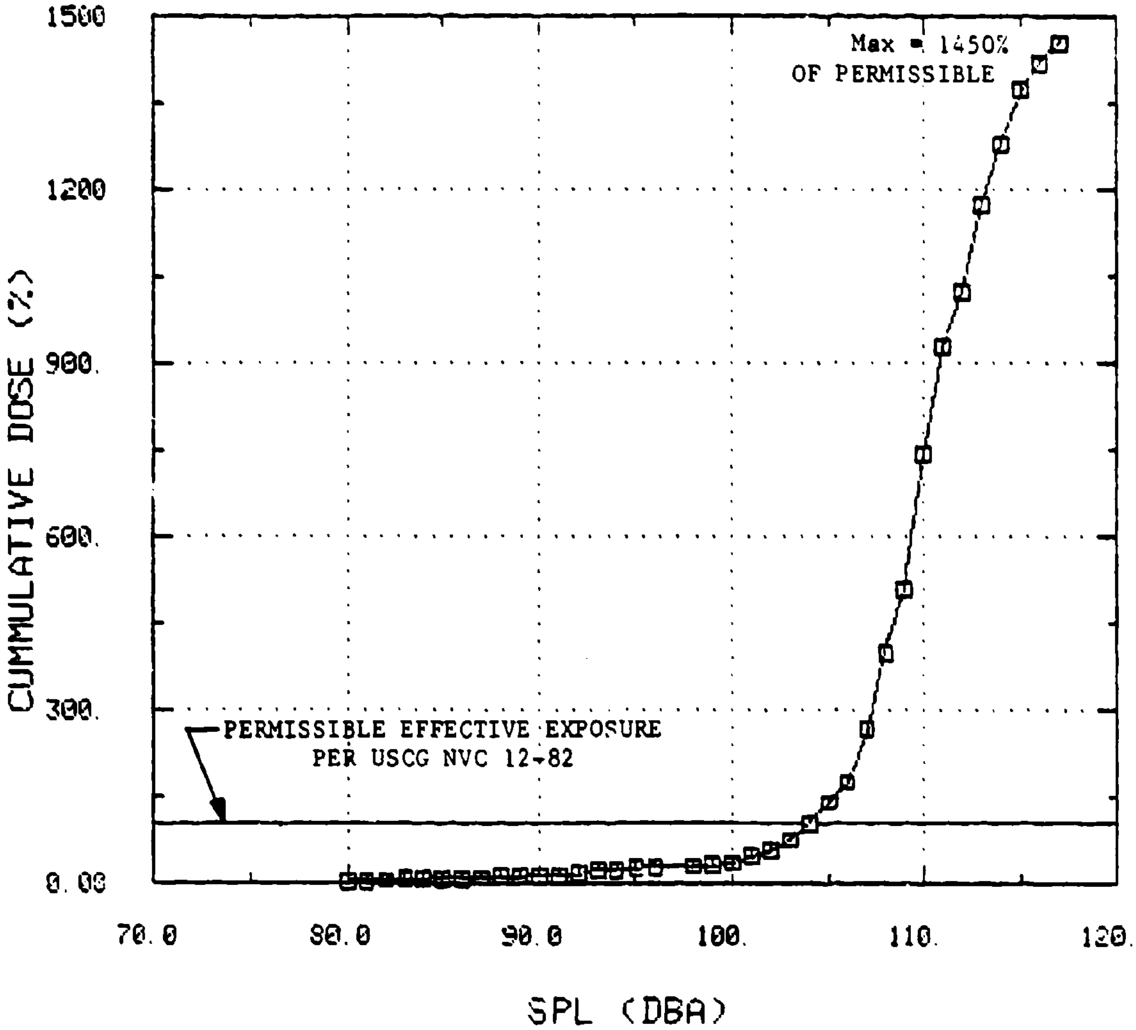


FIGURE B.39. CUMULATIVE DOSE RECORDED ON ROUSTABOUT (Identification Number ND13)

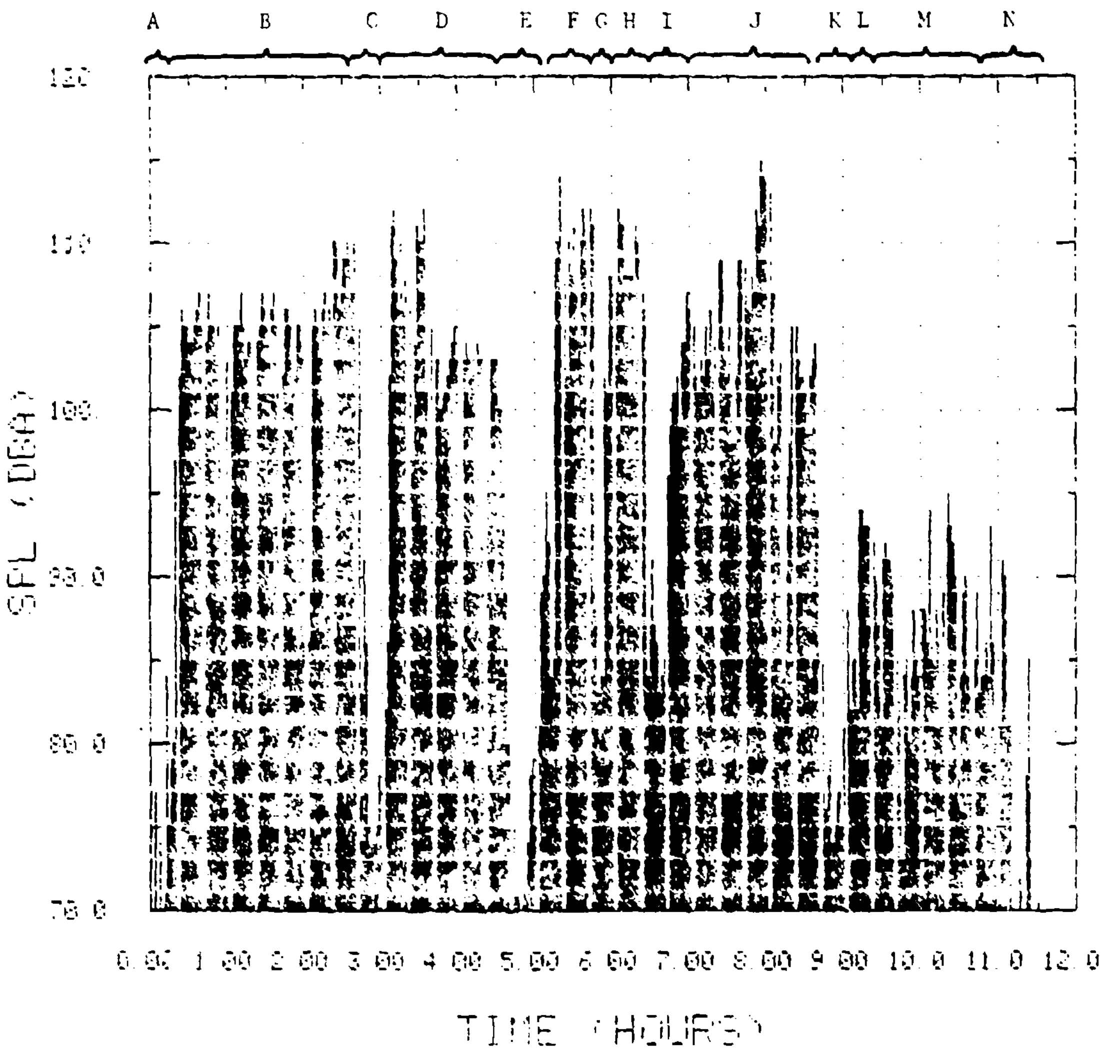


FIGURE B.40. NOISE DOSIMETRY ON ROUSTABOUT
(Identification Number ND14)

TABLE B.XV. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.40

Interval	Activity
A	Preparing equipment.
B	Chipping paint with a needle gun.
C	Inside quarters for morning break.
D	Chipping paint.
E	Inside quarters for lunch.
F	Chipping paint.
G	Working on pipe floor handling personnel basket.
H	Chipping paint.
I	Working on pipe floor handling personnel basket.
J	Chipping paint.
K	Inside quarters for afternoon break.
L	Preparing to paint.
M	Spray painting.
N	Cleaning up equipment.

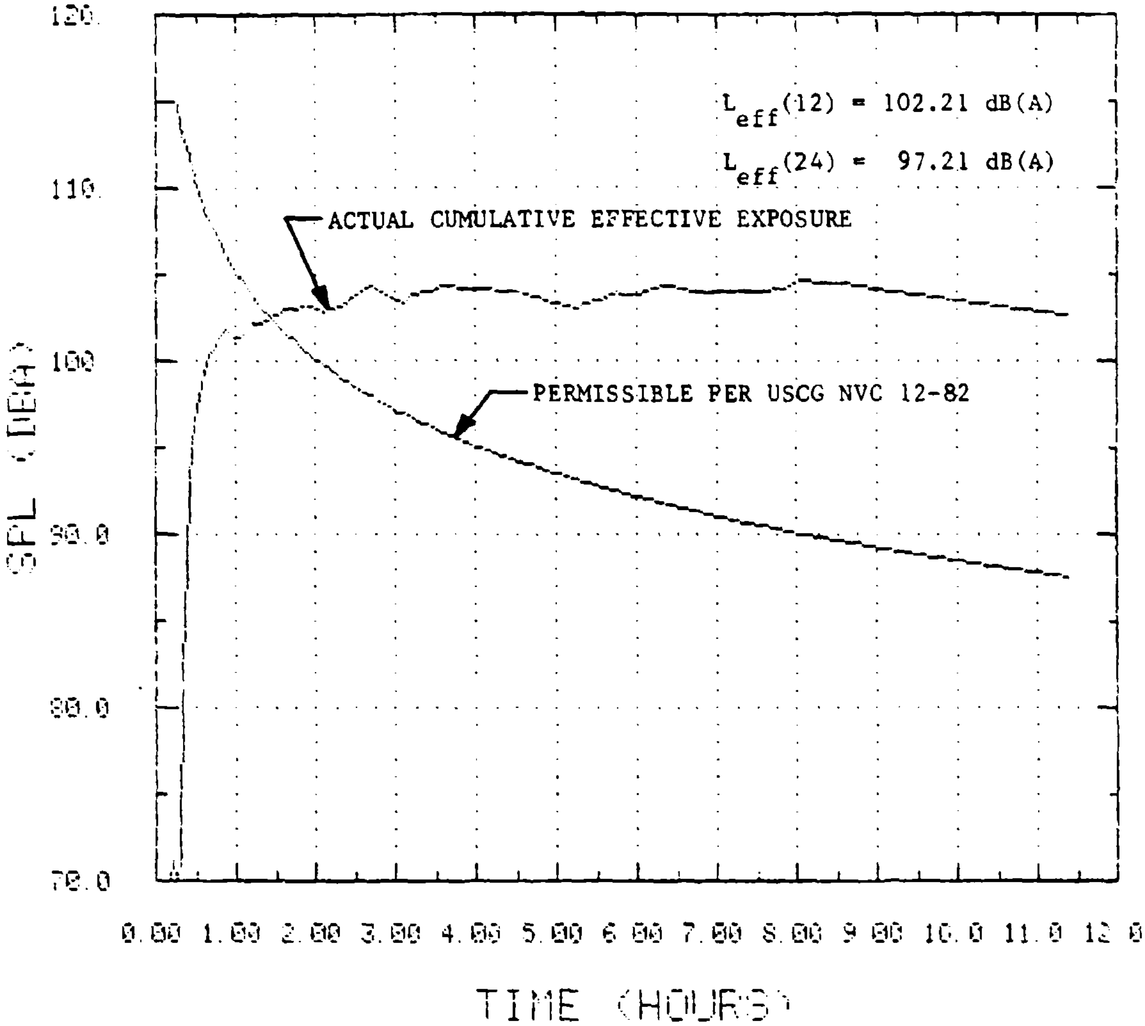


FIGURE B.41. CUMULATIVE EFFECTIVE EXPOSURE ON ROUSTABOUT (Identification Number ND14)

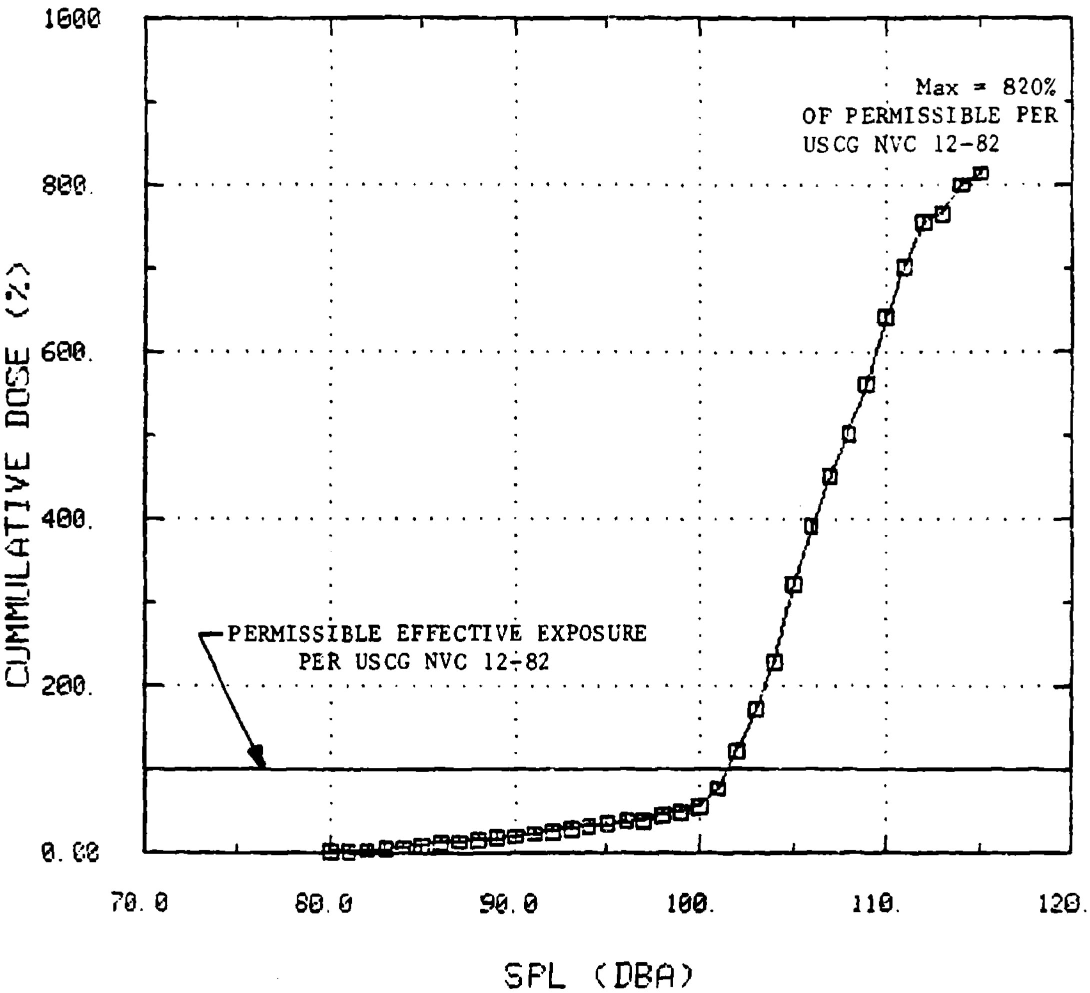


FIGURE B.42. CUMULATIVE DOSE RECORDED ON ROUSTABOUT
(Identification Number ND14)

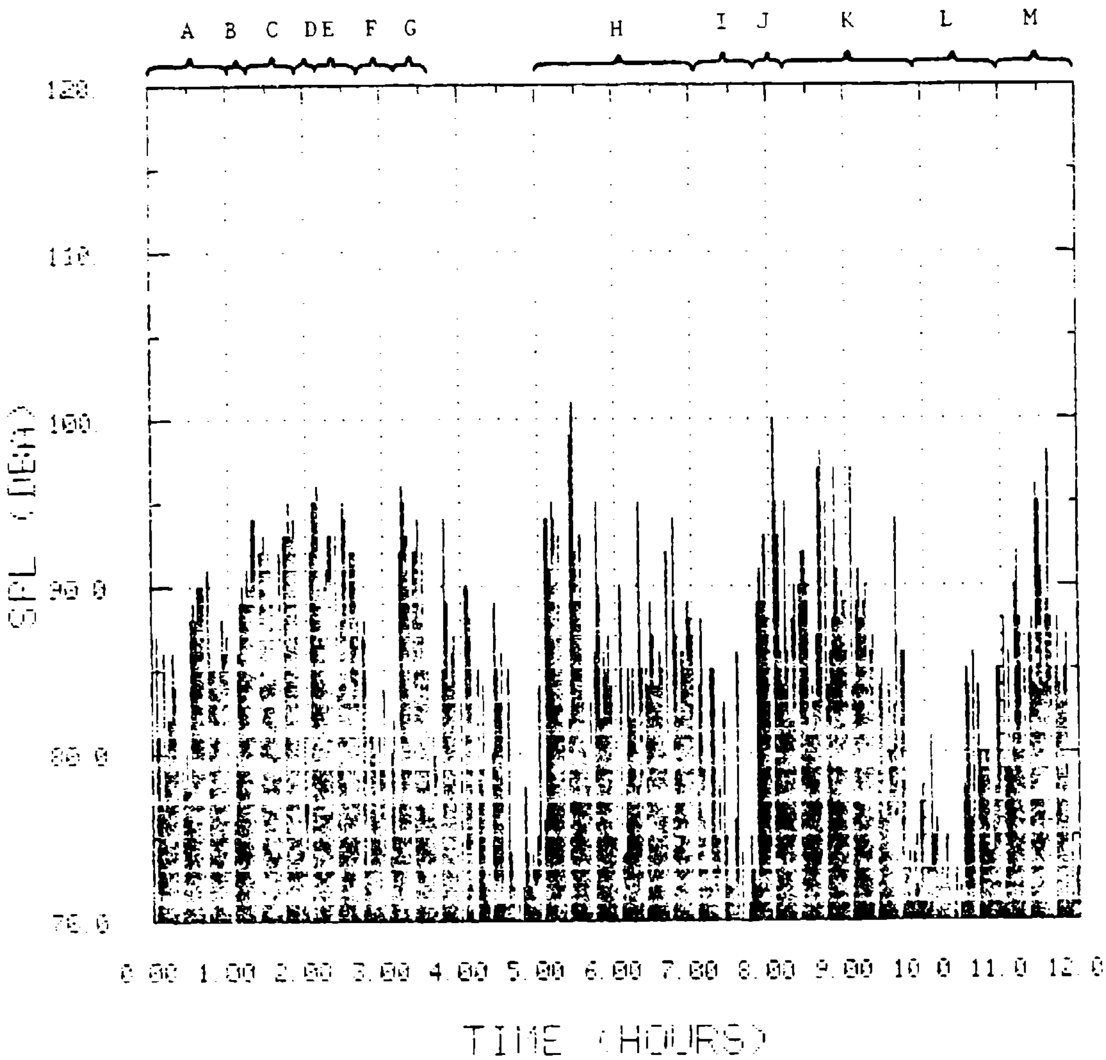


FIGURE B.43. NOISE DOSIMETRY ON WELDER'S ASSISTANT (Identification Number ND15)

TABLE B.XVI. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.43

Interval	Activity
A	Preparing equipment to transfer to field boat. (Worked on various levels of Platform 9 and entered the warehouse several times to gather up equipment and supplies.
B	Inside quarters waiting for field boat.
C	On board field boat to transport equipment to Platform 3.
D	Inside quarters.
E	Setting up welding equipment. Required the assistant to go make several trips to the 10 foot level to transfer equipment and supplies.
F	Inside mechanic's shop.
G	Transferring pipe to 10 foot level.
H	Burnished work for welder. Approximately 16 minutes were spent burnishing. Durations were usually about 30 seconds.
I	Inside quarters.
J	Cutting pipe.
K	Burnished approximately 14 minutes during this interval.
L	Inside quarters.
M	Burnished approximately 11 minutes during this interval.

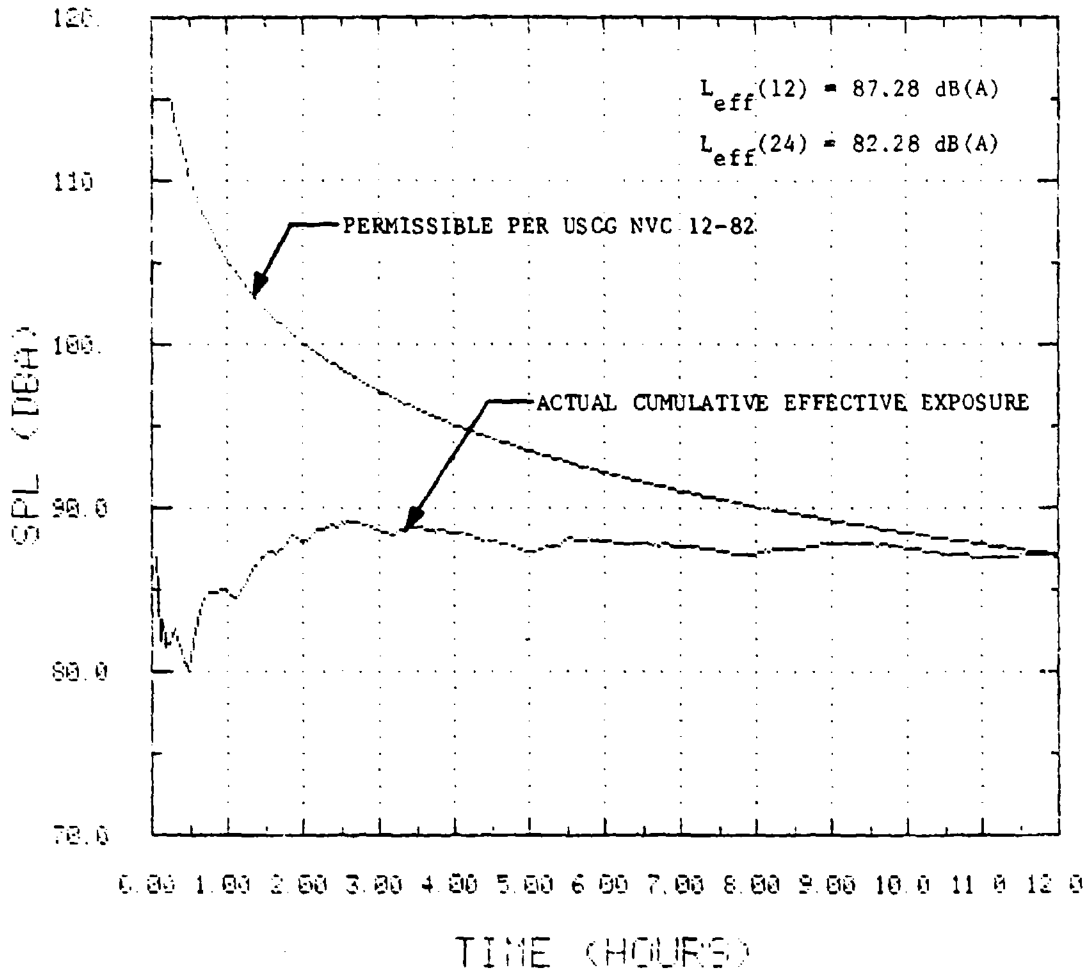


FIGURE B.44. CUMULATIVE EFFECTIVE EXPOSURE ON WELDER'S ASSISTANT (Identification Number ND15)

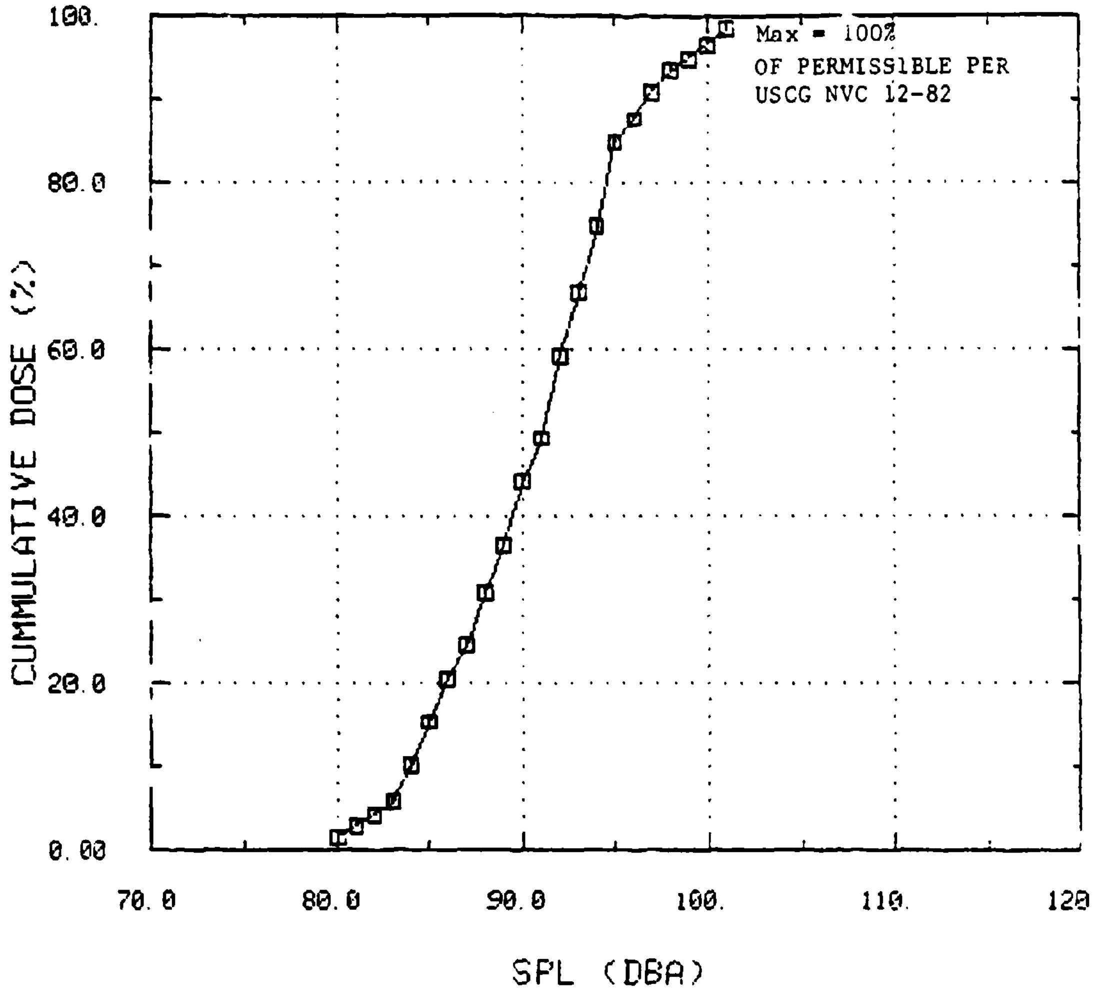


FIGURE B.45. CUMULATIVE DOSE RECORDED ON WELDER'S ASSISTANT (Identification Number ND15)

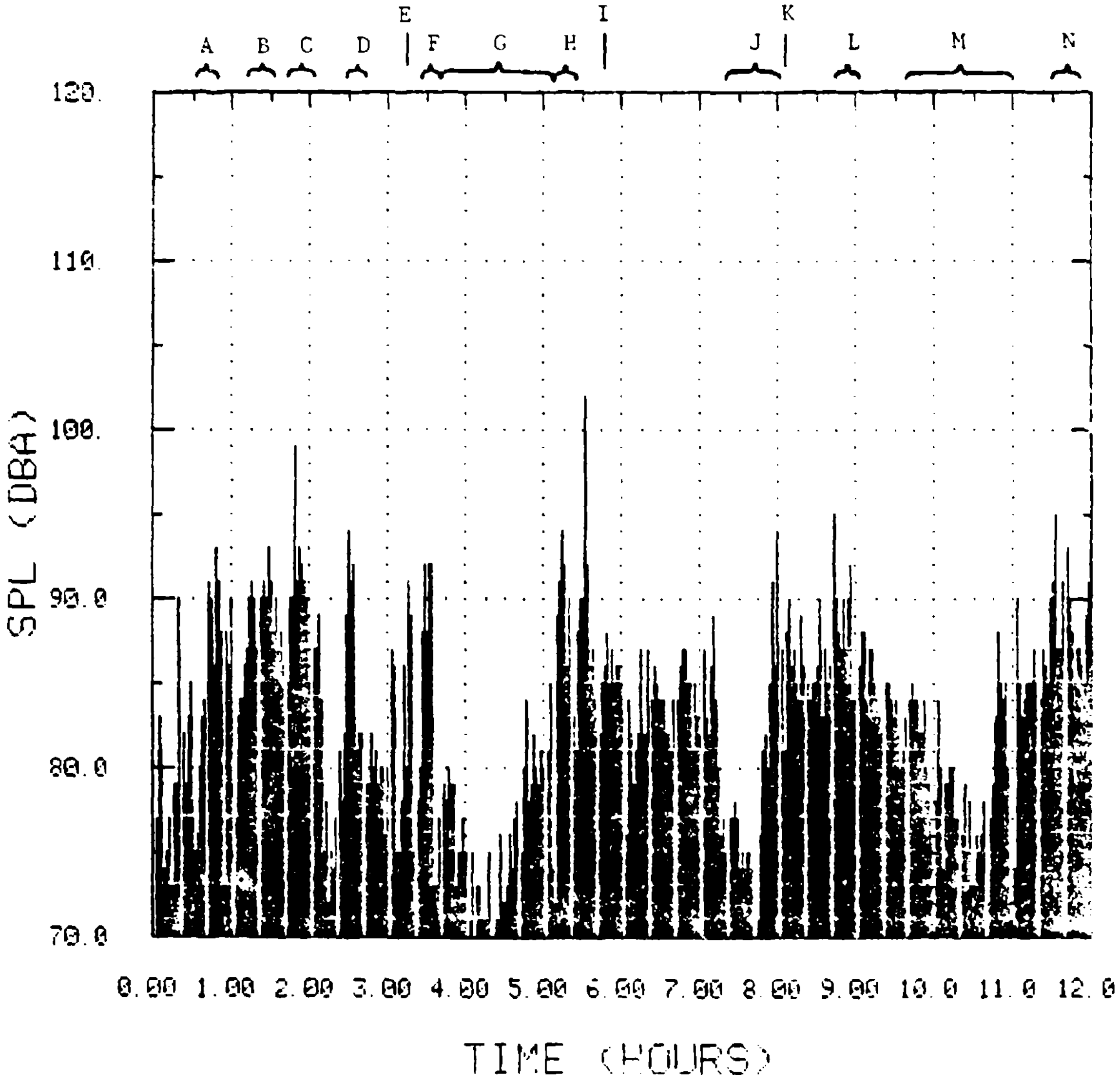


FIGURE B.46. NOISE DOSIMETRY ON CONTRACT WELDER
(Identification Number ND16)

TABLE B.XVII. ACTIVITIES DURING INTERVALS INDICATED ON FIGURE B.46

Interval	Activity
A	On main deck 3 minutes; in and out of berthing space 6 minutes.
B	Loading equipment on field boat.
C	On main deck of Platform 3.
D	On main deck of Platform 3.
E	On main deck of Platform 3.
F	Went down to lower level (welding area) of platform.
G	Inside living quarters (lunch).
H	Started welder.
I	Grinding ends of pipe.
J	Inside living quarters.
K	Went down to lower level to cut pipe.
L	Burnishing 6 minutes and welding 8 minutes.
M	Inside living quarters (dinner).
N	Welding 9 minutes; burnishing 5 minutes.

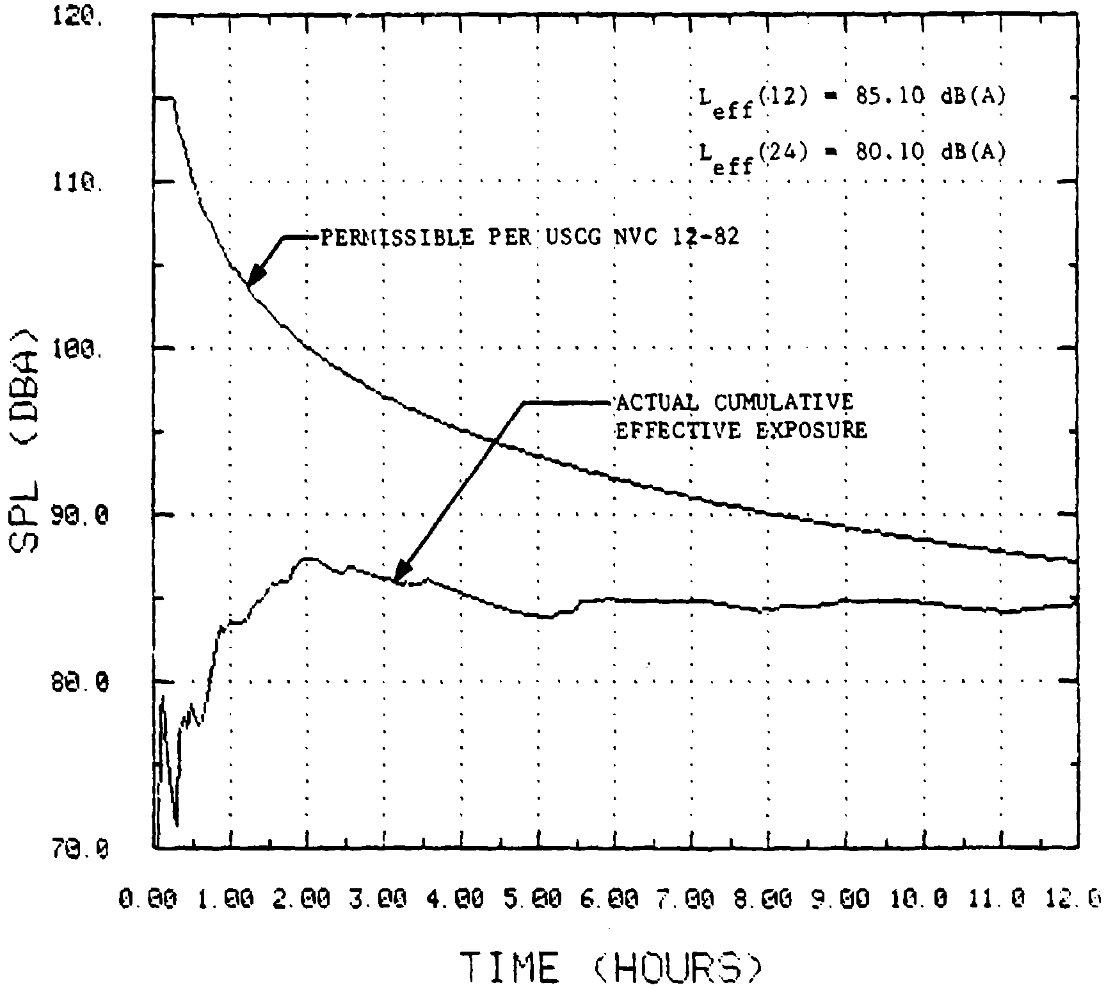


FIGURE B.47. CUMULATIVE EFFECTIVE EXPOSURE ON CONTRACT WELDER (Identification Number ND16)

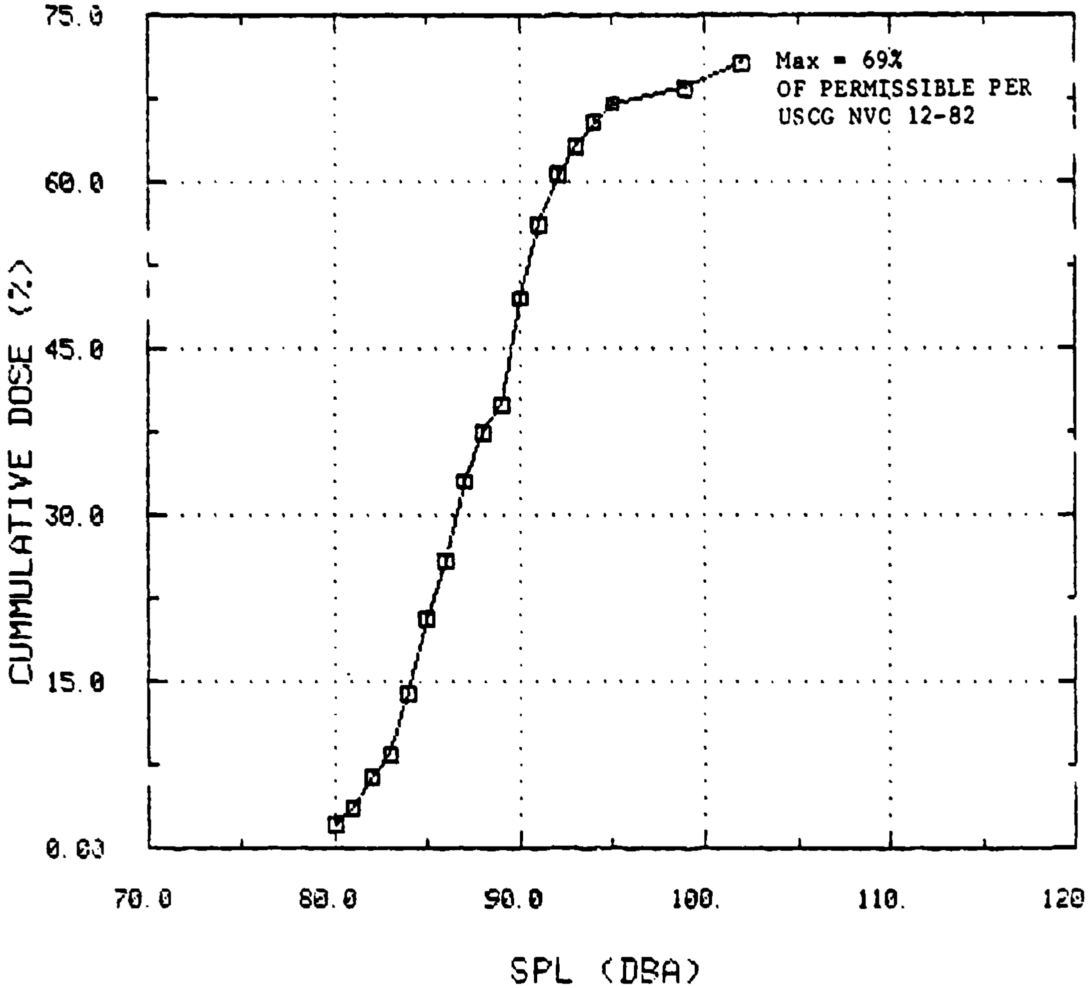


FIGURE B.48. CUMULATIVE DOSE RECORDED ON CONTRACT WELDER (Identification Number ND16)

APPENDIX C

U. S. COAST GUARD NAVIGATION AND VESSEL INSPECTION
CIRCULAR NO. 12-82

RECOMMENDATIONS ON CONTROL OF EXCESSIVE NOISE

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS
U.S. Coast Guard (G-MVI-2)
Washington, D.C. 20593
202-426-2190

NVC 12-82
2 JUN 1982

NAVIGATION AND VESSEL INSPECTION CIRCULAR NO. 12-82

Subj: Recommendations On Control of Excessive Noise

Ref: (a) 46 CFR 32.40-15
(b) 46 CFR 72.20-5
(c) 46 CFR 92.20-5
(d) International Maritime Organization (IMO) Resolution A.468(XII), "Code On Noise Levels On Board Ships".
(e) U.S. Naval Ocean Systems Center, "Study of Airborne Noise On Merchant Ships" (see enclosure (9), reference 1).

1. PURPOSE. This Circular contains the Coast Guard's recommended guidelines to the U.S. maritime industry for addressing conditions of high noise. The guidelines were developed in consideration of the need for protecting crewmembers from noise exposures which may produce permanent noise induced hearing loss; for providing crewmembers with suitable conditions for recuperation from the effects of exposure to high noise levels; and for providing a safe working environment by giving consideration to the need for effective speech communication and for hearing audible alarms and warnings. Amplifying information in attached enclosures is provided as guidance in addressing key aspects of noise control.

2. APPLICATION.

a. The recommendations of this Circular apply to all commercial vessels inspected by the Coast Guard except Mobile Offshore Drilling Units.

b. Although these guidelines are not directed specifically to uninspected commercial vessels, the Coast Guard considers them to be appropriate guidelines should any owner of uninspected vessels also choose to follow them.

DISTRIBUTION - SDL No. 115

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
A																										
B		2	10		3		3	1		2				85	1		6	1								
C					4*		1					1	4*												1	
D	1	1		1							1															
E		1											1*	1*	2											
F			1								1					1										
G																										
H																										

* NON-STANDARD DISTRIBUTION: (See page 8)

2. c. At the time of this publishing, the Coast Guard is collecting data to determine whether separate guidelines would be appropriate for inspected offshore drilling units and fixed structures. However, in lieu of separate guidelines, these guidelines are recommended for the interim.

3. DISCUSSION.

a. According to a recent Coast Guard-sponsored study (enclosure (9), ref. 1), noise exposures of certain personnel aboard U.S. merchant vessels were found to be in excess of those considered to be safe. The study also indicated that high noise levels aboard ship interfere with speech intelligibility, internal shipboard communications and the audibility of warning signals, which potentially impairs the safety of some operations on the vessel. Additional studies from foreign countries and information from other sources overwhelmingly support these findings for virtually all classes of commercial vessels. The studies also demonstrate that unlike shoreside workers who can retreat to a quiet environment after their work shift, merchant seamen are part of a mobile environment and may not have the opportunity to retreat to a quieter, relaxed atmosphere. Crew quarters, recreation areas, mess rooms, etc. are sometimes as noisy as the working environment. Similar problems are also widely reported in the offshore drilling industry. (NOTE: At the time of this publishing, the Coast Guard is still conducting a study on the particular noise problems in the offshore drilling industry.)

b. The effect of noise on hearing is a function of the actual noise level, its component frequencies and the duration of exposure. An excessive combination of these elements results in a shift in a person's threshold of hearing, i.e., an elevation in the lowest level of sound detectable to the ear. A threshold shift may be recoverable to varying degrees, depending upon its magnitude, provided the person retreats to a quiet environment (generally accepted as below 75 db(A)) for a sufficient time. While small threshold shifts may be totally recovered, large shifts are only partially recoverable leaving with each occurrence a small permanent threshold shift, known as hearing loss. The minimum goal of a noise control program should be to insure that an exposure (noise level over a certain duration) is not so great that the temporary threshold shift cannot be recovered during the following rest period.

c. After careful study, the Coast Guard has concluded that the most meaningful method of evaluating excessive noise in the maritime industry is by measuring the cumulative noise exposure during the complete 24-hour day. In addition to consideration of the normal work time noise exposure, the 24-hour exposure measurement considers the time after exposure to high noise to evaluate whether sufficient quiet time is provided to allow for recovery from temporary threshold shift. The term which will be used to express this measurement is

3. c. (cont'd) the "24-hour effective exposure level," or $L_{eff}(24)$, and is defined in technical terms in enclosure (1). The $L_{eff}(24)$ concept differs somewhat from the criteria proscribed by the Occupational Safety and Health Administration (OSHA) because of several factors which distinguish the maritime industry from industry ashore. However, the $L_{eff}(24)$ criteria would afford similar protection.

d. The exposure limit recommended herein (82 dB(A)) is, like almost all exposure limits, based upon an evaluation of a certain degree of risk to some personnel and does not insure that all personnel will not incur hearing damage. For this reason a hearing conservation program containing a system for periodic audiometric testing of personnel is necessary to detect those susceptible persons at the initial outset of a hearing impairment before any appreciable damage is accrued. Since, such a program would generally not be necessary if exposure levels (computed without regard to attenuation contributed by hearing protective devices) were further reduced to 77dB(A), the Circular suggests that new vessels be designed so that the 77dB(A) level may be achieved.

e. The control methods, i.e., engineering controls, administrative controls or hearing protective devices, selected by the owner/operator of a unit to achieve the recommended exposure limits, would depend upon economic and other considerations. Based upon data obtained from the study conducted by the Coast Guard and the state of the art in present noise control technology, the recommendations could be implemented on most units without retrofitting, principally through the use of hearing protectors. Other units may additionally need to administratively limit the time of exposure, and/or install soundproof control booths. Ultimately, however, installation of permanent engineering controls to reduce noise levels is the best means of assuring effective hearing protection. Although this technology may be young in marine applications (in the United States), the Coast Guard has seen several examples where significant reductions in noise levels in engineering compartments through modest engineering controls were achieved. The exposure levels in this proposal are such that they may be economically achieved on many vessels by using these engineering controls. It is encouraged that engineering controls be used whenever economically feasible.

f. In November 1981 the International Maritime Organization (IMO, formerly IMCO) approved a standard on shipboard noise entitled "Code On Noise Levels On Board Ships," which applies basically to new ships of 1600 gross tons or more. The Coast Guard participated in the development of this Code and endorses its recommendations. As the preamble to the Code makes clear however, it was not intended that the Code be adopted verbatim by member nations. Rather, each nation was permitted the flexibility to implement the principles of the Code through a method suited to the maritime industry of that nation. The

3. f. (cont'd) Coast Guard believes therefore, that the recommendations in this Circular are a satisfactory implementation of the IMO Code. (NOTE: The IMO Code contains a section suggesting recommended noise level limits for various types of spaces on a unit. It is believed that this list offers guidance which would be useful to the designers of U.S. vessels and is therefore incorporated verbatim as an enclosure to this Circular. These levels are provided primarily as guidelines which might be useful for design specifications for suitable types of new vessels.)

g. It is considered that implementation of the recommendations in this Circular will involve an ongoing process encompassing a time frame of several months to years, depending upon the vessel. It is anticipated that phases involving measurement, provision of hearing protection devices, installation of some engineering controls, implementation of the hearing conservation program and other administrative aspects could be completed within two years. However, it may take up to four years before complete engineering solutions can be designed and installed.

h. The limits and procedures set out in these guidelines are regarded as minimum acceptable precautions against high noise conditions. For a greater margin of safety, owners and operators may wish to provide higher levels of protection. Also, as technology improves and as more scientific information becomes available, consideration will be given to amending these guidelines accordingly.

4. <u>ACTION</u>.

a. The following paragraphs b through i contain recommended guidelines for protecting crewmembers from conditions of high noise. Additional information in the attached enclosures (1) through (9) are provided to amplify certain provisions of the recommendations. Definitions of terms used are contained in enclosure (1).

b. <u>Recommended Exposure Limit.</u>

(1) Each crewmember's 24-Hour Effectiv osure Level, $L_{eff}(24)$, as defined in enclosure (1), shou onstrained to a maximum of 82 dB(A).

(2) If exposure levels were further reduced, through engineering and administrative controls alone, to an $L_{eff}(24)$ criteria of 77 dB(A), the hearing conservation program outlined below would no longer be necessary in most cases. The Coast Guard believes that the technology to accomplish this objective will be feasible on most deep-sea vessels, over 1600 gross tons, constructed after 1985 and recommends designing to the 77 dB(A) criteria at that time.

4. b. (3) NOTE: The exposure limits specified above are based upon the findings that exposures to high noise in the maritime industry are normally intermittent, as defined in enclosure (1). If work shift noise exposure is continuous, vice intermittent, then exposure levels should be reduced even further.

(4) $L_{eff}(24)$ can be achieved by any combination of engineering controls, administrative controls or hearing protective devices. However, because engineering controls provide the most positive means of assuring adequate protection, it is recommended that engineering controls be given first consideration and evaluated for feasibility before opting for other methods. Discussions on engineering controls and hearing protective devices are included in enclosures (4), (7) and (8).

(5) The Coast Guard realizes that reducing noise levels generally becomes increasingly more difficult on smaller vessels. It was for this reason that the IMO noise level limits referred to in subparagraph c.(2) below were restricted to vessels over 1600 gross tons. On many existing vessels of less than 500 gross tons, the incorporation of effective structural and engineering alterations to attenuate structure-borne noise may be economically prohibitive. However, through the use of hearing protective devices, administrative controls and selective engineering changes, the recommended 24-hour exposure limit, $L_{eff}(24)$, of 82db(A) should still be attainable.

c. <u>Recommended Noise Limits</u>.

(1) Where practicable, maximum noise levels in berthing spaces, and in mess spaces of units over 500 gross tons, should be no greater than 75 dB(A) on existing units and 70 dB(A) on new units.

(2) Annex III, paragraph (1)(e), of the International Regulations for Preventing Collisions at Sea, 1972 (commonly called the 72 COLREGS) contains the following requirements: "The sound pressure level of the vessel's [fog whistle] at listening posts shall not exceed 110 dB(A) and so far as practicable should not exceed 100 dB(A)." The 72 COLREGS are U.S. law and are mandatory for all U.S. vessels navigating on the high seas.

(3) As stated in Discussion paragraph 3.f., the "Code On Noise Levels On Board Ships," a noise standard published in November 1981 by the International Maritime Organization (IMO), contains a listing of suggested noise level limits for various spaces on ship. The Coast Guard considers that these limits would generally be appropriate for adoption as minimum design specifications for ocean-going vessels over 1600 gross tons which would be subject to the IMO Code. This list of limits is

4. c. (3) (cont'd) in enclosure (6). It is not intended that the list supplant any other recommendation in this paragraph 4., nor is it meant to imply that, if followed, would any exposure limit recommended herein be automatically achieved.

d. Hearing Protective Devices.

(1) Unless the $L_{eff}(24)$ computed or measured for a crewmember accounts for and allows such an exposure, crewmembers should be required to wear hearing protective devices whenever entering spaces with noise levels greater than 85 dB(A).

(2) NOTE: Any exposure of persons not wearing hearing protection to noise levels over 105 dB(A) should be avoided. However, if such exposures are unavoidable, they should be constrained to the principle of intermittent exposure (see definition in enclosure (1)) such that each exposure duration is one-seventh of the total allowable exposure at that noise level.

(3) At no time should the unprotected ears of crewmembers be exposed to non-impulse noise levels over 115 dB(A) or to impulse noise levels over 140 dB(A).

e. Evaluation of Noise Conditions.

An evaluation of noise conditions should be conducted on each unit and the results documented. The evaluation should consider noise conditions during all normal operations underway and in port. Enclosure (3) should be consulted with regards to proper equipment and measurement procedures.

f. Warning Notices.

(1) Where the noise level in spaces exceeds 85 dB(A), entrances to such spaces should carry a warning notice advising personnel of the noise hazard and the need for hearing protection. (A guide for design of this sign is the ANSI Specification for Accident Prevention Signs, Z35.1-1972.) If only a minor portion of the space has such noise levels the particular location(s) or equipment should be identified at eye level, visible from each direction of access.

(2) Where hand tools, galley and other portable equipment produce high noise levels in normal working conditions, warning information should be provided, preferably on the device.

g. Instruction to Crewmembers.

(1) Crewmembers should be instructed in the hazards of high and long duration noise exposure and the risk of noise induced hearing

4. g. (1) (cont'd) loss. Instruction should also include a description of the unit's noise control program, the types of hearing protection devices provided and their proper use and care, and the unit's hearing conservation program.

(2) Appropriate crewmembers should receive such instruction as is necessary in the correct use and maintenance of machinery and silencers or attenuators in order to avoid the production or transmission of unnecessary noise.

h. Hearing Conservation Program.

(1) All crewmembers having 24-Hour Effective Exposure Levels (computed, in this case, without regard to attenuation contributed by hearing protective devices) greater than 77 dB(A) or routinely exposed to noise levels greater than 85 dB(A) should be included in a hearing conservation program as outlined in enclosure (5).

(2) Much of the maritime industry utilizes a highly mobile labor force of which individual personnel work a vessel or rig for a limited period and then move on to another unit. Consequently, it is often impractical for operators of these units to individually implement portions of hearing conservation programs involving audiometric testing and recordkeeping. In such cases it is recommended that a program of audiometric testing be coordinated on a group basis between the owner/operators and the employees.

i. Responsibilities.

(1) The owner/operator of a unit should be responsible for ensuring that means for noise reduction and control are applied and maintained according to the recommendations of this Circular. Particular attention should be paid to insuring that the unit's officers are informed of the provisions of the unit's noise control program and the need for instructing crewmembers as provided in paragraph f, and to insuring that hearing protectors are provided and maintained.

(2) Crewmembers should be responsible for complying with the unit's noise control program, as instructed, paying particular attention to wearing provided hearing protectors in the proper manner while working in the prescribed locations.

CLYDE T. LUSK, JR.
Chief, Office of Merchant Marine Safety

NAVIGATION AND VESSEL INSPECTION CIRCULAR NO. **12-82**

2 JUN 1982

Encl: (1) Definitions
(2) Determining the Effective Exposure Level (Examples)
(3) Equipment and Measurement
(4) Hearing Protective Devices
(5) Hearing Conservation Program
(6) IMO Noise Limits
(7) Suggested Engineering Methods for Controlling Noise
(8) Noise Reduction On Towboats and Other Small Vessels
(9) References

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List CG-12; ZTC-68

Enclosure (1) to NVC **12-82**
2 JUN 1982

DEFINITIONS

1. A-weighted sound pressure level or noise level: The quantity measured by a sound level meter in which the frequency response is weighted according to the A-weighting curve, as per ANSI S1.4-1971. The A-weighting values for Octave Bands 31.5 to 8000 Hz are as follows:

Frequency (Hz)	31.5	63	125	250	500	1K	2K	4K	8K
A-Weighting (dB)	-39	-26	-16	-8	-3	0	+1	+1	-1

2. Hearing protector: A device worn to reduce the level of noise heard by the wearer; hearing protective device (HPD).

3. Effective Exposure Level, $L_{eff}(24)$: The constant sound level that produces the same noise exposure as the actual time-varying noise over a 24-hour period within the prescribed sound level limits. L_{eff} is based on a 5 dB exchange rate which assumes that personnel exposures at high noise levels are intermittent. In calculating this level all noise less than 80 dB(A) may be disregarded.

a. The Effective Exposure Level, measured from continuous A-weighted sound pressure signals, is defined as follows (Note: This formula is mainly for use of equipment manufacturers.):

$$L_{eff} = \left(\frac{5}{\log 2}\right) \log \left[\frac{1}{T} \int_0^T \left[\frac{p(t)}{Po}\right]^{4 \log 2} dt \right]$$

where: $p(t)$ = time-varying A-weighted sound pressure, N/m^2
Po = reference sound pressure, $2x10^{-5}$ N/m^2
t = time, in hours
T = total time interval, 24-hours
log = logarithm to the base 10

b. For practical purposes, the Effective Exposure Level can be calculated by the following approximate formula:

$$L_{eff} = 16.61 \log \left[\frac{1}{T} \sum_{i=1}^{n} 10^{L_{Ai}/16.61} \Delta t_i \right]$$

where: L_{Ai} = A-weighted sound level during the i^{th} time interval, Δt_i
Δt_i = i^{th} time interval, in hours
T = $\sum_{i=1}^{n} \Delta t_i$ = total time interval, 24-hours

4. Exchange rate: The amount of decrease in noise level which would allow doubling of the exposure time.

5. Impulse noise: Noise of less than 1 second's duration which occurs as an isolated event, or as one of a series of events with a repetition rate of less than 15 times per second.

6. Integrating sound level meter: A sound level meter designed or adapted to measure the level of the time-averaged A-weighted sound pressure. It is used when sound level fluctuations are too large or erratic to permit accurate readings with a standard sound level meter.

7. Intermittent noise exposure: A daily personnel noise exposure during which the normally encountered noise exposure is interspersed with periods in low level noise, i.e. below 80 dB(A), which are conducive to auditory rest. (Paragraph 4.d.2 of the main text discourages the exposure of personnel not wearing hearing protection to noise levels over 105 dB(A). If such exposures are unavoidable, under the principle of intermittent exposure the individual exposure duration should not exceed the times listed below:

Noise level (dB(A))	106	107	108	109	110	111	112	113	114	115)
Time (min.)	7.4	6.5	5.7	4.9	4.3	3.7	3.2	2.8	2.5	2.1

8. New unit: A unit contracted for on or after 1 January 1986.

9. Noise: For the purposes of this Circular, all unwanted sound.

10. Noise dosimeter: A personal sampling device which automatically measures the wearers cumulative noise exposure over a prescribed period of time.

11. Noise level: See A-weighted sound pressure level.

12. Sound: Energy that is transmitted by pressure waves in air or other materials and is the objective cause of the sensation of hearing.

13. Sound pressure level: The level of sound pressure, L, measured on a logarithmic scale and given by the formula:

$$L = 20 \log_{10} \frac{(p)}{(p_o)} \ .\mathrm{dB}$$

where: p = rms value of measured sound pressure
$p_o = 2 \times 10^{-5}$ N/m^2 (the reference level)

14. Steady noise: A sound where the level fluctuates through a total range of less than 5 dB(A) as measured on the "slow" response of a sound level meter in one minute.

15. Vessel: includes every description of watercraft used, or capable of being used, as a means of transportation on water.

DETERMINING THE EFFECTIVE EXPOSURE LEVEL (EXAMPLES)

1. $L_{eff}(24)$ can be determined through direct readout from personnel noise dosimeters or through manual calculation, comparing measured noise levels against time-motion profiles of the crewmember, or by combining the two methods. Since exposure levels normally vary from day-to-day, it will be necessary to measure several days of exposures to determine the maximum exposure levels unless background data such as from an identical sister-ship is available and is proven to duplicate that vessel's noise conditions. This would apply both to the use of dosimeters and to time-motion profiling.

2. Dosimetry is normally the easier method of determining exposure levels, particularly in jobs where personnel visit various locations of differing noise levels on an unscheduled basis. Commercial noise dosimeters vary in the descriptions and criteria which they are programmed to measure and only those programmed to perform the L_{eff} measurement (i.e. 82 dB(A) criterion level, 80 dB(A) threshold level, 5dB exchange rate) should be utilized for this determination. However, since this criteria is similar to the OSHA hearing conservation criteria, except for the longer evaluation period, proper dosimeters should be readily available. This equipment can also be rented which may be more cost effective for some companies.

3. Examples of performing the L_{eff} calculation are as follows:

Example 1: The $L_{eff}(24)$ limit of 82 dB(A) was determined by calculating the exposure level resulting from the combination of an 8-hour exposure of 90 dB(A), OSHA's current standard, and 16 hours at less than 80 dB(A) (which is disregarded because it is below the threshold level). Using the equation in enclosure (1), this is repeated as follows:

$$L_{eff} = 16.61 \log \left[\frac{1}{T} \sum_{i=1}^{n} 10^{L_{Ai}/16.61} \Delta t_i \right]$$

$$L_{eff}(24) = 16.61 \log [1/24 ((10^{90/16.61} \times 8) + (0 \times 16))]$$

$$L_{eff}(24) = 82 \text{ dB(A)}$$

Example 2: A noise survey is conducted on a 25,000 dwt steam vessel. The results indicate high noise levels in several machinery spaces and a noise level of 78 dB(A) on the mess deck.

Further analysis is performed to determine the actual exposures of the crew. An overview reveals that only engineering personnel are sufficiently exposed to high noise to be in danger of overexposure, so the analysis is limited to this group. At this point the noise consultant must decide whether to measure exposures using (a) personal noise dosimeters or (b) time motion study.

The consultant decides to measure the exposures by performing a time motion study while the vessel is on a 10-day trip. He profiles the various routines of the affected personnel and relates the respective noise levels. An example of the incremental exposures determined over a 24-hour period for the First Assistant Engineer are tabulated as follows:

1 hr. @ 95 dB(A)	5 hrs. @ 93 dB(A)	2 hrs. @ 88 dB(A)
2 hrs. @ 85 dB(A)	12 hrs. @ less than 80 dB(A)	

The effective exposure level resulting from these incremental exposures is computed from the formula in enclosure (1) as follows:

$$L_{eff} = 16.61 \log \left[\frac{1}{T} \sum_{i=1}^{n} 10^{L_{Ai}/16.61} \Delta t_i \right]$$

$$L_{eff}(24) = 16.61 \log [1/24((10^{95/16.61} \times 1) + (10^{93/16.61} \times 5) + (10^{88/16.61} \times 2) + (10^{85/16.61} \times 2) + 0)]$$

$$L_{eff}(24) = 85 \text{ dB(A)}$$

The analysis indicates that the exposures of most of the engineroom personnel are, like the First Assistant, in the vicinity of 85 to 89 dB(A), exceeding the 82 dB(A) recommended limit.

(Note: The analysis of exposure levels described above could also have been accomplished using personal noise dosimeters, probably with much less effort. A problem sometimes experienced with dosimeters is in obtaining the cooperation of the crew, some of whom may be reluctant to wear the device or may want to bias the readings. However, if this can be resolved (many experts do not find this to be a problem), dosimeters offer a more accurate and less time consuming method of determining exposure levels.)

The consultant presents three options for resolving the overexposures, listed as follows:

- Option 1: Require personnel to wear hearing protection in all machinery spaces where noise levels exceed 90dB(A).
- Option 2: Construct a sound-proof booth around the operator's station in the engineroom.
- Option 3: Apply engineering controls at several key noise emitting sources in the engineroom.

The owners decide to implement Option 1. The recommendations of this Circular for warning notices, crew instruction and hearing conservation program are instituted. The crew is offered three models of hearing protectors to choose from. A system of audiometric testing and recordkeeping is developed.

Finally, the consultant also designs a treatment for reducing the mess deck noise level to 68 dB(A) which is subsequently installed.

Example 3: Using dosimetry to evaluate on watch exposure and doing time motion study to profile the remaining 16-hours off watch, another crewmember's exposure is determined as follows:

on watch: L_{eff} (8 hours) = 85 dB(A)
off watch: 2 hrs @ 81 dB(A)
14 hrs @ less than 80 dB(A) (disregard)

$$L_{eff}(24) = 16.61 \log [1/24((10^{85/16.61} \times 8) + (10^{81/16.61} \times 2) + 0)]$$

$$L_{eff}(24) = 78 \text{ dB(A)}$$

(Note: Computing work shift exposures of personnel by time/motion survey is normally more complex than indicated in the above examples as noise levels will vary considerably.)

Enclosure (3) to NVC 12-82
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EQUIPMENT AND MEASUREMENT

1. Equipment.

a. Use of the following equipment is recommended: sound level meter, personal noise dosimeter, octave band analyzer, integrating sound level meter with peak and maximum hold capacity, and acoustic calibrator.

b. Sound level meters should meet the Type II requirements of the ANSI Specification for Sound Level Meters, S1.4-1971 (R1976). For critical measurements which determine compliance with recommended limits, a Type I precision sound level meter should be used.

c. Personal noise dosimeters should meet the Class 2A requirements of the ANSI Specification for Personal Noise Dosimeters, S1.25-1978. The dosimeter should measure L_{eff} utilizing the criteria specified in Definition 3 in enclosure (1).

d. Other measuring equipment should meet appropriate national or international standards.

e. Only equipment certified intrinsically safe should be used in areas where flammable gas/air mixtures may be present.

2. Measurement.

a. All physical measurements should be made following the applicable procedures of ANSI S1.13-1971 (R1976), Methods for Measurement of Sound Pressure Levels, and ANSI S1.2-1962 (R1976), Method for the Physical Measurement of Sound, and accepted practice. Use of ISO Standard 2923-1975(E), "Acoustics-Measurement for Noise On Board Vessels" is also suggested.

b. Noise measurement equipment should be calibrated initally, at subsequent intervals of approximately four hours, at the end of tests and at any other time when tests are interrupted due to battery replacement, etc.

c. Noise measurements should be taken in decibels using an A-weighting filter (dB(A)). The meter should be set to "slow" response and the readings made only to the nearest decibel. A measuring time of at least 5 seconds should be allowed. If a meter fluctuates in level within a range of 5 dB maximum to minimum, an estimate of the level may be made by averaging the excursions of the needle with the eye. It is suggested that C-weighted levels also be taken. Furthermore, to facilitate analysis of noise in certain areas where engineering controls may be applied, measurement of noise by octave band levels should be considered. A form found convenient for recording the noise data is attached. A wind screen on the microphone should be used in locations where air motion is noticeable, such as bridge wings, lookout positions, and near fans and ventilators.

d. Measurements of intermittent and transient sources, such as ship's horn or whistle at bridge and lookout locations are best made with meters with "maximum-hold" and "peak-hold" capability. Certain machinery, such as steering motors, etc. may also need measurements of this type.

e. Measurement of exposure levels at manned and intermittently manned locations is most convenient with an integrating sound level meter. This instrument may be used in two ways: (1) at locations where the sound level fluctuates, perhaps due to a cyclic operation of a machinery item, and the meter is used to measure the average sound level. For this the meter is operated at a fixed location for a period of at least one full cycle of the machine; (2) to assess the average level over a space such as that transited by an oiler on his rounds, the meter is operated while it is carried over the actual path and at an equivalent rate of the oiler, and the average sound level is read at the completion of the path. If an integrating sound level meter is not available, the average sound level may be calculated by averaging the set of sound level measurements on a pressure squared basis.

3. Survey.

When evaluating noise exposures, all operating conditions underway and in port should be considered. For standardization however, a noise survey should normally be conducted under the following conditions:

a. Measurements underway should be taken with ship in the loaded or ballast condition, operating at normal design service speed and with all auxiliary machinery and electrical equipment which is normally in use in operation. Particulars of machinery in operation should be noted.

b. Noise level measurements in spaces containing emergency diesel engine-driven generators, fire pumps or other emergency equipment that would normally be run only in emergency, or for test purposes, should be taken with the equipment operating. Adjoining spaces need not be measured with such equipment operating, however, unless it is likely that the equipment will be operated for periods other than those mentioned above.

c. Measurements in port should be taken with the ship's cargo handling equipment in operation, in those areas and accommodation spaces affected by their operation.

d. Measurements should be made at the principal working and control stations of crewmembers in the machinery spaces and in the adjacent control rooms, if any, with special attention being paid to telephone locations and to positions where voice communication and audible signals are important. Measurements should be taken in all workshops, at points on all normally used access routes and at all other locations which would normally be visited during routine inspection, adjustment and maintenance.

e. In addition to the spaces referenced above, noise levels should be measured in all areas where work is carried out and in all locations with high noise levels where crewmembers may be exposed, even for relatively short periods. Noise levels need not be measured for normally unoccupied spaces, holds, deck areas and other spaces which are remote from noise and where a preliminary survey shows that noise levels are below 70dB(A).

SAMPLE NOISE SURVEY FORM

Vessel Name: Hull No.
Type: Owner:
Built by: Year Built:

Dimensions

Length: Breadth: Depth:
Maximum draft (summer load line): Gross Tonnage:

Machinery

Engines - Type: manufacturer:
number: Normal design service shaft speed:
Generators - Type: manutacturer:
number: Output: kw
Main reduction gear:
Type of propeller: number of Propellers:
Auxiliary engines:
Other machinery notes:

Conditions During Measurement

Vessel's proximate position: Type of voyage:
Draft forward: Draft aft: Depth of water:
Weather - Wind speed: Seas:
Vessel's direction in relation to seas:
Vessel's speed: Shaft speed: r.p.m.
Propeller pitch:
Summary of machinery status: ______________________________

____
____
____
____
____

Appendix (A) to Enclosure (1) to NVC **12-82**
2 JUN 1982

SAMPLE NOISE SURVEY FORM

VESSEL ______________________

DATE __/__/__

____

Data taken by (name) ______________________

____

Sound level meter ______________________

Octave band analyzer ______________________

Acoustic calibrator ______________________

Other ______________________

Calibration time (before) ____ (2) ____ (3) ____ (after) ____

				SOUND PRESSURE LEVELS (dB)											
				WEIGHTED		OCTAVE BAND ANALYSIS									
COMPARTMENT NAME	COMPARTMENT No. (deck-frame-stb/pt)	TIME	MIC LOC	(A)	(C)	32	63	125	250	500	1k	2k	4k	8k	NOISE SOURCE (propulsion, ventilation, etc.); and NOTES.
	- -														
	- -														
	- -														
	- -														
	- -														
	- -														
	- -														
	- -														
	- -														

Enclosure (4) to NVC **12-82**

2 JUN 1982

HEARING PROTECTIVE DEVICES

1. Hearing protective devices (HPD's) must be effective in providing the necessary protection and be acceptable to the individual. Selection, fit and instruction in proper use are critical to effective performance. HPD's come in three basic types, i.e. ear muffs, ear plugs and canal caps (partial inserts); sometimes, for protection in particularly high noise levels, muffs and plugs will be worn together. HPD's should be carefully chosen from the hundreds of models now available. It should be noted that HPD's often differ in effectiveness at different frequencies whereby one device may be especially effective in high frequency noise, another in mid-frequency and another in low frequency.

2. For many reasons, the HPD attenuation (reduction of noise to the ear) realized in actual field use may be substantially less than the attenuation listed by the HPD manufacturer. Manufacturers ratings are computed in a controlled, supervised, laboratory situation, using motivated test subjects and for a short specific time period. However, in actual use, wearers of HPD's are not often as well instructed or motivated to obtain such good results. Unless a crewmember is completely motivated, through training and supervision, to wear the device properly, actual attenuations will not often attain to manufacturers' ratings. An evaluation of HPD attenuation, therefore, must consider two factors: (1) calculation of attenuation based on the manufacturer's attenuation data; and (2) adjustment of this calculation to compensate for real world use.

3. Several methods of calculating the actual noise level under an HPD have been suggested by various sources. The National Institute for Occupational Safety and Health (NIOSH) lists three methods which are detailed in the NIOSH publication "List of Personal Hearing Protectors and Attenuation Data" (enclosure (9), ref. 12). Essentially, however, there are two common methods for this calculation. The preferred method is the one which looks at the frequency spectrum of the noise (by octave band) and applies the corresponding attenuation at that frequency for the HPD. This can be termed the "long method", or NIOSH method #1 in the above reference 12. A rougher method, which is based on several general assumptions which can allow an error of as much as ± 8 dB depending on the frequency breakdown of the noise, is based on the single-number Noise Reduction Rating (NRR) which is provided with each device. Although the NRR can be useful as a quick method of evaluating an HPD, the best professional method of evaluating HPD attenuation is the "long method." These two methods of calculation are described as follows:

a. "Long method" (NIOSH Method #1) calculation: After correcting the sound level at each octave band from 125 to 8000 Hz for "A"-weighting (see Definition #1), subtract the HPD's listed attentuation at that frequency band and add 2 times the HPD's listed standard deviation. These resultant levels are summed logarithmically to yield the calculated A-weighted noise level under the HPD.

b. NRR Calculation: Very simply, the NRR is subtracted from the actual noise level, measured on the C-weighted scale, to yield the estimated A-weighted noise level under the HPD. (Note: If only the actual A-weighted noise level is known, the NRR may still be applied by adding an estimate of the C-A difference, normally approximately 5 dB, to the A-weighted level and then subtracting the NRR.)

4. Adjusting the calculated HPD noise reduction to compensate for real world use is a controversial issue since the HPD effectiveness is directly related to the motivation and understanding of the employee. The Coast Guard recommends that in normal circumstances, where employees are instructed in the importance and use of HPD's, a correction factor of 5 dB less than manufacturers stated attenuation should be applied. If it is not desirable to apply this safety factor, the owner should insure that the audiometric test program is strengthened to detect ineffective HPD performance.

5. As we address the problem of HPD's not achieving desired results, we must hastily add that this problem is not automatically corrected simply by getting the best attenuating devices available. Overprotecting workers may present problems just as serious as underprotecting. When HPD's attenuate more noise than necessary, they also filter out wanted sound such as that from conversation, audible signals and alarms, and operating machinery. In order to hear these sounds, workers will often deliberately misfit or tamper with their HPD's. If they do not, they may miss important communications and signals, endangering the vessel or operation. This is why it is important to select the HPD which protects mainly at the frequency levels necessitated by the particular noise encountered and then train and motivate the personnel to properly wear the devices to attain the calculated attenuation.

6. Once HPD's are properly selected and issued, care must be taken to maintain them. Manufacturers' instructions concerning sanitation, maintenance and replacement should be followed. For example, cushions on ear muffs often harden and crack after a few months use, reducing the effectiveness of the muff, and must be replaced.

HEARING CONSERVATION PROGRAM

1. A Hearing Conservation Program should be designed to prevent hearing damage to crewmembers and to detect and treat, at an early stage, those persons who are beginning to experience a loss in hearing acuity due to workplace noise. Some basic elements of a Hearing Conservation Program are as follows:

a. A well-designed plan for controlling the noise exposures of crewmembers through administrative controls and hearing protective devices (HPD's).

b. Instruction of exposed persons on the hazards of high noise exposure, the design and goals of the unit's Hearing Conservation Program, and the proper use of hearing protective devices.

c. Initial and periodic audiometric tests administered by a trained and appropriately qualified person and reviewed according to accepted practice.

d. Maintenance of audiometric test records.

e. Follow-up analysis of records to detect individuals incurring a significant shift in hearing acuity and subsequent action to prevent further hearing damage to those individuals.

2. As important as the design of a Hearing Conservation Program is, a factor just as critical is the effort spent on convincing the affected personnel of the reasons behind the program and the purpose of the procedures chosen. The pivotal characteristics of a successful Hearing Conservation Program can be broken down as follows:

- education
- motivation
- comfortable and effective HPD's
- support by all levels of supervision
- enforcement
- feed-back

When a hearing Conservation Program is well designed and implemented, the proper use of HPD's can become quickly established and accepted by the crew. Popular misconceptions concerning noise and HPD's can be dissolved through an effective educational program. Many short films are available which are useful in highlighting the pertinent topics and maintaining the interest of personnel (enclosure (9), ref. 13).

NOISE LIMITS RECOMMENDED BY IMO

(Reference paragraph 4.C.2 of main text.) The following are noise level limits recommended by the International Maritime Organization (IMO) in its "Code On Noise Levels On Board Ships" (Enclosure (9), ref. 2) for new vessels over 1600 gross tons.

			dB(A)
1	Work Spaces		dB(A)
	.1	Machinery spaces (continuously manned)	90*
	.2	Machinery spaces (not continuously manned)	110
	.3	Machinery control rooms	75
	.4	Workshops	85
	.5	Non-specified work spaces	90*
2	Navigation spaces		dB(A)
	.1	Navigating bridge and chartrooms	65
	.2	Listening post, including navigating bridge wings and windows	70
	.3	Radio rooms (with radio equipment operating but not producing audio signals)	60
	.4	Radar rooms	65
3	Accommodation spaces		dB(A)
	.1	Cabins and hospitals	60
	.2	Mess rooms	65
	.3	Recreation rooms	65
	.4	Open recreation areas	75
	.5	Offices	65
4	Service spaces		
	.1	Galleys, without food processing equipment operating	75
	.2	Serveries and pantries	75
5	Normally unoccupied spaces		dB(A)
	Spaces not specified		90*

* Coast Guard Note: Reduction to this level will not automatically preclude need for hearing protective devices.

SUGGESTED ENGINEERING METHODS FOR CONTROLLING NOISE

1. General

a. Reducing shipboard noise levels is a complex endeavor which requires careful consideration. This enclosure presents a short discussion of the many practices which are commonly used today.

b. Design and construction of noise control measures should be supervised by persons skilled in noise control techniques. The references listed in enclosure (9) also, offer a wealth of expertise on the subject. Attention is drawn in particular to reference 5, the SNAME Design Guide for Shipboard Airborne Noise Control.

c. Some of the measures which can be taken to control noise levels or reduce the exposure of crewmembers to potentially harmful noise are indicated in paragraphs 2 through 10 of this enclosure. It is emphasized that it will not be necessary to implement all or any of the measures recommended in this enclosure on all ships. The enclosure does not provide detailed technical information needed for putting constructional noise control measures into effect, or for deciding which measures are appropriate in particular circumstances.

d. In applying noise control measures, care should be taken to ensure that rules and regulations concerning ship structure, accommodation and other safety matters are not infringed and that the use of sound reduction materials does not introduce fire or health hazards.

e. The need for noise control should be taken into account in the design stage of a unit, when deciding which of different designs of structures, engines and machinery are to be installed, the method of installation, the siting of machinery in relation to other spaces, and the acoustical insulation and siting of the accommodation spaces.

f. Due to the normal methods of ship construction, it is most probable that noise originating from machinery and propellers reaching the accommodation and other spaces outside the machinery spaces will be of the structure-borne type.

g. When designing efficient and economical measures for controlling noise from machinery installations in existing ships, the A-weighted noise measurements must normally be supplemented by some form of frequency analysis.

2. Isolation of Sources of Noise

a. Where practicable, any engines or machinery producing excessive noise levels should be installed in compartments which do not require continuous attendance.

b. Accommodations should be sited both horizontally and vertically as far away as is practicable from sources of noise such as propellers and propulsion machinery.

c. Machinery casings should, where practicable, be arranged outside superstructures and deck houses containing accommodation spaces. Where this is not feasible, passageways should be arranged between the casings and accommodation spaces, if practicable.

d. Consideration should be given, where practicable, to the placing of accommodation spaces in deck houses not in superstructures extending to the ship's side.

e. Consideration may also be given where applicable to the separation of accommodation spaces from machinery spaces by unoccupied spaces, sanitary and washing rooms.

f. Suitable partitions, bulkheads, decks, etc. may be needed to prevent the spread of sound. It is important that these be of the correct construction and location in relation to the source of sound and the frequency of the sound to be attenuated.

g. Sound absorbing material is useful in preventing the increase of noise level due to reflection from partitions, bulkheads, decks, etc.

3. Exhaust and Intake Silencing

a. Air intake systems to machinery spaces, accommodation spaces and other spaces and exhaust systems from internal combustion engines should be arranged so that the inflow or discharge orifices are remote from places which are normally frequented by crewmembers.

b. Silencers and attenuators often provide effective noise reduction. Lining of ventilation ducts at strategic locations with sound absorbing material (with due regard to structural fire protection standards) can also be extremely effective.

c. To minimize noise levels in accommodations, it is normally necessary to isolate exhaust systems and certain pipework and ductwork from bulkheads, casings, etc.

4. Machinery Controls

a. In continuously manned spaces or spaces where crewmembers might reasonably be expected to spend lengthy periods of time on maintenance or overhaul work, consideration may have to be given to the fitting of sound insulating enclosures or partial enclosures to engines or machinery producing excessive sound levels. When sound insulating enclosures are fitted, it is important that they entirely enclose the noise source.

b. Although it may seem that noise in high noise areas such as enginerooms and machinery spaces eminates from a vague multitude of noise contributing sources, it has been found that most of this noise is usually traceable to a few specific components on certain systems or machinery. These components can usually be traced systematically and then economically treated, substantially reducing engineroom noise levels, often to levels where hearing protectors would not be necessary. A partial list of these major noise elements are as follows:

Steam Turbine Plants	Diesel Plants
Gear boxes	M-G sets
M-G sets	Gear boxes
Valves	Hydraulic systems
Boiler fans	Ventilation system fans
Hydraulic systems	Engine components
Ventilation system fans	- Turbo chargers
Turbines	- Valve covers
Couplers (high speed only)	- Inspection plates
	- Exhaust system
	- Expansion joints
	- Intake system

5. Reduction of Noise in the Aft Body

To reduce the noise influence in the aft part of the vessel, especially in the accommodation spaces, consideration may be given to the various noise/vibration contributions of propeller, shaft, wave action, etc. during the procedures of designing the aft body, propeller, etc.

6. Enclosure of the Operator

In many machinery spaces it may be desirable to protect operating or watchkeeping personnel by providing a sound reducing control room or other similar space.

7. Controls in Accommodation Spaces

a. To reduce noise levels in accommodation spaces it may be necessary to consider the isolation of deck houses containing such spaces from the remaining structure of the ship by resilient mountings.

b. Consideration may also be given to the provision of flexible connections to bulkheads, linings and ceilings and the installation of floating floors within accommodation spaces.

c. The provision of curtains to side scuttles and windows and the use of carpets within accommodation spaces assists in absorbing noise.

8. Selection of Machinery

a. The sound produced by each item of machinery to be fitted should be taken into account at the design stage. It is often possible to control noise by selecting the machine which produces the least airborne, fluid-borne or structure-borne sound.

b. Manufacturers should be requested to supply information on the sound produced by their machinery and also to provide recommended methods of installation in order to keep noise levels to a minimum.

9. Inspection and Maintenance

All items of machinery, equipment and associated working spaces should be regularly inspected with respect to noise by a competent person. Should such inspection reveal defects in the means for noise control, or other defects causing excessive noise, these should be rectified as soon as practicable.

10. Vibration Isolation

a. Where necessary, machines should be supported on specially designed and fitted resilient mountings.

b. Where structure-borne sound from auxiliary machinery, compressors, hydraulic units, generating sets, vents, exhaust pipes and silencers produces unacceptable noise levels in accommodation spaces or on the navigating bridge, resilient mountings should be fitted to isolate the equipment from the structure.

c. When sound insulating enclosures are fitted it is desirable that the machine should be resiliently mounted and that all pipe, trunk and cable connections to it be flexible.

NOISE REDUCTION ON TOWBOATS AND OTHER SMALL VESSELS

1. The problem of noise on small vessels such as towboats, offshore supply boats, crewboats, etc. is in many ways more difficult and complex than on larger vessels. Although enclosure (7) discusses most of the practiced methods of noise control on vessels, a separate enclosure speaking particularly to the problem on small vessels was considered necessary.

2. Small vessels usually incorporate high horsepower propulsion systems into very small frames. Consequently, mechanical vibration from the machinery is not effectively dampened by the mass of the vessel, but rather is transmitted through the light structure and converted to noise as it vibrates about the vessel. This structure-borne noise is the predominant problem on most small vessels and is difficult to control. Because of the magnitude of the problem, it has been accepted that high noise levels are usually unavoidable. As a result, crewmembers are exposed to very high noise levels not just in working areas, but in mess, lounge and berthing areas as well.

3. Despite the difficulties, there is potential for substantial noise reductions on small vessels. Other countries and a few companies in the United States have successfully developed several noise control techniques over the last decade. The techniques are somewhat expensive, but generally not prohibitively so. Investments made in developing and implementing these techniques will afford substantial benefits in days ahead.

4. When considering the application of noise controls, it is suggested that first priority generally be placed upon reducing noise to acceptable levels in accommodation spaces and in those areas where personnel cannot wear protective devices because of operational necessity. This should not discourage application of engineering controls to machinery spaces, since such controls are often the best method of reducing noise in other areas of the vessel. Noise reductions can be more easily achieved on new vessels, incorporated into the vessel design, than retrofitted into existing vessels. Because of the complexity of noise control, it is important that persons having expertise in shipboard noise control be consulted particularly throughout the design and construction phases of new vessel construction and before attempting expensive noise controls on existing vessels.

5. No attempt will be made to describe in detail the various means for reducing noise levels on small vessels. Literature such as that listed in references 6.j. thru 10 of enclosure (9) should be researched for this information. However, the following is a partial list of several methods, most of which are discussed in enclosure (7), which should be considered:

- maximizing distances and providing buffer spaces (voids, tanks, etc.) between accommodation and machinery spaces;
- room isolation, e.g. floating decks and resiliently suspended bulkheads and deckheads;

- resilient mounting of all vibrating machinery;
- effective noise barrier around high noise spaces, to prevent noise transmission to adjacent spaces, and sound absorbing material around high noise spaces, to reduce contribution of reverberant noise within the space;
- flexibly mounting exhaust, ventilation and other service lines;
- insuring that all fit-ups are tight and that all penetrations through spaces are sealed;
- silencers or attenuators on air intakes and exhaust;
- sound absorbtion treatment of accommodation spaces;
- use of low noise components, e.g. hydraulic pumps with low fluid-borne noise levels.

6. The use of room isolation is expensive and can possibly present stability problems by affecting a vessel's center of gravity. However, the results in reducing noise levels can be dramatic. Now that better techniques are being refined and standardized, room isolation should be given serious consideration.

7. The use of resilient mounts on main propulsion engines can also have dramatic results in reducing transmission of noise through the structure to outside spaces. They do however, present substantial problems for shaft alignment and maintenance and in most cases require use of flexible couplings. At the present time the use of resilient mounts for main propulsion engines may not be feasible on many vessels. However, the technology is certainly feasible and should be developed by the industry.

8. The technology for reducing noise on small vessels is feasible; much is already developed. There is an immediate need for an industry forum for guiding this technological development and providing standards and information which could then be disseminated back to the industry. It is believed that if enough interest were expressed to an appropriate technical society a committee would be established to perform this function.

Enclosure (9) to NVC 12-82

2 JUN 1982

REFERENCES

1. "Study of Airborne Noise on Merchant Ships", performed for U.S. Coast Guard by U.S. Naval Ocean Systems Center (NOSC), San Diego, CA. Five volumes: NOSC technical documents #243 (NTIS/AD-A075 356), 254 (NTIS/AD-A075 000/0), #257 (NTIS/AD-A075 001/8), and #267 (NTIS/AD-A080 631/5) and technical report #405 (NTIS/AD-A075 002/6). Available through the National Technical Information Service (NTIS), Springfield, VA 22161, Tel. 703-557-4650.

2. "Code On Noise Levels On Board Ships," International Maritime Organization (IMO) Resolution A.468 (XII); after it is published this code will be available through: New York Nautical Instrument and Service Corp., 140 W. Broadway, New York, N.Y. 10013, Tel. 212-962-4650.

3. "Noise Control In Ships," handbook, 1976, NTNF Report B.0930.4502.1 Norwegian Council for Technical and Scientific Research (NTNF), Gaustadalleen 30, Blindern, Oslo 3, Norway. Available through: Selvig's Publishing House, Ltd., Oslo, Norway.

4. "Noise Abatement On Ships," Report 118, 1976, The Swedish Maritime Research Center, Box 24001, S40022 Gothenburg, Sweden.

5. "SNAME Design Guide for Shipboard Airborne Noise Control", (scheduled for publication in summer 1982) Society of Naval Architects and Marine Engineers, Publications Division, 1 World Trade Center, Suite 1369, New York, NY 10048; Tel. (212) 432-0310.

6. The following references, reports and other literature are available from Det norske Veritas at this address: Det norske Veritas, Chrysler Building, 49th Floor, 405 Lexington Ave., New York, NY 10017; Tel. (212) 697-2056:

   a. "Acoustical Planning In Ship Design," E. Brubakk.
   b. "Noise Prediction and Planning In Ships," A.C. Nilsson, Rpt. No. 78-030.
   c. "Controlling the Noise Problem - Prediction, Measurement and Remedies," pamphlet.
   d. "Prediction of Vibration at the Design Stage - Excitation and Response," pamphlet.
   e. "Prevention of Harmful Vibration In Ships," 2nd Ed. (1982).
   f. "Handbook of Vibration Control In Ships," (1982).
   g. "Propeller Induced Hull Plate Vibration," A.C. Nilsson (1980).
   h. "Propeller Induced Noise In Ships", Nilsson, Persson and Tyvand, SNAME Symposium (1981).
   i. "Modelling Aspects for Finite Element Analysis of Ship Vibration," Computers and Structure, Skaar & Carlsen (1980) Vol. 12, pp. 409-419.
   j. "Noise Control On Small Ships," E. Brubakk, paper presented at Inter-Noise 1979.

7. "Feasible Noise Levels In Accommodation of Vessels Engaged In Towing," a report for the Ministry of Transport, Canada, by Jackson-Talbot and Associates Ltd. Available through: Hull Inspection and Standards Div., Canadian Coast Guard, Tower A, Transport Canada Building, Place de Ville, Ottawa, Ontario K1A 0N7. COST: $25.00.

8. "Noise Control On Diesel Tugs - A Sequel," by T. R. Dyer and B. Lundgaard; presented to Pacific Northwest Section of the Society of Naval Architects and Marine Engineers, November 1, 1980; available though SNAME, See reference (e) for address.

9. "Sound Attenuation - Towboats," Steven Roik, Chairman, Council of Marine Carriers Sound Committee; presented at the British Columbia Towboat Industry Conference, March 1981.

10. "Design Practices for Silencing Diesel Powered Small Boats," NAVSEA 0902-035-1010.

11. "Compendium of Materials for Noise Control," NIOSH, DHEW (NIOSH) Pub. No. 80-116, May 1980. Available through: Superintendent of Documents, Government Printing Office, Washington, D.C. 20402; Stock #017-033-00359-9; Cost: $9.00.

12. "List of Personal Hearing Protectors and Attenuation Data," NIOSH, HEW Pub. No. 76-120. Available through: National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161, ph. 703-557-4650; Stock No. PB 267 461, Cost: $7.50.

13. A list of approximately 20 films on hearing and hearing protection, produced by both manufacturers and professional organizations, is available upon request from E.A.R. Division, Cabot Corporation, Indianapolis, Indiana, 46268; telephone (317) 872-1111.

14. The following ANSI standards, referenced in this Circular may be ordered from The American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018:

> Specification for Accident Prevention Signs, Z35.1-1972;
> Specification for Sound Level Meters, S1.4-1971(R1976);
> Specification for Personal Noise Dosimeters, S1.25-1978;
> Methods for Measurement of Sound Pressure Levels, S1.13-1971(R1976);
> Method for Physical Measurement of Sound, S1.2-1962(R1976).

15. "Acoustics-Measurement of Noise On Board Vessels", International Organization for Standardization, ISO Standard 2923 - 1975(E); can be ordered through ANSI (see reference 14).