an assessment of occupational exposure to noise in the european oil industry (1989-1999)

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ABSTRACT

Daily personal noise exposure data available from member companies for European oil industry work environments (refinery, product distribution and others) were collected and analysed. Comparisons are made with historical data and with current EU exposure limits. The impact of a possible lowering of exposure limits is examined.

KEYWORDS

noise, daily personal noise exposure, occupational noise exposure

CONTENTS

SUMMARY

This review involved the collection, collation and analysis of available full shift noise exposure data obtained by CONCAWE member companies in the period 1989-1999 and provides up-to-date exposure information for both refinery and non-refinery job activities in the European oil industry.

The refinery data suggest a modest improvement in the noise exposure situation since the previous CONCAWE review, published in report 90/53. However, they also confirm that, in the absence of hearing protection, the level of 85 dB(A) $L_{EP,d}$ is still exceeded in many cases, particularly for on-site operators, some readings being above 90 dB(A) $L_{EP,d}$.

The non-refinery data were fewer in number, but covered a wide range of job activities, including oil product distribution, lube blending, airfield refuelling and LPG bottling. Although recorded exposure levels were generally lower than in refineries, the 85 dB(A) $L_{EP,d}$ level was exceeded in a number of cases, with a few readings above 90 dB(A), in particular for airport operators and shipping.

Overall, the review confirms the on-going need for the implementation of effective hearing conservation programmes and it provides some evidence of the extent to which more stringent noise exposure limits would impact on the current exposure situation.

1. INTRODUCTION

Current legislation concerning the prevention of occupational noise-induced hearing loss in the Member States of the European Union is based on a 1986 Directive [1]. A new draft European health and safety at work directive, which included occupational exposure to noise, has been proposed [2]. This incorporates a threshold level of 75 dB(A) $L_{EP,d}$ for daily personal exposure to noise and several action levels, above which noise reduction measures would need to be taken.

In order to assess the impact on oil industry operations of any proposed changes to the current occupational exposure limits for noise which may arise from revisions to EU legislation, CONCAWE initiated the collection, collation and analysis of available full shift noise exposure data obtained by member companies between 1989-1999 in order to gain a clear understanding of the present noise exposure situation in the European oil industry.

The data collection exercise was carried out to update and extend information provided in CONCAWE Report 90/53, entitled 'An Assessment of Occupational Exposure to Noise in Western European Refineries' [3], which covered the period 1982-1988 to determine whether any trends in occupational exposure to noise could be detected. This previous report was limited to noise exposure in the refinery environment whereas the present review has been extended to include noise exposure associated with the entire oil industry downstream operations, i.e.:

- refineries
- fuel distribution terminals
- retail service stations
- LPG facilities
- airport refuelling operations
- lubricant and grease blending and packaging plants

The scope includes not only operational activities but also jobs such as maintenance tasks and laboratory work. The noise control strategies which may be necessary for compliance purposes are not considered in this report.

The data collection and analysis are part of a wider CONCAWE programme relating to noise and hearing conservation in the European oil industry. The other objectives of the CONCAWE programme are:

- to determine the incidence of noise-induced hearing loss in European oil refineries [4];
- to examine and understand the scientific basis for a threshold exposure level for noise-induced hearing loss [5].

2. CURRENT EU NOISE EXPOSURE LIMITS

The Council Directive (86/188/EEC) on the protection of workers from the risks related to exposure to noise [1], which laid down noise exposure limits, required EU Member States to introduce legislation before 1 January, 1990.

The Directive specified that action is required where *daily personal noise exposure* ($L_{EP,d}$), normalised to 8 hours, exceeds the following limit values:

Above 85 dB(A) $L_{EP,d}$ (sometimes referred to as the First Action Level) employer duties include the provision of:

- adequate personal ear protectors;
- a hearing check (in accordance with national law and practice);
- adequate information and training about the risks to hearing arising from noise exposure and the measures that should be taken to minimise the risks.

Above 90 dB(A) $L_{EP,d}$ (sometimes referred to as the Second Action Level) additional employer duties include:

- implementation of a programme of measures for noise exposure reduction;
- marking of areas as ear protection zones with appropriate signs;
- ensuring that personal ear protectors are actually used by the workers.

All these measures are also applicable where the peak sound pressure is likely to exceed 200 Pascals (140 dB re 20 μPa).

It should be noted that the *daily personal noise exposure* does not take account of the attenuating effect of any personal hearing protection used.

The proposed threshold level of 75 dB(A) $L_{EP,d}$ for personal exposure to noise included in the draft European Directive published in 1994, would represent a very substantial reduction in the current exposure limit values.

3. METHODOLOGY OF DATA COLLECTION

CONCAWE devised and issued two proformas so that member companies would record and forward their noise exposure measurements in a common format. These are shown in **Appendix 1**. Companies were requested to indicate the actual method utilised for the derivation of the individual noise exposure data (expressed as $L_{EP,d}$) and, where possible, to record the data to 1 decimal point.

The preferred method for determining noise exposure was the use of personal noise dosimeters, calibrated before and after each period of measurement and many of the results submitted were obtained using this approach. The dosimeter microphones were attached to the lapel or collar of workers and, therefore, took no account of any hearing protection that was being worn. Measurement procedures were consistent with good industrial hygiene practice, for example, as recommended in the CONCAWE guidelines for conducting personal noise dosimetry [6].

Some exposure data were also derived from the results of noise level measurements and a knowledge of the duration of exposure, provided that they were considered to be indicative of personal noise exposure.

All the exposure measurements reported in this study were made using the A-weighted scale.

The vast majority of the exposure data was collected over 8-hour sampling periods. Where data were collected over a longer period, e.g. 10 or 12 hours, member companies were requested to normalise the data to an 8-hour day. As such, the data take into account different shift schedules and are representative of the average levels of noise in the work areas and of the exposure time.

4. NOISE EXPOSURE RESULTS

14 member companies submitted over 2600 full shift noise exposure measurements from 24 work locations across Europe.

The individual noise exposure data were submitted to CONCAWE according to the job group/task inventory shown in **Appendix 2** and, consistent with normal practice, the results did not take into account the use of any hearing protection. More than 1850 or 70% of the measurements were related to refinery activities and the remainder, over 700, were from a wide range of other downstream, i.e. non-refinery, activities.

For each job group the median value and the 10- and 90-percentile values were computed. These have been plotted in **Figure 1**. The median value allows to compare job groups, whereas the range from the 10- to the 90-percentile is indicative of the degree of variability of the exposures within a job group. Descriptive statistics for each job group are also provided in **Table 1**.

Table 1 Descriptive statistics of noise exposure data in European downstream oil industry, 1989 - 1999

Activity code	Job group	Number of results	Noise Exposure Data (dB(A), $L_{EP,d}$)				
			Minimum	10^{th} percentile	Median	90^{th} percentile	Maximum
1.1	Refinery on-site operators	1193	38.0	79.3	85.9	94.0	118.6
1.2	Refinery off-site operators	118	66.9	77.0	81.6	89.5	104.9
1.3	Refinery main-tenance workers	516	65.2	77.0	84.0	93.0	112.0
1.4	Refinery laboratory technicians	12	68.5	69.8	78.5	83.4	85.0
1.7	Refinery utilities operators	36	71.2	83.2	87.8	94.1	98.1
2.1.1-4	Road tanker drivers	212	70.0	76.0	83.8	89.0	99.0
2.1.6	Road distribution terminal workers	53	72.9	80.1	83.7	87.2	87.8
2.1.8	Road distribution terminal maintenance	50	71.0	78.1	83.1	87.5	94.7
2.3	Ship personnel	34	76.0	80.0	87.0	102	108
2.4	LPG gas bottling operators	25	80.0	82.4	85.0	91.2	93.0
4.1	Airport operators	55	79.9	82.0	86.0	89.0	99.0
8.2	Lubes blending plant and packaging operators	142	74.8	78.6	82.8	86.1	87.6

For each category, tables have been compiled to allow a distribution of the noise exposure data to be examined as a function of each individual job activity by determining the **number and percentage of results** for the noise exposure bands less than 75, 75 to 80, 80 to 85, 85 to 90, 90 to 95 and over 95 dB(A) $L_{EP,d}$.

Furthermore, to allow an assessment of the impact of the current and possible future occupational noise exposure limits to be made, tables have also been compiled showing the **cumulative number and cumulative percentage of results** <75, <80, <85, <90, <95 and $\geq$95 dB(A) $L_{EP,d}$.

Where the number of measurements for some job categories was limited, the exposure data for similar job groups were combined together to form broader job categories in order to allow some meaningful degree of statistical analysis. However, where there were sufficient exposure results for a particular job group, the data for the 10-year period of this review were further split into consecutive periods of 3-4 years to allow an evaluation of the exposure trends over time.

4.1. REFINERY DATA

For refinery activities, noise exposure data were submitted for five job groups, namely on-site operators, off-site operators, maintenance workers, laboratory technicians and utilities operators. The distribution of the results for these activities as a function of the noise exposure bands is shown in **Appendix 3** and the cumulative distribution of the same data is presented in **Appendix 4**.

For many job groups in refining, noise exposure measurements have been conducted regularly since 1989. Therefore, it has been possible to sub-divide the results into narrower time bands, namely 1989-1992, 1993-1995 and 1996-1999, in order to examine the trends in exposure to noise over time.

Charts have been produced for on-site operators, off-site operators and maintenance workers to examine any visible trends in the distribution of noise exposure data for these job groups (**Figures 2** to **4**).

In addition, summary tables have been produced for the same three job groups to illustrate the percentage of results which were below 85 dB(A) $L_{EP,d}$ and below 90 dB(A) $L_{EP,d}$, sometimes referred to as the First and Second Action Levels, and those that exceeded 90 dB(A) $L_{EP,d}$. These are shown in **Tables 2 to 4** below. No account was taken of the use of any personal ear protectors.

Table 2 Refinery On-site Operators – Noise Exposure Data Distribution (1989 – 1999) – percentage of total measurements

		Noise Exposure, dB(A) $L_{EP,d}$		
Time period	No. of Results	<85	<90	$\geq$90
1989-92	477	40.3%	74.0%	26.0%
1993-95	328	40.2%	78.4%	21.6%
1996-99	388	46.4%	78.6%	21.4%

Table 3 Refinery Off-site Operators - Noise Exposure Data Distribution (1989 – 1999) – percentage of total measurements

		Noise Exposure, dB(A) $L_{EP,d}$		
Time period	No. of Results	<85	<90	≥90
1989-92	42	54.8%	83.3%	16.7%
1993-95	45	84.4%	93.3%	6.7%
1996-99	31	83.9%	100%	0%

Table 4 Refinery Maintenance Workers - Noise Exposure Data Distribution (1989 – 1999) – percentage of total measurements

		Noise Exposure, dB(A) $L_{EP,d}$		
Time period	No. of Results	<85	<90	≥90
1989-92	204	46.6%	75.0%	25.0%
1993-95	161	59.0%	87.6%	12.4%
1996-99	151	56.3%	82.8%	17.2%

4.2. NON-REFINERY DATA

For non-refinery activities, noise exposure data were submitted for a wide range of job groups within downstream operations. These covered road and rail distribution terminals, marine/shipping, LPG operations, aviation, research and development and lube blending facilities, including oil and grease blending and packaging operations. The distribution of the results for these activities as a function of the noise exposure bands is shown in **Appendices 5** and **6**.

Whilst the number of measurements is less than for refining, sufficient data were available to analyse exposures for distribution road tanker drivers, blending plant and packaging operators in lube blending facilities and for airport operators. **Figures 5** to **7** illustrate the trends in noise exposure for these job groups.

In addition, summary tables have been produced for the same three job groups to illustrate the percentage of results which were below 85 dB(A) $L_{EP,d}$ and below 90 dB(A) $L_{EP,d}$, sometimes referred to as the First and Second Action Levels, and those that exceeded 90 dB(A) $L_{EP,d}$. These are shown in **Tables 5 to 7** below. No account was taken of the use of any personal ear protectors.

Table 5 Distribution Terminals - Road Tanker Drivers - Noise Exposure Data Distribution (1989 – 1999) – percentage of total measurements

		Noise Exposure, dB(A) $L_{EP,d}$		
Time period	No. of Results	<85	<90	≥90
1996-99	212	59.9%	91.5%	8.5%

Table 6 Lube Blending Facilities - Blending and Packaging Operators - Noise Exposure Data Distribution (1989 – 1999) – percentage of total measurements

		Noise Exposure, dB(A) $L_{EP,d}$		
Time period	No. of Results	<85	<90	≥90
1989-92	45	77.8%	100%	0%
1993-95	12	91.7%	100%	0%
1996-99	126	81.7%	100%	0%

Table 7 Airports - Refuelling Operators - Noise Exposure Data Distribution (1989 – 1999) – percentage of total measurements

		Noise Exposure, dB(A) $L_{EP,d}$		
Time period	No. of Results	<85	<90	≥90
1989-92	16	18.8%	93.8%	6.2%
1993-95	19	42.1%	89.5%	10.5%
1996-99	20	30.0%	90.0%	10.0%

5. DISCUSSION

The available measurements, used in this report, were provided by member companies and may not have been collected originally with the purpose of providing a truly representative sample of workers' daily personal noise exposures. It is customary for the determination of occupational exposure to focus on job groups with potentially higher exposures. Therefore the collected data probably provide a slightly worse picture of European downstream oil industry workers daily personal noise exposures than would have been obtained with a sampling strategy based on random monitoring.

5.1. REFINERY DATA

A large number of noise measurements were submitted for most refinery activities. This allowed a detailed analysis of the exposure data for on-site operators, off-site operators and maintenance workers to be made. Taking no account of any hearing protection worn, the analyses indicated:

- On-site operators: 40% of the results below 85 dB(A) $L_{EP,d}$, and 20% in excess of 90 dB(A) $L_{EP,d}$
- Off-site operators: 80% of the results below 85 dB(A) $L_{EP,d}$, and 10% in excess of 90 dB(A) $L_{EP,d}$
- Maintenance workers: 65% of the results below 85 dB(A) $L_{EP,d}$, and 15% in excess of 90 dB(A) $L_{EP,d}$
- With the exception of laboratory technicians, less than 10% of the results for all job groups were below 75 dB(A) $L_{EP,d}$.

The introduction of new technologies, such as the use of headset ear muffs which incorporate radio communication earphones inside the muffs and lip microphones, is becoming more common for certain 'noisy jobs', particularly in refineries. Whilst hearing protection devices are likely to have an effect on the amount of noise energy which reaches the inner ear, an assessment of their impact is outside the scope of this study.

5.2. NON-REFINERY DATA

Although fewer measurement results were submitted for noise exposures associated with the downstream non-refinery activities there is still a reasonable basis for analysis. Adequate information is available for:

- Distribution terminals, particularly road tanker drivers for whom 40% of the results exceeded 85 dB(A) $L_{EP,d}$
- Lube blending facilities, for which most of the results were below 85 dB(A) $L_{EP,d}$
- Airport operators, for which about 70% of the results exceeded 85 dB(A) $L_{EP,d}$
- Marine activities, for which more than 60% of the results exceeded 85 dB(A) $L_{EP,d}$
- LPG bottling, for which over 50% of the results exceeded 85 dB(A) $L_{EP,d}$.

6. CONCLUSIONS

The collection and analysis of noise exposure data from member companies for the period 1989-1999 has provided a clearer view of the present noise exposure situation in the European oil industry. The analysis has provided an indication of the extent of exposure in relation to the current EU noise exposure limits and also to possible future, more stringent limit and action values for daily personal exposure to noise.

The noise exposure results, which do not take into account any hearing protection that is worn, indicate that daily exposure to noise for the majority of refining and some non-refining job activities associated with the downstream oil industry is likely to exceed 85 dB(A) $L_{EP,d}$ and sometimes is in excess of 90 dB(A) $L_{EP,d}$. The results, therefore, reinforce the ongoing need for effective hearing conservation programmes to ensure that the risk to hearing from occupational exposure to noise is controlled.

6.1. REFINERY DATA

An analysis of the available refinery noise exposure data for the three groups of workers for whom there was a large number of results suggested a very modest reduction in exposure for on-site operators and maintenance personnel, and a much more significant reduction for off-site operators. For this latter job group, enquiries to member companies have indicated that automation of valves and pumps and consequent reduced presence in high-noise areas was among the main reasons for the reduction in noise exposure. These conclusions necessarily encompass a wide spectrum of circumstances for the individual refineries in Europe.

Comments from member companies have indicated that the noise environment has improved at some refineries, for example as a result of the shutdown of some process areas. Some other refineries, which have increased in capacity or commissioned new plants, have reported similar or increased noise levels in the workplace, despite the increasing focus on noise control at the design stage.

6.2. NON-REFINERY DATA

Despite the improvements in road tanker and cab design, a significant number of measurements on road tanker drivers indicated that exposure to noise is likely to exceed 85 dB(A) $L_{EP,d}$.

There are indications of a decrease in noise exposure for marine/shipping activities, a relatively unchanged noise exposure situation for airport operators, and an increase in noise exposure associated with LPG gas bottling, which can possibly be attributed to an increase in throughput. However, in all these cases the number of available measurement results is too low to provide definitive conclusions.

For lubes operations, it appears that exposure may have slightly increased for blending and packaging, whereas in oil filling and pre-blending activities the exposure has been reduced.

7. REFERENCES

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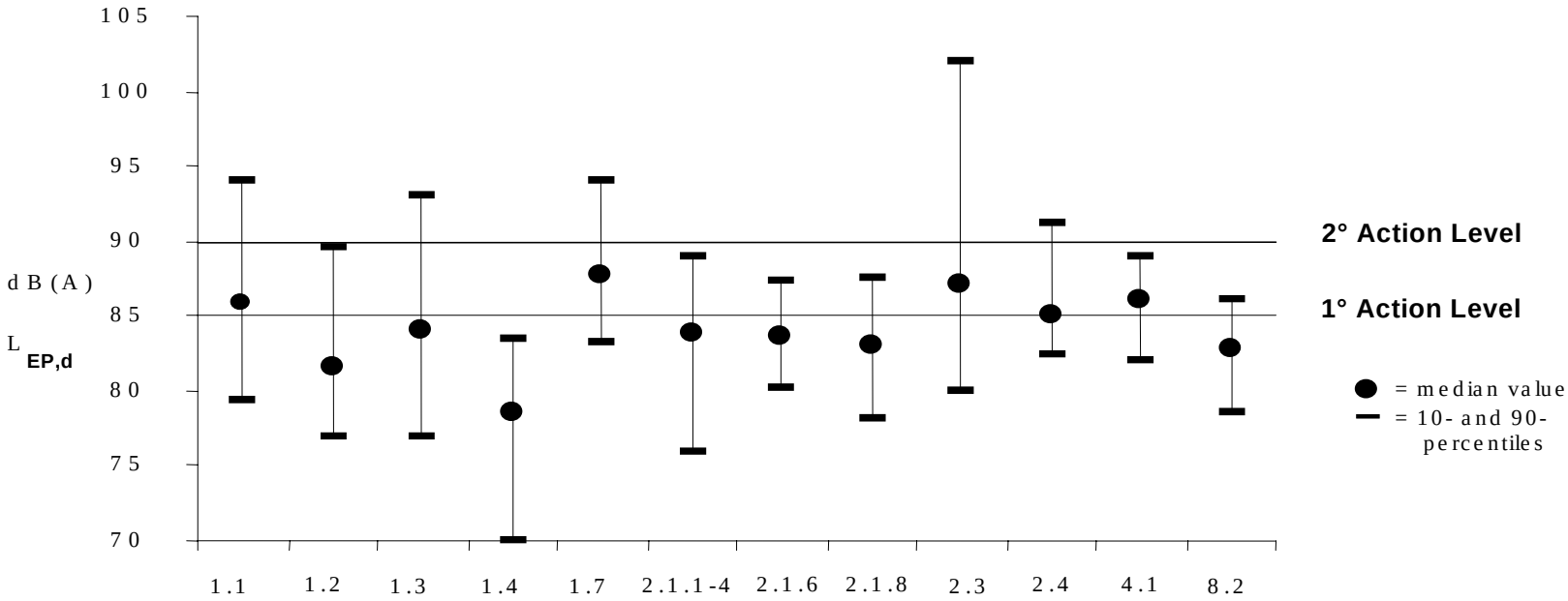
4. CONCAWE (2000) A review of trends in hearing thresholds of European oil refinery workers. Report No. 00/55. Brussels: CONCAWE

5. CONCAWE (2001) A noise exposure threshold value for hearing conservation. Report No. 01/52. Brussels: CONCAWE

6. CONCAWE (1984) Workshop on personal noise dosimetry. Report No. 3/84. Brussels: CONCAWE

Figure 1

PERSONAL DAILY NOISE EXPOSURES FOR SELECTED JOB TITLES IN EUROPEAN DOWNSTREAM OIL INDUSTRY OPERATIONS, 1989-1999



1.1	Refinery on-site operators	2.1.6	Road distribution terminal workers
1.2	Refinery off-site operators	2.1.8	Road distribution terminal maintenance
1.3	Refinery maintenance workers	2.3	Ship distribution personnel
1.4	Refinery lab workers	2.4	LPG bottling operators
1.7	Refinery utilities workers	4.1	Airport refuelling operators
2.1.1-4	Road tanker drivers	8.2	Lubes packaging operators

Figures 2 - 4 Distribution of Refinery Noise Exposure Measurements ($L_{EP,d}$ dB(A))

Figure 2

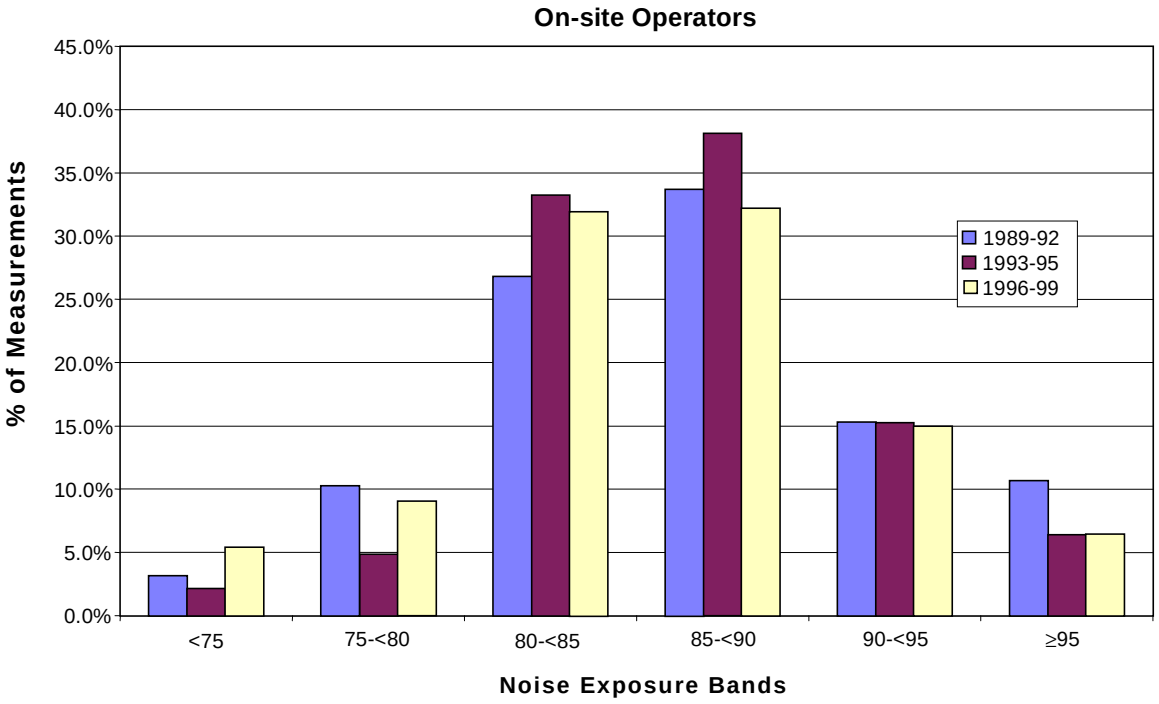


Figure 3

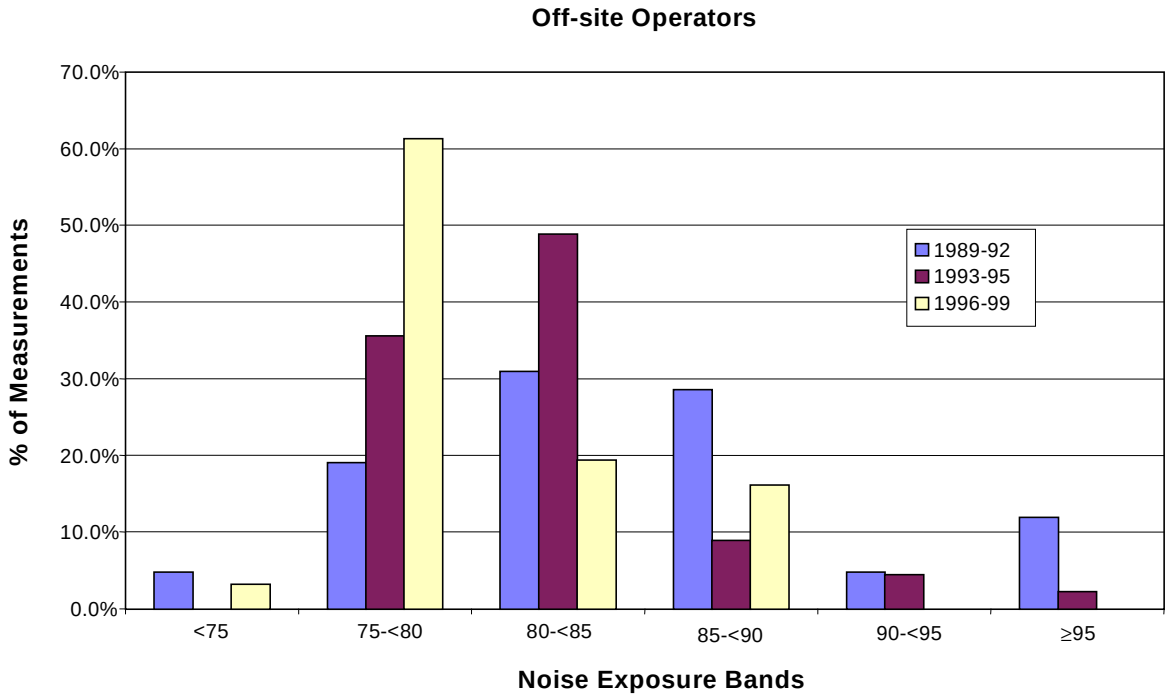
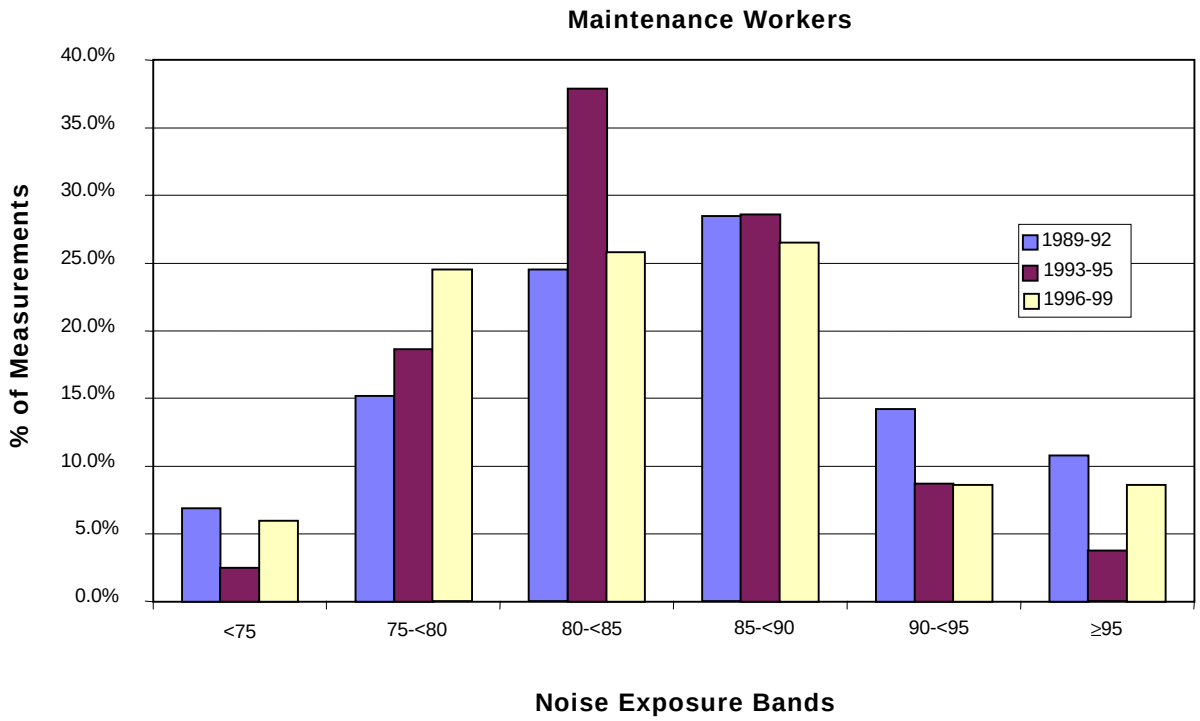


Figure 4



Figures 5 - 7 Distribution of Non-Refinery Noise Exposure Measurements ($L_{EP,d}$ dB(A))

Figure 5

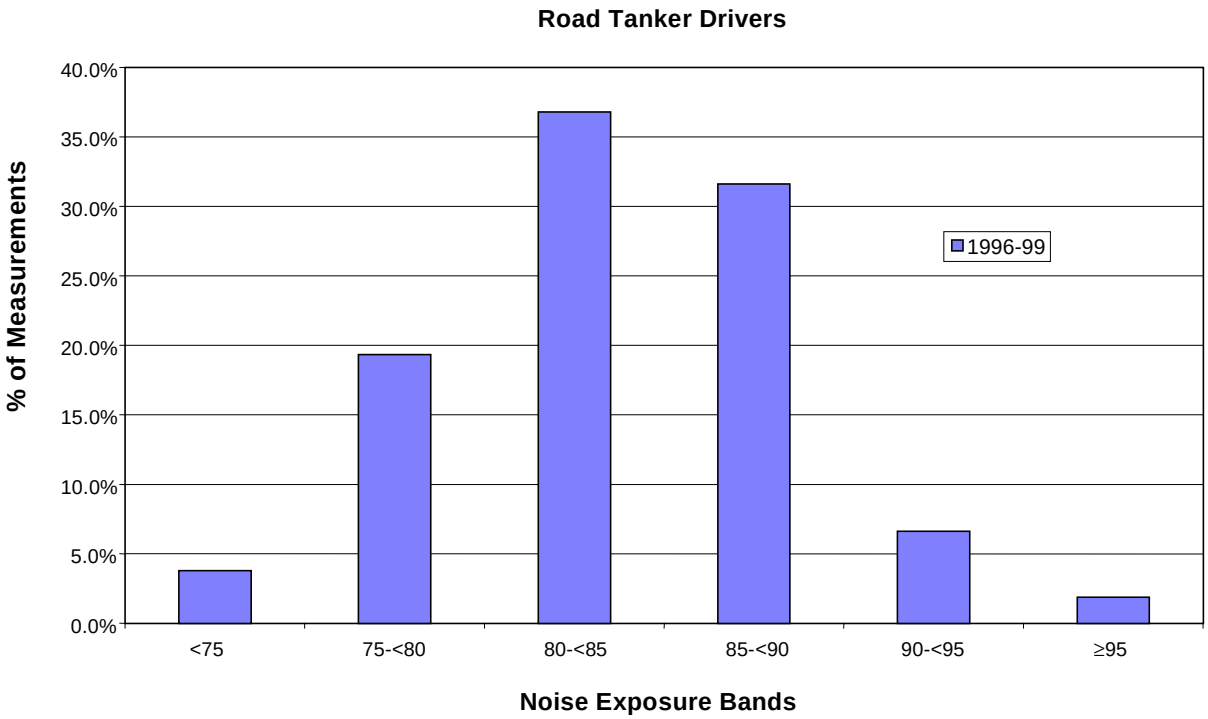


Figure 6

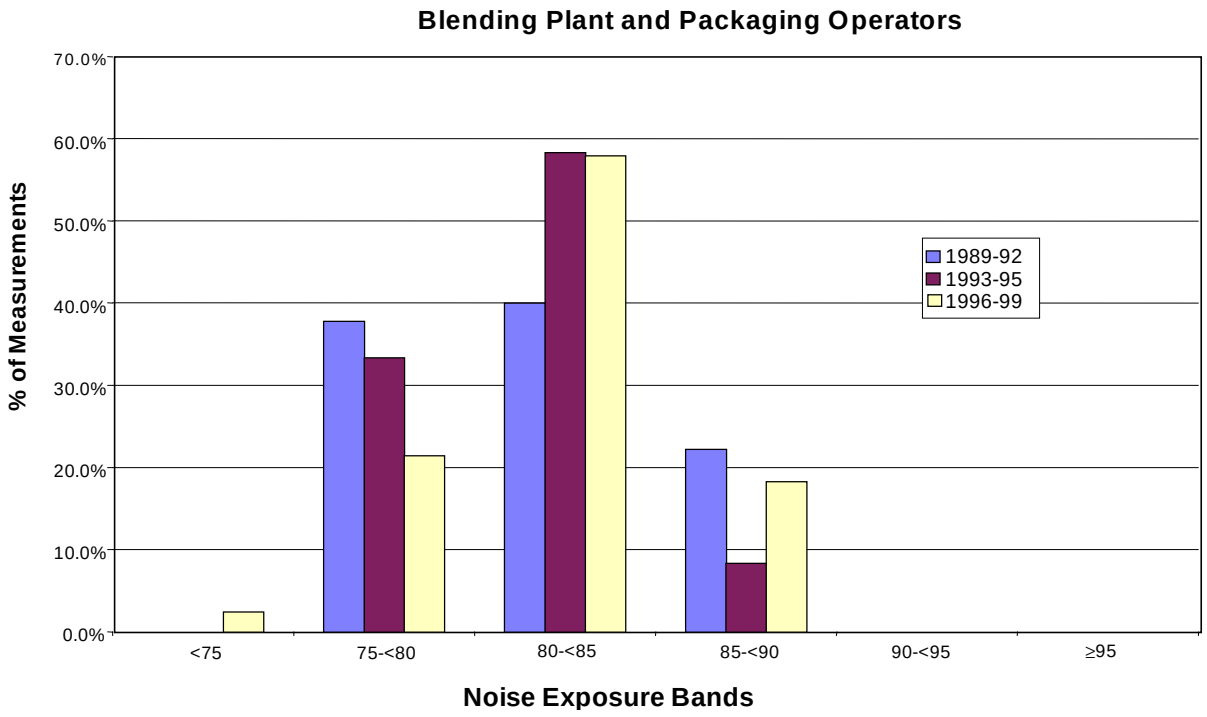
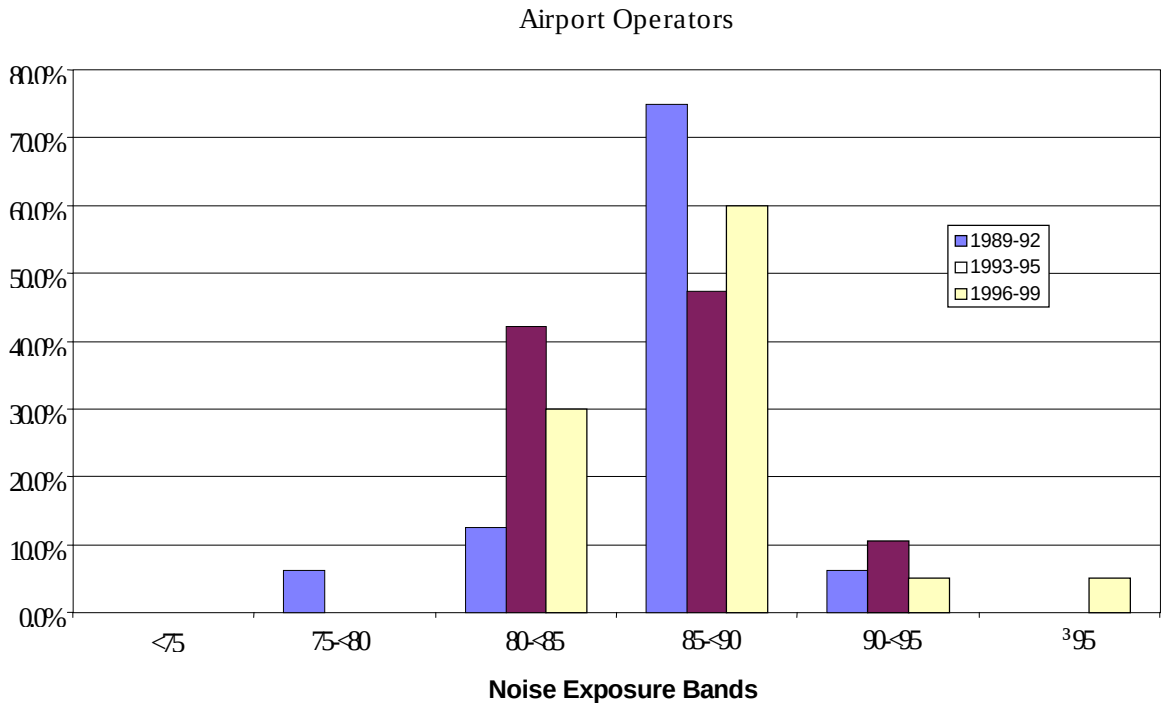


Figure 7



APPENDIX 1: CONCAWE PROFORMA FOR THE SUBMISSION OF NOISE EXPOSURE DATA

Proforma 1. Individual Noise Exposure Measurements - Refining

Company: ……..

Location: ……..

Date of Survey	Activity Code (Appendix 2)	Noise Dosimetry Yes/No (Note 1)	Plant or Work area (Note 2)	Noise Exposure ($L_{EP,d}$) (Note 3)	Measurement Period 12 hr/8 hr (Note 4)	Number of Workers in Job Group (Note 5)	Comments/Additional Information (Note 6)

Notes for Proforma 1

Note 1. If measurements were not obtained using personal noise dosimeters please specify method used in the Comments column.

Note 2. If working in dedicated plant area choose from the following:-

	Refinery Plant		**Refinery Plant**		**Refinery Plant**
1	Crude Distillation	7	Alkylation	13	Other Maintenance
2	Vacuum Distillation	8	Isomerization	14	Laboratory
3	Visbreaker	9	Sulphur Plant	15	Offsite
4	Catalytic Cracker	10	Lube Plant	16	Vehicle Drivers
5	Catalytic Reformer	11	Utilities	17	Coking Unit
6	Hydrotreater	12	Water Treatment	18	Other

Note 3. This is the daily total personal exposure to noise at work normalised to an 8-hour day. It takes account of the average levels of noise in working areas and the time spent in them, but takes no account of any ear protectors worn.
$L_{EP,d}$ (measured using the "A" weighted scale) is ideally derived from measurements using personal noise dosimeters. Sound level meter measurements taken in the vicinity of the ear, together with estimates of exposure time, can however be used to estimate personal noise exposure. Either will be accepted for this exercise.

Note 4. If 8 hour measurement see **Note 3**. If a 12 hour measurement indicate whether it has been adjusted to represent an 8 hour $L_{EP,d}$

Note 5. The number of workers in the same Job Group working at the location where the survey was undertaken.

Note 6. Examples of the type of information required includes:-

- was it routine or non-routine work (e.g. shut down) during the survey period?
- was it part of your scheduled noise exposure programme or "worst case" situation?
- was hearing protection worn?
- what were the major sources of exposure e.g. compressors, fin fan coolers?

Proforma 2. Individual Noise Exposure Measurements - Non Refining

Company: ……..

Location: ……..

Date of Survey (Appendix2)	Activity Code (Note 1)	Noise Dosimetry Yes/No (Note 2)	Plant or Work area (Note 3)	Noise Exposure ($L_{EP,d}$) (Note 4)	Measurement Period 12 hr/8 hr (Note 5)	Number of Workers in Job Group (Note 6)	Comments/Additional Information

Notes for Proforma 2

Note 1. If measurements were not obtained using personal noise dosimeters please specify method used.

Note 2. If the subject is working in dedicated plant area or process e.g. “maintenance” use this column to indicate location e.g. motor repair workshop. If the subject has no dedicated Job Type please indicate his/her MAIN Job Type.

Note 3. This is the daily total personal exposure to noise at work normalised to an 8-hour day. It takes account of the average levels of noise in working areas and the time spent in them, but takes no account of any ear protectors worn.
$L_{EP,d}$ (measured using “A” weighted scale) is ideally derived from measurements using personal noise dosimeters. Sound level meter measurements taken in the vicinity of the ear, together with estimates of exposure time, can however be used to estimate personal noise exposure. Either from of exposure assessment will be accepted for this exercise.

Note 4. If 8 hour measurement see **Note 3**. If a 12 hour measurement indicate whether it has been adjusted to represent an 8 hour $L_{EP,d}$

Note 5. The number of workers in the same Job Type working at the location where the survey was undertaken.

Note 6. Examples of the type of information required includes:-

- was it routine or non-routine work (e.g. shut down) during the survey period?
- was it part of your scheduled noise exposure programme or “worst case” situation?
- was hearing protection worn?
- what were the major sources of exposure e.g. compressors, fin fan coolers?

APPENDIX 2: JOB GROUPS IN DOWNSTREAM OIL INDUSTRY OPERATIONS

Activity Code	Job Group	Description of Tasks
1.	**REFINERY**	
1.1	On-site operators	Carry out tasks such as valve and pump operation, checking temperatures and pressure gauges, check safe operation of plant, sample collection.
1.2	Off-site operators	Carry out tasks in tank farms (e.g. dipping / sampling) and water effluent treatment plants.
1.3	Maintenance workers	Carry out tasks such as draining, cleaning, opening up and working on equipment, maintenance & repair to valves, pumps and gauges.
1.4	Laboratory technicians	Carry out analyses (quality control checks) on refinery streams and products. May conduct research and octane rating tests.
1.5	Tank cleaners	Clean out sludge from bulk storage tanks.
1.6	Miscellaneous	For example, multi-skilled refinery operator.
1.7	Utilities operators	Operate power plant, steam plant.
2.	**DISTRIBUTION**	
2.1	**Road Tanker Terminal**	
2.1.1	Drivers: Top loading	Fill own vehicles via top submerged loading. Deliver gasoline, gas oils, fuel oils etc. to retail service stations and customers.
2.1.2	Drivers: Bottom loading	Fill own vehicles via bottom loading (without vapour recovery). Deliver gasoline, gas oils, fuel oils etc. to retail service stations and customers.
2.1.3	Drivers: Bottom loading	Fill own vehicles via bottom loading (with vapour recovery). Deliver gasoline, gas oils, fuel oils etc. to retail service stations and customers.
2.1.4	Drivers: Other category	Involves delivery only, driving and delivery, or loading / driving / delivery where it is not known if loading was by top or bottom filling.
2.1.5	Rack operators	Fill road tanker vehicles for drivers (normally top submerged loading).
2.1.6	Supervisors / terminal operators	Supervise road tanker filling.
2.1.7	Drum / barrel fillers	Fill 200 l drums with gasoline, gas oils etc.
2.1.8	Maintenance	Maintain and repair loading equipment, pumps, valves.
2.1.9	Miscellaneous	Other activities not described elsewhere.

Appendix 2. *Continued*

Activity Code	Job Group	Description of Tasks
2.2	**Rail Car Terminals**	
2.2.1	Operators: Top loading	Fill rail cars via top submerged loading. (without vapour recovery).
2.2.2	Operators: Top loading	Fill rail cars via top submerged loading. (with vapour recovery).
2.2.3	Operators: Bottom loading	Fill rail cars via bottom loading (without vapour recovery).
2.2.4	Operators: Bottom loading	Fill rail cars via bottom loading (with vapour recovery).
2.2.5	Operators: Off-loading	Off-load product to storage (includes hose connection / disconnection and sampling).
2.2.6	Maintenance	Maintain and repair loading equipment, pumps, valves etc.
2.2.7	Miscellaneous	Other activities not described elsewhere.
2.3	**Marine/Shipping (product carrier, coastal craft, barge)**	
2.3.1.1	Deck crew: Open loading	Fill ships with the cargo hatches open. Specific tasks include connection / disconnection of cargo lines, checking tank fill levels, tank dipping.
2.3.1.2	Deck crew: Unloading	Transfer product from ship to land-based facility. Specific tasks include connection / disconnection of cargo lines, checking tank fill levels, tank dipping.
2.3.2	Deck crew: Closed loading	Fill ships with the cargo hatches closed and displaced vapours discharged remotely; ullage measurements are read automatically.
2.3.3	Deck crew: Closed loading of barges	Similar to ships / closed loading; however, decks of barges are generally flatter and vapour vents may be at lower level.
2.3.4	Bridge crew	Exposure arises as a result of gas-freeing / venting and overseeing (un)loading activities of deck crew.
2.3.5	Jetty staff	Supervise cargo loading operations, including sampling, tank dipping and the connection / handling of hoses.
2.3.6	Miscellaneous	Other activities not described elsewhere.
2.4	**LPG Operations**	
2.4.1	Gas bottling	Fill variety of sizes of LPG cylinders / containers.

Appendix 2. *Continued*

Activity Code	Job Group	Description of Tasks
3.	**SERVICE STATIONS**	
3.1.1	Service station attendants (without vapour recovery)	Fill customers vehicles with gasoline or diesel; also exposed to ambient air concentrations in and around the service station.
3.1.2	Service station attendants (with vapour recovery)	Fill customers vehicles with gasoline or diesel; also exposed to ambient air concentrations in and around the service station.
3.2	Cashiers	Cashier duties during which the cashiers are exposed to ambient concentrations of vapour in the service station shop.
3.3	Service station mechanics	Repair and service vehicles in premises located near the service station forecourt.
3.4	Petrol pump maintenance	Carry out in-situ pump maintenance on the forecourt (exposure to residual fuel).
3.5	Miscellaneous	Other activities not described elsewhere.
4.	**AVIATION / AIRPORTS**	
4.1	Airport operators	Carry out bottom loading of road tankers and the over-wing filling of light aircraft.
4.2	Yard staff	Carry out the fuel testing for water, meter proving, filter cleaning and meter servicing, and tank ullaging.
7.	**RESEARCH AND DEVELOPMENT**	
7.1	Research chemists	Carry out experiments with oil products and additives to develop novel products or enhance the performance of existing products.
7.2	Engine testing technicians	Conduct research and octane rating tests. May conduct testing of engine oil lubricants and fuel products according to standard engine tests protocols.
7.3	Laboratory technicians	Carry out analyses of petroleum products. Blending of products and additives.
8.	**LUBES BLENDING FACILITIES**	
8.1	Blending plant operators	Carry out blending of lubricating oils and additives in vessels and mixing tanks to produce lubricants such as engine oils and gear oils. Conduct routine checks to ensure safe operation of plant. Collect samples.
8.2	Packaging operators	Work in automated filling lines. 1 litre to 25 litre containers are filled with product and packaged for shipping.
8.3	Oil filling / pre-blending	Do preparatory filling of blending vessels and mixing tanks. May fill off 200 litre barrels and semi-bulk containers.
8.4	Grease plant / production	Carry out blending of lubricating oils and additives in vessels and mixing tanks to produce greases. Conduct routine checks around the plant to ensure safe operation. Collect samples.

APPENDIX 3: REFINERY ACTIVITIES 1989-99: DISTRIBUTION OF PERSONAL NOISE EXPOSURE DATA

Activity Code	Job Group	Year	Data Format	Noise Exposure, dB(A) $L_{EP,d}$						Number of Results
				<75	75 - <80	80 - <85	85 - <90	90 - <95	≥95	
1.1	On-site operators	1989-92	% of Results	3.1%	10.3%	26.8%	33.8%	15.3%	10.7%	**477**
		1993-95	% of Results	2.1%	4.9%	33.2%	38.1%	15.2%	6.4%	**328**
		1996-99	% of Results	5.4%	9.0%	32.0%	32.2%	14.9%	6.4%	**388**
1.2	Off-site operators	1989-92	% of Results	4.8%	19.0%	31.0%	28.6%	4.8%	11.9%	**42**
		1993-95	% of Results	0.0%	35.6%	48.9%	8.9%	4.4%	2.2%	**45**
		1996-99	% of Results	3.2%	61.3%	19.4%	16.1%	0.0%	0.0%	**31**
1.3	Maintenance workers	1989-92	% of Results	6.9%	15.2%	24.5%	28.4%	14.2%	10.8%	**204**
		1993-95	% of Results	2.5%	18.6%	37.9%	28.6%	8.7%	3.7%	**161**
		1996-99	% of Results	6.0%	24.5%	25.8%	26.5%	8.6%	8.6%	**151**
1.4	Laboratory technicians	1989-92	% of Results	25.0%	50.0%	25.0%	0.0%	0.0%	0.0%	**4**
		1993-95	% of Results	25.0%	25.0%	50.0%	0.0%	0.0%	0.0%	**4**
		1996-99	% of Results	0.0%	25.0%	50.0%	25.0%	0.0%	0.0%	**4**
1.7	Utilities operators	1989-92	% of Results	4.5%	0.0%	22.7%	59.1%	4.5%	9.1%	**22**
		1993-95	% of Results	0.0%	0.0%	12.5%	0.0%	75.0%	12.5%	**8**
		1996-99	% of Results	0.0%	0.0%	16.7%	50.0%	33.3%	0.0%	**6**
							Total Number of Results:			**1875**

APPENDIX 4: REFINERY ACTIVITIES 1989-99: CUMULATIVE DISTRIBUTION OF PERSONAL NOISE EXPOSURE DATA

Activity Code	Job Group	Year	Data Format	Noise Exposure, dB(A) $L_{EP,d}$						Number of Results
				<75	<80	<85	<90	<95	≥95	
1.1	On-site operators	1989-92	Cumulative % of Results	3.1%	13.4%	40.3%	74.0%	89.3%	10.7%	**477**
		1993-95	Cumulative % of Results	2.1%	7.0%	40.2%	78.4%	93.6%	6.4%	**328**
		1996-99	Cumulative % of Results	5.4%	14.4%	46.4%	78.6%	93.6%	6.4%	**388**
1.2	Off-site operators	1989-92	Cumulative % of Results	4.8%	23.8%	54.8%	83.3%	88.1%	11.9%	**42**
		1993-95	Cumulative % of Results	0.0%	35.6%	84.4%	93.3%	97.8%	2.2%	**45**
		1996-99	Cumulative % of Results	3.2%	64.5%	83.9%	100.0%	100.0%	0.0%	**31**
1.3	Maintenance workers	1989-92	Cumulative % of Results	6.9%	22.1%	46.6%	75.0%	89.2%	10.8%	**204**
		1993-95	Cumulative % of Results	2.5%	21.1%	59.0%	87.6%	96.3%	3.7%	**161**
		1996-99	Cumulative % of Results	6.0%	30.5%	56.3%	82.8%	91.4%	8.6%	**151**
1.4	Laboratory technicians	1989-92	Cumulative % of Results	25.0%	75.0%	100.0%	100.0%	100.0%	0.0%	**4**
		1993-95	Cumulative % of Results	25.0%	50.0%	100.0%	100.0%	100.0%	0.0%	**4**
		1996-99	Cumulative % of Results	0.0%	25.0%	75.0%	100.0%	100.0%	0.0%	**4**
1.7	Utilities operators	1989-92	Cumulative % of Results	4.5%	4.5%	27.3%	86.4%	90.9%	9.1%	**22**
		1993-95	Cumulative % of Results	0.0%	0.0%	12.5%	12.5%	87.5%	12.5%	**8**
		1996-99	Cumulative % of Results	0.0%	0.0%	16.7%	66.7%	100.0%	0.0%	**6**
							Total Number of Results:			**1875**

APPENDIX 5: NON-REFINERY ACTIVITIES 1989-99: DISTRIBUTION OF PERSONAL NOISE EXPOSURE DATA

Activity Code		Job Group	Year	Data Format	Noise Exposure, dB(A) Lep,d						Number of Results
					<75	75 - <80	80 - <85	85 - <90	90 - <95	>95	
2. DISTRIBUTION 2.1 Road Tanker Terminals	2.1.1-4	Road Tanker Drivers *	1996-99	% of Results	3.8%	19.3%	36.8%	31.6%	6.6%	1.9%	**212**
	2.1.6	Supervisors/terminal Operators	1996-99	% of Results	1.9%	7.5%	56.6%	34.0%	0.0%	0.0%	**53**
	2.1.8	Maintenance	1989-92	% of Results	0.0%	0.0%	66.7%	33.3%	0.0%	0.0%	**3**
			1996-99	% of Results	2.1%	17.0%	53.2%	25.5%	2.1%	0.0%	**47**
2.2 Rail Car Terminals	2.2.1&5	Operators *	1993-95	% of Results	0.0%	0.0%	0.0%	33.3%	33.3%	33.3%	**3**
			1996-99	% of Results	7.7%	15.4%	53.8%	15.4%	7.7%	0.0%	**13**
2.3 Marine/Shipping	2.3.1-3 2.3.5	Deck crews * Jetty staff	1989-92	% of Results	0.0%	7.1%	7.1%	35.7%	7.1%	42.9%	**14**
			1996-99	% of Results	0.0%	11.8%	35.3%	23.5%	5.9%	23.5%	**20**
2.4 LPG Operations	2.4.1	Gas bottling	1993-95	% of Results	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	**1**
			1996-99	% of Results	0.0%	0.0%	45.8%	37.5%	16.7%	0.0%	**24**
4. AVIATION	4.1	Airport operators	1989-92	% of Results	0.0%	6.3%	12.5%	75.0%	6.3%	0.0%	**16**
			1993-95	% of Results	0.0%	0.0%	42.1%	47.4%	10.5%	0.0%	**19**
			1996-99	% of Results	0.0%	0.0%	30.0%	60.0%	5.0%	5.0%	**20**
7. RESEARCH & DEVELOPMENT	7.2	Engine testing technicians	1996-99	% of Results	20.0%	20.0%	20.0%	40.0%	0.0%	0.0%	**5**
8. LUBE BLENDING FACILITIES	8.1 8.2	Blending plant operators Packaging operators	1989-92	% of Results	0.0%	37.8%	40.0%	22.2%	0.0%	0.0%	**45**
			1993-95	% of Results	0.0%	33.3%	58.3%	8.3%	0.0%	0.0%	**12**
			1996-99	% of Results	2.4%	21.4%	57.9%	18.3%	0.0%	0.0%	**126**
	8.3	Oil filling/pre-blending	1989-92	% of Results	0.0%	20.8%	54.2%	4.2%	12.5%	8.3%	**24**
			1996-99	% of Results	19.2%	19.2%	35.9%	19.2%	5.1%	1.3%	**78**
	8.4	Grease plant/production	1993-95	% of Results	7.7%	0.0%	46.2%	38.5%	7.7%	0.0%	**13**
		* Includes combined Job Groups						**Total Number of Results:**			**748**

APPENDIX 6: NON-REFINERY ACTIVITIES 1989-99: CUMULATIVE DISTRIBUTION OF PERSONAL NOISE EXPOSURE DATA

Activity Code		Job Group	Year	Data Format	Noise Exposure, dB(A) $L_{EP,d}$						Number of Results
					<75	<80	<85	<90	<95	>95	
2. DISTRIBUTION 2.1 Road Tanker Terminals	2.1.1-4	Road Tanker Drivers *	1996-99	Cumulative % of Results	3.8%	23.1%	59.9%	91.5%	98.1%	1.9%	**212**
	2.1.6	Supervisors/terminal operators	1996-99	Cumulative % of Results	1.9%	9.4%	66.0%	100.0%	100.0%	0.0%	**53**
	2.1.8	Maintenance	1989-92	Cumulative % of Results	0.0%	0.0%	66.7%	100.0%	100.0%	0.0%	**3**
			1996-99	Cumulative % of Results	2.1%	19.1%	72.3%	97.9%	100.0%	0.0%	**47**
2.2 Rail Car Terminals	2.2.1&5	Operators *	1993-95	Cumulative % of Results	0.0%	0.0%	0.0%	33.3%	66.7%	33.3%	**3**
			1996-99	Cumulative % of Results	7.7%	23.1%	76.9%	92.3%	100.0%	0.0%	**13**
2.3 Marine/Shipping	2.3.1-3 2.3.5	Deck crews * Jetty staff	1989-92	Cumulative % of Results	0.0%	7.1%	14.3%	50.0%	57.1%	42.9%	**14**
			1996-99	Cumulative % of Results	0.0%	10.0%	40.0%	60.0%	70.0%	30.0%	**20**
2.4 LPG Operations	2.4.1	Gas bottling	1993-95	Cumulative % of Results	0.0%	0.0%	100.0%	100.0%	100.0%	0.0%	**1**
			1996-99	Cumulative % of Results	0.0%	0.0%	45.8%	83.3%	100.0%	0.0%	**24**
4. AVIATION	4.1	Airport operators	1989-92	Cumulative % of Results	0.0%	6.3%	18.8%	93.8%	100.0%	0.0%	**16**
			1993-95	Cumulative % of Results	0.0%	0.0%	42.1%	89.5%	100.0%	0.0%	**19**
			1996-99	Cumulative % of Results	0.0%	0.0%	30.0%	90.0%	95.0%	5.0%	**20**
7. RESEARCH & DEVELOPMENT	7.2	Engine testing technicians	1996-99	Cumulative % of Results	20.0%	40.0%	60.0%	100.0%	100.0%	0.0%	**5**
8. LUBE BLENDING FACILITIES	8.1 8.2	Blending plant operators Packaging operators	1989-92	Cumulative % of Results	0.0%	37.8%	77.8%	100.0%	100.0%	0.0%	**45**
			1993-95	Cumulative % of Results	0.0%	33.3%	91.7%	100.0%	100.0%	0.0%	**12**
			1996-99	Cumulative % of Results	2.4%	23.8%	81.7%	100.0%	100.0%	0.0%	**126**
	8.3	Oil filling/pre-blending	1989-92	Cumulative % of Results	0.0%	20.8%	75.0%	79.2%	91.7%	8.3%	**24**
			1996-99	Cumulative % of Results	19.2%	38.5%	74.4%	93.6%	98.7%	1.3%	**78**
	8.4	Grease plant/production	1993-95	Cumulative % of Results	7.7%	7.7%	53.8%	92.3%	100.0%	0.0%	**13**
								Total Number of Results:			**748**

* Includes combined Job Groups