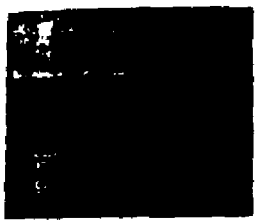
EPRI
Electric Power
Research Institute

Topics:
PCB
Chemical analysis
Transformers
Capacitors
PCDF-PCDD
Insulating oil

EPRI EL/EA-5443
Volume 1
Project 2028-7
Final Report
October 1987



Analysis of Polychlorinated Dibenzofurans and Polychlorinated Dibenzo-*p*-Dioxins in Transformers and Capacitors

Volume 1: PCDF/PCDD at New York State Health Department

Prepared by
New York State Department of Health
Albany, New York

MONS 218328

REPORT SUMMARY

SUBJECTS: Hazardous and toxic waste management / Transmission substation design and operation / Distribution substations

TOPICS:
- PCB
- Chemical analysis
- Transformers
- Capacitors
- PCDF-PCDD
- Insulating oil

AUDIENCE: Environmental managers / Distribution engineers

Analysis of Polychlorinated Dibenzofurans and Polychlorinated Dibenzo-*p*-Dioxins in Transformers and Capacitors

Volumes 1-3

PCDF and PCDD—by-products of PCB pyrolysis and combustion—apparently cause many of the health effects originally attributed to PCB. In parallel and round-robin studies, independent laboratories found that normal equipment operation and arcing failure cause little if any oxidation and do not significantly modify PCB fluids.

BACKGROUND: Partial oxidation of askarels—mixtures of polychlorinated biphenyls (PCB) and tri- and tetrachlorobenzenes—produces polychlorinated dibenzofurans (PCDF) and polychlorinated dibenzo-*p*-dioxins (PCDD). However, analytic techniques for separating the active components in these mixtures had not matured prior to this study. Information had also been insufficient on the quantity and types of PCDF and PCDD in as-manufactured PCB and on the formation of these by-products during normal operation or arcing failure in utility equipment. Because of these uncertainties, utilities and regulators have assumed the worst-case PCDF-PCDD formation when there is a PCB-related accident, thereby overstating the potential toxicity. EPRI report EL/EA-4858 describes portions of the research performed in these projects.

OBJECTIVE: To improve techniques for measuring PCDF/PCDD in the presence of PCB.

APPROACH: Five laboratories (including two whose studies are discussed in report EL/EA-4858) performed round-robin gas chromatography–mass spectrometry analyses of PCDF-PCDD samples using specially prepared carbon-13 (^{13}C) PCDF spiking compounds. After the first set of analyses, each laboratory modified its techniques and analyzed a larger group of samples from utility equipment. Another organization statistically analyzed all the laboratory results.

RESULTS: These three volumes report the second group of PCDF-PCDD analyses. Results from all participating laboratories correlated remarkably well. Some of the results follow.

MONS 218329

- Use of the ^{13}C compounds allowed successful separation of the components in several closely eluting pairs of physiologically active PCDF and less-active compounds.

- Analyses of samples from utility equipment suggested that the PCDF-PCDD present did not result from high-load, high-temperature operation.

Volumes 1 and 2 describe several analytic techniques, with the appendix of Volume 2 including a report on the analysis by the University of Umeå in Sweden, as well. Volume 3 summarizes all the laboratory techniques, presents comprehensive statistical analyses, and provides an executive summary.

EPRI PERSPECTIVE

This research is a landmark in PCDF-PCDD analysis. One important result is the synthesis of new PCDFs for use as spiking compounds in gas chromatography-mass spectrometry analysis. The ability to separate many of the active PCDF compounds from more innocuous materials is also of great value. The high correlation of results from several laboratories indicates that researchers can exercise great flexibility in selecting techniques and developing facilities.

PROJECTS

RP2028-7, RP2028-6, RP2028-10
EPRI Project Managers: Gil Addis; Jacques Guertin
Electrical Systems Division; Environment Division
Contractors: New York State Department of Health; Battelle Columbus Laboratories; Research Triangle Institute

For further information on EPRI research programs, call EPRI Technical Information Specialists (415) 855-2411.

MONS 218330

Analysis of Polychlorinated Dibenzofurans and Polychlorinated Dibenzo-*p*-Dioxins in Transformers and Capacitors

Volume 1: PCDF/PCDD at New York State Health Department

EL/EA-5443, Volume 1
Research Project 2028-7

Final Report, October 1987

Prepared by

NEW YORK STATE DEPARTMENT OF HEALTH
Wadsworth Center for Laboratories and Research
Corning Tower
The Governor Nelson A. Rockefeller Empire State Plaza
Albany, New York 12201

Principal Investigators
D. R. Hilker
G. A. Eadon
K. M. Aldous
R. M. Smith
P. W. O'Keefe
H. Valente
S. Connor
J. Jurusik

Prepared for

Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, California 94304

EPRI Project Managers
G. Addis

Transmission Substations Program
Electrical Systems Division

J. Guertin
Land and Water Quality Studies Program
Environment Division

MONS 218331

ORDERING INFORMATION

Requests for copies of this report should be directed to Research Reports Center (RRC), Box 50490, Palo Alto, CA 94303, (415) 965-4081. There is no charge for reports requested by EPRI member utilities and affiliates, U.S. utility associations, U.S. government agencies (federal, state, and local), media, and foreign organizations with which EPRI has an information exchange agreement. On request, RRC will send a catalog of EPRI reports.

Electric Power Research Institute and EPRI are registered service marks of Electric Power Research Institute, Inc.

Copyright © 1987 Electric Power Research Institute, Inc. All rights reserved.

NOTICE

This report was prepared by the organization(s) named below as an account of work sponsored by the Electric Power Research Institute, Inc. (EPRI). Neither EPRI, members of EPRI, the organization(s) named below, nor any person acting on behalf of any of them: (a) makes any warranty, express or implied, with respect to the use of any information, apparatus, method, or process disclosed in this report or that such use may not infringe privately owned rights; or (b) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report.

Prepared by
New York State Department of Health
Albany, New York

MONS 218332

ABSTRACT

Seven samples of in-service utility fluids were analyzed for nineteen different polychlorinated dibenzofuran (PCDF) and polychlorinated dibenzo-p-dioxin (PCDD) compounds. After spiking with five different ^{13}C-labeled internal standards, the samples were chromatographically simplified (semi-automated). Analyses were conducted with high resolution gas chromatography-mass spectrometry (GC-MS) using a 50-m DB-5 or an OV-225 fused-silica capillary column. Generated calibration plots for eight different individual compounds were linear over four orders of magnitude concentrations. Analyses in triplicate provided some insight on reproducibility of method.

Spiked samples were analyzed with an average error of 28.9%, indicating that for the chosen analytes in this type of oily matrix, the method was quite reproducible and accurate. The relative standard deviation was less than 30% for more than 92% of the analyte determinations. In general, the study showed that the samples of in-service utility fluids have considerably different PCDF-PCDD profiles. Maximum concentrations of tetrachlorodibenzofuran (TCDF) and tetrachlorodibenzo-p-dioxin (TCDD) were 1.2 and 0.001 mg/kg, respectively. Maximum concentrations of octachlorodibenzofuran (OCDF) and octachlorodibenzo-p-dioxin (OCDD) were 40 and 0.02 mg/kg, respectively. And two fluids contained barely detectable quantities of any PCDD or PCDF (maximum concentration: 0.003 mg/kg).

MONS 218333

CONTENTS

Section		Page
1	INTRODUCTION	1-1
2	METHODS	2-1
	In-Service Fluid Samples	2-1
	PCDD and PCDF Standards	2-1
	Sample Extraction and Extract Preparation	2-2
	High Resolution Capillary Gas Chromatography/Low Resolution Mass Spectrometry (HRGC/LRMS)	2-3
	High Resolution Gas Chromatography/High Resolution Mass Mass Spectrometry (HRGC/HRMS)	2-4
3	DISCUSSION	3-1
	Preliminary Baseline Study Data	3-1
	Calibration and Quality Assurance Data	3-2
	Baseline Date	3-5
	In-Service Liquids	3-7
4	REFERENCES	4-1
APPENDIX A	IN-SERVICE LIQUIDS BACKGROUND INFORMATION	A-1
APPENDIX B	ANALYTE CALIBRATION CURVES	B-1
APPENDIX C	ANALYTE RESPONSE FACTOR CURVES	C-1
APPENDIX D	TABLES OF RESULTS	D-1
APPENDIX E	BAR GRAPHS OF RESULTS	E-1
APPENDIX F	TABLES OF RECOVERIES, RELATIVE RECOVERIES AND DETECTION LIMITS	F-1

MONS 218334

ILLUSTRATIONS

Figure		Page
2-1	Typical MSD Raw Data	2-4
3-1	Exact Mass Chromatograms Showing the Retention Time Window for TCDD	3-3
3-2	High Resolution Mass Scans & Summaries	3-4
3-3	Interferance in the Determination of 2378-TCDD in Spiked Aroclor 1260	3-10
3-4	High Resolution Mass Chromatogram of Spiked Aroclor 1260	3-11
3-5	High Resolution Mass Data from the 2,3,7,8-TCDD G.C. Peak from the Spiked Aroclor Sample	3-12

MONS 218335

TABLES

Table		Page
2-1	H-P 5890 Gas Chromatograph Temperature Program	2-3
2-2	Carlo-Erba Gas Chromatograph 4160 Temperature Program	2-5

MONS 218336

SUMMARY

Much concern has been attached to the occurrence of polychlorinated dibenzofuran (PCDF) and polychlorinstad dibenzo-p-dioxin (PCDD) in the environment. Several environmental catastrophes were precipitated by the identification and quantitation of these two classes of compounds. 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), one of 210 possible compounds within these classes, is generally regarded ss the most toxic man-made compound. Much of the controversy generated at the Love Canal was a result of finding 2,3,7,8-TCDD. The Faderal government literally purchased the town of Times Beach, Missouri when 2,3,7,8-TCDD was found widely dispersed in the soil. A transformer fire in the State Office Building in Binghamton, New York spread high concentrations of PCDF and PCDD throughout the building's eighteen stories. Consequently, the building has been closed since February 1981 with ongoing cleanup costs of several million dollars.

The Binghamton Office Building disaster helped to emphasize that PCDF and PCDD contamination is a potential utility problem. This unfortunate event and other rasearch revealed that PCDF and PCDO can be found in some transformers as a result of contamination, severe operating conditions, or fire. And hundreds of thousands of Askarel and polychlorinated biphenyl (PCB)-contaminated mineral oil transformars are still in usa in the Unites States.

An obvious alternative to raplacing currently operating elactrical equipment suspected of contamination is to identify the equipment with the greatest environmental concentrations of PCDF and PCOD. This will raquire an understanding of the factors that control the degrae of contamination. It will also be necessary to have accurate methods of measurement. Establishing accurate measurement methods for PCDF and PCOO in PCB matrices is a goal of this study. In addition, the study measures compound-spacific concentrations of PCDF and PCDD in relatively well-known insulating fluids from commonly used electrical equipment. This determines the measuremant precision. Also, this work constitutes part of a largar inter-laboratory study that will provide insight regarding the accuracy and measurement methods for assessing PCDF and PCDD contamination in utility equipment.

MONS 218337

Seven different pieces of electrical equipment (i.e., load center network transformers, capacitors, precipitators, distribution transformers, and arc furnace transformers) were analyzed for nineteen PCDF and PCDD compounds. Historical information such as manufacturer, age, use, and maintenance was collected on each piece of equipment. Prior to analysis, the fluid samples were chromatographically simplified, concentrating the PCDF and PCDD fractions while eliminating interfering compounds. Each fluid sample was prepared in triplicate and each extract was chemically analyzed by gas chromatography-mass spectrometry (GC-MS). In addition, three common insulating fluids (mineral oil, Aroclor 1016, Aroclor 1260) were spiked with known quantities of compounds of interest. Then, these were concentrated and subjected to a similar "cleanup" procedure as used for the samples from the in-service equipment. This latter analytical procedure served as quality control for the analysis of unknown samples.

Spiked samples were analyzed with an average error of 28.9% indicating that for the chosen analytes in this type of matrix, the method was quite reproducible and accurate. The relative standard deviation was less than 30% for more than 92% of the analyte determinations. In general, the study showed that the samples of in-service utility fluids have considerably different PCDF-PCDD profiles. Maximum concentrations of tetrachlorodibenzofuran (TCDF) and tetrachlorodibenzo-p-dioxin (TCDD) were 1.2 and 0.001 mg/kg, respectively. Maximum concentrations of octachlorodibenzofuran (OCDF) and octachlorodibenzo-p-dioxin (OCDD) were 40 and 0.02 mg/kg, respectively. And two fluids contained barely detectable quantities of any PCDD or PCDF (maximum concentration: 0.003 mg/kg).

MONS 218338

Section 1

INTRODUCTION

Considerable interest has been focused on the analysis of various environmental samples for the closely related families of polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). This interest originated with the documented occurrence of the most toxic isomer, 2,3,7,8-tetrachloro-dibenzo-p-dioxin (2,3,7,8-TCDD). This highly toxic species has been detected in Lake Ontario fish (1), in human adipose tissue (2), and turtles (3) , landfills (4) and municipal incinerators (5),(6),(7) and the combustion products of askarels and transformer fluids (8). Rappe has presented a comprehensive review of the occurrance of 2,3,7,8-TCDD and related isomers (9). Increased activity in this area stimulated the availability of pure native (^{12}C) and labelled (^{13}C) PCDD and PCDF compounds for use as analytical standards. This development coincided with investigations of improved compound separation techniques and was driven by the known fact that other PCDD and PCDF compounds have significant toxicity (10),(11),(12),(13).

PCDD and PCDF compounds have been detected in Utility Askarel fluids and combusted or pyrolyzed Utility Askarel fluids (8),(9),(8). The occurrence of these contaminants in dielectric fluids raises several questions. Fundamental to this work is the question, "What are the predominant isomers and their concentrations in utility fluids in equipment now in use?". Once the specific compounds and their concentrations are known the relative health risk posed by continued use of these fluids can be assessed.

To this end seven samples of dielectric fluids from in-service electrical equipment and three baseline samples were analyzed for the presence of 19 different compounds or groups of isomers. The samples were analyzed using five different ^{13}C-labelled internal standards. In all, 13 different standards were synthesized and used for calibration and quantitation. Fourteen different individual PCDD and PCDF compounds were quantitated along with the total concentration of tetra- through hepta-CDF and tetra-CDD congener classes. The determination of each analyte was replicated three times for each sample in order to generate an average concentration, standard deviation of the concentration, and

MONS 218339

percent relative standard deviation (coefficient of variation). Three of the ten fluid samples were spiked with known amounts of individual compounds as a check on the accuracy of this method. Furthermore, the same ten fluid samples were subjected to an interlaboratory round robin analysis. The results of that study will be published elsewhere. Thus, besides providing an initial view of PCDD and PCDF compound concentrations in in-service utility fluids this work represents the most rigorous study of PCDD and PCDF compounds in an environmental matrix.

Section 2

METHODS

IN-SERVICE FLUID SAMPLES

Samples of in-service dielectric fluids were collected by various utilities and shipped to the Battelle Columbus Laboratories. BCL was responsible for accessioning the fluids and developing a catalogue of background information. The type of equipment from which each in-service fluid used in this study was obtained is listed below:

1. 1962 Load Center Network Transformer
2. Load Center Network Transformer
3. Substation Distribution Transformer
4. 1946 Load Center Network Transformer
5. Precipitator
6. 1976 Arc Furnace Transformer
7. Capacitor

A listing of accumulated background information on each of these pieces of equipment is given in Appendix A. In addition three typical virgin dielectric fluids were blindly spiked to test the method accuracy. These fluids were:

1. Mineral oil
2. Aroclor 1016
3. Aroclor 1260

PCDD AND PCDF STANDARDS

PCDD and PCDF standard compounds including ^{13}C-labelled standard compounds were synthesized by Radian Corp., Austin. The standards were dissolved in solvent at the various concentration levels and shipped in sealed glass vials. Seven vials were received each containing all of the following compounds:

2,3,7,8-TCDD	2,3,7,8-TCDD-$^{13}C_{12}$
2,3,7,8-TCDF	2,3,7,8-TCDF-$^{13}C_{12}$
1,2,3,7,8-PnCDF	
2,3,4,7,8-PnCDF	1,2,3,7,8-PnCDF-$^{13}C_{12}$

MONS 218341

1,2,3,4,7,8-HxCDF	
2.3,4,6,7,8-HxCDF	1,2,3,4,7,8-HxCDF-$^{13}C_{12}$
1,2,3,4,6,7,8-HpCDF	
1,2,3,4,6,7,8,9-OCDF	1,2,3,4,6,7,8,9-OCDD-$^{13}C_{12}$

Each vial contained all of the native compounds at one of the following concentration levels:

7,500 ng/ml
2,500 ng/ml
500 ng/ml
150 ng/ml
40 ng/ml
10 ng/ml
2.5 ng/ml

Each standard solution contained all of the ^{13}C-compounds at 500 ng/ml each.

SAMPLE EXTRACTION AND EXTRACT PREPARATION

Samples of electrical insulating fluids and mineral oil dissolved in hexane were received from Radian Corp. in sealed vials. The volume of a portion of each vial was measured and extracted by adding 25 ml of acetone and mixing thoroughly. Hexane (25 ml) was added and the sample was stirred and extracted for a minimum of 1 h. To remove PCBs and nonplanar aromatics and isolate one fraction containing all tetra- to octa-CDF and -CDD the sample extract was chromatographed on acid alumina, PX-21 carbon and neutral alumina. A preprogrammed Hamilton valve control system designed in our lab was used to reproducibly select solvents and chromatographic columns (9). The recovery of all tetra- to octa-CDFs and -CDDs (as verified with available standards) from an individual chromatographic column is >95%.

The sample extract was applied to an activated acidic alumina column, followed by 30 ml of 3% CH_2Cl_2 in hexane. The CDF/CDD fraction was eluted with 70 ml of 50% CH_2Cl_2 in hexane onto a carbon column followed by 50 ml of 10% benzene in hexane. The CDF/CDD fraction was eluted in the reverse direction with 30 ml of 50% xylene in hexane onto a neutral alumina column (replaces xylene with a volatile solvent) followed by 30 ml of 3% CH_2Cl_2 in hexane. The final purified CDF/CDD fraction was eluted with 70 ml of easily volatilized 50% CH_2Cl_2 in hexane and concentrated by heating to 100°C and then vacuum evaporating to 4-10 µl (8). Prior to GC/MS, extracts were stored in the dark in sealed 150 µl borosilicate capillary tubes.

MONS 218342

HIGH RESOLUTION CAPILLARY GAS CHROMATOGRAPHY/LOW RESOLUTION MASS SPECTROMETRY(HRGC/LRMS)

All sample extracts were analyzed with a Hewlett-Packard 5970 Mass Selective Detector. A portion of each extract was injected into the split-splitless injection port(250°C) and eluted through a 50m(0.25mm i.d.;0.33μm film thickness) Hewlett-Packard 5% phenyl methyl silicone fused silica capillary column. The following temperature program was used:

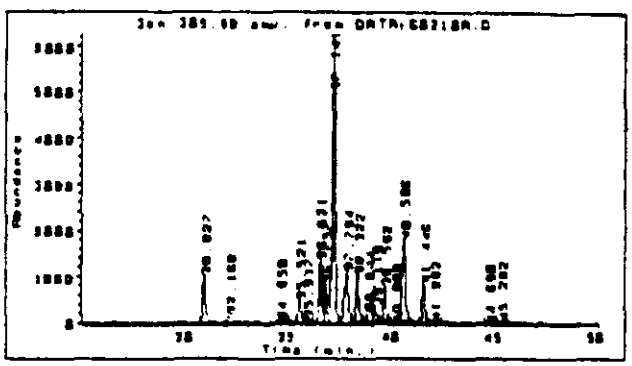
Table 2-1

H-P 5890 GAS CHROMATOGRAPH TEMPERATURE PROGRAM

Level	Initial Temp (°C)	Initial Time (min)	Rate (°C/Min)	Final Temp (°C)	Final Time (min)	Total Time (min)
1	190	1.00	5.0	220	16.00	23.00
2			5.0	235	7.00	33.00
3			5.0	250	18.00	54.00
4			5.0	270	7.00	65.00
5			5.0	300	24.00	95.00

The gas chromatograph was interfaced directly to the source of the mass selective detector and the transfer line and ion source were heated to 275°C and 150°C, respectively. The mass selective detector was operated in the selective ion monitoring (SIM) mode. The m/z values characteristic of native TCDD, TCDF, PnCDF, HxCDF, OCDF and OCDD and TCDD-$^{13}C_{12}$, TCDF-$^{13}C_{12}$, PnCDF-$^{13}C_{12}$, HxCDF-$^{13}C_{12}$ and OCDD-$^{13}C_{12}$ were monitored at various times during the 95 minute runs. The time windows used for monitoring the different congener classes (TCDD, TCDF, etc.) were determined by the previous injection of either window standards (TCDD) or a mixture of combusted PCB. Raw data were collected into and processed by an H-P Quicksilver data system. The data system was used to generate electronic copies of reports of retention times and areas at each m/z value monitored (Figure 2-1). Additional custom software was used to identify G.C. peaks and quantitate analyte levels. This software was written by NYSDOH staff (H. Valente) and runs on an IBM PC or XT. The H-P reports are input in ASCII and transferred by using a

MONS 218343



Mass 305.90 amu

Ret Time	Area
30.827	107155
32.167	22962
34.650	7919
35.521	44916
35.917	8658
36.521	129702
36.757	00014
37.141	500644
37.794	151206
38.322	96838
38.844	30905
39.119	38741
39.562	73974
40.088	2030
40.506	220600
41.446	83751
41.982	12165
44.696	3220
45.282	11243

Figure 2-1: Typical MSD Raw data. The retention time window for TCDF is shown. The Quicksilver data system automatically integrates the gas chromatographic peaks and labels each with its retention time. The list of retention times for each mass monitored is generated by a separate program.

MONS 218344

customized H-P Pascal operating system (sender) and the program called Kermit (receiver).

HIGH RESOLUTION GAS CHROMATOGRAPHY/HIGH RESOLUTION MASS SPECTROMETRY(HRGC/HRMS)

Some extracts were analyzed with a Kratos MS-50 high resolution GC/MS/DS. In this system, portions of the extracts were injected into the on-column injection port of a Carlo-Erba 4160 high resolution gas chromatograph and eluted through a 50m (0.20mm i.d.;0.33um film thickness) Hewlett-Packard 5% methyl phenyl silicone fused silica capillary column. The oven was temperature programmed as follows:

Table 2-2

CARLO-ERBA GAS CHROMATOGRAPH 4160 TEMPERATURE PROGRAM

Level	Initial Temp (°C)	Initial Time (min)	Rate (°C/Min)	Final Temp (°C)	Final Time (min)	Total Time (min)
1	190	1.0	5.0	220	16.00	23.00
2			5.0	235	7.00	33.00
3			5.0	300	50.00	86.00

The gas chromatograph was interfaced to the MS-50 through a direct line heated to 250°C. The ion source temperature was 250°C. The high resolution mass spectrometer was operated in either of two SIM type modes. In normal multiple peak monitoring mode (NMPM), the m/z values of a particular analyte and its corresponding internal standard were observed at 10,000 RP (10% valley) (10) by integrating all the signal detected within 50 ppm of their exact mass values. In high resolution multiple peak monitoring mode (HRMPM) the mass spectrometer is operated at the same high resolving power but the analyte and internal standard exact masses are profiled. The data system adjusts the accelerating and electric sector voltages to focus a mass slightly below the mass of interest. The computer then triggers a 0.3 s analog scan through a 300 ppm section of the mass range which includes the exact mass of the ion of interest (11). In both ion monitoring modes, the raw data were acquired and processed by the Kratos DS-55 data system. Quantitation was done manually by calculating concentrations using peak areas obtained from the DS-55 output.

MONS 218345

Section 3

DISCUSSION

PRELIMINARY BASELINE STUDY DATA

In an initial phase of this project, five fluids were analyzed. These five fluids included the Aroclors 1016, 1242, 1260, tri- and tetrachlorobenzenes, and mineral oil. Each of these fluids was spiked with four ^{13}C-labelled internal standards, i.e. 2,3,7,8-TCDF-$^{13}C_{12}$, 1,2,3,7,8-PnCDF-$^{13}C_{12}$, 2,3,7,8-TCDD-$^{13}C_{12}$, OCDD-$^{13}C_{12}$. Native 1,2,3,4,7,8-HxCDF and 1,2,3,4,6,7,8-HpCDF were also added since the ^{13}C-labelled version of these compounds was not available at the time the samples were prepared. Additionally, one of the fluids, aged mineral oil, was spiked with "blind" levels of certain native PCDD and PCDF compounds and approximately 500 ppm each of Aroclor 1260 and tri- and tetrachlorobenzene and 100 ppb each of 1,2,3,4,7,9-HxCDF, 2,3,4,7,8-PnCDF, 1,2,3,4,8-PnCDF and 2,3,4,8-TCDF. The results of these preliminary analyses are given in Appendix D Tables D-1 and D-2.

The levels of PCDD and PCDF compounds added as a blind spike to the aged mineral oil sample were quantitated with reasonable accuracy. Three of the four compounds spiked were the same compounds as the internal standards used for quantitation. 2,3,7,8-TCDD, 2,3,7,8-TCDF and 1,2,3,7,8-PnCDF were quantitated by comparing the areas for these isomers with 2,3,7,8-TCDD-$^{13}C_{12}$, 2,3,7,8-TCDF-$^{13}C_{12}$, and 1,2,3,7,8-PnCDF-$^{13}C_{12}$ respectively. The percentage error in the determination of the levels of these native isomers was 7.5%, 70% and 0% respectively. Although the level of 1,2,3,7,8-PnCDF is reported as 140 ppb, this includes 100 ppb of 1,2,3,4,8-PnCDF, which had been added. These two isomers were not separated on the SP2330 fused silica capillary column with the conditions that were used. 2,3,4,8-TCDF was added to the mineral oil sample but was not specifically determined. It was detected as part of the total TCDF that was reported (Total TCDF=120 ppb). Thus the percentage error in the determination of Total TCDF(2,3,7,8- and 2,3,4,8-TCDF) is 21%. The determination of 1,2,3,4,7,8-HxCDF (as Total HxCDF) is grossly in error. The total HxCDF added was 220 ppb and 1100 ppb was detected. The HxCDF added by the addition of 500 ppm of Aroclor 1260 and the chlorobenzenes is negligible and does not account for this discrepancy. The

MONS 218346

exact cause of this error is unknown but similar errors have been recorded whenever a compound is determined using an internal standard not of the same congener class. Total PnCDF and total HpCDF were not determined and OCDF was inadvertently destroyed in the clean-up. The spiked Nujol which represents a purified aliphatic hydrocarbon matrix was prepared in this laboratory and provides an additional check on the accuracy of the determinations. All of the compounds added to the aged mineral oil were added to the Nujol. In terms of accuracy the results were similar. In all cases except total HxCDF, the absolute value of the ratio of the difference between the spiked level and the measured level was .90 or less. As before total PnCDF and OCDF levels were not determined.

The results quoted for the Aroclor and chlorobenzene mixtures agree with later determinations of these mixtures (see section on In-service liquids). In general the detection limits for all these results were <1 ppb.

The data in these preliminary experiments were acquired at high resolution using the HRMPM mode of ion monitoring. Typical data are shown in Figures 3-1 and 3-2. The area of the mass peak shown in Figure 3-2 is used to calculate the amount of 2,3,7,8-TCDD. Although least susceptible to interferences, this instrumental technique addresses the largest amount of data and is least automated.

CALIBRATION AND QUALITY ASSURANCE DATA

A calibration curve for each of eight of the analytes of interest was constructed from HRGC/LRMS data. The curve for 2,3,7,8-TCDD is shown in Appendix B Figure 1. The log of the ratio of the area of native 2,3,7,8-TCDD to ^{13}C-labelled TCDD is plotted versus the log of the concentration of native 2,3,7,8-TCDD.

Seven solutions containing concentrations of native 2,3,7,8-TCDD of 2.5, 10, 40, 150, 500, 2500 and 7500 pg/µl and a constant ^{13}C-labelled 2,3,7,8-TCDD concentration of 500 pg/µl were used to construct this curve. The same concentrations of the other analytes and internal standards were used in other curves (Appendix B Figures 2-8). These curves demonstrate a linearity of response of almost four orders of magnitude.

The percentage fit (=100 x (correlation coefficient)^2) of the least squares line in each of the curves constructed with low resolution mass spectrometry data is:

MONS 218347

2,3,7,8-TCDD - 99.7398
2,3,7,8-TCDF - 99.7614
1,2,3,7,8-PnCDF - 99.6357
2,3,4,7,8-PnCDF - 99.0483
1,2,3,4,7,8-HxCDF - 99.7262
2,3,4,6,7,8-HxCDF - 99.3756
1,2,3,4,6,7,8-HpCDF - 99.5848
OCDF - 99.7685

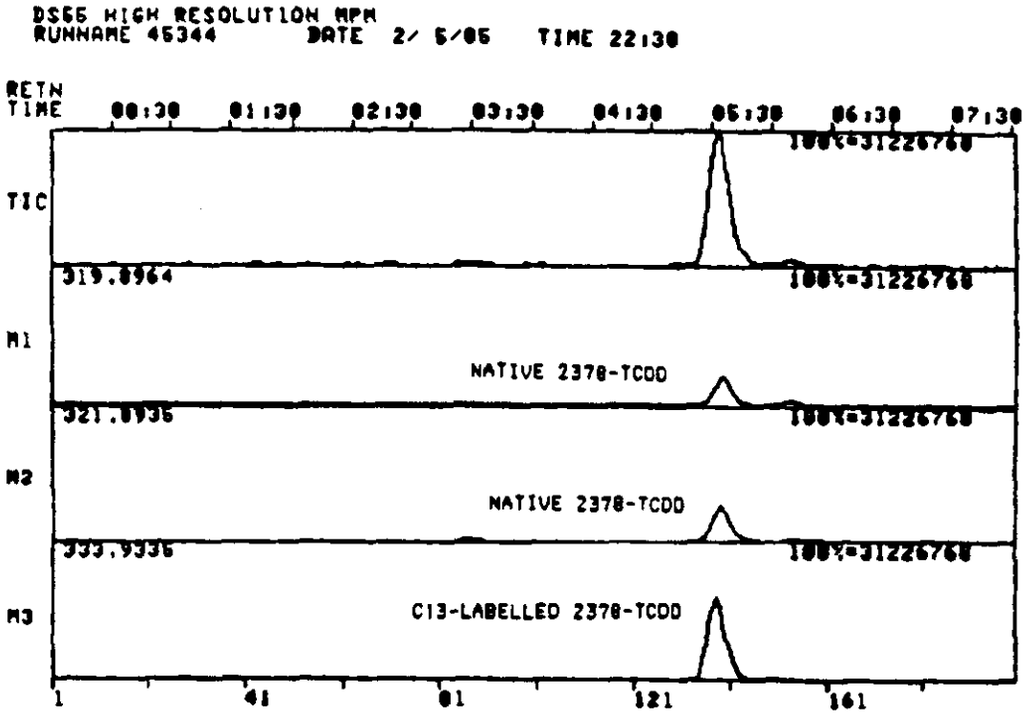


Figure 3-1: Exact Mass Chromatograms showing the retention time window for TCDD. Three 100 mmu. mass windows were monitored one each centered on m/z 321.8936 and m/z 319.8965 respectively for native TCDD and one centered on m/z 333.9338 for $^{13}C_{12}$-labelled-2378-TCDD.

MONS 218348

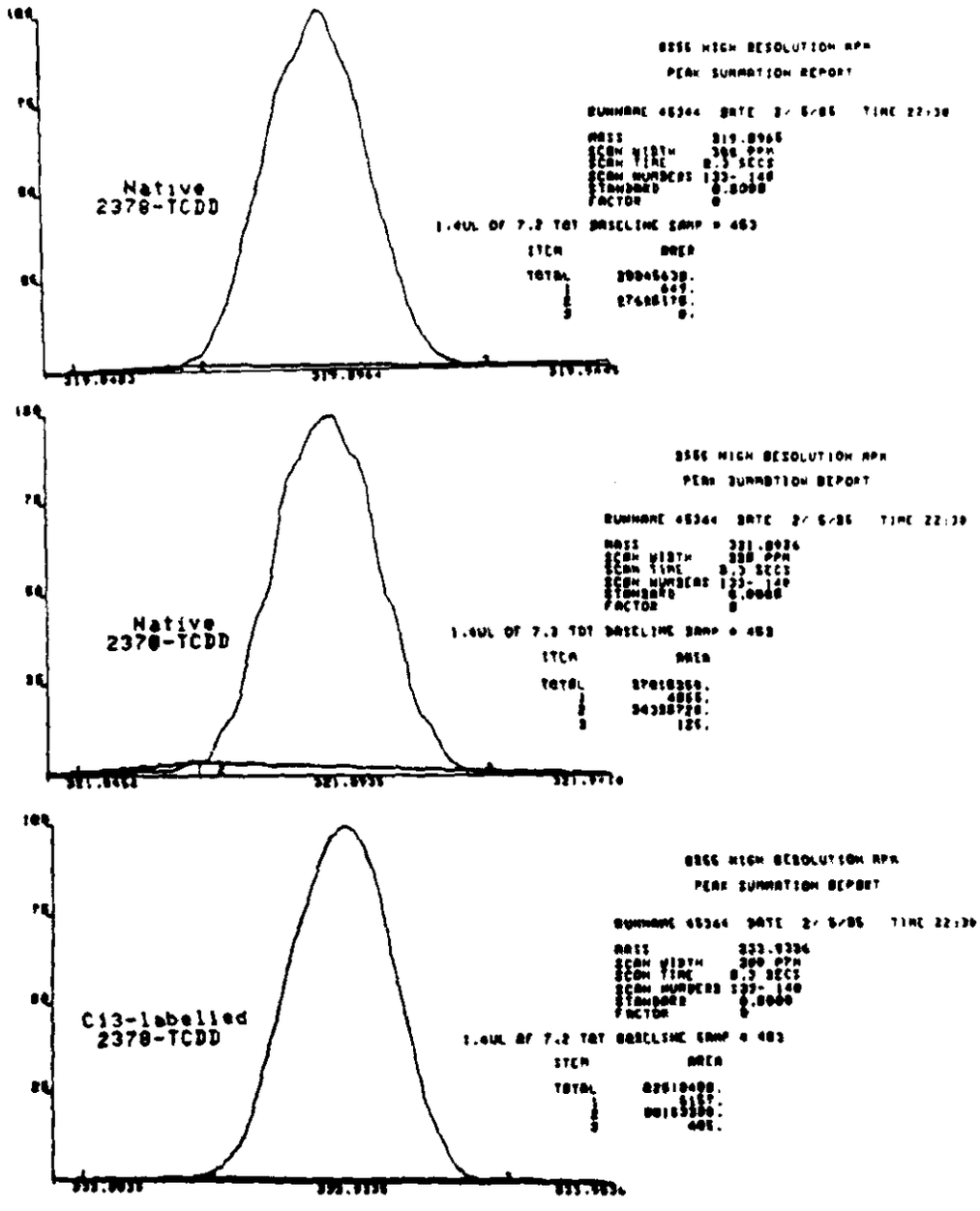


Figure 3-2: High Resolution Mass Scans & Summaries. This figure shows the sum of the mass scans which were taken during the elution of the 2378-TCDD peaks shown in Figure 3-1.

MONS 218349

Each curve also shows the 99% confidence interval for the slope and intercept of the least squares regression line. These calculations were based on equations given in a recently published book on statistics for chemists(12).

Calibration curves derived from high resolution mass spectrometric data(HRGC/HRMS) for some of the analytes are drawn in Appendix B Figures 9-13. The curves were constructed using the same solutions as described above. They also demonstrate linearity over approximately four orders of magnitude.

The percentage fit of the least squares line in each of the curves constructed with high resolution mass spectrometry data is:

2,3,7,8-TCDD - 99.5395
2,3,7,8-TCDF - 99.4736
1,2,3,7,8-PnCDF - 97.0347
1,2,3,4,7,8-HxCDF - 99.949
1,2,3,4,6,7,8-HpCDF - 99.1012

Response factors were calculated daily from data collected from the injection of a portion of one of the standard solutions. The response factors (RF) are used in the following equation to calculate the concentration of analyte in the sample:

$$C_A = (A_N/A_{IS})(RF)(C_{IS}) \qquad (3\text{-}1)$$

where,
C_A = concentration of analyte in the sample
C_{IS} = concentration of internal standard added to the sample before the clean-up procedure
A_N = area counts of the signal due to the analyte
A_{IS} = Area counts of the signal due to the internal standard
RF = Response factor = S_{IS}/S_N
S_{IS} = Area counts per unit mass of the internal standard
S_N = Area counts per unit mass of the native compound

Ideally, for greatest precision, the response factors should not vary from analysis to analysis. The day-to-day variation in response factor(expressed as area ratio) can be demonstrated by comparing the daily area ratios to the area ratios generated for the calibration curve. In Appendix C Figure 14, the area ratios for the 2,3,7,8-TCDD, in the standard injection analyzed on each day of the project are plotted on the calibration curve. The area ratios for other analytes are plotted in Figures 15 through 21 Appendix C. For 2,3,7,8-TCDD only one area ratio fell outside the 99% confidence interval. Since no criteria had been

MONS 218350

specifically established, this area ratio (and consequently, response factor) was adjusted based upon the average of area ratios generated by injections on the previous and following days. Errant ratios obtained for other analytes were treated in this same fashion. This was considered acceptable because it was observed that the area ratios fluctuated only rarely and randomly. These large apparently random changes in the area ratios constituted the greatest factor responsible for any large relative standard deviations in the sample determinations. At the time of analysis no mechanism had been established to efficiently check the daily response factors of so many analytes. In future work, daily checks of the response factors could be made by incorporating more currently available automation into the methodology. Instrument manufacturers are continually developing software and one could expect that among the developments would be an efficient and reliable check of the response factors. We can envision a relatively easy method of checking the response factors against the calibration curve using the relatively general and widely available Lotus 1-2-3 software package. When many response factors can be easily checked, a criteria for the reproducibility of response factors could be included as an analytical specification before analysis commences. Likely criteria could be typical confidence intervals such as the 90, 95 or 99% confidence interval or a percentage of the average response factor calculated from the responses generated during the construction of the calibration curve.

Analysis of blank samples is a final quality assurance point requiring some discussion. A laboratory blank was generated by carrying a sample of the solvents used in the analysis through the clean-up procedure. This sample was spiked with the appropriate internal standards. The internal standards were detected with reasonable recoveries. None of the analytes of interest were detected. The three baseline fluids, which constituted three of the ten samples in the project, were analyzed to quantify any of the PCDD and PCDF analytes which might be present before the blind spiking levels were added. None of the analytes were detected in the mineral oil or Aroclor 1016. However, the recovery of internal standards spiked into these samples was low. Some of the analytes were detected in Aroclor 1260. The results of these analyses are tabulated in Appendix D Tables 3, 4 and 5 and are used in conjunction with the results of the spiked Baseline fluids to determine the accuracy of the analysis.

BASELINE DATA

The actual project consisted of the analysis of ten samples of various utility fluids. Of these ten samples, six were dielectric fluids taken from in-service

MONS 218351

electrical equipment. Three of the samples were mineral oil, Aroclor 1016, and Aroclor 1260 that were spiked before analysis with both the internal standards and blind levels of various native PCDD-PCDF analytes. The results of these analyses are tabulated in Appendix D Tables 3-5. The average percent error is 28.9%. In two cases, an analyte was measured where none had been spiked.

In the spiked Aroclor 1016, 1,2,3,4,7,8-HxCDF was detected even though it had not been spiked. In spiked Aroclor 1260, 1,2,3,7,8,9-HxCDF was detected but not spiked. It is impossible to determine with these results if these compounds were present in the unspiked fluids since the detection limit in the unspiked fluids is greater than the level detected in the spikad fluids.

The % error for the determination of OCDF in the spiked Aroclor 1260 was not included in the 28.9% average percent error calculation. The spike level was so low relative to the native amount of OCDF in Aroclor 1260 that the comparison of the spiked to measured level was not a reasonable indication of accuracy. The % error figure was eliminated from the average based upon the similarity in magnitude of the spiked level and the standard deviation for the triplicate determination (compare the OCDF values in Table D-15).

The average % error in each matrix is listed at the bottom of Tables D-1, D-2 and D-3. The % error in the OCDF determination in Aroclor 1260 (Table D-3) was not included in the local average as explained above. The large average % error in the case of Aroclor 1260 is due to the large error in the determination of 2,3,4,6,7,8-HxCDF and 1,2,3,4,6,7,8-HpCDF. This large error could be accounted for by a low recovery of these compounds in the blank Aroclor 1260. Recovery, as measured in this report, refers to the recovery of the internal standard used to quantitate a particular analyte and not to the recovery of the actual analyte. For these two compounds the internal standard was 1,2,3,4,7,8-HxCDF. This isomer may be different enough that slight differences in the performance of the chromatographic system will cause large differences in recovery. This phenomenon may account for many of the large relative standard deviations observed in this study.

IN-SERVICE LIQUIDS

The results of the triplicate analysis of each of the seven in-service dielectric fluids are tabulated in Appendix D, Tables D-6 to D-15. These results are

MONS 218352

graphically displayed in Appendix E, Figures 1 through 10. In each table the result for each replicate for each analyte is listed along with the average of the three replicates, the standard deviation and the percent relative standard deviation (coefficient of variation). Analytes that were not detected are indicated by the detection limit enclosed in parentheses. In all ten samples, the concentrations range from 0.15 ppb of 2,3,7,8-TCDF in the Substation Distribution Transformer (Appendix D, Table D-11) to 39,600 ppb of OCDF in the Load Center Network Transformer (Appendix D, Table D-6). For all the analytes in all the samples, only 15 average values (out of 180) had percent relative standard deviations over 30%. None of these analyses involved the more toxic compounds namely 2,3,7,8-TCDD or 2,3,7,8-TCDF. The largest relative standard deviations (RSD) occurred in the analysis for Total TCDF or an isomer in one of the higher chlorinated congener classes. Some had percent relative standard deviations as low as 1%. Six of the analyzes with greater than 30% RSD were determinations of total congener concentrations, two were determinations of closely eluting PnCDF isomers and seven were determinations quantitated at < 10 ppb.

The detection limits and recoveries are tabulated in Appendix F Table 1 through 10. Tables 11 through 20 list % recovery versus 2,3,7,8-TCDD-$^{13}C_{12}$. The detection limits were calculated based upon a background response of 1000 counts in the diluted sample extract.
Thus the following equation was used:

$$\text{Detection Limit} = (1000/A_{IS})\ (RF)\ (100) \qquad (3\text{-}2)$$

where,

A_{IS} = area counts due to the internal standard
$RF = S_{IS}/S_N$ = response factor
S_{IS} = area counts per unit mass of internal standard
S_N = area counts per unit mass of native compound

A background area count of 1000 was chosen because this size peak was typical for G.C. peaks whith are just distinguishable from background by the detector and computer combined. Smaller noise peaks are distinguishable in the detector output but these are not generally integrated by the computer and its integration algorithm. Furthermore 1000 counts is a conservative general estimate of the area noise observed just prior to the elution of the internal standards based upon the 2.5 pg/ml standard solution used for the calibration curves.

MONS 218353

Some apparent discrepancies may arise when compering these detection limit values with the results (and detection limits) listed in Appendix D Tables D-6 through D-15. However, the basis for any particular calculation in these two groups of tables may be different. The detection limit calculations in Appendix F Tables 1 through 10 are based on the previous equation for detection limits which includes the area count observed for each internal standard in a diluted extract. Most of the sample extracts were diluted because most contained one or two analytes which were highly concentrated relative to the other analytes. Many of the values listed in Appendix D Tables 4 through 13 were generated from data collected on the concentrated extracts before they were diluted.

In one sample, spiked Aroclor 1260, the replicate analysis of 2378-TCDD generated the following values: 61.7, 65.5 and 32.0 ppb. A possible reason for the discrepancy between the first two determinations and the third is an interference in the 2,3,7,8-TCDD-$^{13}C_{12}$ internal standard peak eluting at 42.194 minutes (see figure 3-3). To check for the occurrence of an interferant and generate the most accurate quantitation, the third extract was reanalyzed by high resolution G.C./high resolution M.S.(see Figure 3-4). The mass profile of the scans acquired during the elution of the 2,3,7,8-TCDD-$^{13}C_{12}$ internal standard shows the presence of an interferant (see Figure 3-5). The small peak in the profile was used with a typical response factor to quantitate 2,3,7,8-TCDD at a level of 106 ppb.

MONS 218354

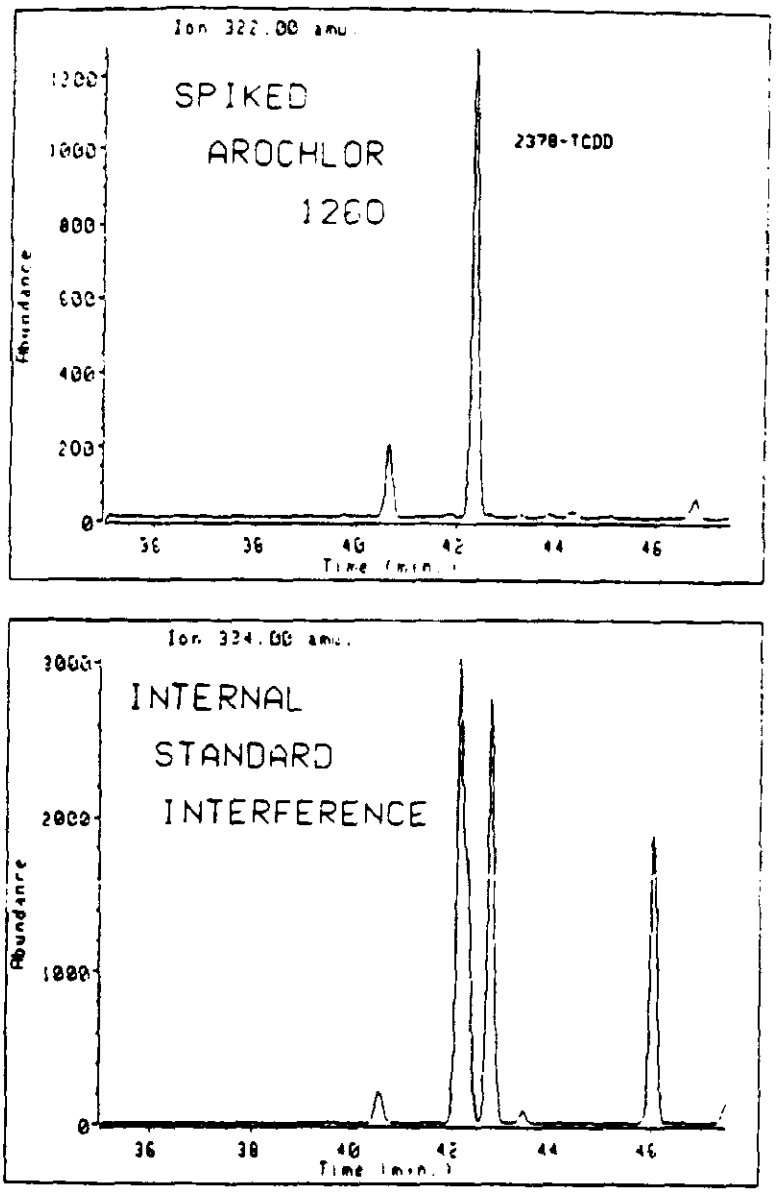


Figure 3-3. Interference in the determination of 2378-TCDD in spiked Aroclor 1260. The internal standard G.C. peak appears to have a coeluting interference which would cause the determination of 2,3,7,8-TCDD to be too low.

MONS 218355

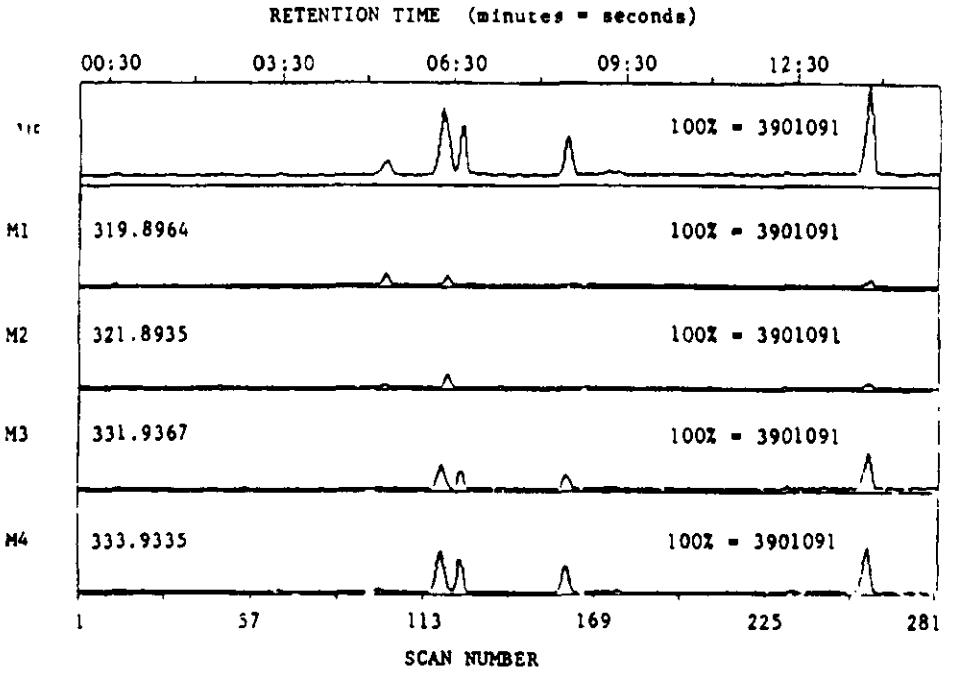
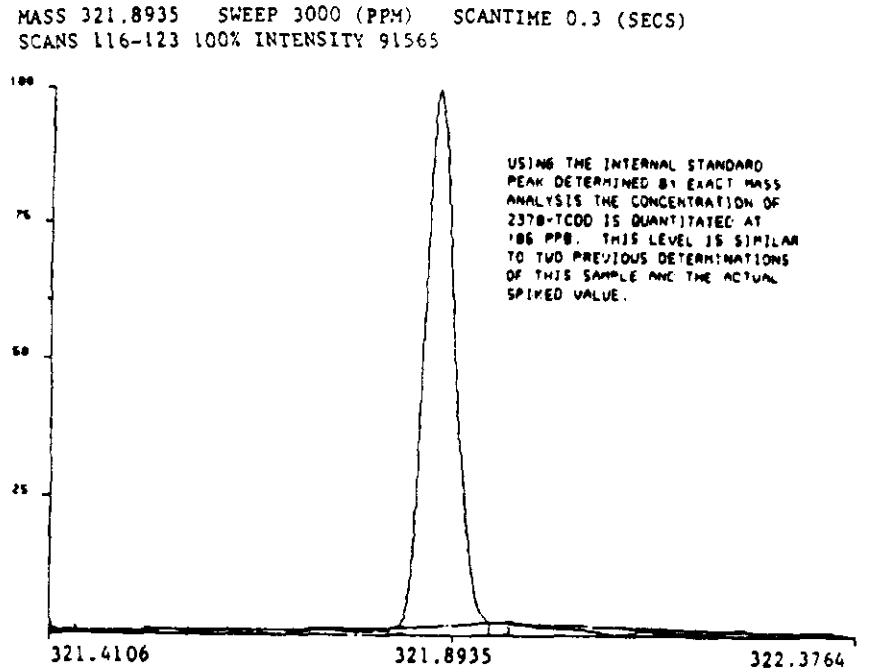


Figure 3-4. High resolution Mass Chromatogram of spiked Aroclor 1260. Notice the same pattern of G.C. peaks as in the low resolution data. This allows, in a sense, the analysis of isobaric components of the internal standard G.C. peak in the low resolution mass data.

MONS 218356



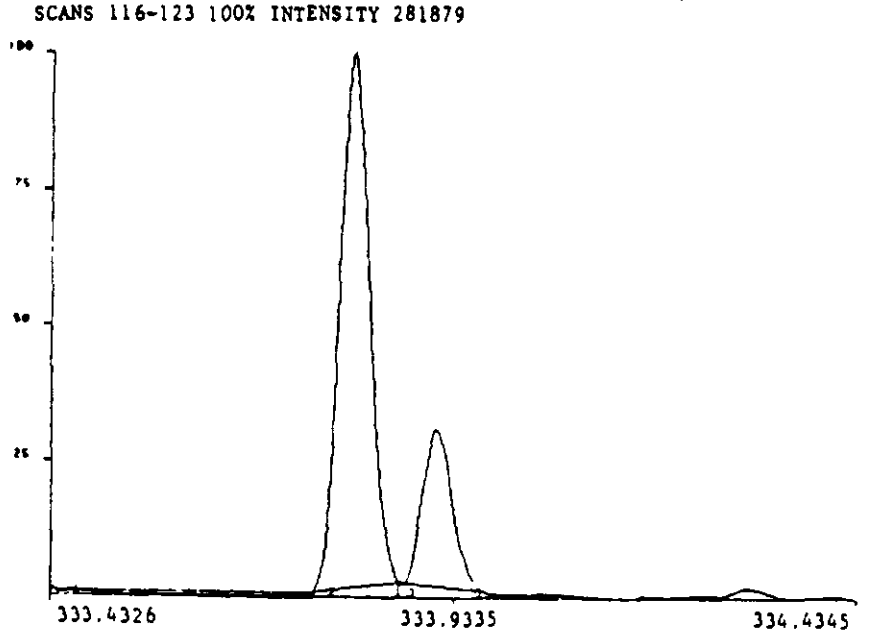


Figure 3-5. High resolution mass data from the 2,3,7,8-TCDD G.C. peak from the spiked Aroclor sample. The mass scan of the internal standard ion shows a coeluting interference responsible for the low determination of 2,3,7,8-TCDD.

MONS 218357

Section 4

REFERENCES

1. P.W. O'Keefe; C. Meyer; D.R. Hilker; K. Aldous; B. Jelus-Tyror; K. Dillon; R. Donnelly; E. Horn and R. Sloan. "Analysis of 2,3,7,8-Tetrachlorodibenzo-p-dioxin in Great Lakes Fish." Chemosphere 12, 1983, p. 325

2. P.W. Albro and et al. "Methods for the Quantitative Determination of Multiple, Specific Polychlorinated Dibenzo-p-dioxin and Dibenzofuran Isomers in Human Adipose Tissue in the Parts-per-Trillion Range." Analytical Chemistry, November 1985, p. 2717.

3. J.J. Ryan; B. P.-Y. Lau; J.A. Hardy; W.B. Stone; P. O'Keefe and J.F. Gierthy. "2,3,7,8-Tetrachlorodibenzo-p-dioxin and Related Dioxins and Furans in Snapping Turtle (Chelydra Serpentina) Tissues from the Upper St. Lawrence River." Chemosphere, Vol. 15 1986, p. 537.

4. R.M. Smith; P.W. O'Keefe; K.M. Aldous; D.R. Hilker and J.E. O'Brien. "2,3,7,8-Tetrachlorodibenzo-p-dioxin in Sediment Samples from Love Canal Storm Sewers and Creeks." Environ. Sci. Tech., Vol. 17 1983, p. 6.

5. K. Olie; P.L. Vermeulen and O. Hutzinger. "Chlorodibenzo-p-dioxins and Chlorodibenzofurans Are Trace Components of Fly Ash and Flue Gas of Some Municipal Incinerators in the Netherlands." Chemosphere, Vol. 6 1977, p. 455.

6. H.R. Buser; H-P. Bosshardt and C. Rappe. "Formation of Polychlorinated Dibenzofurans (PCDFs) from the Pyrolysis of PCBs." Chemosphere, Vol. 7 1978, p. 109.

7. H.R. Buser; H-P. Bosshardt; C. Rappe and R. Lindahl. "Identification of Polychlorinated Dibenzofuran Isomers in Fly Ash and PCB Pyrolyses." Chemosphere, Vol. 7 1978, p. 419.

8. R.M. Smith; P.W. O'Keefe; D.R. Hilker; B. Jelus-Tyror and K.M. Aldous. "Analysis for 2,3,7,8-Tetrachlorodibenzofuran and 2,3,7,8-Tetrachlorodibenzo-p-dioxin in a Soot Sample from a Transformer Explosion in Binghamton, New York." Chemosphere, Vol. 11 1982, p. 715.

9. C. Rappe. "Analysis of Polychlorinated Dioxins and Furans." Chemosphere, Vol. 18 No. 3 1984, p. 78A.

10. A. Poland; E. Glover and A.S. Kende. "Stereospecific, High Affinity Binding of 2,3,7,8-Tetrachlorodibenzo-p-dioxin by Hepatic Cytosol." J. Biol. Chem., August 25, 1976, p. 4936.

11. E.E. McConnell; J.A. Moore; J.K. Haseman and M.W. Harris. "Toxicological Assessment of Hexachlorobiphanyl Isomers and 2,3,7,8-Tetrachlorodibenzofuran in Chicks." Toxicol. Appl. Pharmacol., April 1976, p. 65.

12. J.A. Moore; E.E. McConnell; D.W. Dalgard and M.W. Harris. "Comparative Toxicity of Three Halogenated Dibenzofurans in Guinea Pigs, Mice and Rhesus Monkeys." Ann. N.Y. Acad. Sci., Vol. 320 1979, p. 151.

13. J.E. Huff; J.A. Moore; R. Saracci and L. Tomatis. "Long-Term Hazards of Polychlorinated Dibenzodioxins and Polychlorinated Dibenzofurans." Environ. Health Perspect., November 1980, p. 221.

MONS 218359

14. State-of-the-Art Review: PCDDs and PCDFs in Utility Fluid. Palo Alto, Calif.: Electric Power Research Institute, November 1983. CS-3308-PR.

15. P.W. O'Keefe; R.M. Smith; D.R. Hilker; K.M. Aldous and W. Gilday. "A Semiautomated Cleanup Method for Polychlorinated Dibenzo-p-dioxins and Polychlorinated Dibenzofurans in Environmental Samples." In Chlorinated Dioxins and Dibenzofurans in the Total Environment II, L. Keith, C.Rappe and G. Choudhary, Eds., 1985, pp. 111-124.

16. J.H. Beynon. Mass Spectrometry and Its Application to Organic Chemistry. Amsterdam: Elsevier Publishing Co., 1960, pp. 51-54.

17. D.R. Hilker; K.M. Aldous; R.M. Smith; P.W. O'Keefe; J.F. Gierthy; J. Jurusik; S.W. Hibbins; D. Spink and R.J. Perillo. "Detection of Sulfur Analog of 2,3,7,8-TCDD in the Environment." Chemosphere, Vol. 14 1985, p. 1275.

18. R. Caulcutt and R. Boddy. Statistics for Analytical Chemists. New York: Chapman and Hall, 1983, p. 54.

MONS 218360

Appendix A

IN-SERVICE LIQUIDS BACKGROUND INFORMATION

Type of equipment: Load Center Network Transformer
BCL Laboratory Code: ISL-02-A
Voltage Rating: 750 KVA 12 KV to 480/277 V
Liquid Volume: 2650 lbs.
Year: 1962
PCB/Askarel Type: Aroclor 1260 29% - T3CB 29% - T4CB 2%
PCB Levels (for Oil Filled):
Additional Equipment Identification: 65°C max. rise
Length of Actual Service: 20 yrs.
Major Maintenance:
Recorded Failure in Service:
Was Fluid Changed at Failure:
Any Record of Temperature Excursions:
Are Maintenance Records Available:
Any Other Pertinent Information:

Type of equipment: Load Center Network Transformer
BCL Laboratory Code: ISL-03-A
Voltage Rating: 500 KVA 13 KV to 213 V
Liquid Volume: ?
Year: 1953
PCB/Askarel Type: Aroclor 1260 70% - T3CB 29% - T4CB 1%
PCB Levels (for Oil Filled):
Additional Equipment Identification:
Length of Actual Service: 31 yrs.
Major Maintenance:
Recorded Failure in Service:
Was Fluid Changed at Failure:

MONS 218361

Any Record of Temperature Excursions:
Are Maintenance Records Available:
Any Other Pertinent Information:

Type of equipment: Substation Distribution Transformer
BCL Laboratory Code: ISL-04-0
Voltage Rating:
Liquid Volume: 200 gal.
Year:
PCB/Askarel Type:
PCB Levels (for Oil Filled): 100 ppm
Additional Equipment Identification: 65 °C max. rise
Length of Actual Service: 20 yrs.
Major Maintenance:
Recorded Failure in Service: Major arcing and in-service failure
Was Fluid Changed at Failure:
Any Record of Temperature Excursions:
Are Maintenance Records Available:
Any Other Pertinent Information:

Type of equipment: Load Center Network Transformer
BCL Laboratory Code: ISL-08-A
Voltage Rating: 500 KVA 12 KVA to 213 V
Liquid Volume: 3175 lbs.
Year: 1946
PCB/Askarel Type: Aroclor 1260 about 67% - T3CB 30% - T4CB 2%
PCB Levels (for Oil Filled):
Additional Equipment Identification: 55 °C max. rise
Length of Actual Service: 28 yrs.
Major Maintenance: None Noted
Recorded Failure in Service:
Was Fluid Changed at Failure:
Any Record of Temperature Excursions:
Are Maintenance Records Available:
Any Other Pertinent Information: Carbon present throughout the Askaral

Type of equipment: Precipitator
BCL Laboratory Code: ISL-17-A

MONS 218362

Voltage Rating: 480 to 53,500 V
Liquid Volume: 143 gal.
Year:
PCB/Askarel Type:
PCB Levels (for Oil Filled):
Additional Equipment Identification: Serial No. TH 5875, 50 KVA
Length of Actual Service: 1947 - 1974 (27 yrs.)
Major Maintenance:
Recorded Failure in Service:
Any Record of Temperature Excursions:
Are Maintenance Records Available:
Any Other Pertinent Information: Full load rise of 45°C.

Type of equipment: Arc Furnace Transformer
BCL Laboratory Code: ISL-23-0
Voltage Rating: 12470/280
Liquid Volume: 4500
Year: 1976
PCB/Askarel Type: Mineral Oil
PCB Levels (for Oil Filled): 150 ppm
Additional Equipment Identification: 7500/8750 KVA, 4.7% imp.,
No-load Secondary tap changer, FOA, 65°C rise insulation.
Length of Actual Service: 8 yrs.
Major Maintenance: Top cover of transformer and tap changer removed each year for
internal visual inspection and check of connections.
Recorded Failure in Service: None
Was Fluid Changed at Failure:
Any Record of Temperature Excursions: None occurred
Are Maintenance Records Available: Yes
Any Other Pertinent Information: Oil chemical test and gas chromatography tests
run yearly.

Type of equipment: Capacitor
BCL Laboratory Code: ISL-27-?
Voltage Rating: 7200 KVAR 100
Liquid Volume: 4" x 13.5" x 22"
Year:
PCB/Askarel Type:
PCB Levels (for Oil Filled):

MONS 218363

Additional Equipment Identification:

Length of Actual Service: ?

Major Maintenance:

Recorded Failure in Service:

Was Fluid Changed at Failure:

Any Record of Temperature Excursions:

Are Maintenance Records Available:

Any Other Pertinent Information:

MONS 218364

Appendix B

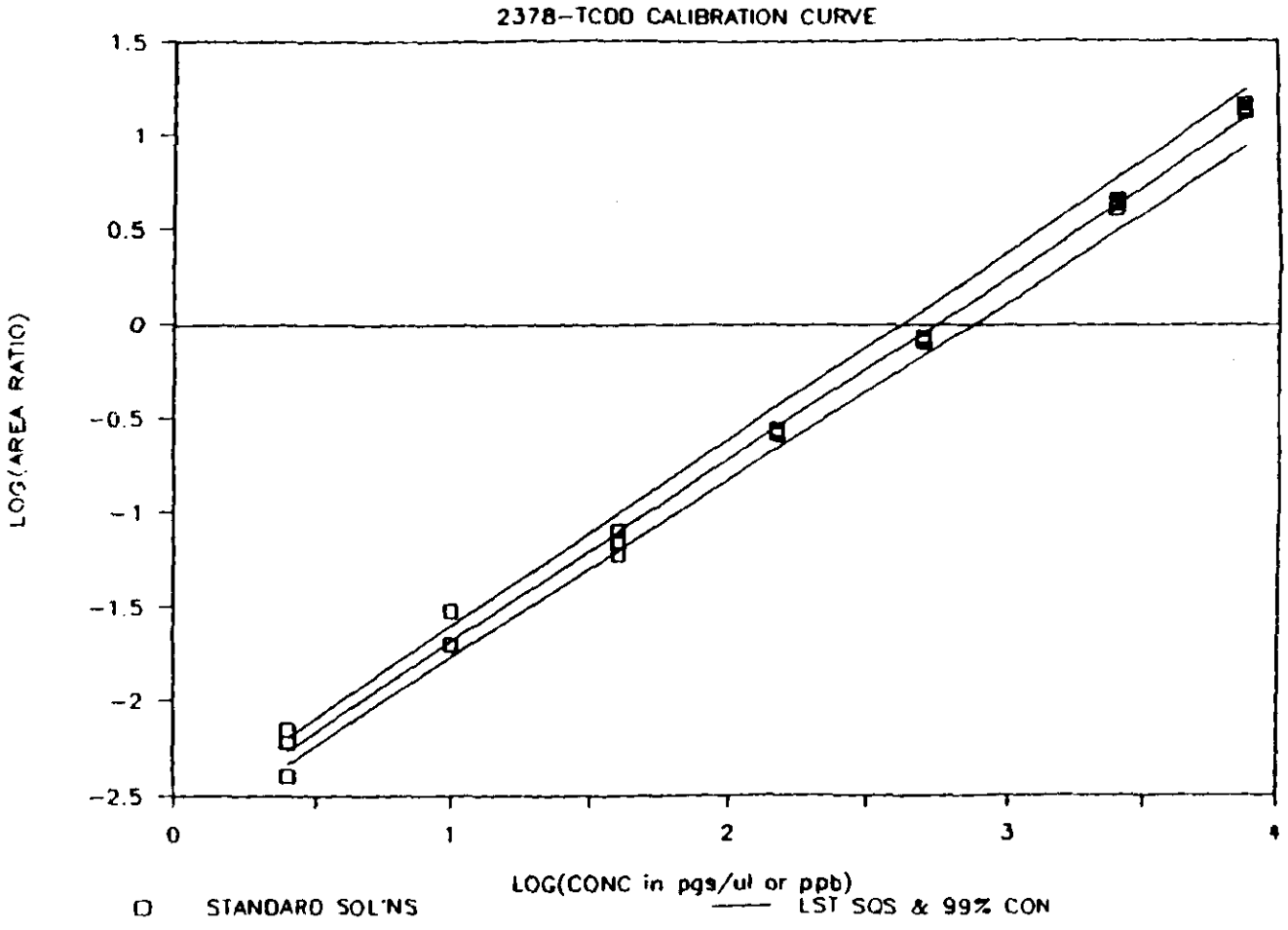
ANALYTE CALIBRATION CURVES

Figures B-1 through B-8. Calibration curves constructed with data obtained from the low resolution mass selective detector. Along with the least squares line the 99% confidence interval is also plotted.

Figures B-9 through B-13. Calibration curves constructed with data obtained from the high resolution mass spectrometer.

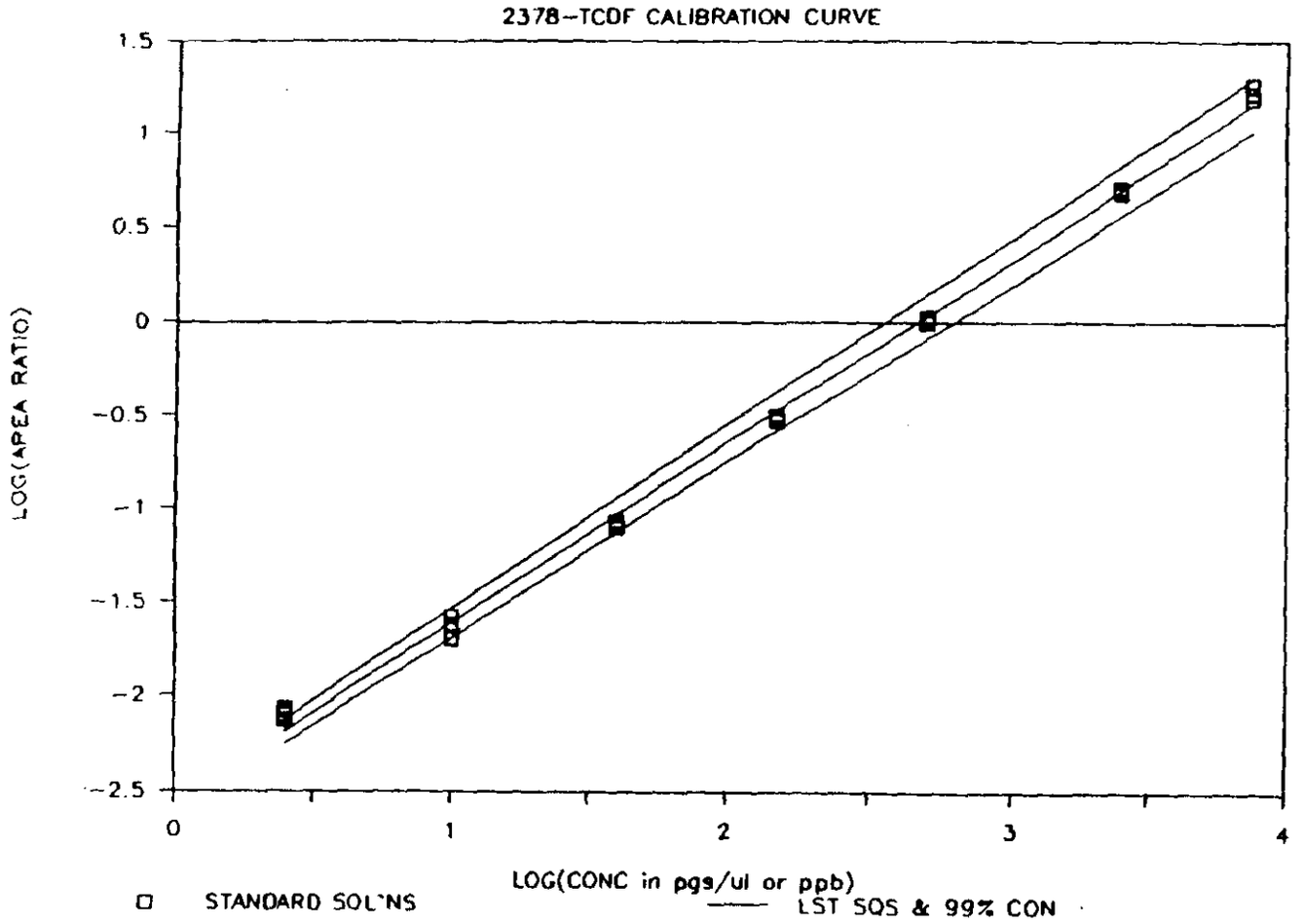
MONS 218365

FIGURE B-1:EPRI BASELINE PROJECT



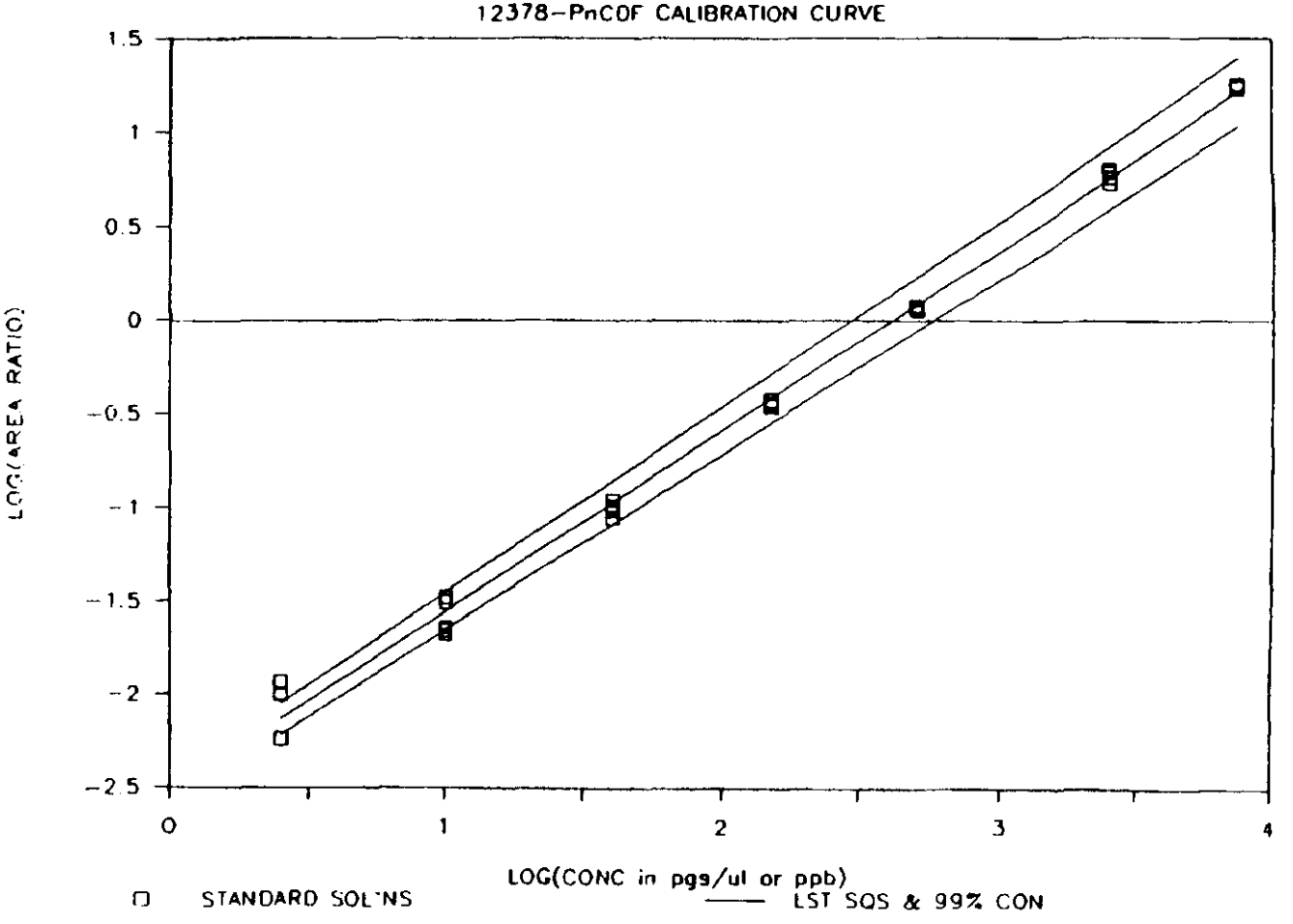
MONS 218366

FIGURE B-2: EPRI BASELINE PROJECT



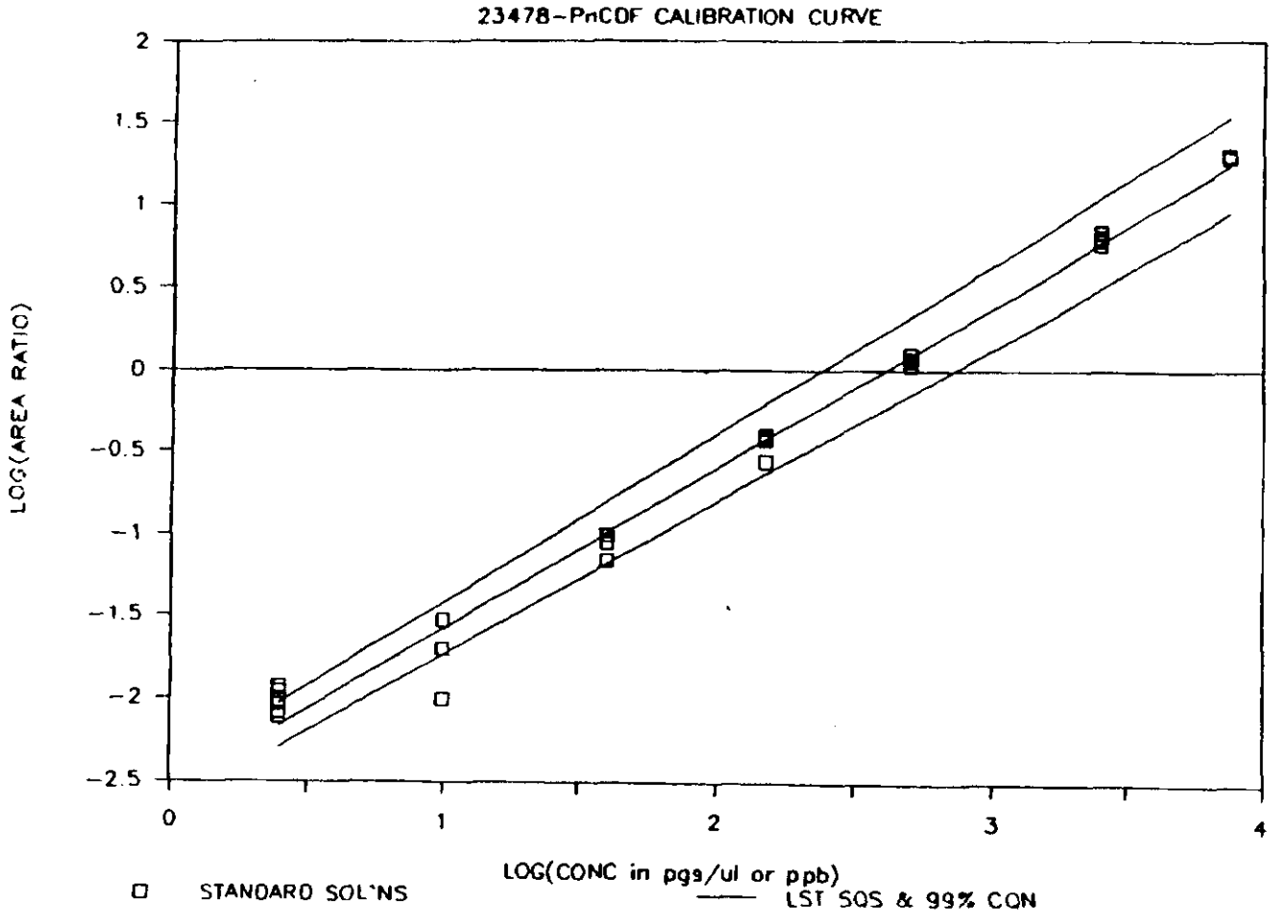
MONS 218367

FIGURE B-3: EPRI BASELINE PROJECT



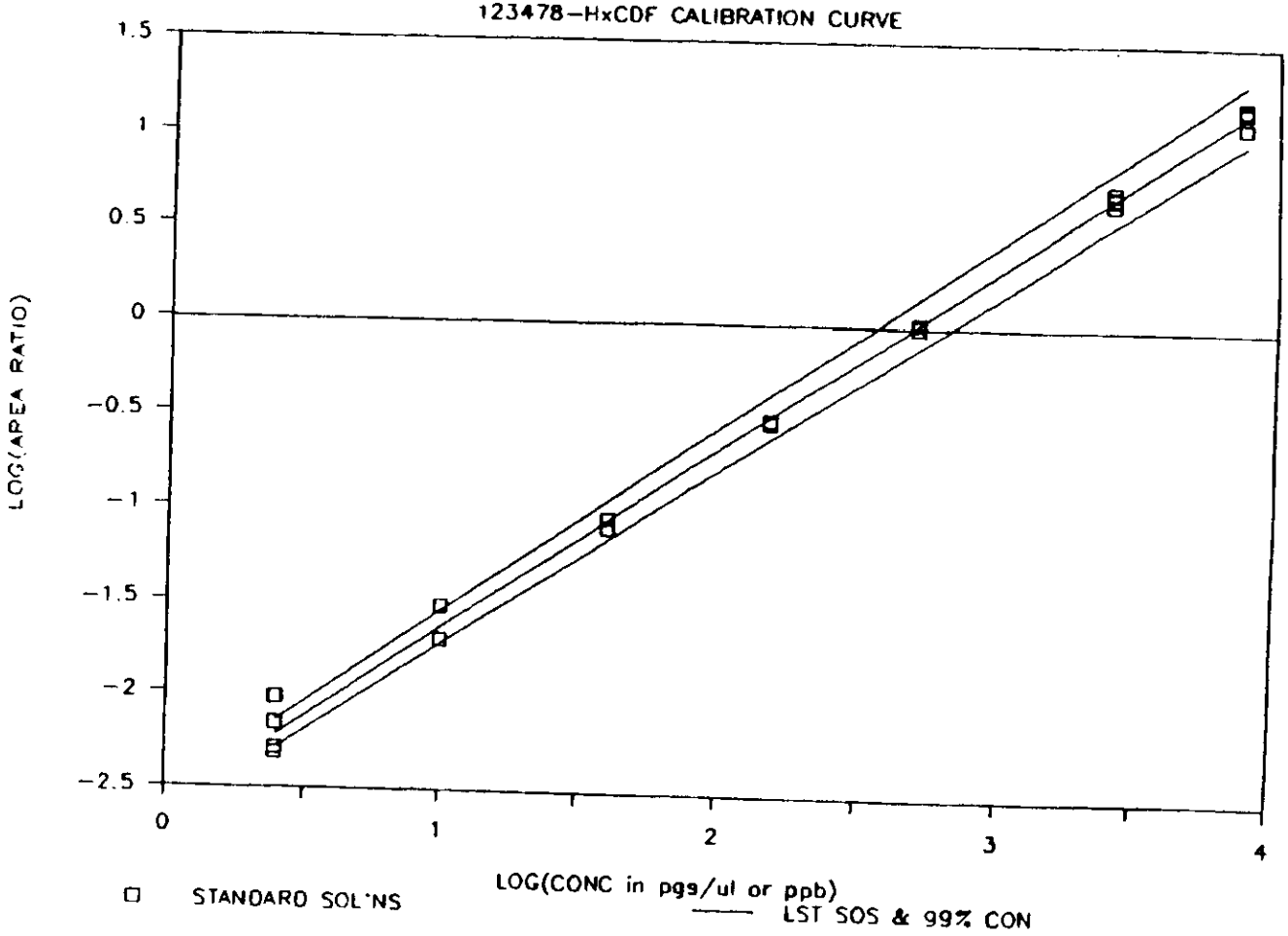
MONS 218368

FIGURE B-4: EPRI BASELINE PROJECT



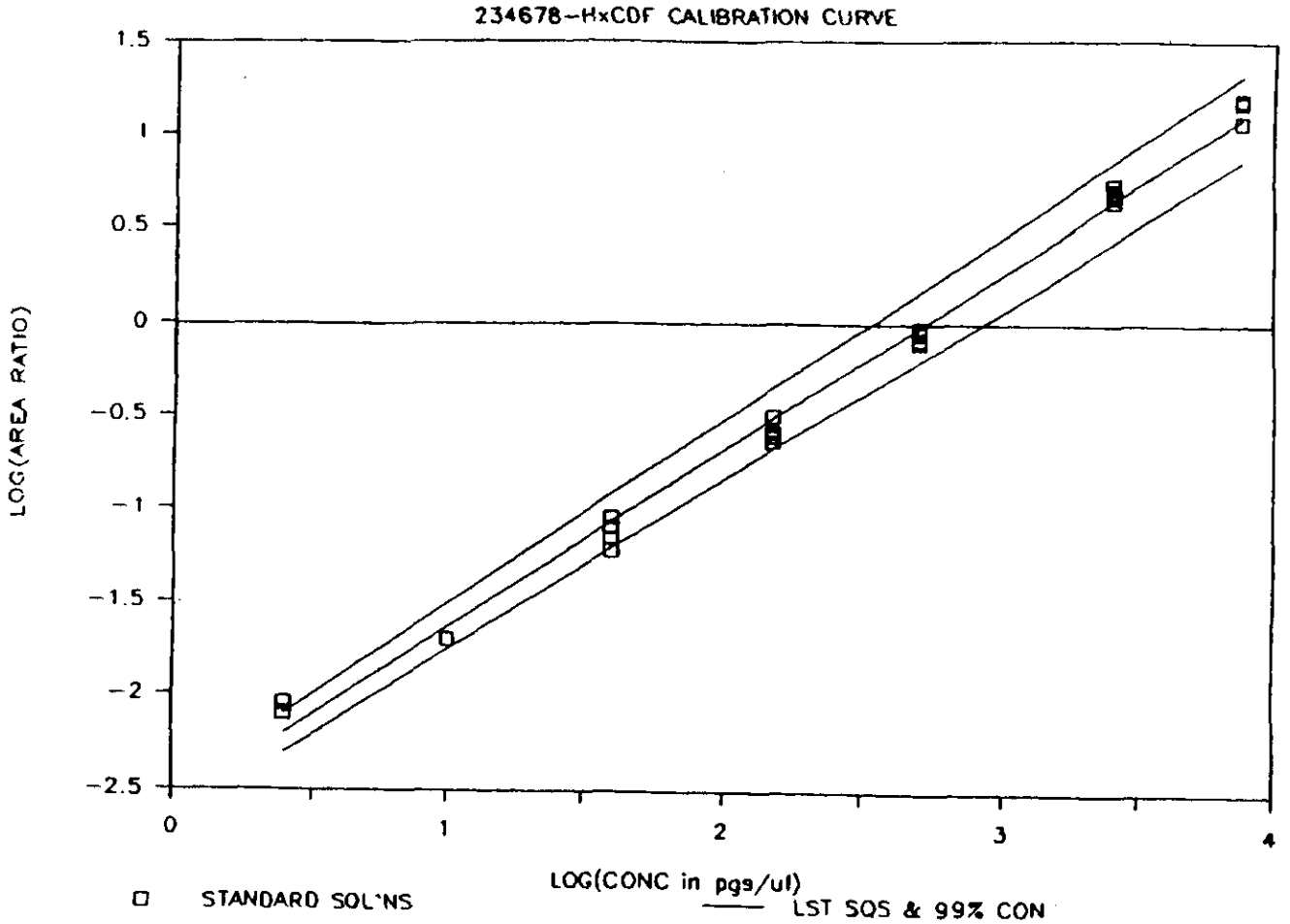
MONS 218369

FIGURE B-5: EPRI BASELINE PROJECT



MONS 218370

FIGURE B-6: EPRI BASELINE PROJECT



MONS 218371

FIGURE B-7: EPRI BASELINE PROJECT

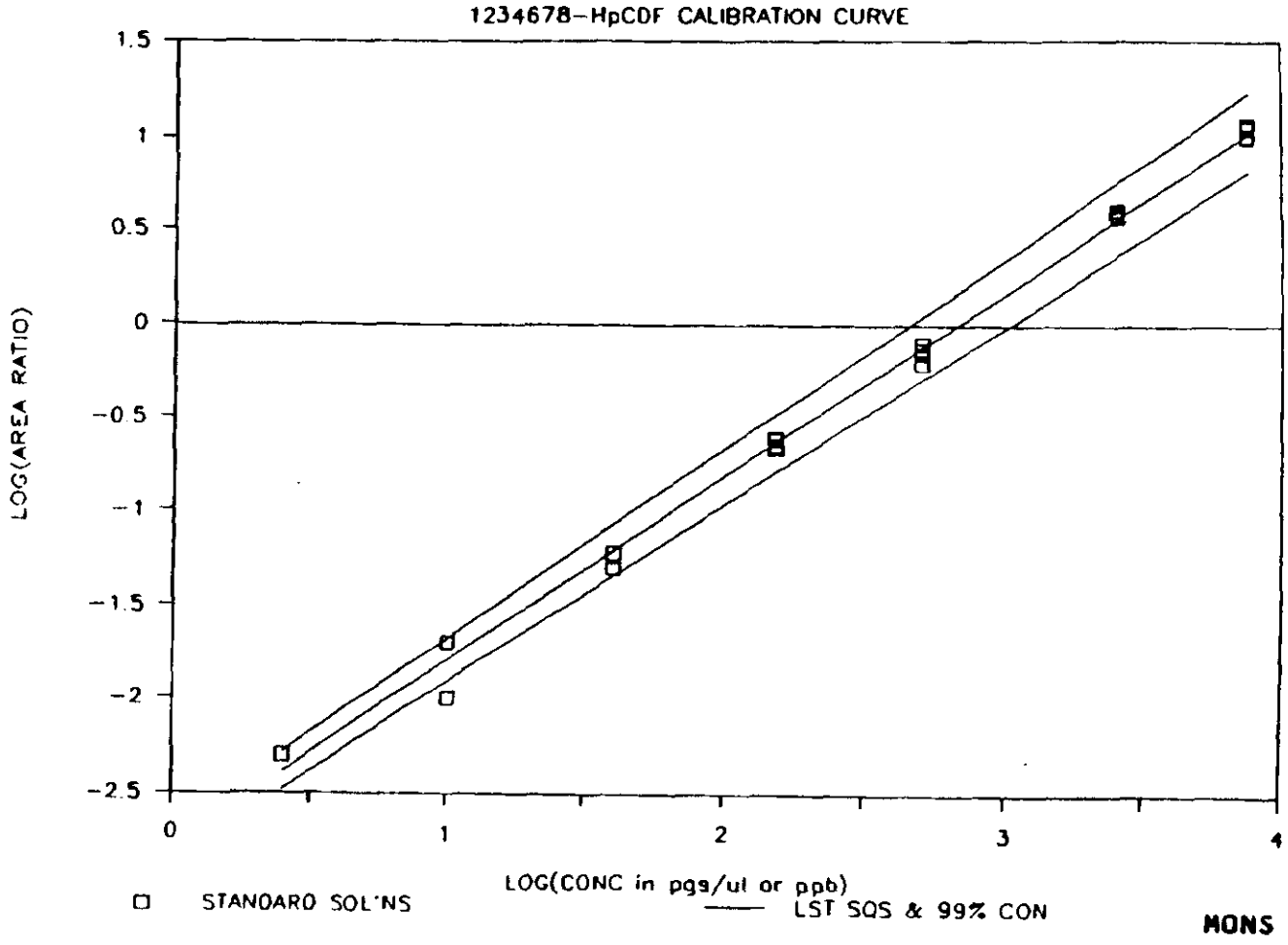
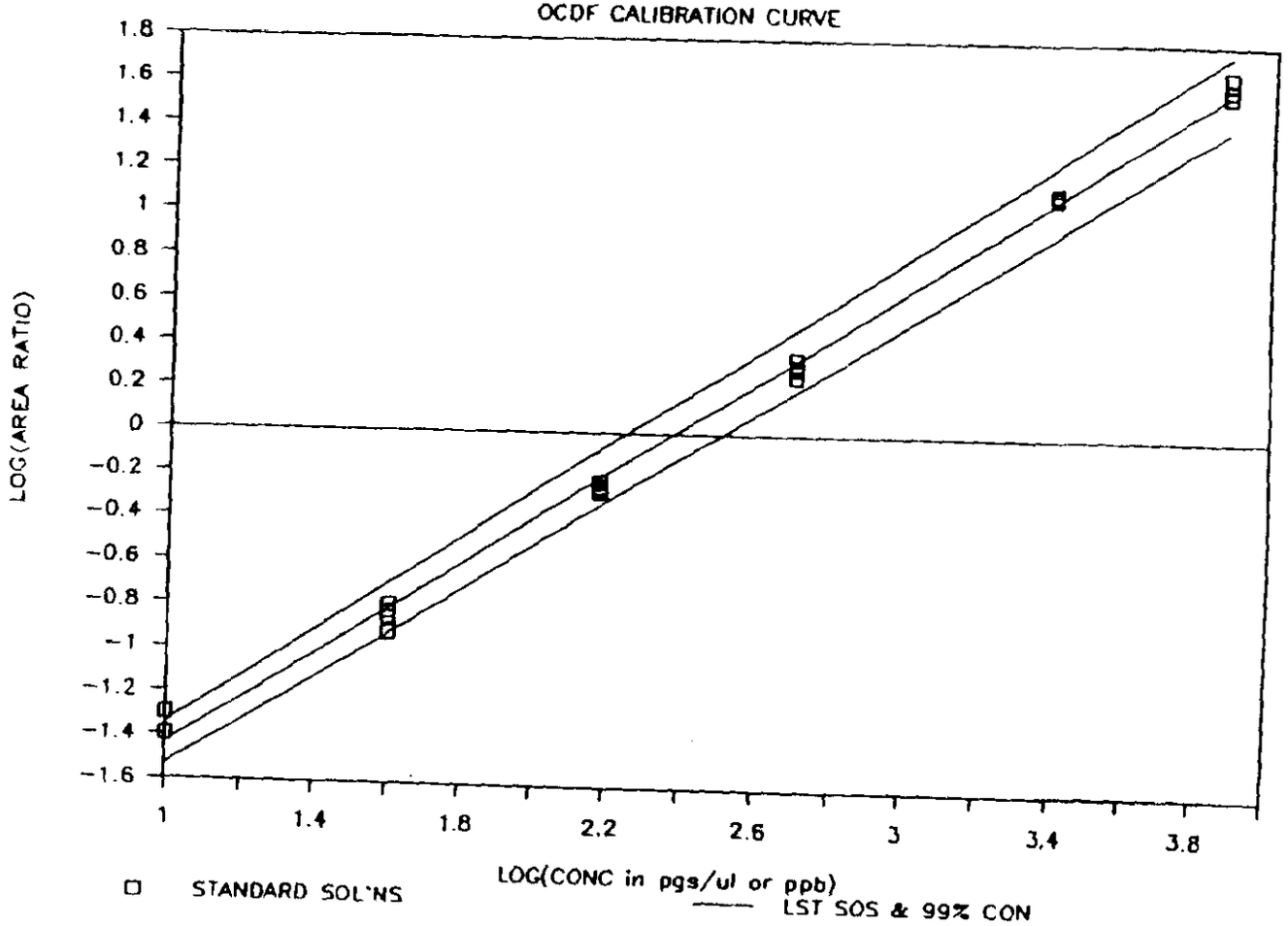
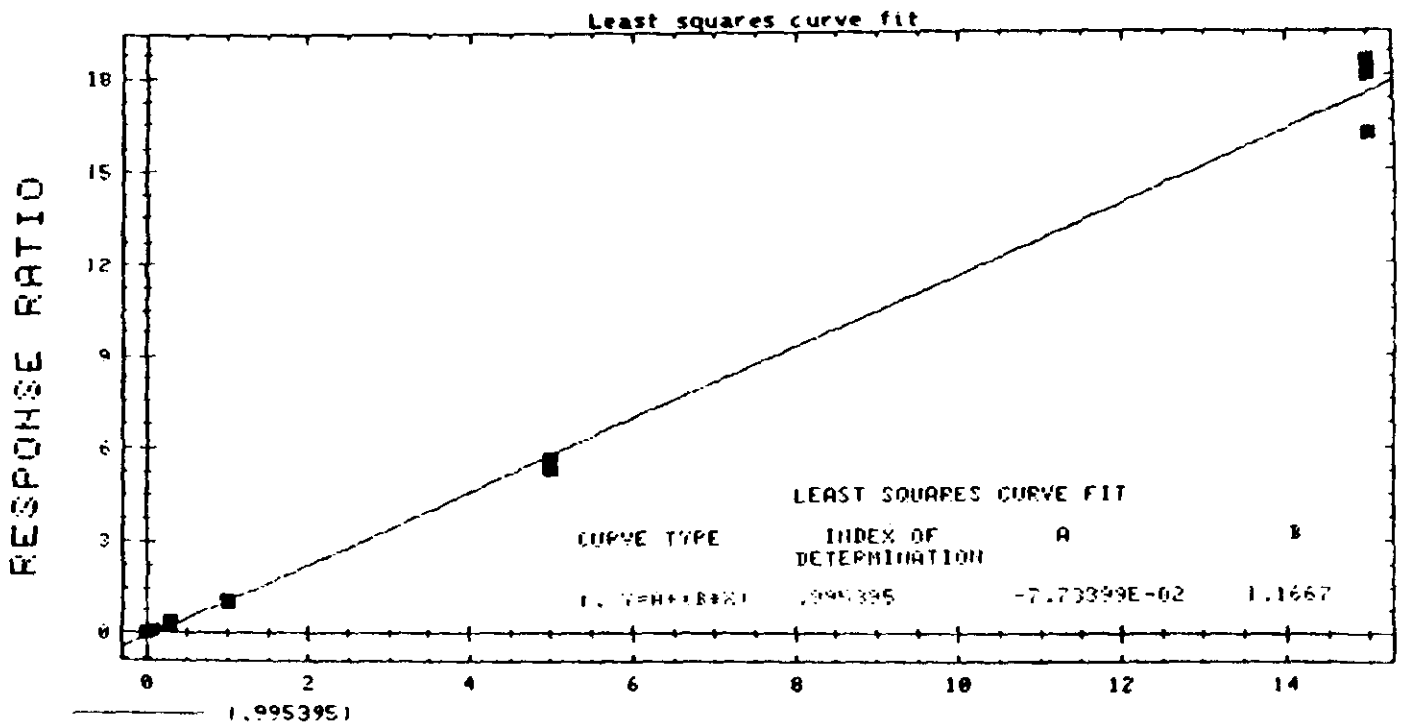


FIGURE B-8: EPRI BASELINE PROJECT



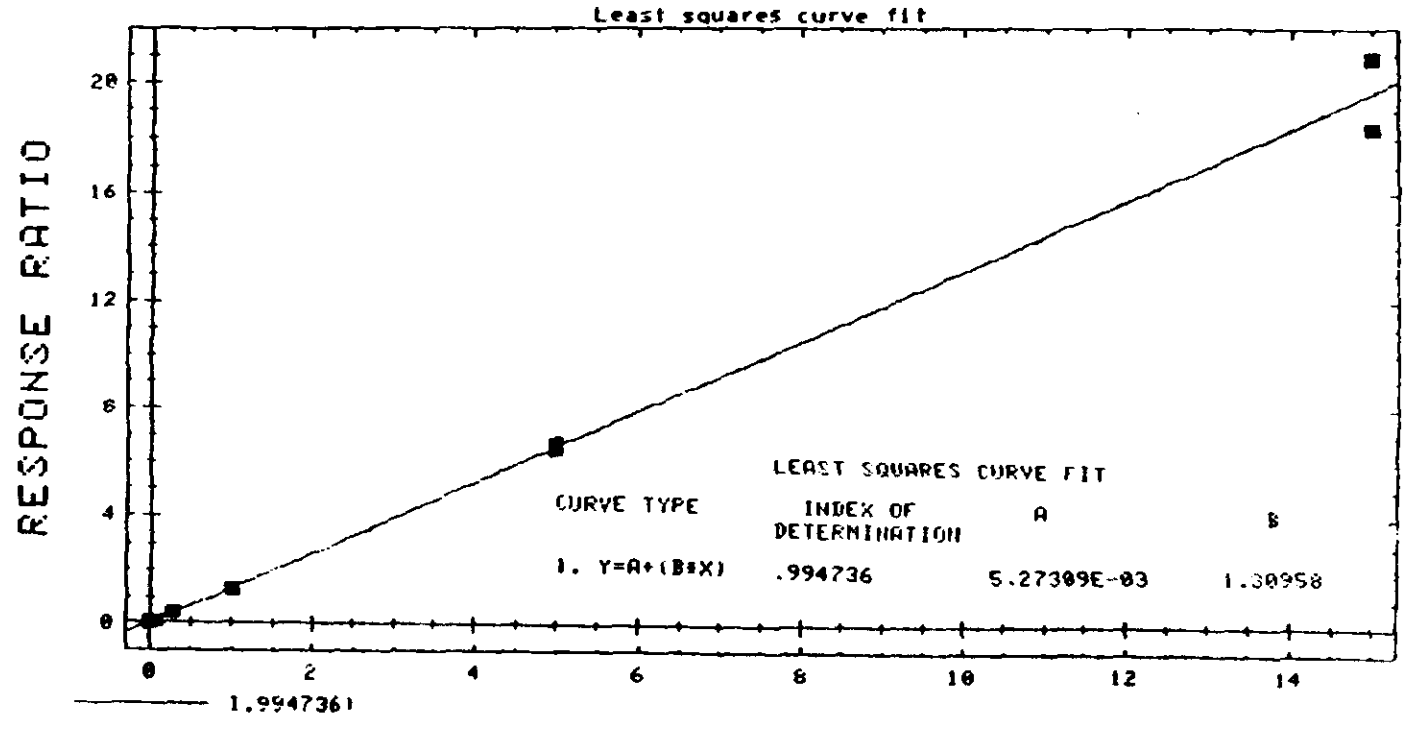
MONS 218373

Figure B-9: CALIBRATION CURVE FOR 2,3,7,8-TCDD



MONS 218374

Figure B-10: CALIBRATION CURVE FOR 2,3,7,8-TCDF



AMT.(CONC.)RATIO

MONS 218375

Figure B-11: CALIBRATION CURVE FOR 1,2,3,7,8-PnCDF

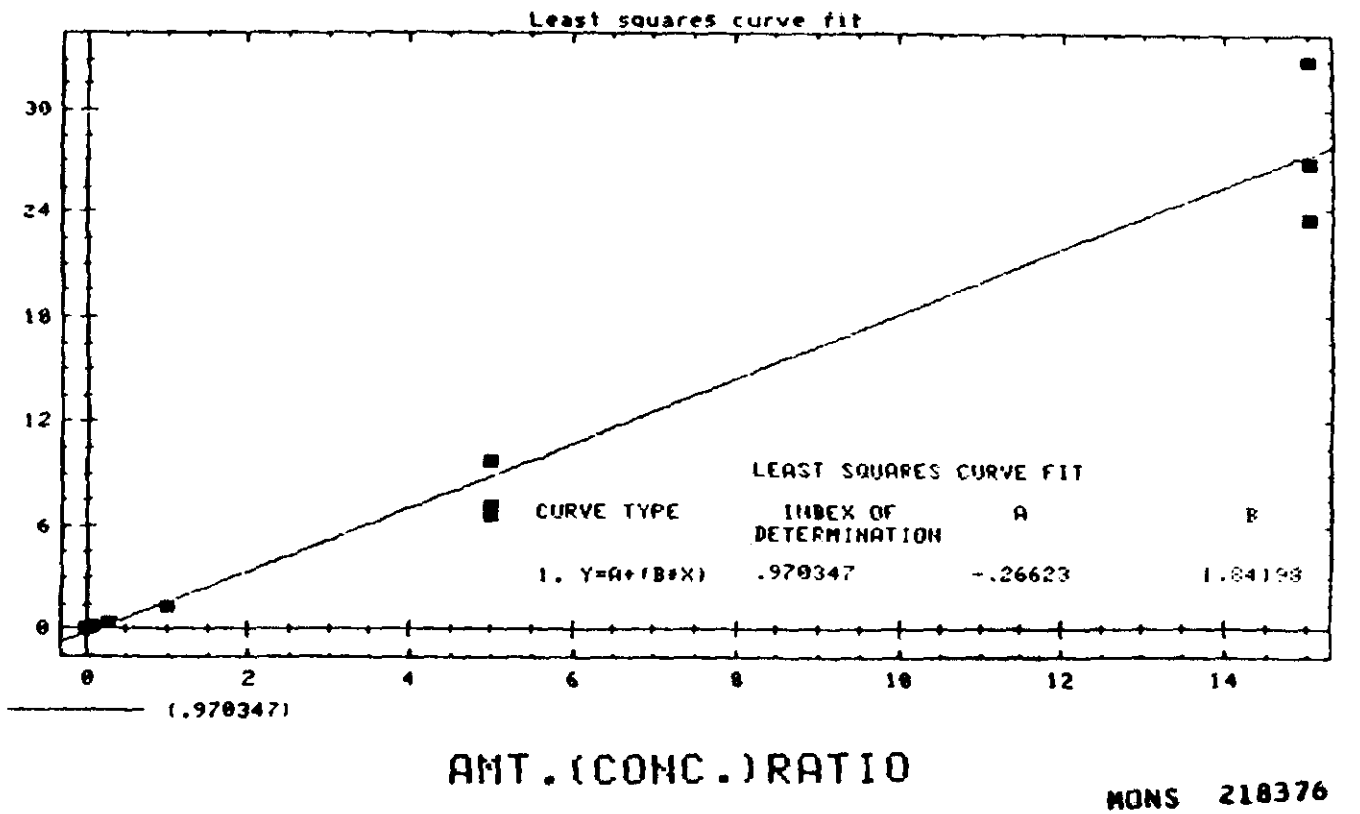
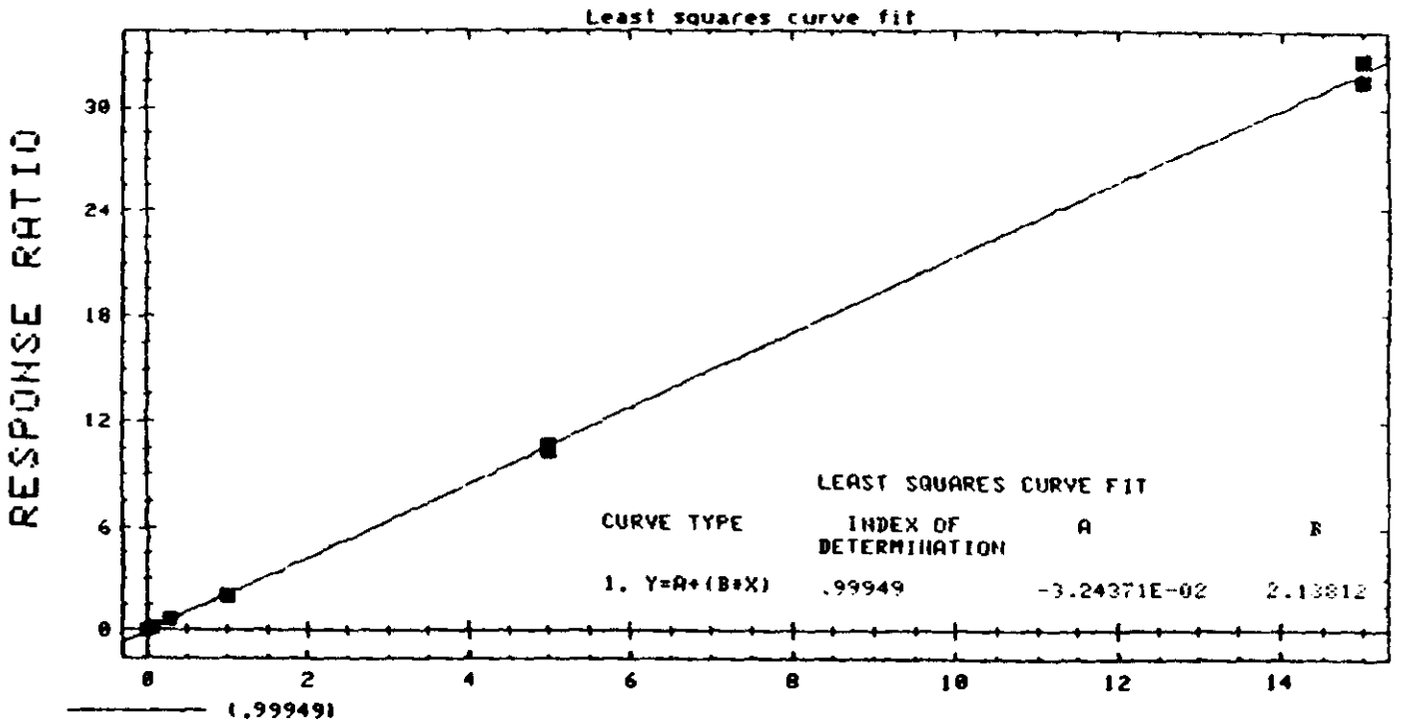


Figure B-12:

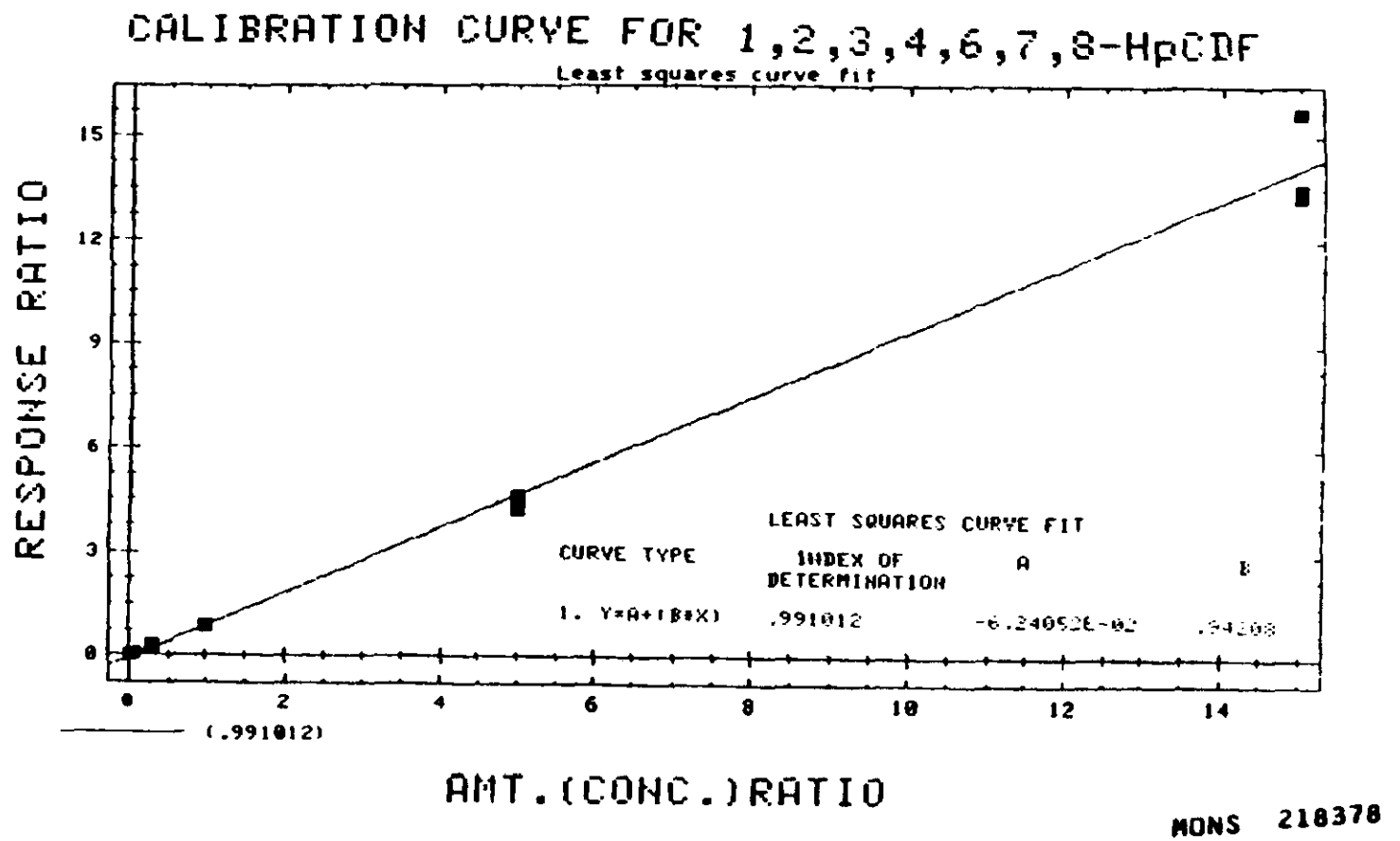
CALIBRATION CURVE FOR 1,2,3,4,7,8-HxCDF



AMT.(CONC.)RATIO

MONS 218377

Figure B-13:


CALIBRATION CURVE FOR 1,2,3,4,6,7,8-HpCDF
Least squares curve fit
RESPONSE RATIO
15
12
9
6
3
0
0
2
4
6
8
10
12
14
(.991012)
LEAST SQUARES CURVE FIT
CURVE TYPE
INDEX OF DETERMINATION
A
B
1. Y=A+(B*X)
.991012
-6.240526E-02
.94308
AMT.(CONC.)RATIO
MONS 218378

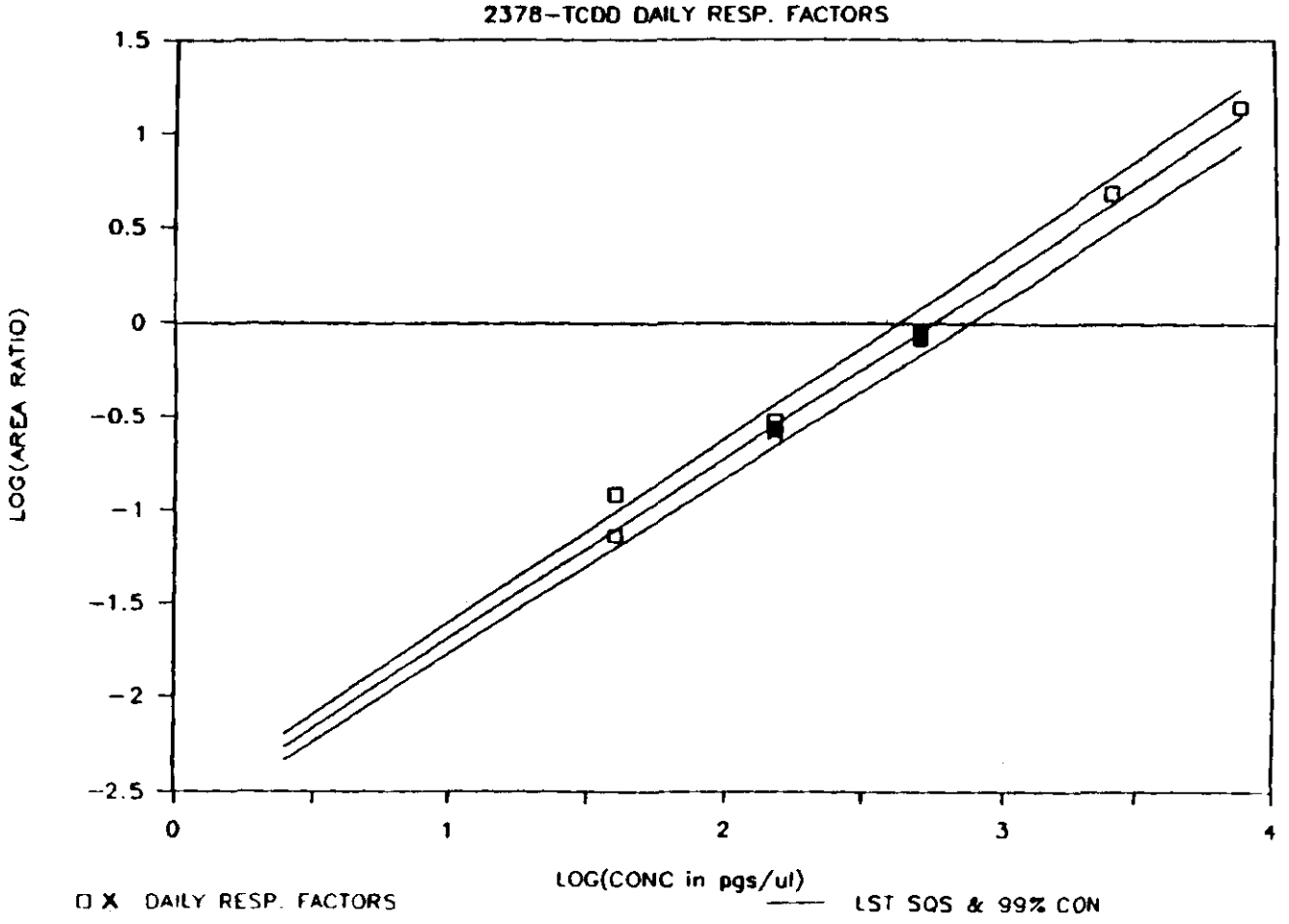
Appendix C

ANALYTE RESPONSE FACTOR CURVES

Figures C-1 through C-8. Area ratios from daily response factor determinations plotted onto the calibration curves.

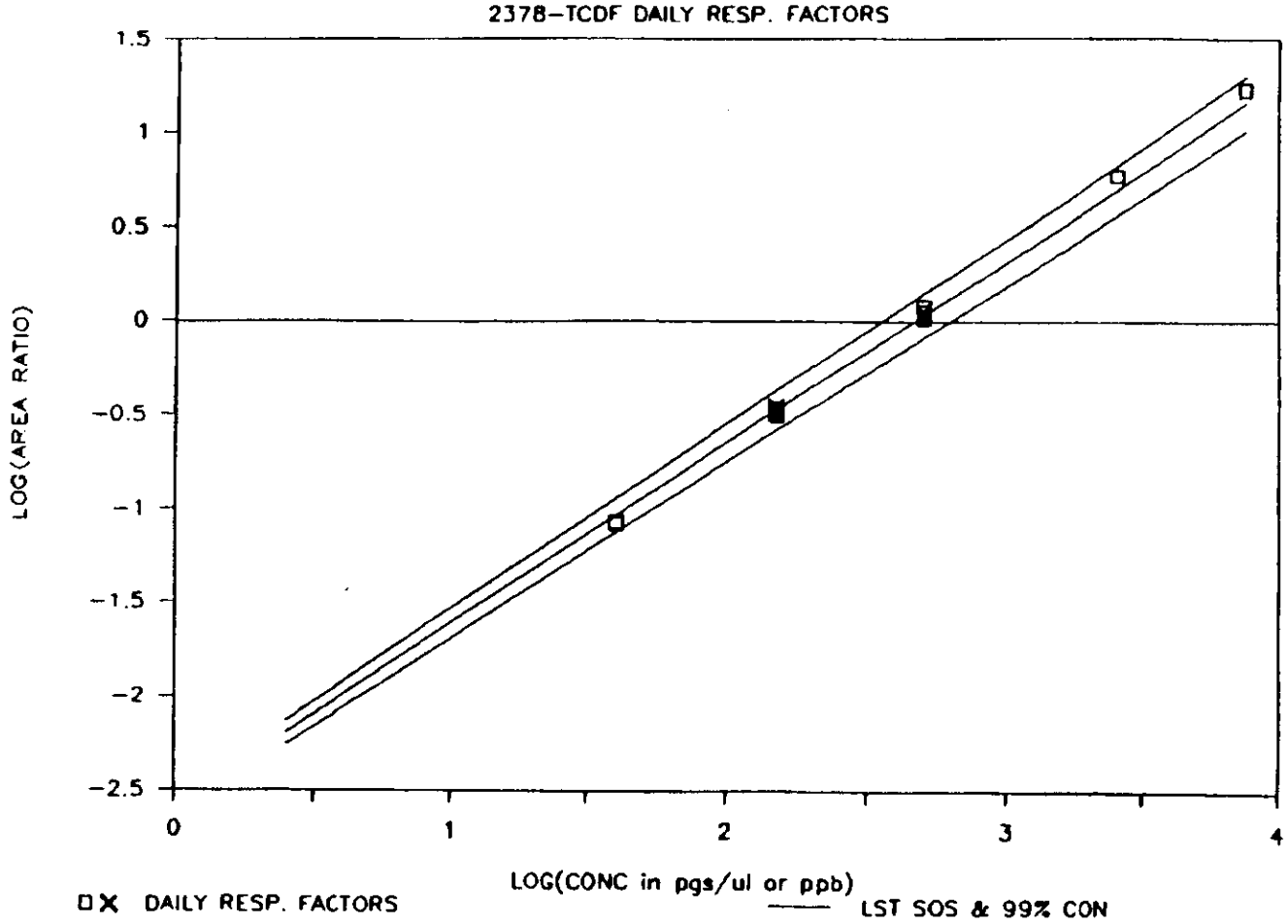
MONS 218379

FIGURE C-1:EPRI BASELINE PROJECT



MONS 218380

FIGURE C-2: EPRI BASELINE PROJECT



MONS 218381

FIGURE C-3:EPRI BASELINE PROJECT

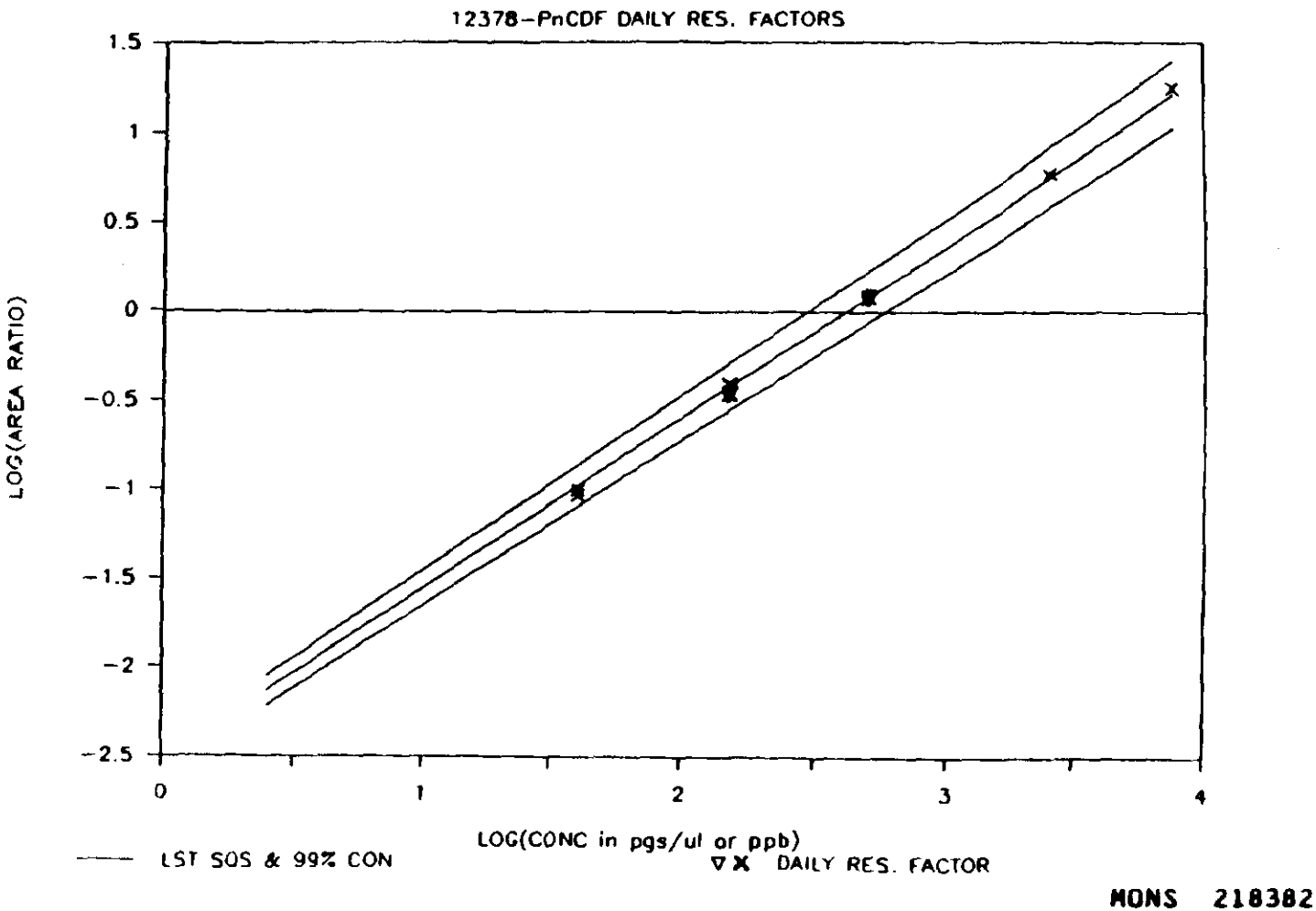
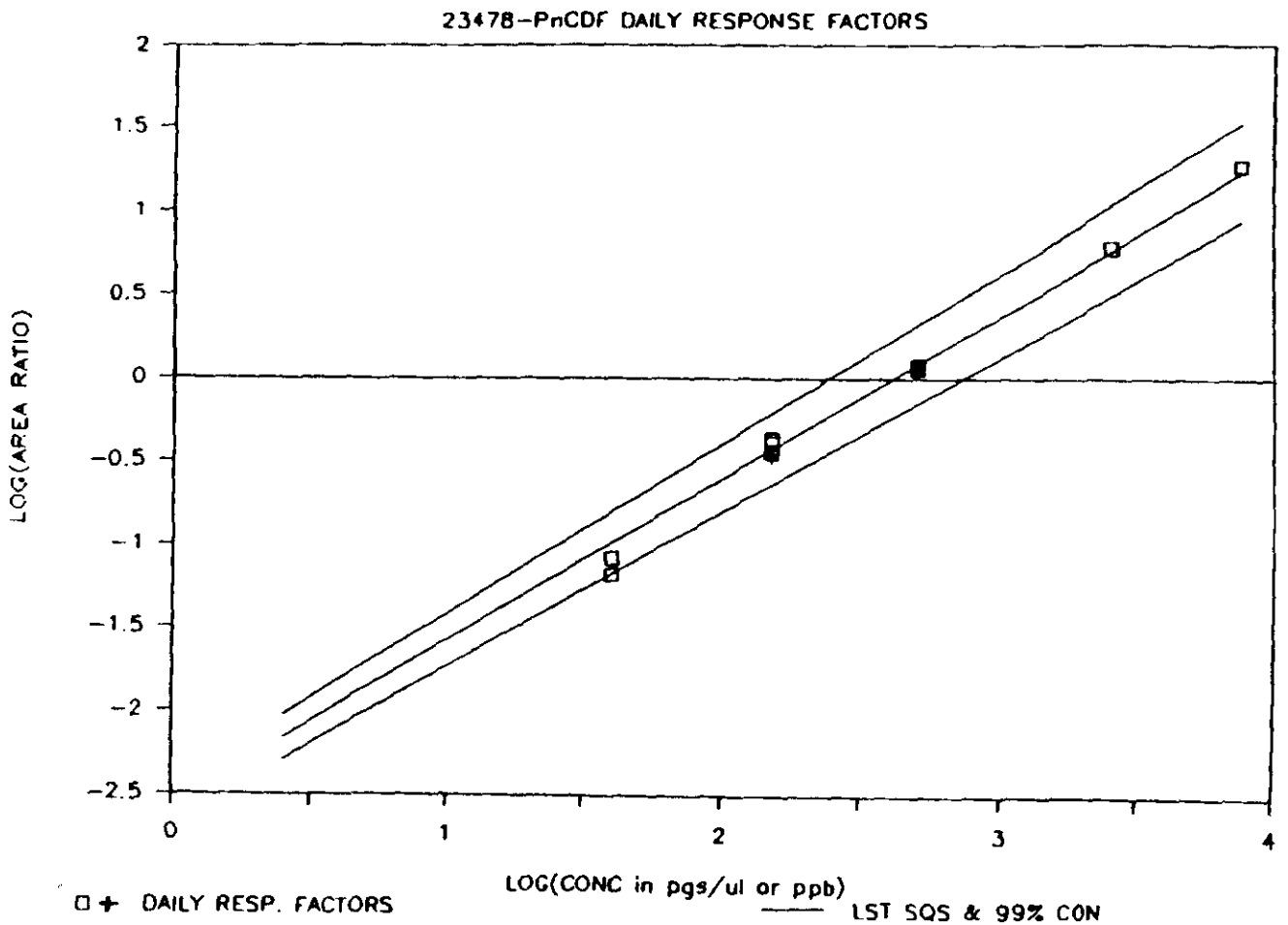
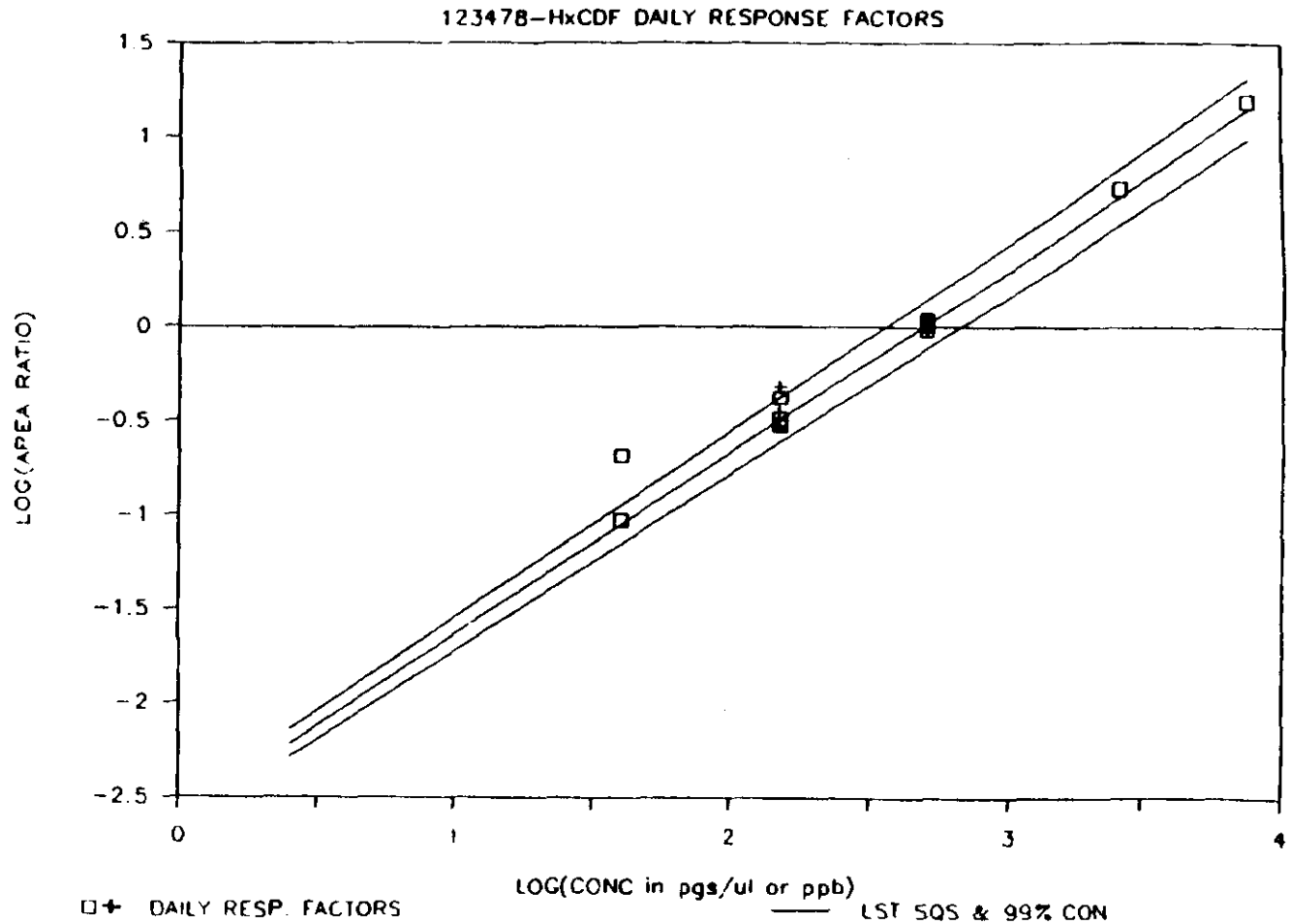


FIGURE C-4: EPRI BASELINE PROJECT



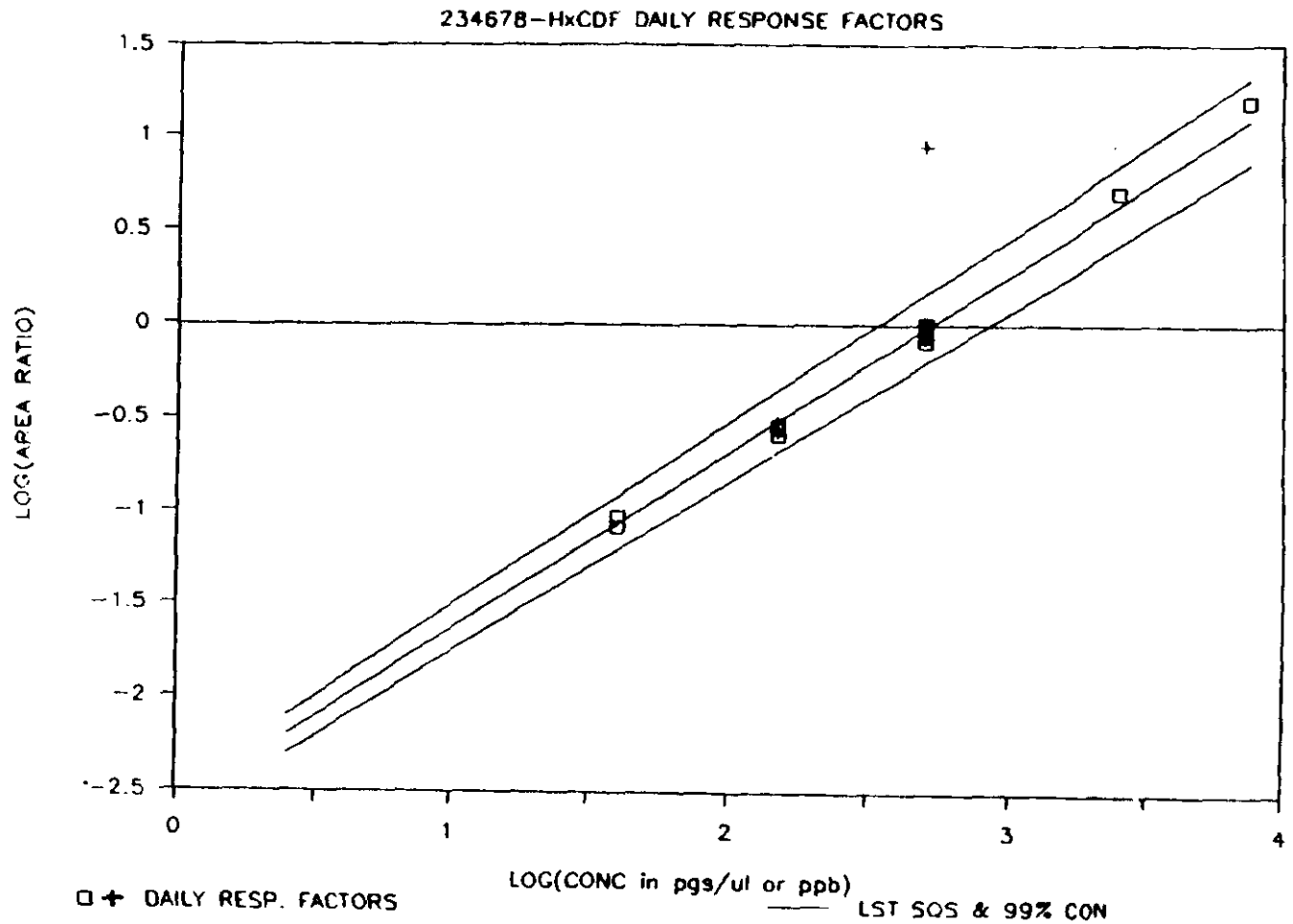
MONS 218383

FIGURE C--5: EPRI BASELINE PROJECT



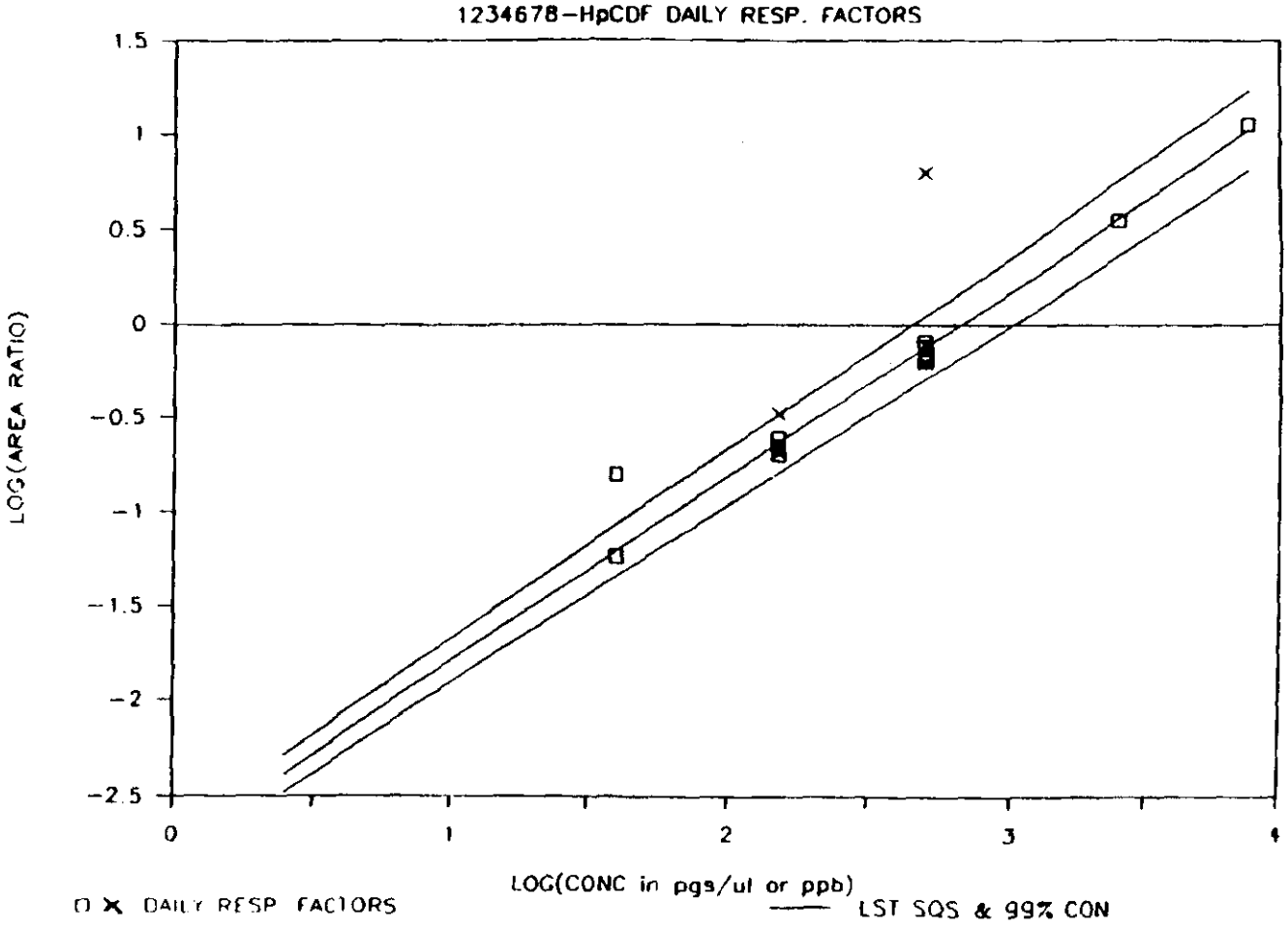
MONS 218384

FIGURE C-6: EPRI BASELINE PROJECT



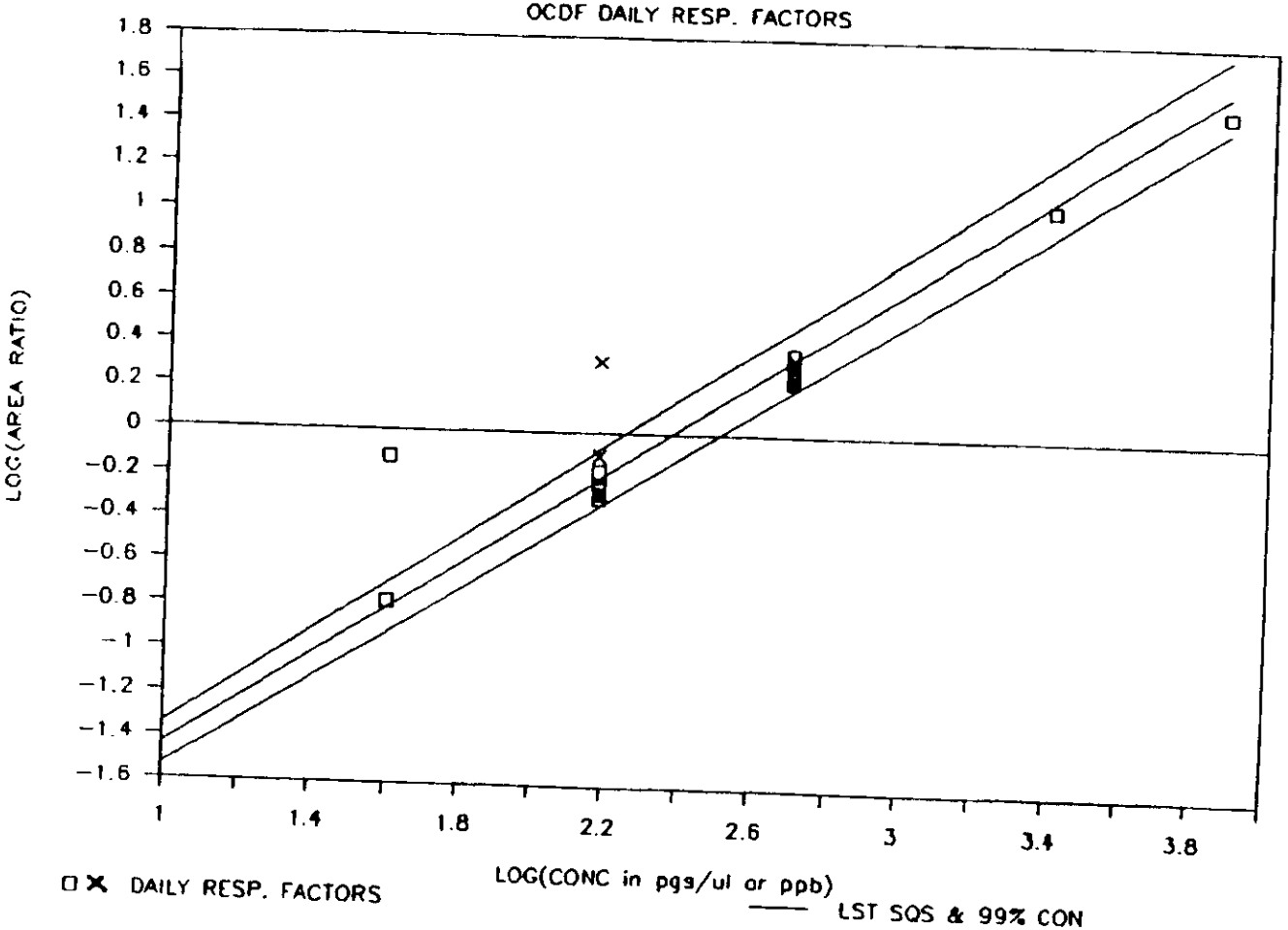
MONS 218385

FIGURE C--7: EPRI BASELINE PROJECT



MONS 218386

FIGURE C-8: EPRI BASELINE PROJECT



MONS 218387

Appendix D

TABLES OF RESULTS

TABLE D-1

BASELINE SAMPLES
PRELIMINARY RESULTS OF SPECIFIC COMPOUND ANALYSIS

SAMPLES	CONC. 2378-TCDD ppb (D.L.)	RET. TIME (min.)	RATIO (%)	CONC. 2378-TCDF ppb (D.L.)	RET. TIME (min.)	CONC. 12378-PCDF ppb (D.L.)	RET. TIME (min.)
Aroclor 1016 E-729-09-01	--			0.14(0.12)	22.34	0.40(0.08)	23.41
Aroclor 1016 E729-09-01	0.51(0.19)	17.63	77	0.34(0.08) ND[1]	22.48	0.32(0.24) ND[1]	23.48
Aroclor 1242 E729-10-01	0.45(0.03)		106	150(1.6)	22.34	1000(25) 62(1.4)[2]	23.03
Aroclor 1260 E729-11-0	7.3(0.72)	17.35	79	190(1.7)	22.15	220(5)	23.20
Tri/Tetra Cl Benz E729-12-01	0.46(0.13)	17.29	44	0.43(0.05)	22.27	0.63(0.09)	23.24
Aged Mineral Oil E729-08-01	43(0.01)	17.55	80	34(0.27)	22.44	140*	23.52
Blind Spike Levels	40			20		40	
Blank	0.93(0.06)	17.58	83	0.14(0.05)	22.53	N.D.(0.41)	23.55
Nujol Spike	10(0.08)	17.58	91	12(0.58)	22.45	24(0.34)	23.48

*Sum of 1,2,3,7,8-PnCDF and 1,2,3,4,8-PnCDF
1.) ND = Not Detected in a second analysis
2.) The results of an alternative interpretation of the high resolution mass data.

MONS 218388

TABLE D-2

EPRI BASELINE STUDY
PRELIMINARY TOTAL CONGENER GROUP RESULTS

SAMPLE	TOTAL TCDD ppb (D.L.)	TOTAL TCDF ppb (D.L.)	TOTAL PENTA CDF ppb (D.L.)	TOTAL HEXA CDF ppb (D.L.)	TOTAL HEPTA ppb (D.L.)	OCDF ppb (D.L.)
Aroclor 1016 E729-09-01	N.D.(0.6)	0.42	7.3	350	92	N.D.(12)
Aroclor 1242 E729-10-01	N.D.(0.2)	1900	584	140	130	2300
Aroclor 1260 E729-11-0	N.D.(1.0)	940	932	5500	2970	NA
Chlorobenzenes E729-12-01	N.D.(0.2)	3.0	12.5	1000	91	NA
Aged Mineral Oil E729-08-01	42	95	--	1100	--	NA
Blind Spike Levels	40	20	40	120	0	0
Total Spiked	40	120	240	220	0	160
Blank	N.D.(0.4)	0.75	--	28	--	NA
Nujol	11 (10)*	22 (10)*	--	420 (10)*	19 (10)*	NA

* Spike Level
NA - Not Available

MONS 218389

TABLE D-3

EPRI BASELINE PROJECT: ANALYSIS OF AGED MINERAL OIL

	BLANK AGED MINERAL OIL (in ppb)	SPIKED MIN OIL (in ppb)	SPIKED LEVEL (in ppb)	%ERROR
TOTAL TCDF	(0.61)	178	200	11.0
TOTAL PnCDF	(1.03)	282	300	6.0
TOTAL HxCDF	(102.3)	400	475	15.8
TOTAL HpCDF	(164)	356	400	11.0
OCDF	(58.3)	3.37	NS	NA
TOTAL TCDD	(0.93)	18.8	25	24.8
OCDD	(58.3)	(2.1)	NS	NA
2,3,7,8-TCDD	(0.93)	18.8	25	24.8
2,3,7,8-TCDF	(0.61)	178	200	11.0
2,3,4,8-TCDF	(0.61)	91.3	100	8.7
1,2,3,7,8-PnCDF	(1.03)	135	150	10.0
1,2,3,4,8-PnCDF	(1.03)	(0,06)	NS	NA
2,3,4,7,8-PnCDF	(1.03)	141	150	6.0
1,2,3,4,7,8-HxCDF	(102)	227	250	9.2
1,2,3,4.7,9-HxCDF	(102)	(0,22)	NS	NA
1,2,3,7,8,9-HxCDF	(102)	(0.22)	NS	NA
1,2,3,6,7,8-HxCDF	(102)	41.5	50	17.0
2,3,4,6,7,8-HxCDF	(120)	160	175	8.6
1,2,3,4,6,7,8-HpCDF	(164)	354	400	11.5
			AVE. % ERR	12.5

1.) Numbers in parentheses indicate detection limits in ppb
2.) Average detection limit of three determinations
3.) NS = not spiked; NA = not applicable
4.) 2,3,7,8-TCDF value is the sum of 2,3,7,8- and 2,3,4,8-TCDF concentrations.

MONS 218390

TABLE D-4

EPRI BASELINE PROJECT: ANALYSIS OF AROCLOR 1016

	BL AROCLOR 1016 (in ppb)	SPIKED AROCL 1016 (in ppb)	SPIKED LEVEL (in ppb)	% ERROR
TOTAL TCDF	(0.41)[1]	63	53	-18.9
TOTAL PnCDF	(0.50)	312	316	1.3
TOTAL HxCDF	(22.2)	212	185	-14.6
TOTAL HpCDF	(36)	627	526	-19.2
OCDF	(7.9)	120	132	9.1
TOTAL TCDD	(0.58)	48.2	53	9.1
OCDD	(16)	(2.1)[2]	NS[3]	NA[3]
2,3,7,8-TCDD	(0.58)	48.2	53	9.1
2,3,7,8-TCDF	(0.41)	62.3	53	-17.5
2,3,4,8-TCDF	(0.41)	(0.71)[2]	NS	NA
1,2,3,7,8-PnCDF	(0.50)	159	158	-0.6
1,2,3,4,8-PnCDF	(0.50)	(0.38)[2]	NS	NA
2,3,4,7,8-PnCDF	(0.52)	148	158	6.3
1,2,3,4,7,8-HxCDF	(22)	3.98	NS	NA
1,2,3,4,7,9-HxCDF	(22)	(0.26)[2]	NS	NA
1,2,3,7,8,9-HxCDF	(22)	(0.26)[2]	NS	NA
1,2,3,6,7,8-HxCDF	(22)	56.5	53	-6.6
2,3,4,6,7,8-HxCDF	(26)	151	132	-14.4
1,2,3,4,6,7,8-HpCDF	(36)	625	526	-18.8
			AVE % ERR	11

1.) Numbers in parentheses indicate detection limits
2.) Average detection limit of three determinations
3.) NS = not spiked; NA = not applicable

MONS 218391

TABLE D-5

EPRI BASELINE PROJECT SAMPLE: ANALYSIS OF AROCLOR 1260

	SPIKED AROCL 1260 (in ppb)	SPIKED-BLANK (in ppb)	SPIKED LEVEL (in ppb)	% ERROR
TOTAL TCDF	1613	1093	1137	3.9
TOTAL PnCDF	1320	412	222	NA[3]
TOTAL HxCDF	2473	1253	834	NA[3]
TOTAL HpCDF	2390	732	111	NA[3]
OCDF	5037	403	222	-81.5[4]
TOTAL TCDD	64	64	111	42.3
OCDD	(4.78)[1,2]	NA[3]	NS[3]	NA[3]
2,3,7,8-TCDD	64	64	111	42.3
2,3,7,8-TCDF	1210	1033	1027	-0.6
2,3,4,8-TCDF	436	NA	194	NA
1,2,3,7,8-PnCDF	205	127	111	-14.4
1,2,3,4,8-PnCDF	140	61	NS	NA
2,3,4,7,8-PnCDF	294	119	111	-7.2
1,2,3,4,7,8-HxCDF	1240	647	500	-29.4
1,2,3,4,7,9-HxCDF	(0.5)[1,2]	NA	NS	NA
1,2,3,7,8,9-HxCDF	38	38	NS	NA
1,2,3,6,7,8-HxCDF	336	336	278	-20.9
2,3,4,6,7,8-HxCDF	297	260	56	-364.3[4]
1,2,3,4,6,7,8-HpCDF	845	358	111	-222.5[4]
			AVE % ERR	75

1.) Numbers in parentheses indicate detection limits
2.) Average detection limit of three determinations
3.) NS = not spiked; NA = not applicable
4.) These values are discussed in the text

MONS 218392

TABLE D-6

EPRI BASELINE PROJECT SAMPLE
1953 LOAD CENTER NETWORK TRANSFORMER

	DET. 1	DET. 2	DET.3	AVE.	SD	CV
TOTAL TCDF	232	121	337	230	108.1	47
TOTAL PnCDF	1930	1690	1760	1793	123.4	6.9
TOTAL HxCDF	6840	6570	6520	6643	172.1	2.6
TOTAL HpCDF	10100	8610	8880	9196	793.9	8.5
OCDF	39000	37700	42100	39600	2234	5.6
TOTAL TCDD	(1.32)	(62.2)	(2.76)			
OCDD	11.8	9	14.3	12	3	25
	10	10.4	17			
2,3,7,8-TCDD	(1.32)	(62.2)	(2.76)			
2,3,7,8-TCDF	48.9	42.9	67.7	53.17	12.94	24.3
2,3,4,8-TCDF	16.5					
1,2,3,7,8-PnCDF	19.2	29.4	15.6	21.4	7.16	33
1,2,3,4,8-PnCDF	919	705	772	798.7	109.5	13.7
2,3,4,7,8-PnCDF	101	107	105	104.3	3.06	2.9
1,2,3,4,7,8-HxCDF	4790	4610	4620	4673	101.2	2.2
1,2,3,4,7,9-HxCDF	(2.34)	(4.14)	(5)			
1,2,3,7,8,9-HxCDF	(2.34)	(4.14)	(5)			
1,2,3,6,7,8-HxCDF	360	367	362	363	3.61	1
2,3,4,6,7,8-HxCDF	51.2	42.4	40.6	44.7	5.67	12.7
1,2,3,4,6,7,8-HpCDF	3890	3280	3990	3720	384.3	10.3

1.) Average of six (6) results

MONS 218393

TABLE D-7

EPRI BASELINE PROJECT SAMPLE:
LOAD CENTER NETWORK TRANSFORMER

	DET. 1	DET. 2	DET.3	AVE.	SD	CV
TOTAL TCDF	228	182	518	309.3	182.2	58.9
TOTAL PnCDF	430	303	435	389.3	74.8	19.2
TOTAL HxCDF	983	897	938	939.3	43	4.6
TOTAL HpCDF	2400	1940	1850	2063	295	14.3
OCDF	6800	8000	7010	7270	640.9	8.8
TOTAL TCDD	(0.35)	(0.43)	(7.1)			
OCDD	(27.4)	(26.6)	(27.1)			
2,3,7,8-TCDD	(0.05)	(0.12)	(2)			
2,3,7,8-TCDF	68.6	61.1	90.9	73.5	15.5	21.1
2,3,4,8-TCDF		6.95				
1,2,3,7,8-PnCDF	29.4	30.7	28.9	29.7	0.93	3.13
1,2,3,4,8-PnCDF	88.8	38.1	72.3	66.4	25.9	39
2,3,4,7.8-PnCDF	60.6	39.6	59.4	53.2	11.8	22.2
2,3,4,7,8-HxCDF	619	596	610	608.3	11.6	1.9
1,2,3,4,7,9-HxCDF	1.5	1.54	1.8	1.6	0.16	10
1,2,3,7,8,9-HxCDF	37.9	17.7	36.1	29.9	7.	25
	33.9	22.2	31.5			
1,2,3,6,7,8-HxCDF	43	44.6	42.3	43.3	1.18	
2,3,4,6,7,8-HxCDF	15.2	9.1	12.3	12.2	3.05	2.7
1,2,3,4,6,7,8-HpCDF	662	545	631	612.7	60.6	25

MONS 218394

TABLE D-8

EPRI BASELINE PROJECT SAMPLE:
CAPACITOR

	DET. 1	DET. 2	DET.3	AVE.	SD	CV
TOTAL TCDF	686	700	942	776	144	15
TOTAL PnCDF	368	351	346	355	11.5	3.3
TOTAL HxCDF	39.7	51.9	42	44.5	6.48	15
TOTAL HpCDF	8.3	12.5	9.51	10.1	2.16	21
OCDF	13.4	15.3	16.6	15.1	1.60	11
TOTAL TCDD	(0.16)	(0.39)	(0.83)			
OCDD	(1.1)	(0.38)	(0.29)			
2,3,7,8-TCDD	(0.16)	(0.39)	(0.83)			
2,3,7,8-TCDF	197	226	273	232	38.40	7
2,3,4,8-TCDF		44.1				
1,2,3,7,8-PnCDF	8.3	9.6	8.37	8.757	0.73	8.4
1,2,3,4,8-PnCDF	11.5	7.7	8.7	9.3	1.97	21
2,3,4,7,8-PnCDF	61.3	61.5	71.1	64.63	5.60	8.7
1,2,3,4,7,8-HxCDF	16.5	21.5	15.8	13.53	4.55	34
1,2,3,4.7,9-HxCDF	0.3	0.36	0.38	0.35	0.04	12
1,2,3,7,8,9-HxCDF	0.19	0.36	0.24	0.263	0.09	33
1,2,3,6,7,8-HxCDF	3.4	4.36	3.94	3.9	0.48	12
2,3,4,6,7,8-HxCDF	1.7	2	1.75	1.817	0.16	8.9
1,2,3,4,6,7,8-HpCDF	3.4	4.8	3.38	3.86	0.81	21

MONS 218395

TABLE D-9

EPRI BASELINE PROJECT SAMPLE: PRECIPITATOR TRANSFORMER

	DET. 1	DET. 2	DET.3	AVE.	SD	CV
TOTAL TCDF	1500	953	1100	1184	283.1	23.9
TOTAL PnCDF	10500	10200	10800	10500	300	2.9
TOTAL HxCDF	10500	10900	10700	10700	200	1.9
TOTAL HpCDF	2000	2020	2100	2040	52.9	2.6
OCDF	190	187	181	186	4.6	2.5
TOTAL TCDD	(0.05)	0.42	0.98			
OCDD	1.04	0.98	1.01	1.01	0.03	3
2,3,7,8-TCDD	(0.05)	(0.02)	(0.09)			
2,3,7,8-TCDF	480	349	395	408	66.5	16.3
2,3,4,8-TCDF		101				
1,2,3,7,8-PnCDF	799	796	818	804.3	11.9	1.5
1,2,3,4,8-PnCDF	307	256	317	293.3	32.7	11.2
2,3,4,7,8-PnCDF	1930	1920	1970	1940	26.5	1.4
1,2,3,4,7,8-HxCDF	4390	4410	4360	4387	25.2	0.6
1,2,3,4,7,9-HxCDF	22.5	21.6	22	22	0.45	2.1
1,2,3,7,8,9-HxCDF	162	177	175	171.3	8.2	4.8
1,2,3,6,7,8-HxCDF	1030	1030	1000	1020	17.3	1.7
2,3,4,6,7,8-HxCDF	366	404	398	389.3	20.4	5.2
1,2,3,4,6,7,8-HpCDF	690	678	700	689.3	11	1.6

MONS 218396

TABLE D-10

EPRI BASELINE PROJECT SAMPLE:
1976 ARC FURNACE TRANSFORMER

	DET. 1	DET. 2	DET.3	AVE.	SD	CV
TOTAL TCDF	0.53	0.38	0.31	0.41	0.11	28
TOTAL PnCDF	1.72	1.94	2.14	1.93	0.21	11
TOTAL HxCDF	1.78	1.14	2.43	1.78	0.64	36
TOTAL HpCDF	0.51	0.23	0.19	0.31	0.17	56
OCDF	0.46	0.3	0.24	0.33	0.11	34
TOTAL TCDD	(0.09)	(0.08)	(20)			
OCDD	3.02	3.38	3.8	3.4	0.39	11
2,3,7,8-TCDD	(0.09)	(0.08)	(20)			
2,3,7,8-TCDF	0.2	0.24	0.23	0.223	0.02	9.3
2,3,4,8-TCDF		(0.54)				
1,2,3,7,8-PnCDF	0.21	0.26	0.23	0.23	0.03	11
1,2,3,4,8-PnCDF	(0.16)	(0.13)	(0.08)			
2,3,4,7,8-PnCDF	0.45	0.51	0.41	0.46	0.05	11
1,2,3,4,7,8-HxCDF	1.08	0.54	1.13	0.917	0.33	36
1,2,3,4,7,9-HxCDF	(0.2)	(0.06)	(0.03)			
1,2,3,7,8,9-HxCDF	0.22	0.11	0.28	0.203	0.09	42
1,2,3,6,7,8-HxCDF	0.25	0.13	0.27	0.217	0.08	35
2,3,4,6,7,8-HxCDF	(0.21)	(0.14)	(0.07)			
1,2,3,4,6,7,8-HpCDF	(0.28)	(0.08)	(0.09)			

MONS 218397

TABLE D-11

EPRI BASELINE PROJECT SAMPLE: SUBSTATION DISTRIBUTION TRANSFORMER

	DET. 1	DET. 2	DET.3	AVE.	SD	CV
TOTAL TCDF	0.15	0.18	0.23	0.19	0.04	22
TOTAL PnCDF	(0.34)	(0.6)	(0.53)			
TOTAL HxCDF	0.56	0.52	0.71	0.6	0.1	16.7
TOTAL HpCDF	(0.65)	(0.23)	(0.21)			
OCDF	(0.63)	(2.4)	(3.8)			
TOTAL TCDD	(0.61)	0.19	0.1			
OCDD	20.8	16.8	17.1	18.2	2.23	12
2,3,7,8-TCDD	(0.6)	(0.12)	(0.09)			
2,3,7,8-TCDF	0.15	0.18	0.13	0.15	0.025	16
2,3,4,8-TCDF			(1.5)			
1,2,3,7,8-PnCDF	(0.34)	(0.09)	(0.07)			
1,2,3,4,8-PnCDF	(0.34)	(0.09)	(0.07)			
2,3,4,7,8-PnCDF	(0.34)	0.09	0.11			
1,2,3,4,7,8-HxCDF	0.56	0.52	0.53	0.54	0.02	3.7
1,2,3,4,7,9-HxCDF	(0.21)	(0.19)	(0.16)			
1,2,3,7,8,9-HxCDF	(0.21)	(0.19)	(0.16)			
1,2,3,6,7,8-HxCDF	(0.21)	(0.19)	(0.16)			
2,3,4,6,7,8-HxCDF	(0.32)	(0.2)	(0.18)			
1,2,3,4,6,7,8-HpCDF	0.65	(0.23)	(0.21)			

MONS 218398

TABLE D-12

EPRI BASELINE PROJECT SAMPLE:
1962 LOAD CENTER NETWORK TRANSFORMER

	DET. 1	DET. 2	DET.3	AVE.	SD	CV
TOTAL TCDF	553	552	512	539	23.4	4.3
TOTAL PnCDF	1170	1130	I100	I133	35.1	3.I
TOTAL HxCDF	1760	1780	1820	1790	30.5	1.7
TOTAL HpCDF	1780	1580	I610	I657	107.8	6.5
OCDF	3960	4410	4730	4366	387.7	8.9
TOTAL TCDD	(I.16)	(0.82)	(0.71)			
OCDD	18.7	24.2	28.4	23.8	4.9	20.6
2,3,7,8-TCDD	(1.16)	(0.82)	(0.71)			
2,3,7,8-TCDF	195	184	182	187	7	3.7
2,3,4,8-TCDF		42.4				
I,2,3,7,8-PnCDF	59.4	60.8	61.4	60.5	1	1.7
1,2,3,4,8-PnCDF	230	216	206	217	12	5.5
2,3,4,7,8-PnCDF	I70	151	173	164.6	II.9	7.2
1,2,3.4,7,8-HxCDF	1000	1030	1110	1047	56.9	5.4
1,2,3,4,7,9-HxCDF	(0.89)	(0.86)	(0.59)			
1.2,3,7,8,9-HxCDF	(0.89)	(0.86)	(0.59)			
1.2.3,6,7,8-HxCDF	64.9	65.2	61.7	63.9	1.9	3
2,3,4,6,7,8-HxCDF	70	58	56	61	7.6	12
1,2,3,4,6,7,8-HpCDF	815	761	784	787	27	3.4

MONS 218399

TABLE D-13

EPRI BASELINE PROJECT SAMPLE: SPIKED AGED MINERAL OIL

	DET. 1	DET. 2	DET.3	AVE.	SD	CV
TOTAL TCDF	145	195	194	178	28.6	16.1
TOTAL PnCDF	251	312	283	282	30.5	10.8
TOTAL HxCDF	396	455	350	400	52.6	13.2
TOTAL HpCDF	354	341	372	356	15.6	4.4
OCDF	3.49	3.55	3.06	3.37	0,27	7.9
TOTAL TCDD	17	21.3	18.2	18.8	2.219	12
OCDD	(5.09)	(0,49)	(0.67)			
2,3,7,8-TCDD	17	21.3	18.2	18.8	2,219	12
2,3,7,8-TCDF	146	195	192	177.7	27.5	15.5
2,3,4,8-TCDF		91.3				
1,2,3,7,8-PnCDF	121	153	132	135	16.3	12.1
1,2,3,4,8-PnCDF	(0.04)	(0.07)	(0.07)			
2,3,4,7,8-PnCDF	127	158	138	141	15.7	11.1
1,2,3,4,7,8-HxCDF	224	259	199	227	30.1	13.3
1,2,3,4,7,9-HxCDF	(0.53)	(0.07)	(0.05)			
1,2,3,7,8,9-HxCDF	(0.53)	(0.07)	(0.05)			
1,2,3,6,7,8-HxCDF	42.1	47.4	35.1	41.5	6.2	14.9
2,3,4,6,7,8-HxCDF	150	161	170	160	10	6.3
1,2,3,4,6,7,8-HpCDF	351	341	369	353.7	14.2	4

MONS 218400

TABLE D-14

EPRI BASELINE PROJECT SAMPLE: SPIKED AROCLOR 1016

	DET. 1	DET. 2	DET.3	AVE.	SD	CV
TOTAL TCDF	60.8	62.7	65.5	63	2.4	3.8
TOTAL PnCDF	276	336	324	312	31.7	10.1
TOTAL HxCDF	201	209	225	212	12.2	5.8
TOTAL HpCDF	578	712	591	627	73.9	11.8
OCDF	133	107	121	120.3	13	10.8
TOTAL TCDD	39.6	50.4	54.5	48.2	7.7	15.9
OCDD	(1.44)	(0.41)	(4.52)			
2,3,7,8-TCDD	39.6	50.4	54.5	48.2	7.7	15.9
2,3,7,8-TCDF	60.8	60.5	65.5	62.3	2.8	4.5
2,3,4,8-TCDF		(0.72)				
1,2,3,7,8-PnCDF	138	171	168	159	18.2	11.4
1,2,3,4,8-PnCDF	(0.30)	(0.09)	(0.75)			
2,3,4,7,8-PnCDF	122	159	163	148	22.6	15.3
1,2,3,4,7,8-HxCDF	2.56	3.8	5.6	3.98	1.52	38
1,2,3,4,7,9-HxCDF	(0.21)	(0.05)	(0.52)			
1,2,3,7,8,9-HxCDF	(0.21)	(0.05)	(0.52)			
1,2,3,6,7,8-HxCDF	58.5	54.6	56.5	6.5	2	3.5
2,3,4,6,7,8-HxCDF	140	150	162	150.7	11	7.3
1,2,3,4,6,7,8-HpCDF	575	709	592	625	73	11

MONS 218401

TABLE D-15

EPRI BASELINE PROJECT SAMPLE: SPIKED AROCLOR 1260

	DET. 1	DET. 2	DET.3	AVE.	SD	CV
TOTAL TCDF	1630	1620	1590	1613	20.82	1.3
TOTAL PnCDF	1330	1290	1340	1320	26.46	2
TOTAL HxCDF	2490	2380	2550	2473	86.2	3.5
TOTAL HpCDF	2470	2300	2400	2390	85.4	3.6
OCDF	4850	5090	5170	5037	166.5	3.3
TOTAL TCDD	65.1	65.5	106	79.9	23	30
OCDD	(3.73)	(0.72)	(9.89)			
2,3,7,8-TCDD	65.1	65.5	106[1]	79.9	23	30
2,3,7,8-TCDF	1210	1220	1200	1210	10	0.83
2,3,4,8-TCDF		436				
1,2,3,7,8-PnCDF	207	203	206	205	2.08	1
1,2,3,4,8-PnCDF	139	139	142	140	1.73	1.2
2,3,4,7,8-PnCDF	304	288	291	294.3	8.5	2.9
1,2,3,4,7,8-HxCDF	1228	1209	1284	1240	38.99	3.1
1,2,3,4,7,9-HxCDF	(0.41)	(0.09)	(0.99)			
1,2,3,7,8,9-HxCDF	37.8	35.8	39.9	37.8	2.05	5.5
1,2,3,6,7,8-HxCDF	339	321	347	336	13.32	4
2,3,4,6,7,8-HxCDF	313	286	291	297	14.36	4.9
1,2,3,4,6,7,8-HpCDF	865	805	865	845	34.64	4.1

1.) Analyzed by high resolution m.s.

MONS 218402

Appendix E

BAR GRAPHS OF RESULTS

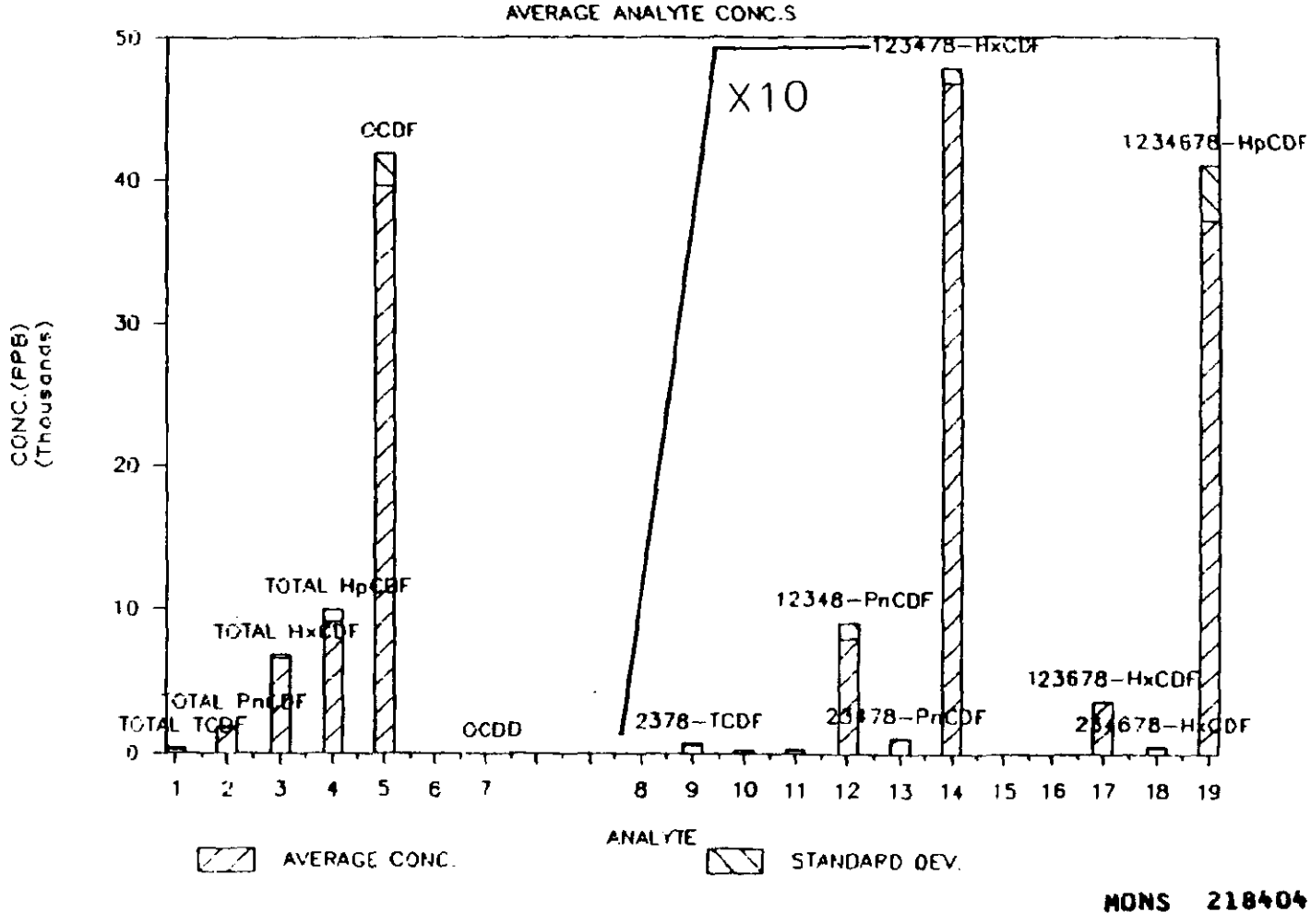
Figures E-1 through E-10. Bar plots of the results. The numbers listed along the analyte axis in each of these figures represent the following isomers or groups of isomers:

1. Total TCDF
2. Total PnCDF
3. Total HxCDF
4. Total HpCDF
5. OCDF
6. Total TCDD
7. OCDD
8. 2,3,7,8-TCDD
9. 2,3,7,8-TCDF
10. 2,3,4,8-TCDF
11. 1,2,3,7,8-PnCDF
12. 1,2,3,4,8-PnCDF
13. 2,3,4,7,8-PnCDF
14. 1,2,3,4,7,8-HxCDF
15. 1,2,3,4,7,9-HxCDF
16. 1,2,3,7,8,9-HxCDF
17. 1,2,3,6,7,8-HxCDF
18. 2,3,4,6,7,8-HxCDF
19. 1,2,3,4,6,7,8-HpCDF

In the Figures a bracket is used to indicate that most of the individual isomer determinations were multiplied by a factor of 10 before they were plotted. Thus, for example the concentration of 123478-HxCDF in the first figure is 4.7×10^{3} ppb.

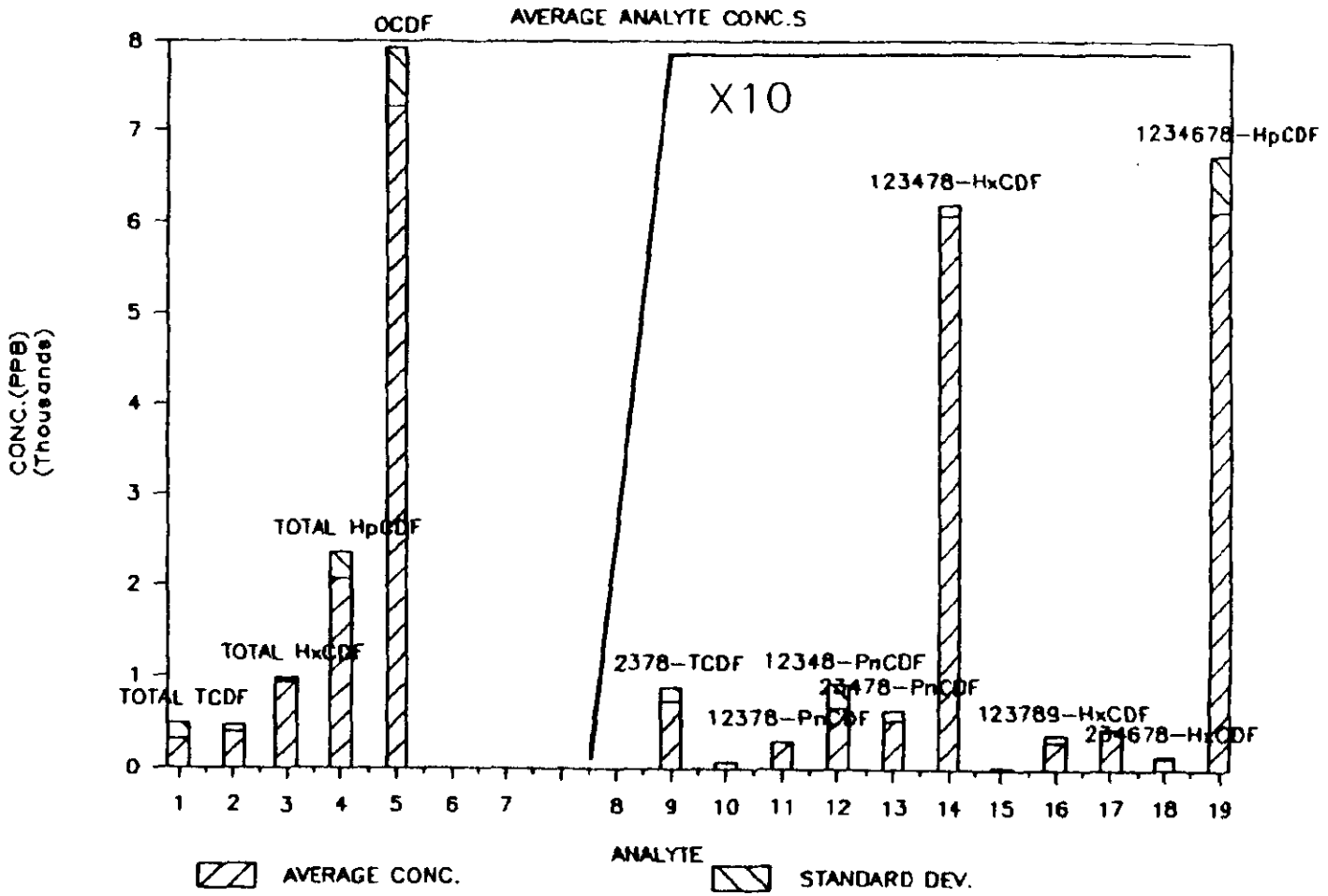
MONS 218403

FIG E-1: LOAD CENTER NETW. TRANSFORMER



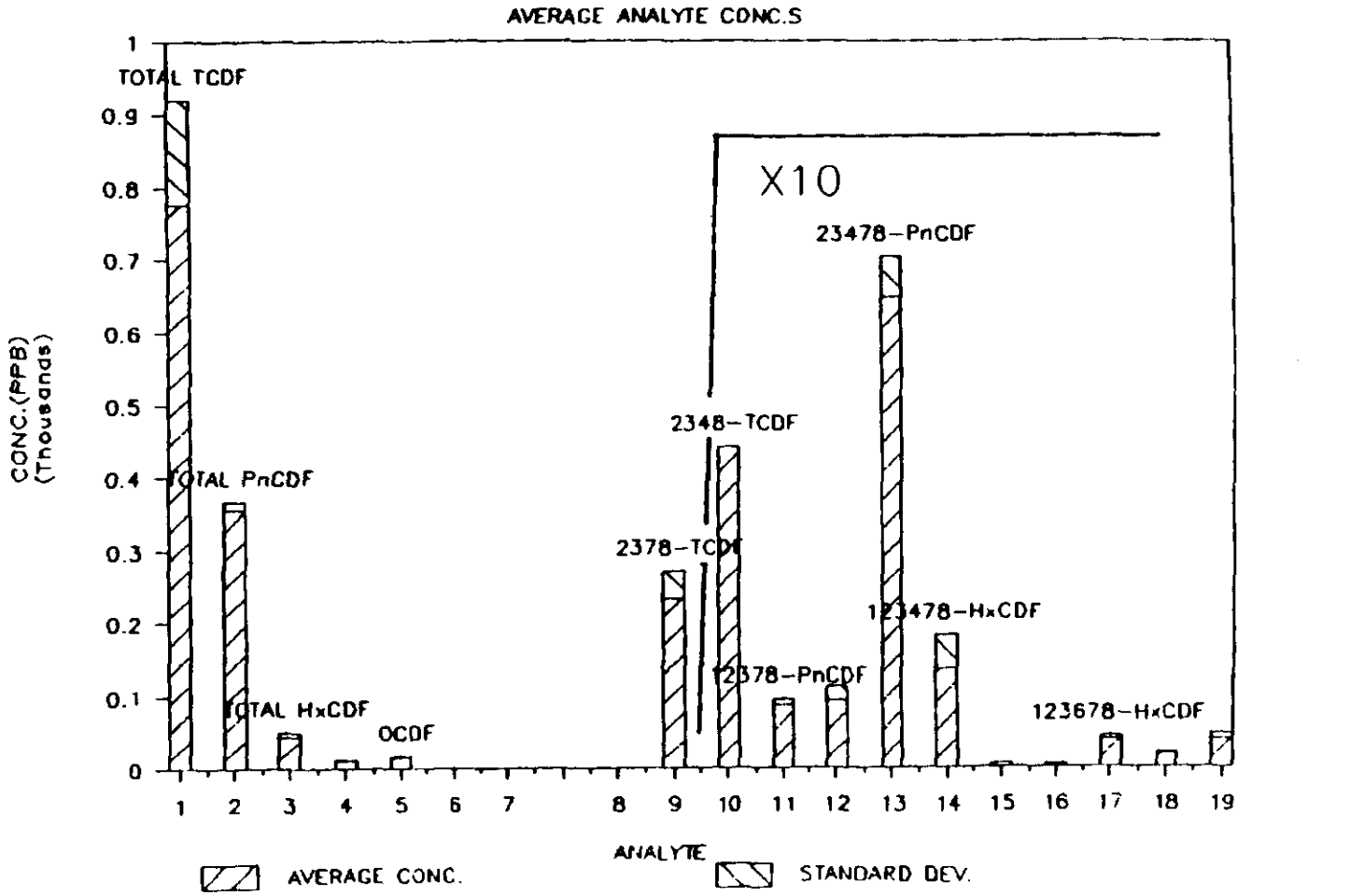
MONS 218404

FIG E-2: LOAD CNTR NETWORK TRANSFORMER



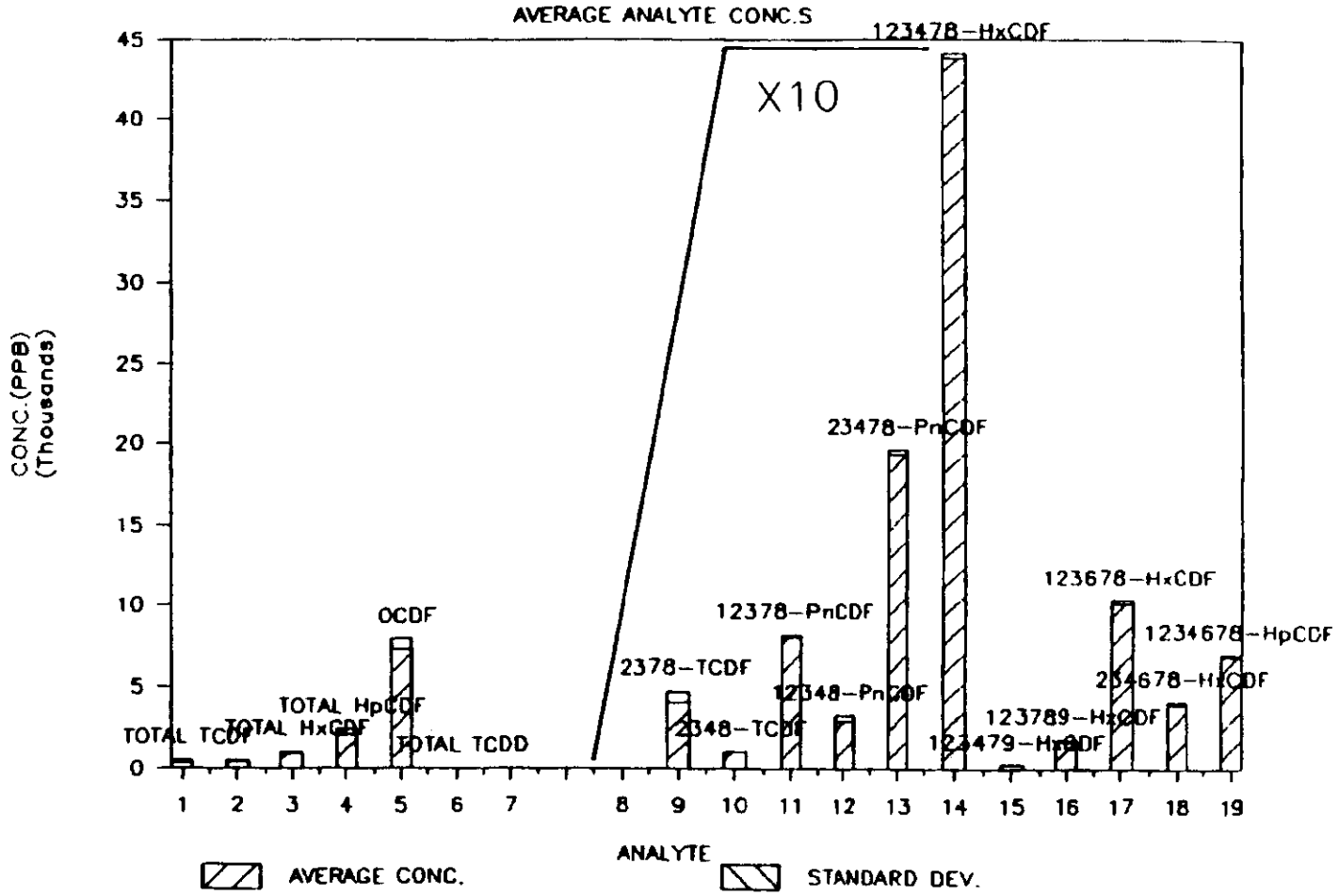
MONS 218405

FIG E-3: CAPACITOR



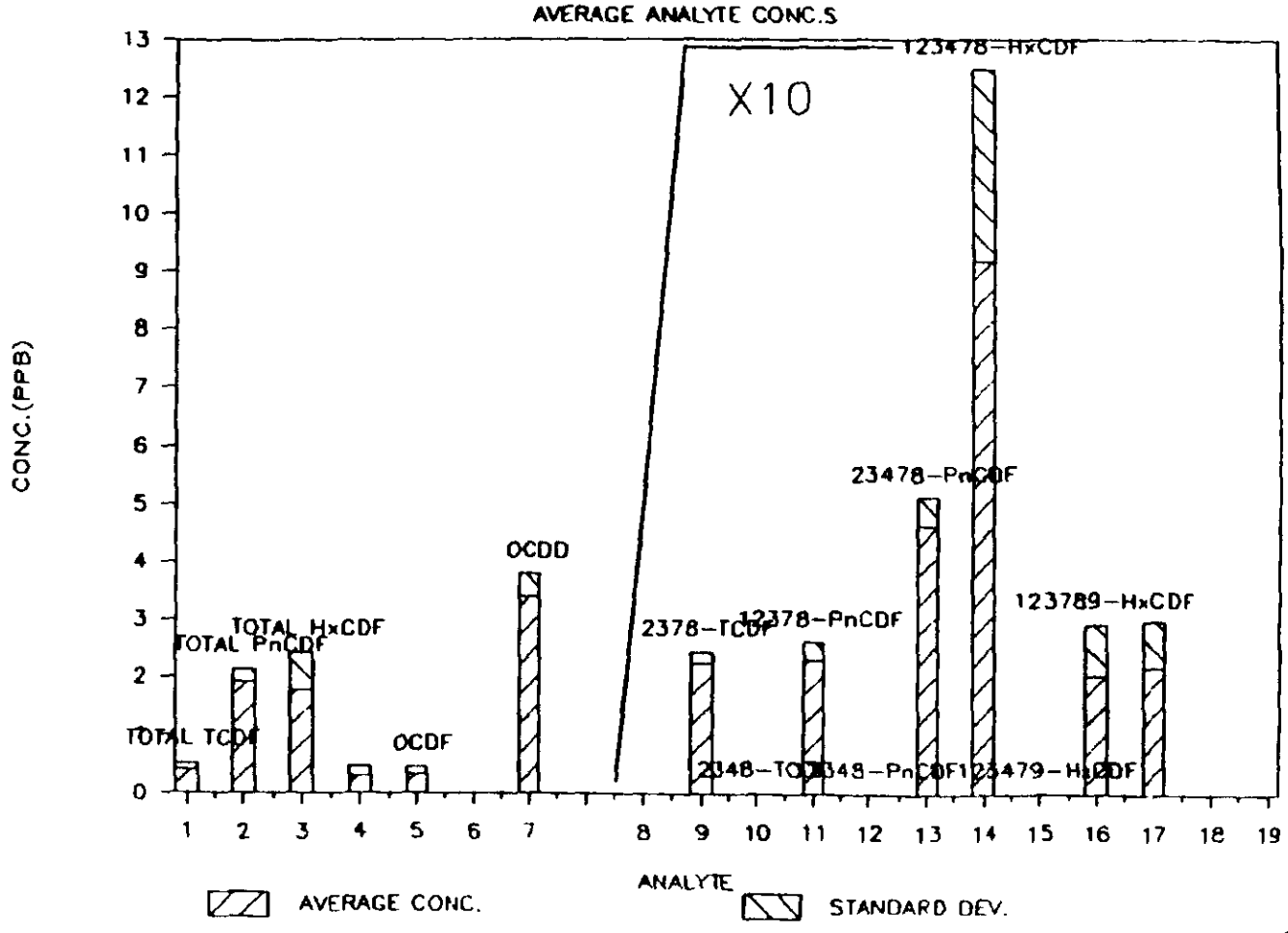
MONS 218406

FIG E-4: PRECIPITATOR TRANSFORMER



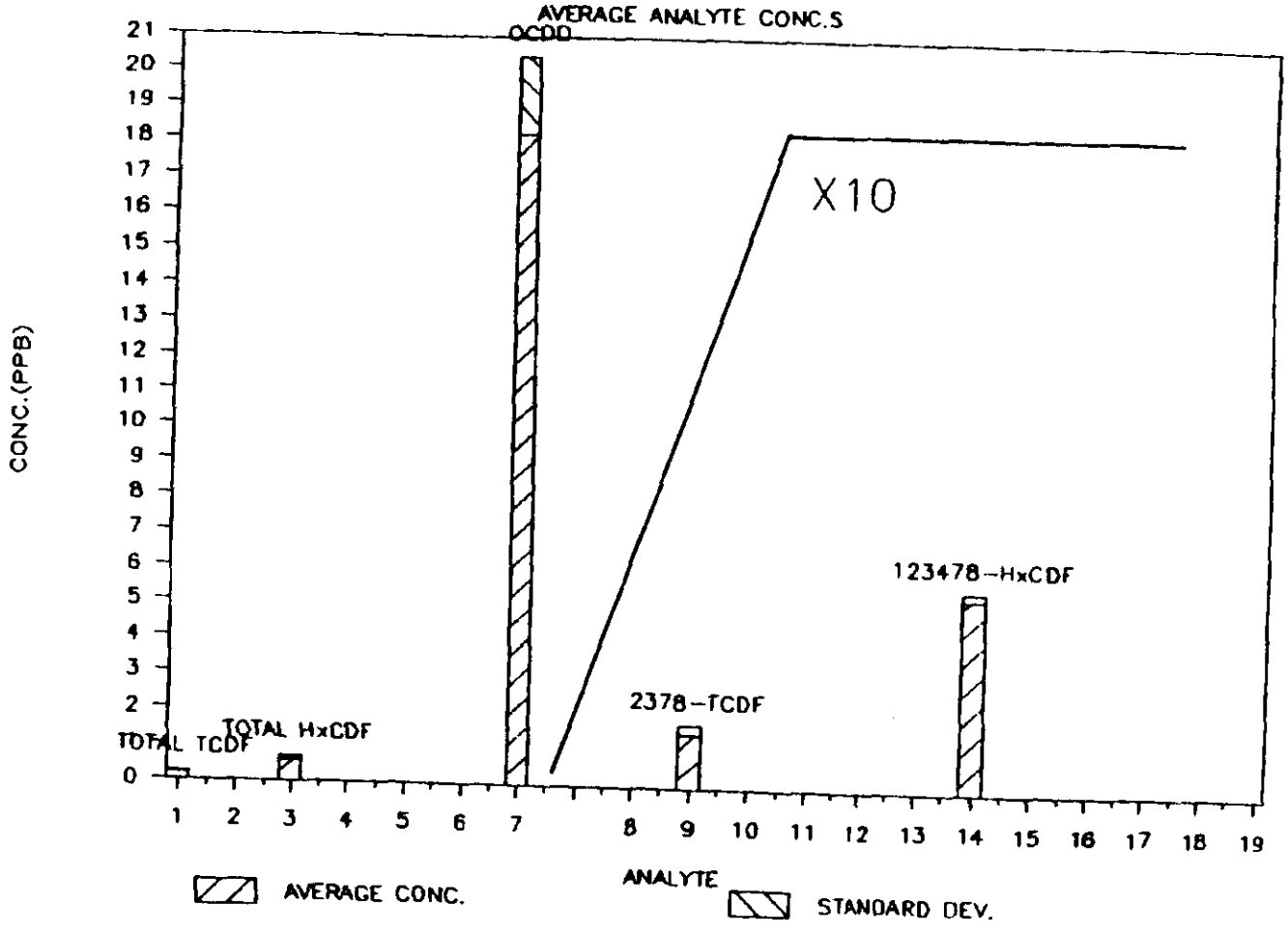
MONS 218407

FIG E-5: ARC FURNACE TRANSFORMER



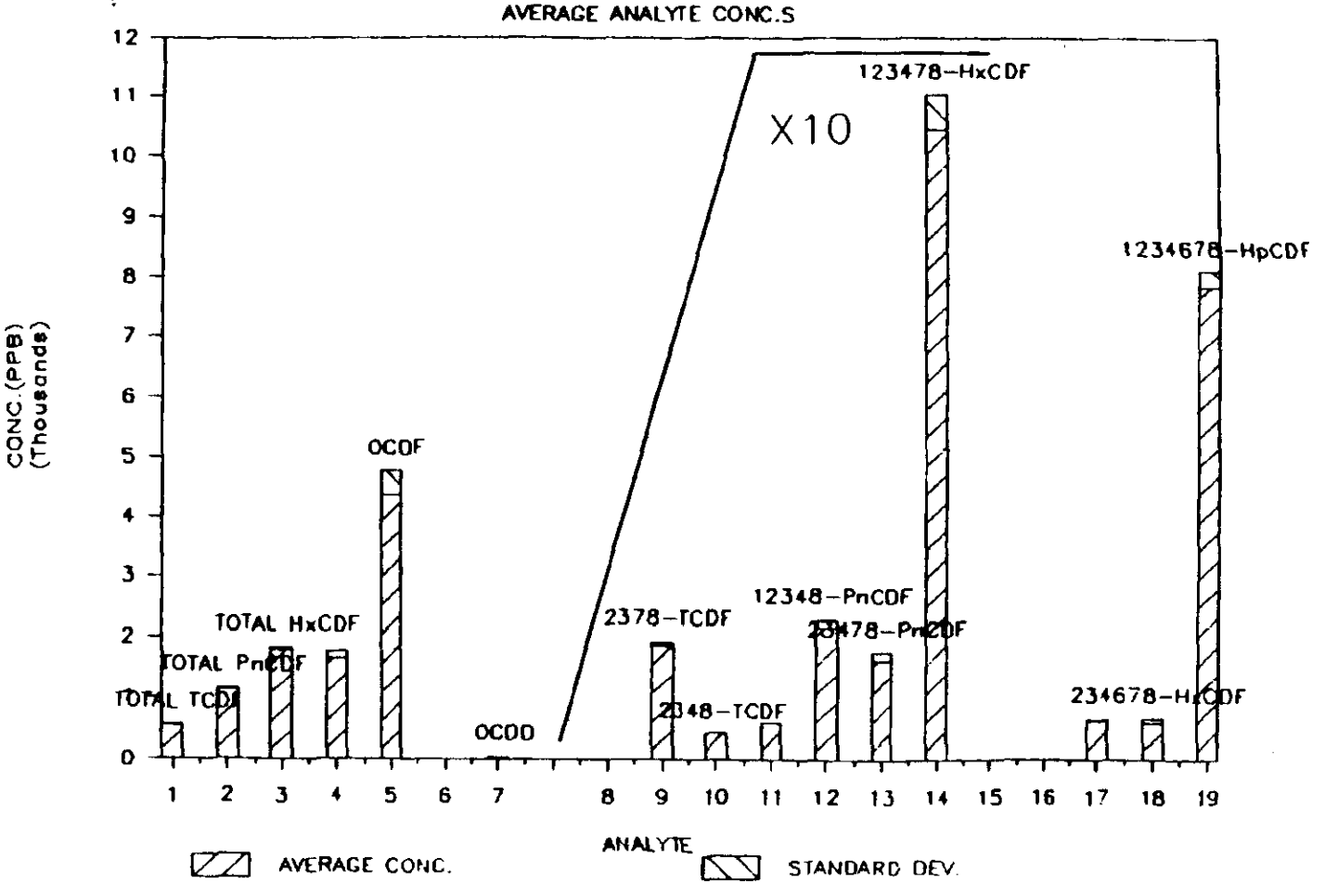
MONS 218408

FIG E-6: SUBSTATION DISTRIBUTION TRANSF



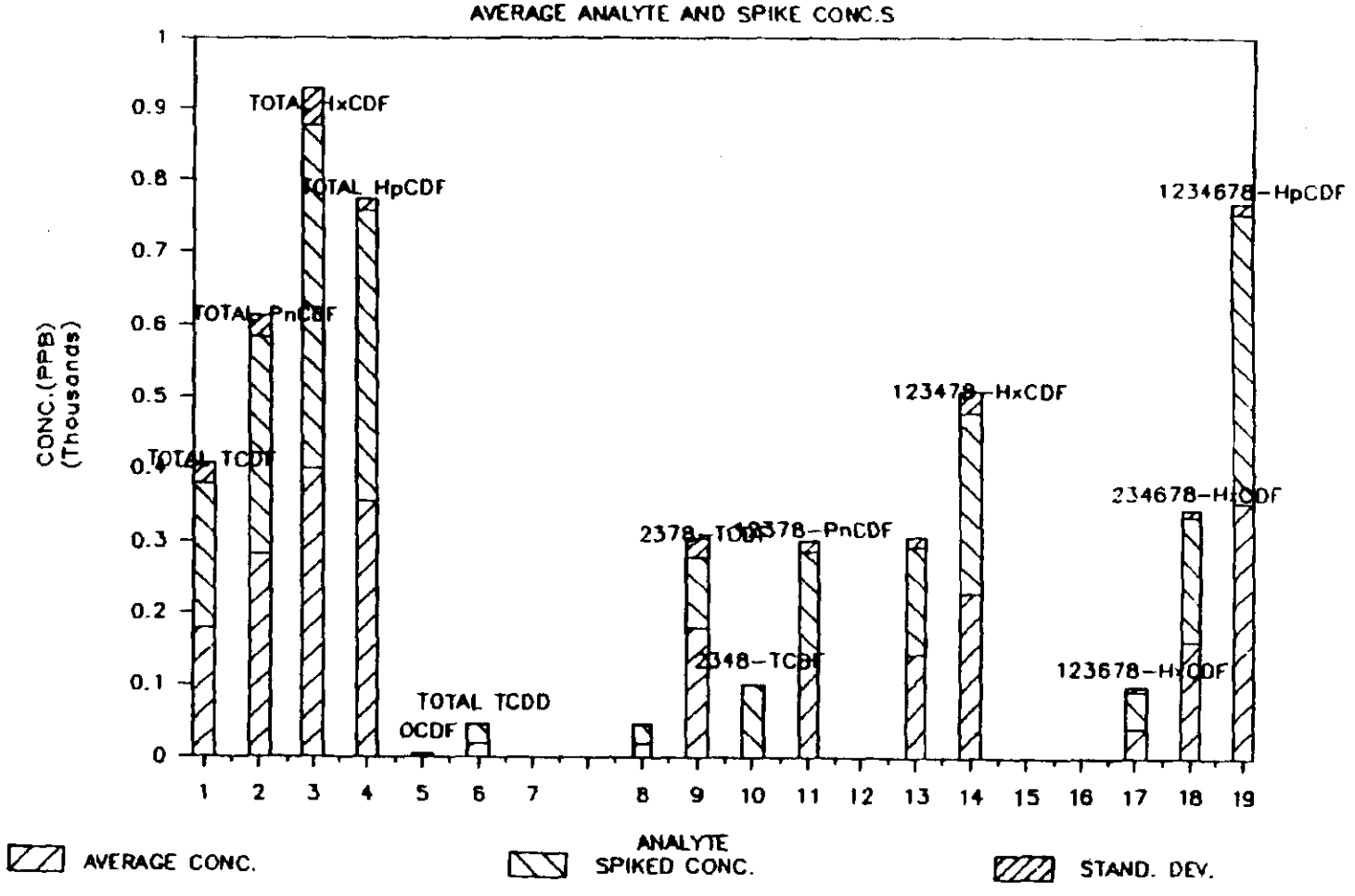
MONS 218409

FIG E-7: LOAD CNTR NETWORK TRANSFORMER



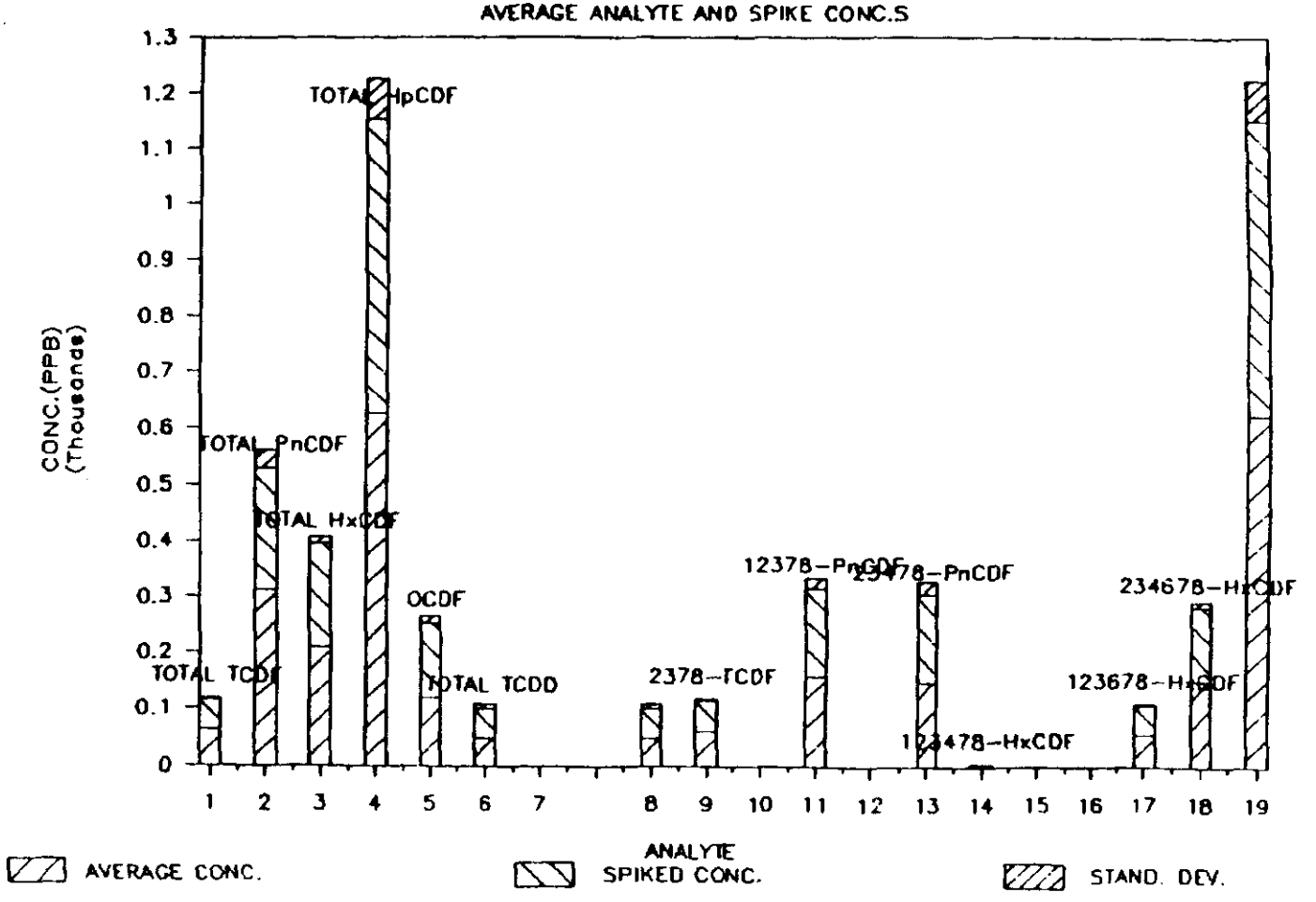
MONS 218410

FIGURE E-8: SPIKED MINERAL OIL



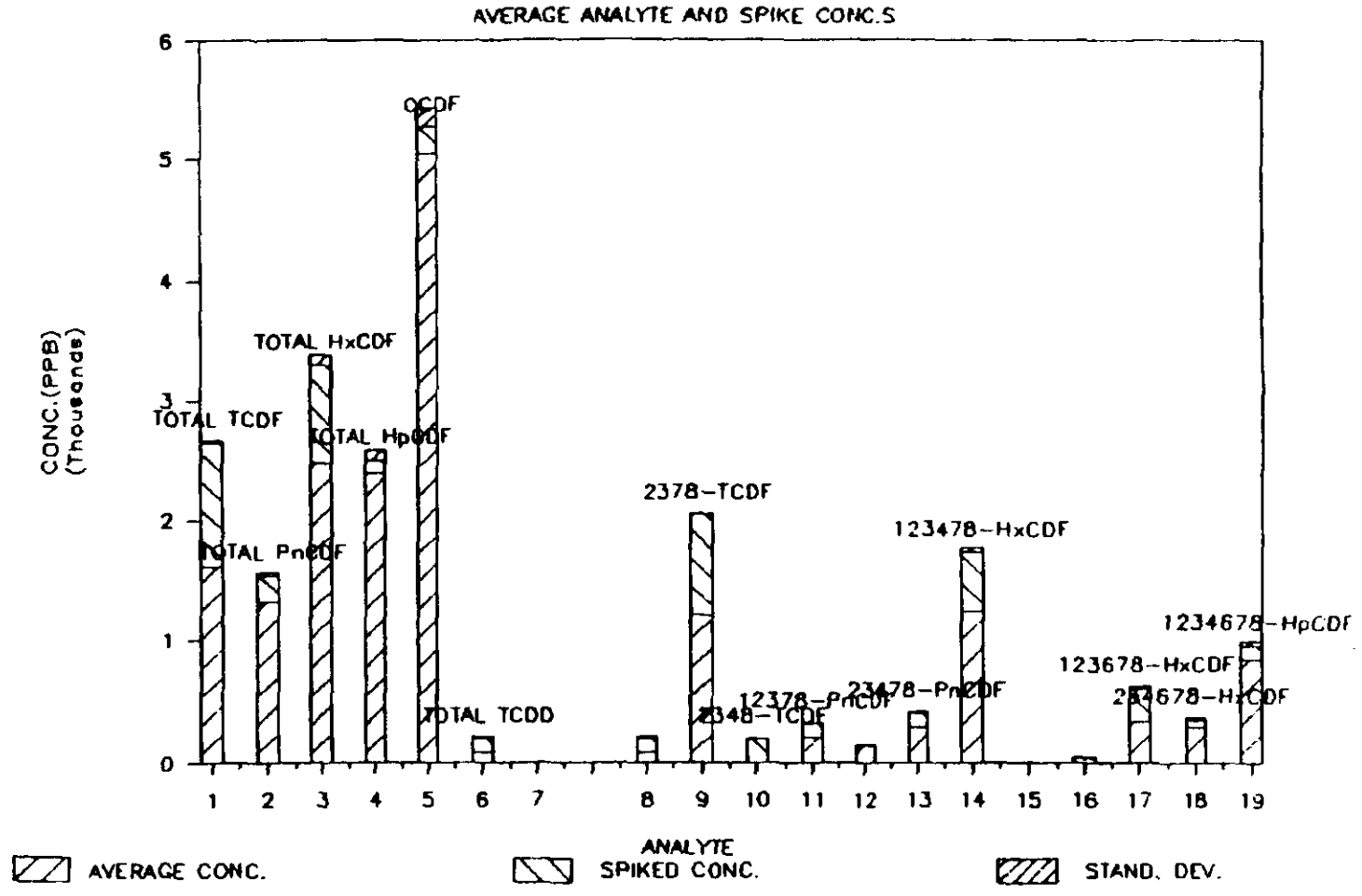
MONS 218411

FIGURE E-9: SPIKED AROCLOR 1016



MONS 218412

FIGURE E-10: SPIKED AROCLOR 1260



MONS 218413

Appendix F

TABLES OF RECOVERIES, RELATIVE RECOVERIES AND DETECTION LIMITS

MONS 218414

TABLE 1

RECOVERIES AND DETECTION LIMITS
EPRI BASELINE PROJECT SAMPLE:
1953 LOAD CENTER NETWORK TRANSFORMER

	DET. 1		DET. 2		DET. 3	
	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)
TOTAL TCDF	43	2.1	16	4.3	3	15.1
TOTAL PnCDF	47	2.1	19	4.0	10	5.2
TOTAL HxCDF	55	2.1	24	3.7	14	4.5
TOTAL HpCDF	55	2.9	24	3.7	14	6.1
OCDF	24	10.2	8	23.5	7	19.0
TOTAL TCDD	43	3.0	16	6.3	1	47.4
OCDD	24	20.3	8	46.9	7	38.1
2,3,7,8-TCDD	43	3.0	16	6.3	1	47.4
2,3,7,8-TCDF	43	2.1	16	4.3	3	15.1
2,3,4,8-TCDF	NA	NA	16	0.1	NA	NA
1,2,3,7,8-PnCDF	47	2.1	19	4.0	10	5.2
1,2,3,4,8-PnCDF	47	2.1	19	4.0	10	5.2
2,3,4,7,8-PnCDF	47	2.2	19	4.2	10	5.5
1,2,3,4,7,8-HxCDF	55	2.1	24	3.7	14	4.5
1,2,3,4,7,9-HxCDF	55	2.1	24	3.7	14	4.5
1,2,3,7,8,9-HxCDF	55	2.1	24	3.7	14	4.5
1,2,3,6,7,8-HxCDF	55	2.1	24	3.7	14	4.5
2,3,4,6,7,8-HxCDF	55	2.5	24	4.4	14	5.3
1,2,3,4,6,7,8-HpCDF	55	2.9	24	5.1	14	6.1

1.) NA = not applicable

MONS 218415

TABLE 2

RECOVERIES AND DETECTION LIMITS
EPRI BASELINE PROJECT SAMPLE:
1946 LOAD CENTER NETWORK TRANSFORMER

	DET. 1		DET. 2		DET. 3	
	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)
TOTAL TCDF	29	1.2	18	2.1	10	2.9
TOTAL PnCDF	28	1.5	17	2.5	27	1.3
TOTAL HxCDF	31	1.5	18	2.7	30	1.3
TOTAL HpCDF	31	2.0	18	3.5	30	1.7
OCDF	22	5.6	7	17.9	18	5.9
TOTAL TCDD	35	1.6	18	3.2	4	19.0
OCDD	22	10.9	7	34.6	18	11.4
2,3,7,8-TCDD	35	1.6	18	3.2	4	19.0
2,3,7,8-TCDF	29	1.2	18	2.1	10	2.9
2,3,4,8-TCDF	NA	NA	18	0.2	NA	NA
1,2,3,7,8-PnCDF	28	1.5	17	2.5	27	1.3
1,2,3,4,8-PnCDF	28	1.5	17	2.5	27	1.3
2,3,4,7,8-PnCDF	28	1.5	17	2.5	27	1.3
1,2,3,4,7,8-HxCDF	31	1.5	18	2.7	30	1.3
1,2,3,4,7,9-HxCDF	31	1.5	18	2.7	30	1.3
1,2,3,7,8,9-HxCDF	31	1.5	18	2.7	30	1.3
1,2,3,6,7,8-HxCDF	31	1.5	18	2.7	30	1.3
2,3,4,6,7,8-HxCDF	31	1.7	18	3.0	30	1.5
1,2,3,4,6,7,8-HpCDF	31	2.0	18	3.5	30	1.7

1.) NA = not applicable

MONS 218416

TABLE 3

RECOVERIES AND DETECTION LIMITS
EPRI BASELINE PROJECT SAMPLE:
CAPACITOR

	DET. 1		DET. 2		DET. 3	
	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)
TOTAL TCDF	35	0.1	17	0.2	2	1.3
TOTAL PnCOF	34	0.2	16	0.2	55	0.1
TOTAL HxCDF	38	0.2	19	0.2	63	0.1
TOTAL HpCDF	38	0.2	19	0.2	63	0.1
OCDF	35	0,7	23	0.3	59	0.1
TOTAL TCDD	61	0.1	18	0.2	5	0.9
OCDD	35	1.4	23	0.6	59	0.3
2,3,7,8-TCDD	61	0.1	18	0.2	5	0.9
2,3,7,8-TCDF	35	0.1	17	0.2	2	1.3
2,3,4,8-TCDF	NA	NA	17	0.3	NA	NA
1,2,3,7,8-PnCDF	34	0.2	16	0.2	55	0.1
1,2,3,4,8-PnCDF	34	0.2	16	0.2	55	0.1
2,3,4,7,8-PnCDF	34	0.2	16	0.2	55	0.1
1,2,3,4,7,8-HxCDF	38	0.2	19	0.2	63	0.1
1,2,3,4,7,9-HxCDF	38	0.2	19	0.2	63	0.1
1,2,3,7,8,9-HxCDF	38	0.2	19	0.2	63	0.1
1,2,3,6,7,8-HxCDF	38	0.2	19	0.2	63	0.1
2,3,4,6,7,8-HxCDF	38	0.2	19	0.2	63	0.1
1,2,3,4,6,7,8-HpCDF	38	0.2	19	0.2	63	0.1

1.) NA = not applicable

MONS 218417

TABLE 4

RECOVERIES AND DETECTION LIMITS
EPRI BASELINE PROJECT SAMPLE: PRECIPITATOR TRANSFORMER

	DET. 1		DET. 2		DET. 3	
	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)
TOTAL TCDF	16	4.2	24	1.5	21	2.2
TOTAL PnCDF	17	4.3	28	1.5	32	1.6
TOTAL HxCDF	19	4.4	29	1.6	34	1.7
TOTAL HpCDF	19	5.7	29	2.1	34	2.3
OCDF	14	15.0	17	7.1	24	6.2
TOTAL TCDD	16	6.5	26	2.3	56	3.3
OCDD	14	30.6	17	14.5	24	12.7
2,3,7,8-TCDD	16	6.5	26	2.3	56	3.3
2,3,7,8-TCDF	16	4.2	24	1.5	21	2.2
2,3,4,8-TCDF	NA	NA	24	0.2	NA	NA
1,2,3,7,8-PnCDF	17	4.3	28	1.5	32	1.6
1,2,3,4,8-PnCDF	17	4.3	28	1.5	32	1.6
2,3,4,7,8-PnCDF	17	4.3	28	1.5	32	1.6
1,2,3,4,7,8-HxCDF	19	4.4	29	1.6	34	1.7
1,2,3,4,7,9-HxCDF	19	4.4	29	1.6	34	1.7
1,2,3,7,8,9-HxCDF	19	4.4	29	1.6	34	1.7
1,2,3,6,7,8-HxCDF	19	4.4	29	1.6	34	1.7
2,3,4,6,7,8-HxCDF	19	4.7	29	1.7	34	1.9
1,2,3,4,6,7,8-HpCDF	19	5.7	29	2.1	34	2.3

1.) NA = not applicable

MONS 218418

TABLE 5

RECOVERIES AND DETECTION LIMITS
EPRI BASELINE PROJECT SAMPLE:
1976 ARC FURNACE TRANSFORMER

	DET. 1		DET. 2		DET. 3	
	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)
TOTAL TCDF	67	0.1	37	0.1	78	0.05
TOTAL PnCDF	81	0.1	51	0.1	128	0.03
TOTAL HxCDF	82	0.1	51	0.0	123	0.04
TOTAL HpCDF	82	0.2	51	0.1	123	0.05
OCDF	63	0.5	24	0.4	119	0.11
TOTAL TCDD	74	0.1	45	0.1	0.4	28.12
OCDD	63	1.0	24	0.8	119	0.19
2,3,7,8-TCDD	74	0.1	45	0.1	0.4	28.12
2,3,7,8-TCDF	67	0.1	37	0.1	78	0.05
2,3,4,8-TCDF	NA	NA	37	0.7	NA	NA
1,2,3,7,8-PnCDF	81	0.1	51	0.1	128	0.03
1,2,3,4,8-PnCDF	81	0.1	51	0.1	128	0.03
2,3,4,7,8-PnCDF	81	0.1	51	0.1	128	0.04
1,2,3,4,7,8-HxCDF	82	0.1	51	0.0	123	0.04
1,2,3,4,7,9-HxCDF	82	0.1	51	0.0	123	0.04
1,2,3,7,8,9-HxCDF	82	0.1	51	0.0	123	0.04
1,2,3,6,7,8-HxCDF	82	0.1	51	0.0	123	0.04
2,3,4,6,7,8-HxCDF	82	0.1	51	0.1	123	0.04
1,2,3,4,6,7,8-HpCDF	82	0.2	51	0.1	123	0.05

1.) NA = not applicable

MONS 218419

TABLE 6

RECOVERIES AND DETECTION LIMITS
EPRI BASELINE PROJECT SAMPLE:
SUBSTATION DISTRIBUTION TRANSFORMER

	DET. 1		DET. 2		DET.3	
	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)
TOTAL TCDF	36	0.2	69	0.04	76	0.04
TOTAL PnCDF	48	0.2	80	0.04	66	0.05
TOTAL HxCDF	60	0.1	36	0.09	33	0.11
TOTAL HpCDF	60	0.2	36	0.12	33	0.13
OCDF	66	0.1	4	2.14	7	1.33
TOTAL TCDD	38	0.3	80	0.05	73	0.07
OCDD	66	1.0	4	21.61	7	2.54
2,3,7,8-TCDD	38	0.3	80	0.05	73	0.07
2,3,7,8-TCDF	36	0.2	69	0.04	76	0.04
2,3,4,8-TCDF	NA	NA	69	0.04	NA	NA
1,2,3,7,8-PnCDF	48	0.2	80	0.04	66	0.05
1,2,3,4,8-PnCDF	48	0.2	80	0.04	66	0.05
2,3,4,7,8-PnCDF	48	0.2	80	0.04	66	0.05
1,2,3,4,7,8-HxCDF	60	0.1	36	0.09	33	0.11
1,2,3,4,7,9-HxCDF	60	0.1	36	0.09	33	0.11
1,2,3,7,8,9-HxCDF	60	0.1	36	0.09	33	0.11
1,2,3,6,7,8-HxCDF	60	0.1	36	0.09	33	0.11
2,3,4,6,7,8-HxCDF	60	0.2	36	0.10	33	0.11
1,2,3,4,6,7,8-HpCDF	60	0.2	36	0.12	33	0.13

1.) NA = not applicable

MONS 218420

TABLE 7

RECOVERIES AND DETECTION LIMITS
EPRI BASELINE PROJECT SAMPLE:
1962 LOAD CENTER NETWORK TRANSFORMER

	DET. 1		DET. 2		DET. 3	
	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)
TOTAL TCDF	42	2.0	45	1.4	55	1.2
TOTAL PnCDF	51	2.0	47	1.6	62	1.3
TOTAL HxCDF	51	2.3	40	2.2	60	1.5
TOTAL HpCDF	51	3.3	40	3.1	60	2.2
OCDF	30	8.6	29	26.7	26	7.7
TOTAL TCDD	46	2.8	50	2.0	59	1.7
OCDD	30	19.4	29	124.7	26	17.3
2,3,7,8-TCDD	46	2.8	50	2.0	59	1.7
2,3,7,8-TCDF	42	2.0	45	1.4	55	1.2
2,3,4,8-TCDF	NA	NA	45	0.2	NA	NA
1,2,3,7,8-PnCDF	51	2.0	47	1.6	62	1.3
1,2,3,4,8-PnCDF	51	2.0	47	1.6	62	1.3
2,3,4,7,8-PnCDF	51	1.8	47	1.5	62	1.1
1,2,3,4,7,8-HxCDF	51	2.3	40	2.2	60	1.5
1,2,3,4,7,9-HxCDF	51	2.3	40	2.2	60	1.5
1,2,3,7,8,9-HxCDF	51	2.3	40	2.2	60	1.5
1,2,3,6,7,8-HxCDF	51	2.3	40	2.2	60	1.5
2,3,4,6,7,8-HxCDF	51	2.6	40	2.5	60	1.7
1,2,3,4,6,7,8-HpCDF	51	3.3	40	3.1	60	2.2

1.) NA = not applicable

MONS 218421

TABLE 8

RECOVERIES AND DETECTION LIMITS
EPRI BASELINE PROJECT SAMPLE:
SPIKED AGED MINERAL OIL

	DET. 1		DET. 2		DET. 3	
	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)
TOTAL TCDF	50	0.5	45	2.7	39	0.1
TOTAL PnCDF	55	0.6	44	3.2	43	0.1
TOTAL HxCDF	55	0.7	43	3.7	40	0.1
TOTAL HpCDF	55	1.1	43	4.8	40	0.1
OCDF	49	3.6	33	13.1	27	0.5
TOTAL TCDD	54	0.8	47	4.0	40	0.1
OCDD	49	6.3	33	123.6	27	0.9
2,3,7,8-TCDD	54	0.8	47	4.0	40	0.1
2,3,7,8-TCDF	50	0.5	45	2.7	39	0.1
2,3,4,8-TCDF	NA	NA	45	0.2	NA	NA
1,2.3,7,8-PnCDF	55	0.6	44	3.2	43	0.1
1,2,3,4,8-PnCDF	55	0.6	44	3.2	43	0.1
2,3,4,7,8-PnCDF	55	0.6	44	3.2	43	0.1
1,2,3,4,7,8-HxCDF	55	0.7	43	3.7	40	0.1
1,2,3,4,7,9-HxCDF	55	0.7	43	3.7	40	0.1
1,2,3,7,8,9-HxCDF	55	0.7	43	3.7	40	0.1
1,2,3,6,7,8-HxCDF	55	0.7	43	3.7	40	0.1
2,3,4,6,7,8-HxCDF	55	0.8	43	4.1	40	0.1
1,2,3,4,6,7,8-HpCDF	55	1.1	43	4.8	40	0.1

1.) NA = not applicable

MONS 218422

TABLE 9

RECOVERIES AND DETECTION LIMITS
EPRI BASELINE PROJECT SAMPLE:
SPIKED AROCLOR 1016

	DET. 1		DET. 2		DET. 3	
	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)
TOTAL TCDF	52	0.3	32	2.2	30	0.9
TOTAL PnCDF	68	0.2	37	2.0	44	0.8
TOTAL HxCDF	77	0.2	36	2.4	42	1.0
TOTAL HpCDF	77	0.4	36	4.0	42	1.4
OCDF	103	0.5	37	7.0	40	2.2
TOTAL TCDD	57	0.4	34	3.1	42	1.1
OCDD	103	1.4	37	100.7	40	5.0
2,3,7,8-TCDD	57	0.4	34	3.1	42	1.1
2,3,7,8-TCDF	52	0.3	32	2.2	30	0.9
2,3,4,8-TCDF	NA	NA	32	2.3	NA	NA
1,2,3,7,8-PnCDF	68	0.2	37	2.0	44	0.8
1,2,3,4,8-PnCDF	68	0.2	37	2.0	44	0.8
2,3,4,7,8-PnCDF	68	0.2	37	2.1	44	0.7
1,2,3,4,7,8-HxCDF	77	0.2	36	2.4	42	1.0
1,2,3,4,7,9-HxCDF	77	0.2	36	2.4	42	1.0
1,2,3,7,8,9-HxCDF	77	0.2	36	2.4	42	1.0
1,2,3,6,7,8-HxCDF	77	0.2	36	2.4	42	1.0
2,3,4,6,7,8-HxCDF	77	0.3	36	3.2	42	1.1
1,2,3,4,6,7,8-HpCDF	77	0.4	36	4.0	42	1.4

1.) NA = not applicable

MONS 218423

TABLE 10

RECOVERIES AND DETECTION LIMITS
EPRI BASELINE PROJECT SAMPLE:
SPIKED AROCLOR 1260

	DET. 1		DET. 2		DET. 3	
	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)	%REC	DET LIM. (in ppb)
TOTAL TCDF	52	0.5	75	2.4	63	4.6
TOTAL PnCDF	58	0.6	80	2.7	60	6.0
TOTAL HxCDF	64	0.6	91	2.8	61	6.8
TOTAL HpCDF	64	0.8	91	3.8	61	9.4
OCDF	57	1.8	72	9.4	45	24.8
TOTAL TCDD	161	0.3	112	2.5	98	4.8
OCDD	57	3.1	72	74.6	45	42.3
2,3,7,8-TCDD	161	0.3	112	2.5	98	4.8
2,3,7,8-TCDF	52	0.5	75	2.4	63	4.6
2,3,4,8-TCDF	NA	NA	75	1.0	NA	NA
1,2,3,7,8-PnCDF	58	0.6	80	2.7	60	6.0
1,2,3,4,8-PnCDF	58	0.6	80	2.7	60	6.0
2,3,4,7,8-PnCDF	58	0.6	80	2.7	60	5.8
1,2,3,4,7,8-HxCDF	64	0.6	91	2.8	61	6.8
1,2,3,4,7,9-HxCDF	64	0.6	91	2.8	61	6.8
1,2,3,7,8,9-HxCDF	64	0.6	91	2.8	61	6.8
1,2,3,6,7,8-HxCDF	64	0.6	91	2.8	61	6.8
2,3,4,6,7,8-HxCDF	64	0.6	91	2.9	61	7.1
1,2,3,4,6,7,8-HpCDF	64	0.8	91	3.8	61	9.4

1.) NA = not applicable

MONS 218424

TABLE 11

RECOVERIES RELATIVE TO 2378-TCDD-13C12
EPRI BASELINE PROJECT SAMPLE:
1953 LOAD CENTER NETWORK TRANSFORMER

	DET. 1		DET. 2		DET. 3	
	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD
TOTAL TCDF	43	100	16	100	3	300
TOTAL PnCDF	47	109	19	119	10	1000
TOTAL HxCDF	55	128	24	150	14	1400
TOTAL HpCDF	55	128	24	150	14	1400
OCDF	24	56	8	50	7	700
TOTAL TCDD	43	100	16	100	1	100
OCDD	24	56	8	50	7	700
2,3,7,8-TCDD	43	100	16	100	1	100
2,3,7,8-TCDF	43	100	16	100	3	300
2,3,4,8-TCDF	NA	NA	16	100	NA	NA
1,2,3,7,8-PnCDF	47	109	19	119	10	1000
1,2,3,4,8-PnCDF	47	109	19	119	10	1000
2,3,4,7,8-PnCDF	47	109	19	119	10	1000
1,2,3,4,7,8-HxCDF	55	128	24	150	14	1400
1,2,3,4,7,9-HxCDF	55	128	24	150	14	1400
1,2,3,7,8,9-HxCDF	55	128	24	150	14	1400
1,2,3,6,7,8-HxCDF	55	128	24	150	14	1400
2,3,4,6,7,8-HxCDF	55	128	24	150	14	1400
1,2,3,4,6,7,8-HpCDF	55	128	24	150	14	1400

1.) NA = not applicable

MONS 218425

TABLE 12

RECOVERIES RELATIVE TO 2378-TCDD-13C12
EPRI BASELINE PROJECT SAMPLE:
1946 LOAD CENTER NETWORK TRANSFORMER

	DET. 1		DET. 2		DET. 3	
	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD
TOTAL TCDF	29	83	18	100	10	1000
TOTAL PnCDF	28	80	17	94	27	2700
TOTAL HxCDF	31	89	18	100	30	3000
TOTAL HpCDF	31	89	18	100	30	3000
OCDF	22	63	7	39	18	1800
TOTAL TCDD	35	100	18	100	1	100
OCDD	22	63	7	39	18	1800
2,3,7,8-TCDD	35	100	18	100	1	100
2,3,7,8-TCDF	29	83	18	100	10	1000
2,3,4,8-TCDF	NA	NA	18	100	NA	NA
1,2,3,7,8-PnCDF	28	80	17	94	27	2700
1,2,3,4,8-PnCDF	28	80	17	94	27	2700
2,3,4,7,8-PnCDF	28	80	17	94	27	2700
1,2,3,4,7,8-HxCDF	31	89	18	100	30	3000
1,2,3,4,7,9-HxCDF	31	89	18	100	30	3000
1,2,3,7,8,9-HxCDF	31	89	18	100	30	3000
1,2,3,6,7,8-HxCDF	31	89	18	100	30	3000
2,3,4,6,7,8-HxCDF	31	89	18	100	30	3000
1,2,3,4,6,7,8-HpCDF	31	89	18	100	30	3000

1.) NA = not applicable

MONS 218426

TABLE 13

RECOVERIES RELATIVE TO 2378-TCDD-13C12
EPRI BASELINE PROJECT SAMPLE:
CAPACITOR

	DET. 1		DET. 2		DET. 3	
	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD
TOTAL TCDF	35	57	17	94	2	40
TOTAL PnCDF	34	56	16	89	55	1100
TOTAL HxCDF	38	62	19	106	63	1260
TOTAL HpCDF	38	62	19	106	63	1260
OCDF	35	57	23	128	59	1180
TOTAL TCDD	61	100	18	100	5	100
OCDD	35	57	23	128	59	1180
2,3,7,8-TCDD	61	100	18	100	5	100
2,3,7,8-TCDF	35	57	17	94	2	40
2,3,4,8-TCDF	NA	NA	17	94	NA	NA
1,2,3,7,8-PnCDF	34	56	16	89	55	1100
1,2,3,4,8-PnCDF	34	56	16	89	55	1100
2,3,4,7,8-PnCDF	34	56	16	89	55	1100
1,2,3,4,7,8-HxCDF	38	62	19	106	63	1260
1,2,3,4,7,9-HxCDF	38	62	19	106	63	1260
1,2,3,7,8,9-HxCDF	38	62	19	106	63	1260
1,2,3,6,7,8-HxCDF	38	62	19	106	63	1260
2,3,4,6,7,8-HxCDF	38	62	19	106	63	1260
1,2,3,4,6,7,8-HpCDF	38	62	19	106	63	1260

1.) NA = not applicable

MONS 218427

TABLE 14

RECOVERIES RELATIVE TO 2378-TCDD-13C12
EPRI BASELINE PROJECT SAMPLE:
PRECIPITATOR TRANSFORMER

	DET. 1		DET. 2		DET. 3	
	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD
TOTAL TCDF	16	100	24	92	21	38
TOTAL PnCDF	17	106	28	108	32	57
TOTAL HxCDF	19	119	29	112	34	61
TOTAL HpCDF	19	119	29	112	34	61
OCDF	14	88	17	65	24	43
TOTAL TCDD	16	100	26	100	56	100
OCDD	14	88	17	65	24	4
2,3,7,8-TCDD	16	100	26	100	56	100
2,3,7,8-TCDF	16	100	24	92	21	38
2,3,4,8-TCDF	NA	NA	24	92	NA	NA
1,2,3,7,8-PnCDF	17	106	28	108	32	57
1,2,3,4,8-PnCDF	17	106	28	108	32	57
2,3,4,7,8-PnCDF	17	106	28	108	32	57
1,2,3,4,7,8-HxCDF	19	119	29	112	34	61
1,2,3,4,7,9-HxCDF	19	119	29	112	34	61
1,2,3,7,8,9-HxCDF	19	119	29	112	34	61
1,2,3,6,7,8-HxCDF	19	119	29	112	34	61
2,3,4,6,7,8-HxCDF	19	119	29	112	34	61
1,2,3,4,6,7,8-HpCDF	19	119	29	112	34	61

1.) NA = not applicable

MONS 218428

TABLE 15

RECOVERIES RELATIVE TO 2378-TCDD-13C12
EPRI BASELINE PROJECT SAMPLE:
1976 ARC FURNACE TRANSFORMER

	DET. 1		DET. 2		DET. 3	
	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD
TOTAL TCDF	67	91	37	82	78	19500
TOTAL PnCDF	81	109	51	113	128	32000
TOTAL HxCDF	82	111	51	113	123	30750
TOTAL HpCDF	82	111	51	113	123	30750
OCDF	63	85	24	53	119	29750
TOTAL TCDD	74	100	45	100	0.4	100
OCDD	63	85	24	53	119	29750
2,3,7,8-TCDD	74	100	45	100	0.4	100
2,3,7,8-TCDF	67	91	37	82	78	19500
2,3,4,8-TCDF	NA	NA	37	82	NA	NA
1,2,3,7,8-PnCDF	81	109	51	113	128	32000
1,2,3,4,8-PnCDF	81	109	51	113	128	32000
2,3,4,7,8-PnCDF	81	109	51	113	128	32000
1,2,3,4,7,8-HxCDF	82	111	51	113	123	30750
1,2,3,4,7,9-HxCDF	82	111	51	113	123	30750
1,2,3,7,8,9-HxCDF	82	111	51	113	123	30750
1,2,3,6,7,8-HxCDF	82	111	51	113	123	30750
2,3,4,6,7,8-HxCDF	82	111	51	113	123	30750
1,2,3,4,6,7,8-HpCDF	82	111	51	113	123	30750

1.) NA = not applicable

MONS 218429

TABLE 16

RECOVERIES RELATIVE TO 2378-TCDD-13C12
EPRI BASELINE PROJECT SAMPLE:
SUBSTATION DISTRIBUTION TRANSFORMER

	DET. 1		DET. 2		DET. 3	
	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD
TOTAL TCDF	36	95	69	86	76	104
TOTAL PnCDF	48	126	80	100	66	90
TOTAL HxCDF	60	158	36	45	33	45
TOTAL HpCDF	60	158	36	45	33	45
OCDF	66	174	4	5	7	10
TOTAL TCDD	38	100	80	100	73	100
OCDD	66	174	4	5	7	10
2,3,7,8-TCDD	38	100	80	100	73	100
2,3,7,8-TCDF	36	95	69	86	76	104
2,3,4,8-TCDF	NA	NA	69	86	NA	NA
1,2,3,7,8-PnCDF	48	126	80	100	66	90
1,2,3,4,8-PnCDF	48	126	80	100	66	90
2,3,4,7,8-PnCDF	48	126	80	100	66	90
1,2,3,4,7,8-HxCDF	60	158	36	45	33	45
1,2,3,4,7,9-HxCDF	60	158	36	45	33	45
1,2,3,7,8,9-HxCDF	60	158	36	45	33	45
1,2,3,6,7,8-HxCDF	60	158	36	45	33	45
2,3,4,6,7,8-HxCDF	60	158	36	45	33	45
1,2,3,4,6,7,8-HpCDF	60	158	36	45	33	45

1.) NA = not applicable

MONS 218430

TABLE 17

RECOVERIES RELATIVE TO 2378-TCDD-13C12
EPRI BASELINE PROJECT SAMPLE:
1962 LOAD CENTER NETWORK TRANSFORMER

	DET. 1		DET. 2		DET. 3	
	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD
TOTAL TCDF	42	91	45	90	55	93
TOTAL PnCDF	51	111	47	94	62	105
TOTAL HxCDF	51	111	40	80	60	102
TOTAL HpCDF	51	111	40	80	60	102
OCDF	30	65	29	59	26	44
TOTAL TCDD	46	100	50	100	59	100
OCDD	30	65	29	59	26	44
2,3,7,8-TCDD	46	100	50	100	59	100
2,3,7,8-TCDF	42	91	45	90	55	93
2,3,4,8-TCDF	NA	NA	45	90	NA	NA
1,2,3,7,8-PnCDF	51	111	47	94	62	105
1,2,3,4,8-PnCDF	51	111	47	94	62	105
2,3,4,7,8-PnCDF	51	111	47	94	62	105
1,2,3,4,7,8-HxCDF	51	111	40	80	60	102
1,2,3,4,7,9-HxCDF	51	111	40	80	60	102
1,2,3,7,8,9-HxCDF	51	111	40	80	60	102
1,2,3,6,7,8-HxCDF	51	111	40	80	60	102
2,3,4,6,7,8-HxCDF	51	111	40	80	60	102
1,2,3,4,6,7,8-HpCDF	51	111	40	80	60	102

1.) NA = not applicable

MONS 218431

TABLE 18

RECOVERIES RELATIVE TO 2378-TCDD-13C12
EPRI BASELINE PROJECT SAMPLE:
SPIKED AGED MINERAL OIL

	DET. 1		DET. 2		DET. 3	
	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD
TOTAL TCDF	50	93	45	96	39	98
TOTAL PnCDF	55	102	44	94	43	108
TOTAL HxCDF	55	102	43	91	40	100
TOTAL HpCDF	55	102	43	91	40	100
OCDF	49	91	33	70	27	68
TOTAL TCDD	54	100	47	100	40	100
OCDD	49	91	33	70	27	68
2,3,7,8-TCDD	54	100	47	100	40	100
2,3,7,8-TCDF	50	93	45	96	39	98
2,3,4,8-TCDF	NA	NA	45	96	NA	NA
1,2,3,7,8-PnCDF	55	102	44	94	43	108
1,2,3,4,8-PnCDF	55	102	44	94	43	108
2,3,4,7,8-PnCDF	55	102	44	94	43	108
1,2,3,4,7,8-HxCDF	55	102	43	91	40	100
1,2,3,4,7,9-HxCDF	55	102	43	91	40	100
1,2,3,7,8,9-HxCDF	55	102	43	91	40	100
1,2,3,6,7,8-HxCDF	55	102	43	91	40	100
2,3,4,6,7,8-HxCDF	55	102	43	91	40	100
1,2,3,4,6,7,8-HpCDF	55	102	43	91	40	100

1.) NA = not applicable

MONS 218432

TABLE 19

RECOVERIES RELATIVE TO 2378-TCDD-13C12
EPRI BASELINE PROJECT SAMPLE:
SPIKED AROCLOR 1016

	DET. 1		DET. 2		DET. 3	
	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD
TOTAL TCDF	52	91	32	94	30	71
TOTAL PnCDF	68	119	37	109	44	105
TOTAL HxCDF	77	135	36	106	42	100
TOTAL HpCDF	77	135	36	106	42	100
OCDF	103	181	37	109	40	95
TOTAL TCDD	57	100	34	100	42	100
OCDD	103	181	37	109	40	95
2,3,7,8-TCDD	57	100	34	100	42	100
2,3,7,8-TCDF	52	91	32	94	30	71
2,3,4,8-TCDF	NA	NA	32	94	NA	NA
1,2,3,7,8-PnCDF	68	119	37	109	44	105
1,2,3,4,8-PnCDF	68	119	37	109	44	105
2,3,4,7,8-PnCDF	68	119	37	109	44	105
1,2,3,4,7,8-HxCDF	77	135	36	106	42	100
1,2,3,4,7,9-HxCDF	77	135	36	106	42	100
1,2,3,7,8,9-HxCDF	77	135	36	106	42	100
1,2,3,6,7,8-HxCDF	77	135	36	106	42	100
2,3,4,6,7,8-HxCDF	77	135	36	106	42	100
1,2,3,4,6,7,8-HpCDF	77	135	36	106	42	100

1.) NA = not applicable

MONS 218433

TABLE 20

RECOVERIES RELATIVE TO 2378-TCDD-13C12
EPRI BASELINE PROJECT SAMPLE:
SPIKED AROCLOR 1260

	DET. 1		DET. 2		DET. 3	
	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD	%REC	%REC vs 13C-TCDD
TOTAL TCDF	52	32	75	67	63	64
TOTAL PnCDF	58	36	80	71	60	61
TOTAL HxCDF	64	40	91	81	61	62
TOTAL HpCDF	64	40	91	81	61	62
OCDF	57	35	72	64	45	46
TOTAL TCDD	161	100	112	100	98	100
OCDD	57	35	72	64	45	46
2,3,7,8-TCDD	161	100	112	100	98	100
2,3,7,8-TCDF	52	32	75	67	63	64
2,3,4,8-TCDF	NA	NA	75	67	NA	NA
1,2,3,7,8-PnCDF	58	36	80	71	60	61
1,2,3,4,8-PnCDF	58	36	80	71	60	61
2,3,4,7,8-PnCDF	58	36	80	71	60	61
1,2,3,4,7,8-HxCDF	64	40	91	81	61	62
1,2,3,4,7,9-HxCDF	64	40	91	81	61	62
1,2,3,7,8,9-HxCDF	64	40	91	81	61	62
1,2,3,6,7,8-HxCDF	64	40	91	81	61	62
2,3,4,6,7,8-HxCDF	64	40	91	81	61	62
1,2,3,4,6,7,8-HpCDF	64	40	91	81	61	62

1.) NA = not applicable

MONS 218434

