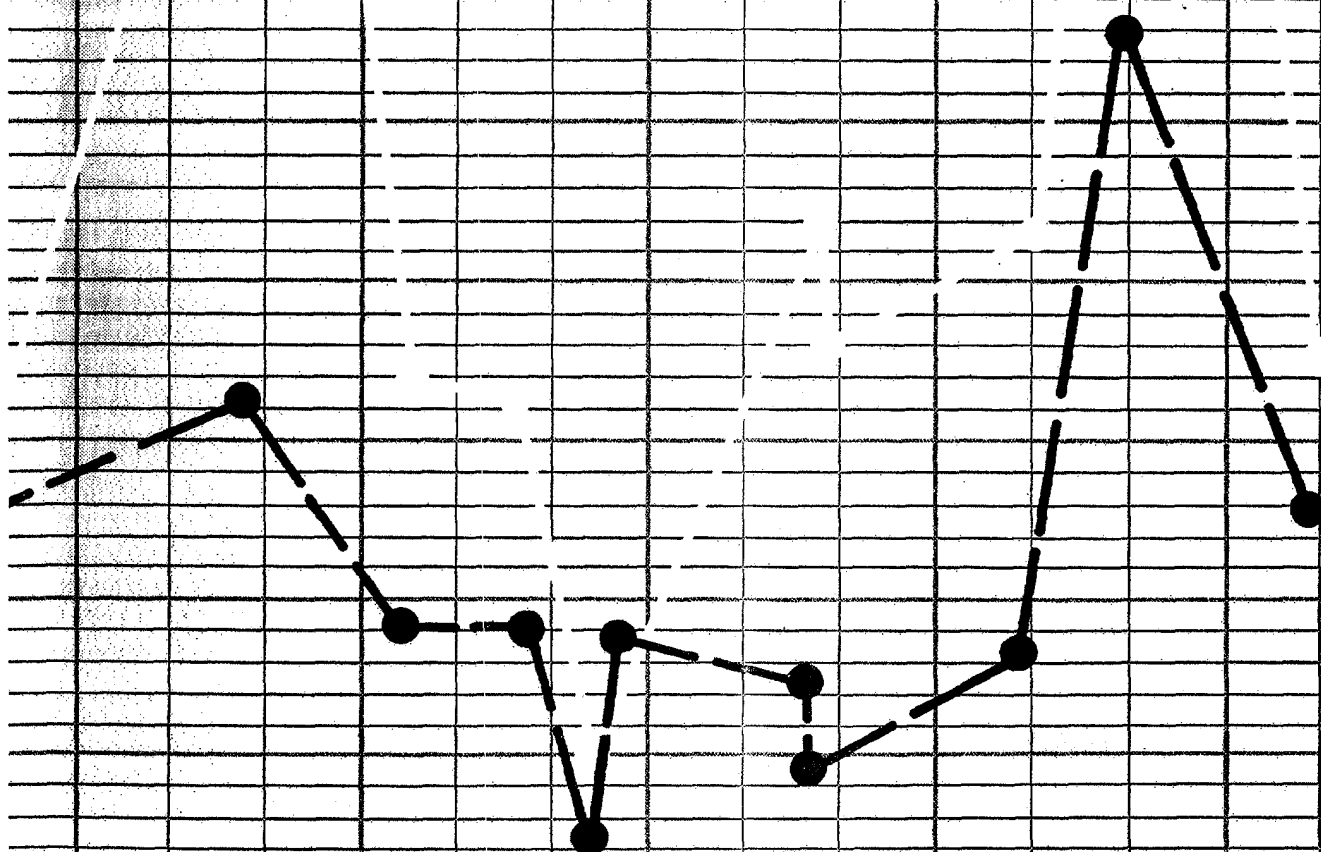


ORAL AND INHALATION LEAD EXPOSURES IN HUMAN SUBJECTS



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ORAL AND INHALATION LEAD EXPOSURES IN HUMAN SUBJECTS

(Kehoe Balance Experiments)

by

Stanley B. Gross, Ph.D.*
Department of Environmental Health
University of Cincinnati

*Current Address: 9036 Jeffery Road, Great Falls, Virginia 22066

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About the Author:

Dr. Stanley B. Gross is an environmental toxicologist with over 25 years of experience in research. He has formal training in chemistry, biochemistry, and medicine from West Virginia University, and completed his postdoctoral training in environmental toxicology under Dr. Emil Pfitzer at the University of Cincinnati Department of Environmental Health, Kettering Laboratory. Before joining the Department, he served at Battelle Memorial Institute as the Life Scientist on a U.S. Public Health Service contract to design an overview system for evaluating the public health hazards of chemicals in the environment. The resulting two volume report raised questions about mercury pollution prior to the discovery of the problem of the mercury contamination of Lake Erie.

Dr. Gross joined the Department in 1967 to develop automated information systems for toxicology, environmental and occupational health. Some of the concepts he published at that time are now being implemented within the federal govern-

ment. In 1969, Dr. Gross began measuring the human body burden of lead, a project initiated by Dr. Robert A. Kehoe. His publications emphasize the changes in the concentrations of lead, cadmium, and other trace metals with age and pathological condition in a wide variety of organs in the human. He also developed a method for classifying lead body burdens based on various types of exposure.

Dr. Gross is presently a senior level toxicologist with the Hazard Evaluation Division, Office of Pesticide Programs, Environmental Protection Agency in Washington. He has been active in the development of toxicological testing guidelines. He maintains memberships in the Society of Toxicology, the American Industrial Hygiene Association, the American Conference of Governmental Industrial Hygienists, the American Chemical Society, Society for Environmental Geochemistry and Health, Sigma Xi, and the American Association for the Advancement of Science.

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ABSTRACT

The Kehoe lead balance experiments were carried out from 1937 to 1972 and involved over 21,000 days of measured exposure of lead in humans. Lead balance, lead in the diet, feces, urine and blood were measured under normal conditions and during periods of oral and airborne lead supplementation. A considerable amount of natural variability was seen throughout all of the experimental periods due primarily to variations in dietary lead. The overall mean blood lead concentration for all subjects was 25 ug/100 gm, with individual control means ranging from 18 to 40 ug/100 gm. The urinary lead concentration averaged 29 ug/l overall, with individual control means ranging from 19 to 45 ug/l. The overall average diet contained 181 ug/day (159 ug/day based on median data); however, the mean dietary lead for the individual control periods decreased from approximately 300 ug/day in 1937 to 100 ug/day in 1970. Fecal lead had an overall mean of 225 ug/day (212 ug/day based on median data) on a per sample basis which exceeded the dietary lead average due to the fact that most subjects did not defecate on a daily basis. When averaged over the entire control period, fecal lead was 196 ug/day, still in excess of the overall average diet. Lead balance was calculated as dietary lead minus the lead in the feces and urine and did not include an estimate of inhaled lead. Although three subjects were in positive balance during their control periods, the overall average balance was a loss of 32 ug/day ranging from -106 to +25 ug/day for individual control periods. The balance data indicate that an appreciable amount of lead absorbed from the air was excreted.

The ingestion experiments involved daily supplements of 300, 1000, 2000 and 3000 ug of lead per day. Except for the subject SW who received the 300 ug supplementation, all subjects experienced increased lead in the blood, urine, feces and body burden proportional to their ingested lead. For SW, the blood and urine did not increase even though his body lead burden and fecal lead did. On an overall basis, the feces, blood, urine, and balance increased by 0.83 ug/day, 0.017 ug/100 gm, 0.045 ug/day and 0.133 ug/day for each increase of 1 ug of lead in the diet.

The inhalation exposure experiments involved chamber concentrations of 10, 20, 75 and 150 ug/m³ for varying exposure times. These chamber exposures resulted in overall exposure rates ranging from 0.6 to 35.9 ug/m³ when averaged over the entire exposure period. The influence of the natural variability of the dietary lead permeated all of the inhalation experimental periods and tended to override the responses of the blood, urinary and fecal lead at adjusted exposure rates below 10 ug/m³ (below chamber concentrations of 75 ug/m³). On an overall basis, the blood, urine and feces increased by 0.57 ug/100gm, 1.41 ug/day and 1.47 ug/day for each increase of 1 ug/m³ of lead in the air.

All subjects who experienced obvious increases in body lead during their exposure periods showed obvious and prompt body lead washout during their post exposure periods.

ORAL AND INHALATION EXPOSURES TO LEAD IN HUMAN SUBJECTS (KEHOE BALANCE EXPERIMENTS)

INTRODUCTION

The Kehoe balance experiments involved human subjects who were monitored during natural and experimental exposures to oral and inhaled lead. The experiments reported here were begun in 1937 as part of an intensive effort to investigate the health effects of such exposures. Kehoe began his investigations on lead in the summer of 1924 (Ash, 1966 and Campbell, 1966) and published his first paper on the effects of lead in workers in 1925 (Kehoe, 1925). In a series of reports published in 1933 (Kehoe, et al., 1933) he and his co-workers revealed a remarkably early and keen understanding of the impact of lead in our biosphere: They found that lead was ubiquitous, permeating all aspects of life, primitive or industrialized; that lead was found to be a natural constituent of food and human tissues and that the blood, urine and feces increased with increases in exposure. These observations were made at a time when the use of leaded gasoline in automobiles was limited.

Kehoe's expressed purpose in conducting the ingestion experiments (Kehoe, et al, 1940), which also applied to the inhalation experiments, was to understand further the physiological behavior of lead in the body and to establish quantitative

relationships between the body's responses to increased exposure. This would, in turn, provide data on which to base standards for clinical and hygienic practice. These experiments were also concerned with the quantitative variability of lead in the diet, feces, urine and blood under normal conditions over extended periods of time.

The most detailed summary by Kehoe of his work over the years can be found in the Harben Lectures presented in 1960 (Kehoe, 1961a). Several reports (Kehoe, et al., 1939, Kehoe, et al., 1940 and Kehoe, et al., 1943) preceded the Harben Lectures and several publications have been written since (Kehoe, 1961b; Kehoe, 1966; Kehoe, 1969; and Kehoe, 1976). The present report presents many of the raw data and numerous statistical summaries which provide an overview of all of the experiments, including several studies which have not yet been published. The present analysis extensively utilized more recent computer techniques to present this large volume of data. It does not provide the detailed analyses of each experiment which has been characteristic of Dr. Kehoe's past reports. Dr. Kehoe was preparing such an analysis at the time of this writing.

MATERIALS AND METHODS

The data from two subjects have been omitted because of early withdrawal from their experiments. Personal data for the other 16 subjects are shown in Table 1. Eleven of the subjects were male Caucasians, five were Negroes, one of whom was female. Their ages ranged from 22 to 55 years with a mean of 34 years. Each subject was hired by the Laboratory for the purpose of serving as an experimental subject.

There was a substantial overlap in time of many of the experiments (Figure 1). The early experiments involved dietary supplementations of 1000 (subject MR), 2000 (subject EB), 3000 (subject IF) and 300 (subject SW) micrograms (ug) of lead per day. The first inhalation subject, MOB, was exposed to

chamber concentrations of approximately 75 ug/m³ for 7 hours per day, five days per week. MOB and the next 6 subjects (FC, MB, JUS, SB, LD and JOS) were exposed to chamber concentrations of approximately 150 ug/m³ for varying daily time periods. The next four subjects (NK, SS, HR and DH) were exposed to chamber concentrations of approximately 10 or 20 ug/m³ for varying periods of time. The last subject (PB, the only female) was also exposed to 150 ug/m³. Except for the dose-response data, tabular data for individual subjects have been presented in alphabetical order for ease of reference. Each subject participated in one or more control (C), exposure (E) and/or post exposure (P) periods as shown in

Table 2. The periods are listed alphabetically by the subject's initials and are designated by letters and numbers in this table and throughout the other tables, figures and the text. The "Time on Collection" in Table 2 (Column 3) was considered the duration of each period even though calendar-wise the length of the period included "Off Time" (Column 4), which represented gaps in the data (shown graphically in Figures 3 A to P). These gaps are relatively short and generally do not represent important losses of data.

There were several special studies (Table 2) which are not described here in detail, but are presented in order to show as completely as possible the exposure history of each subject. The CORN exposure period (and post exposure period, PCORN) for MOB was a feeding study. The CNE period for DH was a short inhalation chamber control period in which no lead aerosol was generated. After a long oral exposure period, MR participated in a variety of dietary manipulations while still receiving daily supplements of 1000 ug of lead. These periods are referred to as E-DC's and P-DC's and were each of a four-week duration in the following sequence: (a) the administration of milk in large volume, (b) large doses of ascorbic acid, (c) deprivation of calcium, (d) deprivation of both dietary calcium and phosphate, (e) the administration of excess calcium, (f) excess phosphate, and (g) excess calcium and phosphate. Subject LD participated in a feeding experiment midway between days 200 and 300 on Figure 3-I during his control period, but this has not been represented as separate exposure and post exposure periods.

A. Experimental Procedures

Since the procedures used in these experiments have already been published on several occasions, they will be presented here only in summary detail.

Clinical Evaluations. All of the subjects were given thorough examinations by a physician other than Dr. Kehoe before being accepted as experimental subjects. Similar examinations were continued throughout the course of the experiments in order to monitor the subjects' health and to assure that none of the subjects experienced any harmful effects due to their exposures to lead. These evaluations included medical histories, physical examinations, and laboratory analyses. The histories were concerned with general well-being and emphasized gastrointestinal and neuromuscular functions. The physical examinations included information on body weight, temperature, pulse rate, blood pressure, respiratory rate, neurological reflexes, hand strength (measured with a dynamometer), as well as examinations of the fundi, teeth and mouth. The laboratory analyses included red and white cell counts, white cell differential counts, hemoglobin and hematocrit determinations and stipple cell and

reticulocyte counts. The urine was examined for color, specific gravity, sugar, pH, protein and formed elements. Porphyrin analyses of urine were performed for the inhalation subjects only. None of these clinical and laboratory data are presented in this report; however, none of the subjects was found to have experienced any harmful signs or symptoms due to their exposures.

Sample Collections and Lead Analyses. Samples of the subjects' diet, feces, urine and blood were collected for lead analyses throughout the oral and the inhalation experiments. The preparation and analyses of the samples were carried out in the Analytical Section of the Laboratory. The samples or sample aliquots used were dried, charred and ashed at 500°C using lead free nitric acid as an ashing aide. The ash was then analyzed using the spectrograph (Kehoe, et al., 1935) or dissolved in acid and analyzed using the colorimetric dithizone procedure of Cholak, et al. (1948). The more recent experiments depended more on the use of the dithizone method, which was shown to be quantitatively comparable to the spectrographic method (Cholak, 1964).

Collection containers were constantly carried by each subject to all of their daily activities. Duplicate samples of all ingested foods and beverages including medicines were collected by each person on a 24-hour basis. These were combined, homogenized and one third of the homogenate was diluted to 250 ml. Fifty ml of this solution was then used for the lead analyses. Feces were collected for similar daily periods when available. The entire fecal sample was ashed and diluted to 50 or 100 ml depending on the quantity of feces. Five to 10 ml of this solution was used for the lead analyses. The urine was collected without preservatives, mixed thoroughly and 100 ml aliquots were used for lead analyses. Two 10 gram samples of blood at each sampling were drawn on approximately a weekly basis. An entire 10 gram sample was used for the lead analysis.

Ingestion Experiments. The ingestion experiments involved daily supplementation of the natural dietary lead in the form of lead acetate solutions, one third of the total being taken with each main meal. The solutions were given to the subjects in standard containers and were emptied each time in a uniform manner, so that the slight loss due to incomplete emptying was made as nearly constant as possible. A similar amount of the solution was added to the composite daily food samples using the same technique.

Inhalation Experiments. Subjects received airborne lead supplementation by spending time in one of two identical respiratory chambers built for this purpose (Kehoe, et al., 1961a). The chambers were cubical rooms, 10 feet in each dimension and were equipped as office-laboratories where the subjects carried out data handling tasks or simple laboratory

procedures. Each room was equipped with two airlocks, one for the door and one for the passage of small items in and out of the chamber, providing for a minimum of disturbance in the lead concentration within the chamber.

Table 3 summarizes the chamber conditions used for each inhalation experiment and also includes the data on the subjects' pulmonary analyses. The small particle aerosols, ranging in median count diameters from 0.05 to 0.11 micrometers (μm), were generated by burning tetra-ethyl lead mixed with propane or natural gas to produce lead sesquioxide particles which were introduced into the chamber make-up air. To obtain low concentrations, the tetra-ethyl lead was diluted with dodecane. The composition of the particles was confirmed by X-ray diffraction analyses (Cullity, 1956) from samples taken from inside the chamber.

For the preparation of aerosol particles of 0.75 μm or greater, a custom-made dust feeder was used in place of the burner to introduce lead sesquioxide at various rates into the chamber make-up air. Lead sesquioxide was deposited inside of a tube of the generator while a rotating blade scraped off particles of the lead oxide. The concentrations in the chamber were controlled by varying the thickness of the oxide deposited on the wall of the tube and by varying the position of the feeder. Daily air samples were obtained and visually examined to insure that the particles were of the correct size range. For particles in the range of 0.75 μm or larger, the dust samples were collected on membrane filters and sized under oil immersion by light field microscopy. For the small particle aerosols, the dust was collected on grids and sized by the electron microscope. Particle sizes were plotted on log-probit graph paper to obtain the quantitative sizings shown in Table 3. The shape of the aerosol particles have been presented in a photograph (Kehoe, 1961a).

Chamber samples for lead concentration analyses were collected with electrostatic precipitators

operated for periods of approximately two hours for every four hours of exposure. The collected dust was removed from the precipitator tubes by rinsing with nitric acid and analyzing the solutions by the dithizone procedure.

The pulmonary deposition measurements were made while the subjects were inside the chamber. The subject breathed through a mask (Kehoe, 1961a) attached through tubing to a three-way "T" tube equipped with two check valves. The subject inhaled the chamber aerosol through one valve and exhaled through a second valve through an electrostatic precipitator into a Douglas gas bag. The amount of the gas in the bag represented the volume of respired air. The amount of lead trapped by the precipitator indicated the amount of lead remaining in the expired air. The difference between the calculated amount of lead inspired and the amount of lead recovered in the precipitator divided by the inspired lead times 100% yielded the percent of lead deposited in the respiratory tract.

B. DATA PROCESSING

Most of the original data were contained on computer tapes and had to be reformatted for the present analyses. The initial data processing was carried out at the Southwestern Ohio Regional Computer Center at the University of Cincinnati. The subsequent statistical analyses used in this report were developed at the Litton Computer Services of Reston, Virginia. The computer plots (Figures 3 A to P) were prepared for the Author by Digital Graphics, Incorporated, Rockville, Maryland using Cal-Comp plotter programs from California Computer Products, Inc., Anaheim, California. Most of the statistical analyses were made using the Biomedical Computer Programs (Dixon, 1970), the Statistical Package for Social Sciences (Nie, et al., 1975) or a desk top computer. A number of source programs were written by the Author and his associates.

RESULTS

Before considering the results, it should be useful to clarify briefly some of the terminology used in this report. The term "parameter" refers to one or more of the measurements made on each subject, that is the lead in the diet, feces, urine, blood and/or lead balance. The term "balance" refers to "measured balance" and has been used as an indirect measure of true balance, the difference between total body absorption of lead (input) and its excretion (output). Measured balance was calculated by the formula: $\text{Balance} = \text{Dietary lead} - (\text{Fecal lead} + \text{Urinary lead})$ which does not include the contribution to the body made by airborne lead. Chamber concentrations were measured while the subjects were confined to the chambers and a limited number of air samples

from a few of the subject's homes were obtained. However, it was not possible to obtain quantitative estimates of non-experimental airborne lead exposures or to obtain an adequately quantitative integrated dose to the lungs during the subject's stay in the chambers. Nevertheless, measured balance provided a useful means for examining changes in the subject's body burden of lead throughout these experiments.

Figure 2 shows the types of curves that would be expected for lead levels in the feces, urine and blood during each of the experimental periods. Under equilibrium or steady state conditions of the control period, these parameters should remain constant as shown in Part A of the Figure. When the subjects

were exposed to constant additional amounts of lead in the diet or in the air, these parameters should increase as shown in Part B. There should be two portions to Part B: an exponential increase which levels off into the second phase, period of stability or "exposure equilibrium." The differences in the parameters between control levels and the exposure equilibrium levels constitute a "dose-response" due to the exposure. During this time, the soft tissues of the body should become saturated with lead commensurate with the exposure rate. The opposite changes (Part C) should be expected when the experimental lead exposure was stopped. There should be an exponential decrease in each parameter followed by a "post-exposure equilibrium" in which the lead in the blood, urine and feces should return to control levels.

Because of the absence of airborne lead in the balance equation, the changes in balance should simulate the curves for blood, urine and feces only when lead in the diet was increased, but would be exactly reversed when the subject was exposed to increased airborne lead. That is, measured balance should decrease during increased airborne lead exposure periods and increase during post exposure periods. These changes in lead balance would be seen only if airborne lead absorption remained constant during dietary supplementation and if dietary lead remained constant during airborne lead exposures.

A. Data Plots and Statistical Summaries

The raw data for each subject are shown in Figures 3 A to P, and are summarized statistically in Tables 4 and 5. The Figures are presented in order of increasing overall rates of exposure, beginning first with the oral experiments. Individual data points are shown in separate graphs on the ordinate. The individual experimental periods are separated by the vertical lines. The seasons are represented on the abscissa by January for winter, April for spring, July for summer, and October for fall. Periods of "off time" (Table 2) also shown on the abscissa sometimes overlapped the seasonal designations. When this occurred, preference was given the off-time designations and the seasonal arrow was omitted. The time scale for subjects FC and MOB had to be greatly compressed in order to plot their data on one page. The vertical scales for the parameters were chosen to include at least 99% of the data over the whole experiment. This caused some of the scales of individual parameters to be considerably compressed. The data exceeding the scale limits are presented by the short arrows at the top and bottom of each parameter graph. The curves running through the center of the data points are weekly averages of the plotted data, excluding the off scale data. The curves for the averages help

to delineate the trends within the scatter of the data.

Selection of Data. Abnormally high data were included in the final data set if there was other corroborating information. For example, high fecal leads which were associated with high dietary leads were retained. The overall means for each parameter of each experimental period were obtained and any data which fell outside of 4 SD's of these means were excluded during the final calculations. This process resulted in the exclusion of relatively few data points.

All of the remaining data for each of the control periods were used even though there was a considerable amount of natural fluctuation within the period. Many of the exposure and post-exposure periods did not exhibit any response to experimental manipulation nor did they reach equilibrium conditions. This was because of natural variability of lead in the diet and/or air or because the experimental period was too short. In these cases an arbitrary selection of data which represented equilibrium conditions was made. It was observed that those experiments which achieved an equilibrium period did so by 20 weeks or 140 days. This was based on the inspection of weekly data plots (not presented in this report). For experimental periods greater than 240 days, the data from day 140 on were used to calculate equilibrium means. This allowed the use of at least 100 days of data in the calculations. For shorter periods (less than 240 days), the data from the last half of the period were used even though many of the exposure and post-exposure periods were of short duration.

The lead distributions in the diet and feces (but not urine and blood) for most of the experimental periods were found to be statistically skewed to the right. Therefore, the statistical data have been presented both in terms of means (Table 4) and in terms of medians and log-means (Table 5). The dose-response data in subsequent tables and figures have been calculated from data means only because the results obtained using medians were not appreciably different from those results based on the means.

B. Control Periods

The control periods ranged from 31 to 602 days in length. Inspection of the data plots of each individual (Figures 3 A to P) reveals relatively stable levels for all the parameters during the control periods of subjects SB, MOB, PB, IF, HR, JOS and SS. The periods of EB, NK and MR reflected overall increases in several parameters; DH and JUS, overall decreases; and FC, LD, and SW had wide fluctuations throughout their periods. The control periods of MB, DH and JUS showed fluctuations in the lead of the urine and feces without corresponding changes in diet, suggesting possible changes due to fluctuation

tuations in airborne lead.

The overall arithmetic means (and ranges) for the 16 control periods were 181 ug Pb/day (97-334) for the diet, 225 ug Pb/sample (110-425) for the feces, 29 ug Pb/day (19-45) for the urine, 25 ug Pb/100 gm (18-40) for the blood and -32 ug Pb/day (-106 to +25) for lead balance. The corresponding data based on medians (and log means) were 159 (162) ug/day, 212 (205) ug/sample 33 (27) ug/day, 25 (24) ug/100 gm and -32 ug/day, for the diet, feces, urine, blood and balance, respectively. The control period means are presented graphically by year in Figures 4 A to C. Besides a considerable amount of variability between subjects, there was an overall decrease with time which was statistically significant for the diet ($r = -0.86$, $P < 0.01$) and blood ($r = -0.63$, $P < 0.01$).

Fecal Lead. Fecal lead in Tables 4 and 5 is expressed on a per sample basis rather than on the average daily fecal excretion. Each sample included all evacuations, if any, over a 24-hour period. For most subjects, the fecal lead excreted on a per sample basis was greater than the amount of lead in the daily diet. Since most of the subjects did not defecate on a daily basis, their evacuations included unabsorbed lead from more than one day's diet (assuming an insignificant amount of lead to have been secreted into the intestinal tract). In Table 6, the fecal lead has been converted to a per day basis (column 3) by multiplying the average for fecal lead on a per sample basis by the subject's evacuation rate (column 2, Table 6) over his or her experimental period. For most subjects the daily average was substantially lower than the per sample average. This adjustment resulted in an overall control period average for fecal lead of 196 ug/day with a range of 102 to 425 ug/day. Based on median data, the overall average was 164 ug/day. Expressed on a per day basis, most of the fecal leads still exceeded the daily intake of the diet (column 4). The overall mean percent of diet was 109% (105% based on median data), with a range of 83 to 177%.

Urinary Lead. Most of the literature presents urinary lead on a concentration basis. Table 7 has been used to compare daily urinary lead concentrations to 24 hour urinary lead excretion. The concentration data was derived from the same daily samples used in Tables 4 and 5. The control periods had an overall mean of 25 ug/liter which ranged from 16 to 37 ug/liter of urine. The overall average ratio of the concentration data to the 24 hour data was 0.93; however, individual's mean ratios ranged from 0.58 to 1.15.

C. Experimental and Parameter Variability

Coefficients of variability (CV's) for each parameter are presented in Table 8 for each control period by the year of the experiment. The cor-

responding SD's are presented graphically in Figures 5 A to C. Blood exhibited the least amount of variation with an average CV of 22%. This was followed by the urine with 34%, the diet with 57%, the feces with 73% and balance, 1526%. The CV's for balance were large because the means for balance used in the denominator in calculating the CV's were so near to zero (Table 4). The variability of the diet, feces and balance for LD's control period was inordinately high because of several episodes of excessive lead ingestion (see Figure 3 I).

The variability of the lead parameters was relatively stable over the years of the experiments; however, there were overall decreases as seen in Figures 5 A to C. The CV's for blood tended to decrease significantly ($r = -0.53$, $P < 0.05$) with time. The decrease in the SD for blood seen in Figure 5 C was in excess of the decrease in the control period means (Figure 4 C). The decrease in dietary lead variability (Figure 5 B) was also associated with a decrease in mean dietary lead (Figure 4 B). However, the decrease did not attain statistical significance ($r = 0.23$, $P > 0.05$).

Chamber conditions (Table 9) were also generally stable over the years of the inhalation experiments. The overall CV's were impressively small, but individual variability of the chamber conditions in some cases was 2-3 times that of the overall average. Daily exposure times spent in the chamber were generally constant throughout the experimental periods; however, in some instances these hours varied considerably (column 4, Table 9). There were five different particle sized aerosols used in the chamber exposures. An inspection of the CV's for the deposition data grouped by particle size did not indicate any analytical variation between the groups. However, when the percents of deposition recorded for the 38 inhalation periods which used 0.05 um aerosols were arranged according to the year of the experiment, there was a tendency for the rate of deposition to increase ($r = 0.37$, $p < 0.01$). The regression equation through these data suggested that the deposition average for 1951 was 30.2% and in 1969 it was 48.0%, an increase of 63% over the years.

Correlations Between Diet, Feces, Urine, Blood and Balance. The correlations between several of the parameters during the control periods in Table 10 are arranged for each subject by year. Under control conditions none of the parameters had high inter-parameter correlations, and therefore, were not predictive of any other parameters even though several of the coefficients were statistically significant. Thus, neither blood nor urine could be used to predict changes in diet or balance. The correlation coefficients between the parameters for the data of the combined experimental and post experimental periods are arranged in Table 11 for each subject by increasing doses of lead. By comparison to the cor-

relations for the control period data, there was a larger number of higher and more significant inter-parameter correlations. However, none of these parameters could be used to predict any of the other parameters.

D. Oral Supplementation Experiments.

Oral Exposure Responses. The data points for the individual oral exposures are shown in Figures 3 A to D. Definite exposure responses were obvious in all of the parameters for the upper three dosage levels (MR, EB and IF). The changes were seen in the diet, feces and balance for SW; however, his blood and urine did not show any responses. Equilibrium exposure conditions were achieved for MR and EB but not for IF. IF's exposure period was terminated before equilibrium could be achieved. The considerable amount of fluctuation in urinary lead seen for the exposure periods of MR and EB was probably due to the concurrent fluctuations in dietary lead which is difficult to see in the figures because of the scale compression. Both MR and EB had long exposure periods during which time their blood leads increased to equilibrium averages of 53 and 60 ug/100 gm, respectively, with a few individual values exceeding 80 ug/100 gm. Their daily urinary leads increased to means of 79 and 117 ug/day, respectively, with most of the values remaining below 160 ug for MR and 240 ug for EB.

The dose-responses to the oral supplementation shown in Table 12 are plotted in Figure 6. The daily lead in feces and lead balance were linear for all 4 subjects. The responses of lead in blood and urine were linear for the intermediate exposure rates (1000 and 2000 ug/day). The final blood and urine lead levels of IF were low because his exposure was terminated prior to achieving equilibrium conditions. Although fecal and dietary lead and lead balance were changed, no responses of the blood and urine were seen for SW even though he received dietary supplementation of 300 ug/day.

The solid lines in Figure 6 represent the overall regressions of each parameter with increasing oral lead supplementations. The lines have been drawn through the origin and are placed so as to give the two intermediate exposure levels the most influence. The calculated oral response data in the top of Table 15 are based on these regression lines. The slopes of the lines represent increases of 0.017 ug/100 gm for blood, 0.045 ug/day for urine, 0.83 ug/day for feces and 0.133 ug/day for balance with each increase of 1 ug of Pb in the diet.

Oral Post-Exposure Responses. Post exposure responses for the oral subjects are summarized in Table 13. Obvious washout responses (exponential decreases) were seen in the post exposure data of MR, EB and IF. There were suggestions of decreases in the blood and urine along with the diet and feces

for SW even though SW showed no substantial increases in his blood and urinary lead during exposure. All of the individuals reverted to negative balance during their post exposure periods. The urine and blood lead for MR, EB and IF, even with long post exposure times, did not return to pre-exposure control levels.

E. Inhalation Supplementation Experiments

Inhalation Exposure Responses. Individual's data points for each of twelve inhalation exposure subjects are found in Figures 3 E to P. The exposure periods of NK, SS, HR, DH, LD and JOS were of such short duration that exposure equilibrium conditions could not be achieved. The responses that were observed for subjects NK, SS, HR and DH were associated with increases and decreases in dietary lead rather than increasing exposure to airborne lead. Parameter responses due to the chamber exposures were not visibly apparent until exposure rates of 75 ug/m³ or more were used. Mean blood leads for most of the exposure experiments remained below 40 ug/100 gm and exceeded this level during only 3 exposure periods (LD-E4, and JOS-E3 and E4).

The dose-responses to the inhalation exposures which are summarized in the bottom half of Table 12 and in Figures 7 A to E are presented in terms of adjusted exposure rates. Particle size information has also been included in the dose-response data in Figures 7 A-D. The adjusted rates represent the exposures averaged over the whole experimental period and were obtained using the following formula:

$$\text{Adjusted Inhalation Rate} = \frac{\sum ct}{T}$$

where c represents each daily chamber concentration in ug/m³, t represents the time in hours for each day, summed for each exposure ($\sum ct$) divided by the total time of the experimental period T, in hours. T was obtained by multiplying the total number of calendar days (experimental time plus weekends and off times) by 24 hours. Expressing the responses for each inhalation experiment on the basis of the adjusted exposure rates allowed for the comparisons between experiments which used different concentrations and exposure times.

Blood, urine, and fecal lead increased and lead balance decreased statistically (Table 14) over the whole range of the exposures; however, the responses in the lower ranges (less than 10 ug/m³) were related primarily to changes in dietary lead. This relationship was demonstrated statistically (Table 14) and by the fact that balance for the lower exposure rates were positive (Figure 7 A). Diet also had its influence at the higher exposure rates, along with particle size which had a major influence. Blood

(Figure 7 E) and urine (Figure 7 D) levels for the experiments which used the larger particles (MOB, JUS, MB, PB and FC) were found in the lower portions of the response data distribution.

The dotted lines in Figures 7 A to E were used to join the data points obtained from the same individual. The linear regression lines are based on all of the response data; however, the curves were forced through the origin using the regression analysis of Ryan et al., (1976) as provided by Mr. Bernard Sobel (Ethyl Corporation). The calculated response data in Table 15 were derived from these regression lines in which blood lead increased by 0.57 ug/100 gm, urine increased 1.41 ug/day, feces increased 1.47 ug/day and balance decreased 3.32. ug/day for each 1 ug/m³ increase in airborne lead.

Inhalation Post-Exposure Responses. Subject HR did not participate in a post exposure period. Obvious experimental washout curves for blood and urine were seen in the post-exposure periods of LD,

JOS, MOB, SB, MB, FC and JUS. Many post exposure periods were too short to show any washout: NK-P1, SS-P1, 2 and 3, PB and FC-P1. The absence of washout curves for NK, SS and DH was probably due to the fact that there were no obvious responses to the exposures of these subjects. From the post-exposure summary in Table 13 it can be seen that the final levels of lead in blood and urine were for the most part dependent on changes in dietary lead. Two subjects, NK and SS, showed increases in blood, urine and lead balance during their post exposure periods due to increased dietary lead. Seven of the subjects who had the higher airborne exposure rates (From JOS to MOB in Table 13) were in more negative balance than during their control periods, indicating that they were still losing lead from their bodies at the end of the post exposure periods. The magnitude of washout (rate of negative balance) was not proportional to their exposure rates.

DISCUSSION

These experiments, carried out over a 34 year period, involved 102 separate experimental periods and over 21,000 days of measured exposure to lead. A considerable amount of time was required to collect, organize, analyze, verify and present this large amount of data. The original data used to derive the results presented have been put on computer tapes and will be made available to qualified researchers through the Department of Environmental Health at the University of Cincinnati or through Ethyl Corporation, Baton Rouge, Louisiana for the cost of duplicating the computer tapes.

Experimental Control. These studies have had the advantage of being under the control of the same investigators (Kehoe, Cholak, Schafer and Yeager) over the duration of the experiments. Thus, good experimental control was maintained over the years. There was, however, some improvement in precision of the lead analyses as can be seen in the reduction of the SD's shown in Figures 6 A to C. This can also be seen in the distribution of blood data in Figures 3 A to P in which the differences between adjacent data were smaller in the more recent experiments. Blood lead had the least amount of variability. The larger variability of lead in the diet, feces and urine, by comparison to blood, was in part artificial. Each lead determination had a precision of plus or minus 0.2 to 0.5 ug per Pb determination. This precision applied to each 10 ml blood sample which was used in its entirety. However, this analytical variability was amplified 5 to 20 times when calculating the amount of lead in the 24 hour samples of the diet, feces and urine from the respective aliquots used in the lead analyses. Such variability did not affect the reliability of the data averages which usually involved substantial numbers of observations.

The natural variability of the data produced troublesome fluctuations at times throughout these experiments. Every effort was made to retain as much of the data as possible and to select data without introducing investigator bias. This was achieved by using 4 SD's to exclude potentially contaminated samples and by the selection of equilibrium data based on objective criteria applied to all of the exposure and post-exposure periods.

A. Normal Exposures to Lead

The control periods provided one of the best practical estimates of normal exposures to lead. Carrying collection containers to all personal activities no doubt altered somewhat the subject's normal patterns of behavior. The striking variability of lead in each of the measured parameters was impressively large at times but was so consistent from individual to individual and within the same individual that such variability cannot be considered abnormal. The time of year was shown for the data on each of the plots (Figure 3 A to P) in an effort to identify possible fluctuations which could be associated with seasonal changes. Seasonal changes in the concentrations of lead in the air have been reported (Tepper and Levin, 1972) but no seasonal effects were observed in the Kehoe data. The lack of seasonal influences due to fluctuations in the ambient air concentrations is not surprising since the responses to such fluctuations would be obscured by the natural variability of the diet, which also showed no seasonal trends.

Dietary Lead. Estimates of lead in the subject's diet were based on the analyses of duplicate diets and duplicate samples of other ingested items (such

as medicines). Since the duplicates were not measured exactly, over- and underestimated portions were possible. Requiring each participant to quantitatively measure each food item would have distorted the normal dietary patterns. Most likely any excessively large samples were counterbalanced by correspondingly small samples.

The range of natural dietary lead was considerable. It was not uncommon for the daily dietary lead to be as low as 30 ug and as high as 500 ug. Temporary fluctuations such as these had no effect on the levels of lead in the blood and in the urine. Much of the literature suggests that the average diet contains approximately 300 ug Pb/day which was often based on past reports by Kehoe (1961a). With the inclusion of the more recent experiments, the overall average of the Kehoe studies has been reduced to 180 ug/day (or 159 ug/day based on median data which are more representative of the normal diet). The decrease in dietary lead (Figure 4 B) suggests that normal diet in 1970 was more on the order of 100 ug/day (87 ug/day based on medians). The decrease from the 300 ug/day in 1935 was considered by Kehoe (1961a) to be due primarily to decreased contamination of food during its processing and handling.

There is a limited number of published studies which involve measuring lead in actual dietary samples. However, none of these are comparable to the present study in the number of individuals and the number of days measured. Thompson (1971) sampled 5 individuals for 12 to 28 days and found mean intakes of 274 ug/day (range of 237-306 ug/day). Coulston et al. (1972) measured one day samples from 17 individuals in an institutional setting and obtained a 113 ug/day average (range 74-215). A number of other studies (WHO, 1977) have found comparable estimates of daily lead intake based on lead concentrations in various individual foods.

Fecal Lead. Fecal lead on a per sample basis varied more widely than did the daily ingested lead and was considerably higher than the lead in the diet. The correlation between fecal and dietary lead was poor (Table 10). This phenomenon was probably due in major part to the fact that most subjects did not defecate on a daily basis and thus the fecal lead represented unabsorbed dietary lead from more than one day's dietary intake. This assumes that biliary secretion of lead is quite limited (N.A.S. 1972). The practice of using single fecal samples, therefore, cannot be used reliably to predict dietary lead.

Converting fecal lead to an average daily basis brought the fecal lead more in line with dietary lead (shown graphically in Figure 4 B); however, the conversion resulted in an overall ratio of fecal lead to dietary lead of 1.09 which suggested that fecal lead amounted to 109% of the lead found in the diet. This

percentage varied considerably from individual to individual (Table 6). These results are at variance with the notion that fecal lead represents 90 to 95% of the lead in the diet (Kehoe, 1961a; NAS, 1972; WHO, 1977). However, five of the subjects (LD, DH, NK, MR, SS) had very high fecal leads which averaged 149% (ranging from 135 to 177%) of the diet while the other 11 subjects excreted an average of 92% (ranging from 83-104%) of the dietary lead in the feces. Under the increased dietary lead load of the ingestion experiments the percent of the dietary lead found in the feces decreased reflecting an increased absorption rate.

Thompson (1971) found fecal lead to average 240 ug/day (range of 207-271) in 5 subjects on collection from 12 to 28 days. The Kehoe subjects averaged 196 ug/day over their control periods. Tepper and Levin (1972) reported median fecal leads of 85 to 150 ug/day based on 10 day collections from groups of 20 subjects from 8 cities over the U.S. The Tepper and Levin data are somewhat lower than the median fecal data shown in Table 5.

Urinary Lead. Like most of the other parameters daily urinary excretion of lead varied considerably from day to day (Figure 3 A to P) and from individual to individual (Table 8). Thompson (1971) reported the average urinary lead to be 16 to 30 ug/day which compared well with the 19-45 ug/day in these studies. Although there are numerous references to acceptable levels of urinary lead excretion (Lane et al. 1968, NIOSH, 1972, NAS, 1972), there are very few published reports on urinary lead excretion per se in adults under normal conditions besides the data already published by Kehoe. Most literature reports involved exposed populations, chelation studies or analyses of other indicators of exposure such as urinary delta-aminolevulinic acid.

The lead in the urine averaged 18% of the diet with a range of 9 to 47%. The 47% (of LD) was the only such value with all of the other values ranging from 9 to 22%.

On an overall basis, daily urinary excretion (29 ug/day) approximated the 24 hour urinary lead concentration (25 ug/l); however, the individual ratios of the concentration to the daily urinary output were quite variable ranging from 0.3 to as much as 12 times. Based on the means and standard deviations, 95 to 99% of the control lead concentrations (Table 6) were well below the 80 ug/l cited as normal (Lane et al. 1968) and were in good agreement with the data reported in the "Three City Study" (USPHS, 1965).

Blood Lead. Except for 2 early subjects (MR and SW), the control average blood concentrations were at 30 ug/100 gm of blood or less. Blood lead had the least amount of variability although individual data points (Figures 3 A to P) varied considerably at times. Such variability was probably analytical in nature. Keppler (1970) reported on a study by 66

laboratories which analyzed blood from the same sample. Eliminating the extreme upper 10% and lower 10% still left a range of 14-53 ug/100g. Lerner (1975) reported on 35 samples taken from one volunteer in a single collection. The samples were submitted coded to the Kettering Laboratory. Values ranged from 12 to 42 ug/100g. Rejecting the 42 as an outlier, the range was 12 to 28 ug/100g with a standard deviation of 3.9.

Balance. Balance as measured here was extremely variable. This was due in part to the lack of daily defecation and to the natural variability of lead in the diet and the feces. The balance data for several of the individuals were somewhat unexpected (high or low) based on other studies presented in the literature and on the results obtained from these experiments as a whole. The -32 ug/day overall balance would represent background lead of approximately 10 ug/m³ (Table 15), which is over 5 times higher than what would be expected (Table 1-7, NAS, 1972). Five of the same subjects who had high fecal leads (LD, DH, NK, MR and SS) contributed very substantially to the overall negative balance average with balances ranging from -48 to -106 ug/day. The other eight subjects had balances which ranged from -3 to -31 ug/day. Rabinowitz (1974) using stable isotopes techniques in human balance studies reported that air contributed only 17 ug/day to the body. It is possible that some of the Kehoe subjects were exposed to relatively high airborne lead outside of the Laboratory, they had had high past exposures, or they were receiving less lead in their control diets than they experienced previously.

On the other extreme are the three subjects who were in positive balance, with one of these (FC) gaining 21 ug/day and another (HR), 25 ug/day. Balance becomes positive only when the diet increases. According to the data in Table 15, an increase of 200 ug/day would be necessary to increase balance by 27 ug/day. Both FC's and HR's dietary control lead were low (238 and 156 ug/day, respectively). An average increase of 200 ug/day in dietary lead in these subjects over their previous diets was not likely. However, the control diets for both of these subjects were higher than any of their other experimental periods.

Although the measured control balance data may not adequately represent the true balance in these subjects, the spread of the control data suggests that the subjects' exposure prior to their control periods probably influenced the balance results during their control periods. The fact that fecal lead generally represented more than that found in the diet and that balance was generally negative suggests that most (if not all) of the lead absorbed from diet or the air was excreted from the body and that under these normal exposure rates (for Cincinnati) these subjects were probably in lead balance with their environment. This observation is consis-

tent with the findings based on tissue lead concentrations from humans from the Cincinnati area as previously reported by this author (Gross, et al., 1975).

B. Oral Supplementation Experiments

There was only one subject for each of the 4 levels used in these experiments. Except for SW, the levels of oral supplementation were considerably in excess of the normal diets. The responses of balance and fecal lead were surprisingly linear for all four subjects (Figure 6). On the other hand, blood and urinary responses were linear only for MR and EB, both of whom achieved equilibrium conditions during the exposure periods. The decreased responses of blood and urine for IF were probably due to the fact that his experiment was terminated after 113 days before equilibrium conditions could be achieved. Doubling the dietary intake of lead as for SW, did not effect his blood or urinary levels, even though his body was in a definite positive balance state of 59 ug/day (Table 12). Blood lead concentrations usually reflect increases and decreases in the concentrations of lead in soft tissues but not necessarily those in the bones (Gross, 1976). Since the blood lead of SW did not reflect the increase in body lead, this suggests that the absorbed lead was taken up by his bones rather than by his soft tissues.

All subjects during the ingestion experiments were in strong positive balance due to the retention of dietary lead. Fecal lead dropped from 109% to 83% of the dietary lead and urinary lead dropped from 18% to 4.5% of the diet. The post exposure periods of MR, EB and IF were all accompanied by strong washout periods in which the blood and urinary lead levels decreased with time and each subject went into strong negative balance. Post-exposure parameter levels were not quite comparable to pre-exposure levels because the post-exposure dietary lead levels were not the same (Table 13). The positive balance in the post-exposure period for MR cannot be satisfactorily explained.

Overall Responses to Increased Dietary Intake. Assuming the data from Figure 6 are generally representative of the magnitude of the changes in the various parameters with increases in dietary lead, blood lead would remain in the normal range (40 ug/100 gm or less) up to dietary levels of approximately 1000 ug/day over an extended period of time. This represents 3 to 10 times the amount of lead normally found in an average adult diet. Since lead acetate used to supplement the diets of these subjects is a soluble form of lead, it is possible that this form of lead may have been more readily absorbed than the lead occurring naturally in the diet. These curves probably do not apply to children since they apparently can absorb more of their dietary

lead than adults. Other factors such as dietary calcium, iron, zinc and vitamin D which can modify the absorption rates from the intestinal tract (WHO, 1977), may also effect the rate of absorption of lead.

C. Inhalation Supplementation Experiments

Exposure Rate Selection. Only three chamber concentrations (10, 20 and 150 $\mu\text{g}/\text{m}^3$, except for MOB-E1) and a wide range of exposure times, ranging from 3 hours every other day to 13 hours a day, 6 days per week were used to supplement the subject's airborne lead exposures. The exposure rate of FC 1 was excluded from any analyses because this exposure was for only 9 days. The chamber concentrations of 150 $\mu\text{g}/\text{m}^3$ were chosen to simulate the acceptable work place concentrations. The Threshold Limit Value at that time of these experiments was 150 $\mu\text{g}/\text{m}^3$ for the 40 hour week (ACGIH, 1971) which, when converted to the adjusted rates, corresponded to 35.7 $\mu\text{g}/\text{m}^3$. The lower end of the exposure range simulated community exposures which can be expected to vary depending on whether the area is urban or rural, the traffic density and the time of day, the weather conditions (inversions vs. good air circulation) and on the proximity to industries which emit lead fumes (NAS, 1972).

Factors Affecting Dietary Lead Responses.

Dietary Lead. The influence of the natural variability of dietary lead was unexpected. In reports from the literature, dietary lead was measured directly during the inhalation studies by Rabinowitz et al. (1974) and Coulston and Goldberg (1972 and 1973) and indirectly by fecal lead analyses by Tepper and Levin (1972). However, none of these investigators examined the influence of potential changes of the diet as it might have affected airborne lead responses.

Dietary lead intake during the control periods was also important since elevated dietary lead would tend to dampen and lower dietary intake and would tend to exaggerate the exposure responses. In several cases, the control period diets were apparently not representative when compared to the diets of the exposure and post-exposure periods: SS had an unusually low (146 $\mu\text{g}/\text{day}$) control compared to an overall average for all of his dietary lead levels of 201 $\mu\text{g}/\text{day}$ which ranged from 137 to 460; the control diet for MOB was 211 $\mu\text{g}/\text{day}$ compared to the lower overall average of 153; and FC had a high control of 238 $\mu\text{g}/\text{day}$ compared to an overall average of 171. There was no way to determine what was an appropriate control period level nor to adjust the data for the influence of changes in the diet. Since there was a relatively large number of different inhalation exposure periods (44 in all), hopefully any elevated control diets were balanced out by any low diets (Figure 7 C) to provide a

reasonable overall response curves (Figures 7 A, B, C & E).

Particle Size. Particle size affects the deposition and therefore the absorption and retention of lead from the lungs. According to the ICRP lung model (Task Group on Lung Dynamics, 1973) small size particles with mass median equivalent diameters (MMED) of 1.0 micrometer (μm) or less are deposited in the lower respiratory tract (alveoli and small bronchioles) and the larger particles (5 - 10 μm) are deposited in the upper respiratory tract (of the naso-pharynx, trachea and bronchial tree). Particles deposited in the upper pulmonary tract can be removed from the lung by mucociliary action and subsequently swallowed.

Thirty-eight of the inhalation exposures involved aerosols with median count diameters of 0.05 μm while 5 subjects were exposed to larger particles: 0.11 μm (PB), 0.75 μm (MB), 0.9 μm (FC-E3) and 1.20 μm (MOB-E2 and JUS). According to the Panel on Airborne Lead (NAS, 1972), median count diameters of 0.05 and 0.9 μm correspond to MMED of 0.26 and 2.9 μm and atmospheric lead particles range from 0.15 to 0.3 μm MMED. All of the experiments in the low exposure range (less than 10 $\mu\text{g}/\text{m}^3$) involved particles of count diameters of 0.05. Above 10 $\mu\text{g}/\text{m}^3$, all particle sizes were represented and the influence of size was apparent. All of the blood and urine dose responses of the larger particles were in the lower portions of the distributions of Figures 7 D and E. Also fecal lead (Figure 7 B) tended to increase when the larger particle sizes were used even in the face of decreased dietary lead (Figure 7 C).

Pulmonary Deposition. Deposition varied considerably between individuals ranging from 30% (SS and JOS) to about 70% (HR) and was also quite variable for measurements on the same individual (Table 3). An examination of the deposition measurements for only those experiments which used only particles of 0.05 μm showed that there was an increase in measured deposition of 63%. This may have been due to modifications of the techniques used in measuring deposition. There was no apparent association between deposition and particle size but there was an association between deposition and ventilation rate. As ventilation rates decreased from 18.5 l/min (SB) to 8.52 l/min (HR), deposition rates increased from 34% to 64.2%, respectively. This phenomena was also observed by Mehani (1966) and Muir and Davis (1967) and Hatch and Gross (1964) and was explained on the basis of an increase in the number of respirations per minute which increased the influence of the dead space of the respiratory tract.

Overall Responses to Increased Airborne Lead.

The linear regression lines drawn in Figures 7 A, B, D & E suggest the magnitude of the overall responses of lead balance and lead in the urine, feces and blood to increasing rates of airborne lead

exposure. None of these parameters was statistically predictive of the exposure rates.

A number of studies have attempted to relate blood lead to airborne lead exposure. Using a relatively large population sample, Tepper and Levin (1972) found no correlation between normal blood lead and ambient air lead levels. Goldsmith and Hexter (1967) and Azar et al. (1973) report logarithmic increases in blood lead concentrations of 1.3 and 1.0 $\mu\text{g}/100\text{ ml}$ in blood per 1 $\mu\text{g}/\text{m}^3$ increases in air lead. These studies suffer from the fact that the air level measurements could not be directly related to the individuals from whom blood lead concentrations were obtained. It is also probable that the correlation of the raw data (as opposed to the log-log data) would not be statistically related to exposure. Coulston et al. (1972, 1973) studied exposures of 40 individuals but did express their final results on the basis of blood changes with exposure. Their control blood concentrations ranged from 12-29 $\mu\text{g}/100\text{ ml}$ and increased to averages of 27 $\mu\text{g}/100\text{ ml}$ for daily exposures of 3.2 $\mu\text{g}/\text{m}^3$ and to 35 $\mu\text{g}/100\text{ ml}$ for exposures of 10.9 $\mu\text{g}/\text{m}^3$.

The regression curve in Figure 7 E suggests that blood lead increased by only 0.57 $\mu\text{g}/100\text{ gm}$ which is considerably lower than the rates presented by Goldsmith and Hexter and Azar. This curve was calculated by giving equal weight to all of the data points; however, the line was statistically forced through the origin which greatly reduced the influence of the responses of the low exposure rates. Assuming this curve to be representative of the type of responses which might apply to the population at large, normal blood lead concentrations (40 $\mu\text{g}/100\text{ gm}$ or less) would be maintained at ambient air concentrations to 26 $\mu\text{g}/\text{m}^3$. This is over 12 times the air levels sustained in most cities. Based on a 40 hour work week, this is equivalent to 110 $\mu\text{g}/\text{m}^3$.

Besides those discussed above, there are a number of other factors which need to be considered in applying these data to the population at large. Lead sesquioxide was used throughout these experiments. Lead is found in various chemical forms in the atmosphere as halides, mixed oxides and halides, carbonates, etc. (NAS, 1972; Ter Haar, 1975). Different chemical species of lead might have different solubilities in tissue fluids and therefore potentially different absorption characteristics. Par-

ticle charge, shape and other physical factors can also influence the deposition, and therefore retention and absorption of lead by the lung.

D. Significance

The experiments reported here represent the most extensive and intensive investigation of the physiology of lead in humans ever undertaken. No other laboratory has engaged in research on the effect of lead on humans to the extent of that of Dr. Kehoe and his colleagues. Dr. Kehoe has had more personal experience in the investigation of lead under a wide variety of normal environmental conditions, during many different industrial operations and in the evaluation of many cases of lead poisoning in children as well as in adults. His investigations have served as standard references for almost 50 years. The results of the present analysis will further substantiate the importance of lead research from the Kettering Laboratory.

These experiments provide the best practical estimates of normal exposures to lead. The results emphasize the importance of the natural background variability both in evaluating humans in their natural environments and during exposures to specific sources of lead. These data suggest humans tend to be in balance with their environment and that adults can tolerate rather high exposures to lead without developing frank intoxication. An individual can absorb large quantities of lead for short periods of time without showing this in the urine or blood. After termination of increased exposure, considerable amounts of previously absorbed lead can be readily excreted from the soft tissues (as reflected by balance and decreases in blood lead concentrations) and, on a more prolonged basis, excreted from the bones (as reflected by the continued excessive negative balance).

Each of the individual experiments examined here provided considerably more information than could be presented in this brief summary. Especially important would be an effort to develop mathematical models which could be used to describe the kinetics of lead movement in and out of the body; and hopefully, provide the ability to quantify the contributions of lead by each of the absorption routes to the blood, urine and to body burden of lead.

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Table 1
Personal Data on Subjects^a

Subject	Age (yrs)	Sex	Race	Previous Occupation
EB	48	M	N	Post Office
MB	42	M	N	Chauffeur/Butler
MOB	28	M	N	Student
PB	37	F	N	Lab Assistant
SB	25	M	C	Valve Company
FC	29	M	C	Farmer
LD	33	M	C	Merchant
IF	34	M	C	
DH	23	M	C	Student
NK	50	M	C	Wood Worker
HR	22	M	N	Student
MR	30	M	C	Student
JOS	32	M	C	Welder
JUS	55	M	C	Merchant
SS	24	M	C	Student
SW	30	M	C	Garage Owner

^aPersonal communication from Ms. Jan Stewart of the Department of Environmental Health, University of Cincinnati.

Table 2
Experimental Periods Arranged Alphabetically By Subjects' Initials

Subject	Period ^a	Time on ^b Collection (days)	Off ^c Time (days)	Rate of ^d Exposure
EB	C	56		2000.0 ug/day
	E	646		
	P1	908		
	P2	84		
MB	C	148	29	29.4 ug/m ³
	E	333		
	P	702	48	
MOB ^e	C	244	9	22.4 ug/m ³
	E1	628	50	
	P1	866	87	
	Corn	21		28.4 ug/m ³
	P Corn	182	2	
	E2	384		
	P2	431	37	
PB	C	232		28.4 ug/m ³
	E	237		
	P	28		
SB	C	384		27.4 ug/m ³
	E	504		
	P	378		
FC	C	536	85	64.8 ug/m ³
	E1	9		
	P1	47		30.6 ug/m ³
	E2	616		
	P2	535	65	30.1 ug/m ³
	E3	364		
	P3	499	75	
LD	C	602	36	9.3 ug/m ³ 19.7 ug/m ³ 27.1 ug/m ³ 35.9 ug/m ³
	E1	112		
	E2	115		
	E3	109		
	E4	112		
	P	196		
IF	C	478	48	3000.0 ug/day
	E	113		
	P	166		
DH ^e	C	224		5.6 ug/m ³ 7.3 ug/m ³ 7.6 ug/m ³ 8.8 ug/m ³
	CNE	28		
	E1	112		
	E2	112		
	E3	112		
	E4	112		
	P	84		

Table 2
Experimental Periods Arranged Alphabetically By Subjects' Initials (continued)

Subject	Period ^a	Time on ^b Collection (days)	Off ^c Time (days)	Rate of ^d
NK	C	202		
	E1	98		.6 ug/m ³
	E2	196		1.2 ug/m ³
	E3	112		1.9 ug/m ³
	E4	112		2.4 ug/m ³
	P1	14		
	E5	112		3.3 ug/m ³
	E6	112		3.6 ug/m ³
	E7	112		4.0 ug/m ³
	P2	108		
HR	C	166	22	
	E1	140		2.4 ug/m ³
	E2	112		3.7 ug/m ³
	E3	60		7.5 ug/m ³
MR ^e	C	31		
	E	1095		1000.0 ug/day
	E-DC1	28		"
	P-DC1	35		"
	E-DC2	28		"
	P-DC2	32		"
	E-DC3	28		"
	P-DC3	14		"
	E-DC4	28		"
	E-DC5	28		"
	P-DC5	33	16	"
	E-DC6	28		"
	P-DC6	28		"
	E-DC7	14		"
	P-DC7	42		"
	P	283	18	"
JOS	C	392	21	
	E1	112		9.4 ug/m ³
	E2	112		19.3 ug/m ³
	E3	112		27.1 ug/m ³
	E4	112		35.7 ug/m ³
	P	179		
JUS	C	140		
	E	772	12	28.1 ug/m ³
	P	504	7	
SS	C	129		
	E1	168		.6 ug/m ³
	E2	108	4	1.3 ug/m ³
	E3	112		1.8 ug/m ³
	E4	112		2.4 ug/m ³
	P1	21		
	E5	112		2.7 ug/m ³
	E6	108	4	3.4 ug/m ³

Table 2
Experimental Periods Arranged Alphabetically By Subjects' Initials (continued)

Subject	Period ^a	Time on ^b Collection (days)	Off ^c Time (days)	Rate of ^d Exposure
	E7	112		4.3 ug/m ³
	P2	63	27	
	E8	140		2.4 ug/m ³
	E9	112		3.2 ug/m ³
	E10	140		5.4 ug/m ³
	E11	105		6.2 ug/m ³
	E12	112		7.0 ug/m ³
	E13	113		7.2 ug/m ³
	P3	22	5	
SW	C	361		
	E	420		300.0 ug/day
	P	63		

^a The C, E and P Periods refer to control, exposure and post exposure periods, respectively.

^b Days during which food, feces, urine and blood samples were collected.

^c Days in which the subject was off collection for vacation, sickness and other times when samples were not collected.

^d Rates expressed as ug/day refer to the oral experiments. Rates expressed as ug/m³ refer to average 24 hour inhalation exposures calculated over the total experimental period. (See RESULTS).

^e Periods designated as Corn, E-DC's, P-DC's and CNE are discussed in the text.

Table 3
Inhalation Chamber Exposure Conditions and Pulmonary Analyses

Subject & Exposure Period		Chamber Conditions				Pulmonary Analyses		
		Concentration (mg/m ³) ^a	Hours ^a Per Day	Days Per Week	Particle ^b Size (microns)	N ^c	Deposition ^a %	Min. Vol. ^a (l/min.)
MB		0.152/0.027 (0.094/0.228)	6.8/0.6 (3.0/7.0)	5	50% 0.75 90% 1.80	26	54.1/8.3 (38.7/69.0)	14.83/1.70 (10.70/20.20)
MOB	1	0.077/0.012 ^d (0.056/.111)	6.7/0.6 (2.5/7.0)	5	50% 0.05 90% 0.17	27	39.9/14.8 (16.0/94.8)	
	2	0.144/0.026 (0.054/0.223)	7.0 ^e	5	50% 1.20 90% 6.0	18	53.4/11.4 (24.4/76.5)	12.12/3.65 (5.55/17.80)
PB		0.147/0.063 (0.032/0.363)	7.0/0.7 (2.0/8.0)	5	50% 0.11 90% 0.23	21	51.9/16.7 (18.4/74.5)	9.56/1.30 (7.60/13.50)
SB		0.153/0.015 (0.095/0.200)	6.2/2.2 (3.0/10.0)	5	50% 0.05 90% 0.17	67	34.0/5.2 (13.6/45.2)	18.50/1.89 (12.50/22.00)
FC	1	0.288/0.183 (0.153/0.624)	6.9/0.2 (6.5/7.0)	5	50% 0.05 90% 0.17	2	46.5/0.7 (46.0/47.0)	13.08/2.90 (11.03/15.13)
	2	0.154/0.015 (0.107/0.220)	7.0/0.2 (5.0/7.0)	5	Same	15	34.6/9.6 (19.3/48.5)	10.11/1.12 (8.20/11.60)
	3	0.152/0.067 (0.056/0.850)	7.0/0.5 (3.0/8.0)	5	50% 0.90 90% 2.00 max 4.00	9	43.2/13.4 (20.6/60.5)	17.37/3.09 (13.40/21.00)
LD	1	0.150/0.012 (0.123/0.193)	3.0/0.0 (3.0/3.0)	3.5	50% 0.05 90% 0.17	16	40.2/4.0 (33.3/49.3)	17.25/2.10 (13.40/23.60)
	2	0.154/0.014 (0.113/0.182)	6.0/0.0 (6.0/6.0)	3.5	50% 0.05 90% 0.17	16	40.6/10.4 (20.7/70.5)	17.36/1.56 (14.30/20.00)
	3	0.147/0.013 (0.120/0.167)	9.0/0.3 (7.0/10.0)	3.5	Same		38.7/3.7 (30.3/44.5)	17.50/2.00 (14.10/20.70)
	4	0.151/0.012 (0.114/0.174)	11.9/0.7 (8.0/12.0)	3.5	Same		37.2/3.5 (28.7/42.5)	19.05/1.04 (16.90/21.00)
DH	1	0.021/0.003 (0.011/0.029)	7.6/0.8 (3.0/8.0)	6	50% 0.05 90% 0.17	9	52.5/15.3 (17.2/69.0)	10.53/0.87 (9.00/11.70)
	2	0.021/0.003 (0.015/0.030)	9.7/0.5 (8.0/10.0)	6	Same	11	45.0/16.5 (7.0/61.6)	9.20/0.86 (7.70/10.60)
	3	0.020/0.003 (0.014/0.023)	11.3/0.9 (8.0/13.0)	6	Same	13	57.0/6.2 (48.8/69.0)	9.82/0.89 (8.20/11.30)
	4	0.021/0.008 (0.014/0.074)	13.0/1.3 (4.0/15.0)	6	Same	9	50.7/17.8 (18.7/74.4)	9.29/1.14 (7.60/11.00)

Table 3
Inhalation Chamber Exposure Conditions and Pulmonary Analyses (continued)

Subject & Exposure Period		Chamber Conditions				Pulmonary Analyses			
		Concentration (mg/m³) ^a	Hours ^a Per Day	Days Per Week	Particle ^b Size (microns)		N ^c	Deposition ^a %	Min. Vol. ^a (l/min.)
NK	1	0.009/0.001 (0.007/0.012)	3.0/0.0 (3.0/3.0)	3.5	50% 0.05 90% 0.17	10	36.1/7.2 (25.3/48.2)	18.39/0.60 (17.10/19.10)	
	2	0.010/0.001 (0.008/0.14)	6.0/0.0 (6.0/6.0)	3.5	Same	26	37.5/11.2 (13.5/55.5)	19.0/0.62 (17.40/20.50)	
	3	0.010/0.002 (0.007/0.015)	9.0/0.0 (9.0/9.0)	3.5	Same	9	44.4/4.4 (39.2/52.0)	19.87/0.94 (18.80/21.40)	
	4	0.010/0.001 (0.008/0.013)	11.9/0.7 (7.0/12.0)	3.5	Same	15	34.5/8.8 (24.0/48.5)	19.07/0.86 (17.30/21.30)	
	5	0.010/0.001 (0.008/0.013)	9.0/0.1 (8.0/9.0)	6	Same	14	33.5/9.9 (11.2/51.0)	18.32/0.97 (17.20/19.70)	
	6	0.009/0.001 (0.007/0.013)	10.9/0.8 (5.0/11.0)	6	50% 0.05 90% 0.17	3	32.9/2.2 (30.6/35.0)	17.97/1.80 (15.90/19.20)	
	7	0.010/0.002 (0.001/0.013)	12.0/0.2 (10.0/12.0)	6	Same	7	59.6/5.3 (52.0/66.0)	10.50/1.13 (9.60/12.90)	
HR	1	0.020/0.002 (0.011/0.035)	3.5/0.5 (2.0/4.0)	6	50% 0.05 90% 0.17	19	71.1/5.9 (53.5/79.6)	8.43/0.62 (7.30/9.4)	
	2	0.020/0.003 (0.014/0.042)	5.2/0.4 (5.0/6.0)	6	Same	12	67.1/4.1 (61.0/74.0)	8.27/0.54 (7.50/9.10)	
	3	0.020/0.002 (0.011/0.024)	10.4/0.7 (7.0/11.0)	6	Same	5	54.5/21.2 (27.4/70.5)	8.56/0.79 (7.60/9.50)	
JOS	1	0.148/0.011 (0.128/0.177)	3.0/0.0 (3.0/3.0)	3.5	50% 0.05 90% 0.17	14	38.20/5.1 (31.1/48.2)	20.51/2.23 (16.00/23.60)	
	2	0.157/0.012 (0.187/0.136)	6.0/0.0 (6.0/6.0)	3.5	Same	15	31.4/5.9 (21.4/39.0)	17.69/1.22 (16.40/20.20)	
	3	0.148/0.011 (0.108/0.168)	9.0/0.3 (7.0/9.0)	3.5	Same	16	30.5/6.4 (20.4/46.8)	17.09/1.25 (15.20/19.40)	
	4	0.147/0.011 (0.119/0.168)	11.9/0.4 (9.0/12.0)	3.5	Same	16	34.3/4.4 (24.6/41.7)	16.59/1.13 (13.90/18.40)	
JUS		0.143/0.033 (0.004/0.234)	7.0/0.0 (7.0/7.0)	5	50% 1.20 90% 5.00 max 15.00	15	64.2/10.4 (34.0/72.0)	16.33/0.51 (15.60/17.10)	
SS	1	0.010/0.002 (0.007/0.020)	3.0/0.0 (3.0/3.0)	3.5	50% 0.05 90% 0.17	20	36.8/8.1 (15.9/45.2)	19.00/1.3 (16.10/21.70)	

Table 3
Inhalation Chamber Exposure Conditions and Pulmonary Analyses (continued)

Subject & Exposure Period	Chamber Conditions				Pulmonary Analyses		
	Concentration (mg/m ³) ^a	Hours ^a Per Day	Days Per Week	Particle ^b Size (microns)	N ^c	Deposition ^a %	Min. Vol. ^a (l/min.)
SS 2	0.010/0.002 (0.008/0.015)	6.0/0.0 (6.0/6.0)	3.5	Same	12	35.7/9.8 (18.8/48.5)	19.07/1.33 (16.70/20.60)
3	0.010/0.001 (0.008/0.013)	8.9/0.5 (5.0/9.0)	3.5	Same	14	28.3/8.6 (11.8/40.0)	18.82/1.33 (17.20/21.90)
4	0.010/0.001 (0.00/0.01)	12.0/0.0 (12.0/12.0)	3.5	Same	12	29.5/10.3 (13.7/41.0)	18.50/1.19 (16.70/20.00)
5	0.009/0.002 (0.002/0.013)	8.9/0.8 (3.0/9.0)	6	Same	2	20.3/2.3 (18.6/21.9)	18.65/3.18 (16.40/20.90)
6	0.010/0.001 (0.001/0.012)	10.9/0.6 (6.0/11.0)	6	Same	8	54.6/8.3 (37.3/64.0)	7.03/0.69 (6.40/8.40)
7	0.010/0.002 (0.005/0.016)	12.0/0.0 (12.0/12.0)	6	Same	13	48.4/12.6 (24.0/69.0)	7.64/0.98 (5.40/8.90)
8	0.020/0.002 (0.13/0.025)	3.5/0.5 (3.0/4.0)	6	50% 0.05 90% 0.17	19	57.4/7.1 (41.0/71.0)	9.17/0.83 (7.50/10.60)
9	0.020/0.003 (0.014/0.040)	5.2/0.4 (5.0/6.0)	6	Same	12	52.4/14.8 (31.0/72.0)	8.87/0.78 (7.20/10.10)
10	0.020/0.004 (0.008/0.049)	6.8/0.5 (5.0/7.0)	6	50% 0.05 90% 0.17	13	56.5/6.9 (47.2/69.5)	9.43/0.68 (7.90/10.50)
11	0.019/0.003 (0.010/0.030)	8.7/0.5 (7.0/9.0)	6	Same	14	51.9/6.0 (41.8/62.0)	9.21/0.40 (8.60/9.90)
12	0.019/0.003 (0.013/0.030)	10.5/0.5 (9.0/11.0)	6	Same	12	47.0/9.0 (38.3/73.8)	8.85/0.63 (8.00/9.80)
13	0.018/0.003 (0.012/0.027)	12.1/0.8 (6.0/13.0)	6	Same	6	38.4/11.6 (21.3/54.8)	9.37/0.64 (8.70/10.40)

^a Means/SD over (minimum/maximum values)

^b Particle size data obtained from a summary table prepared by Larry Schafer, supervisor of the chamber operations.

^c The N's represent the number of deposition and respiratory rate determinations.

^d Based on the 27 deposition analyses, rather than daily samples.

^e Assumed to be 7 hours per day and 5 days per week taken from Larry Schafer's summary table. Data were not recorded on the original data sheets.

Table 4
Arithmetic Data Summary For Individuals ^a

Subject & Period ^b		N ^c (days)	Diet (mg/day)	Feces ^d (mg/sample)	Urine (mg/day)	Blood (mg/100g)	Balance (mg/day)
EB	C	56	0.334/0.140 (0.140/0.810)	0.333/0.172 (0.070/0.740)	0.037/0.012 (0.014/0.065)	0.027/0.005 (0.025/0.035)	-0.021/0.242 (-0.472/0.790)
	E	507	2.182/0.250 (1.460/3.330)	1.880/0.991 (0.300/6.000)	0.117/0.034 (0.001/0.240)	0.060/0.015 (0.007/0.100)	0.188/1.051 (-3.920/2.477)
	P1	769	0.293/0.137 (0.060/1.170)	0.304/0.195 (0.050/1.550)	0.052/0.025 (0.001/0.180)	0.034/0.009 (0.004/0.060)	-0.062/0.232 (-1.320/1.104)
	P2	43	0.299/0.108 (0.120/0.640)	0.249/0.099 (0.120/0.480)	0.040/0.012 (0.021/0.068)	0.029/0.007 (0.020/0.040)	-0.006/0.163 (-0.310/0.354)
MB	C	148	0.209/0.070 (0.090/0.480)	0.213/0.116 (0.050/0.910)	0.038/0.007 (0.023/0.063)	0.024/0.005 (0.020/0.030)	-0.015/0.143 (-0.763/0.386)
	E	194	0.197/0.083 (0.060/0.590)	0.299/0.159 (0.070/0.940)	0.076/0.013 (0.042/0.147)	0.040/0.006 (0.030/0.050)	-0.138/0.195 (-0.895/0.503)
	P	563	0.264/0.110 (0.030/0.630)	0.287/0.152 (0.060/1.010)	0.045/0.010 (0.011/0.089)	0.028/0.005 (0.020/0.040)	-0.024/0.193 (-758/0.556)
MOB	C	244	0.211/0.087 (0.060/0.570)	0.304/0.208 (0.030/1.200)	0.031/0.008 (0.003/0.054)	0.026/0.009 (0.020/0.060)	0.003/0.229 (-0.870/0.508)
	E1	489	0.188/0.099 (0.060/0.570)	0.314/0.199 (0.060/1.230)	0.056/0.012 (0.019/0.110)	0.039/0.008 (0.025/0.065)	-0.046/0.226 (-0.976/0.483)
	P1	727	0.174/0.098 (0.060/0.600)	0.353/0.253 (0.050/2.250)	0.040/0.013 (0.005/0.093)	0.027/0.007 (0.020/0.055)	-0.059/0.256 (-1.380/0.934)
	CORN	11	3.012/3.664 (0.480/13.620)	4.451/2.887 (2.600/11.350)	0.212/0.055 (0.147/0.348)	0.051/0.006 (0.045/0.060)	-0.167/5.472 (-10.753/13.386)
	PCORN	92	0.104/0.050 (0.030/0.300)	0.217/0.117 (0.030/0.690)	0.034/0.009 (0.012/0.058)	0.025/0.006 (0.010/0.030)	-0.080/0.158 (-0.578/0.271)
	E2	245	0.117/0.065 (0.030/0.420)	0.389/0.203 (0.060/1.080)	0.051/0.011 (0.029/0.091)	0.032/0.005 (0.020/0.040)	-0.275/0.225 (-1.066/0.023)
	P2	292	0.125/0.096 (0.030/0.600)	0.208/0.139 (0.020/0.930)	0.026/0.009 (0.008/0.064)	0.022/0.004 (0.020/0.030)	-0.028/0.189 (-0.888/0.745)
FB	C	232	0.134/0.059 (0.030/0.360)	0.217/0.126 (0.020/0.640)	0.025/0.010 (0.008/0.062)	0.023/0.004 (0.014/0.029)	-0.009/0.149 (-0.612/0.293)
	E	98	0.115/0.049 (0.030/0.240)	0.259/0.187 (0.030/0.860)	0.036/0.014 (0.005/0.075)	0.033/0.006 (0.023/0.042)	-0.036/0.196 (-0.784/0.369)
	P	15	0.134/0.106 (0.060/0.450)	0.530/0.294 (0.200/0.880)	0.034/0.019 (0.010/0.077)	0.032/0.003 (0.030/0.034)	-0.077/0.310 (-0.791/0.426)
SB	C	384	0.107/0.080 (0.030/0.480)	0.110/0.059 (0.030/0.430)	0.024/0.007 (0.009/0.049)	0.021/0.003 (0.019/0.030)	-0.023/0.095 (-0.505/0.302)
	E	365	0.109/9.107 (0.030/0.750)	0.167/0.113 (0.040/0.800)	0.051/0.011 (0.023/0.089)	0.032/0.005 (0.019/0.045)	-0.080/0.156 (-0.758/0.687)
	P	239	0.082/0.051 (0.030/0.270)	0.121/0.057 (0.030/0.410)	0.024/0.006 (0.010/0.041)	0.020/0.005 (0.007/0.028)	-0.046/0.086 (-0.380/0.244)
FC	C	536	0.238/0.118 (0.060/0.740)	0.200/0.120 (0.040/1.010)	0.022/0.008 (0.003/0.052)	0.022/0.006 (0.010/0.045)	0.021/0.134 (-0.732/0.544)
	E1	5	0.182/0.117 (0.090/0.410)	0.127/0.066 (0.050/0.260)	0.024/0.007 (0.017/0.041)	0.020/N=1 (0.020/0.020)	0.036/0.125 (-0.127/0.289)
	P1	23	0.138/0.050 (0.090/0.300)	0.133/0.070 (0.050/0.330)	0.019/0.004 (0.012/0.032)	0.020/0.0 (0.020/0.020)	-0.009/0.090 (-0.272/0.130)

Table 4
Arithmetic Data Summary For Individuals^a (continued)

Subject & Period ^b	N ^c (days)	Diet (mg/day)	Feces ^d (mg/sample)	Urine (mg/day)	Blood (mg/100g)	Balance (mg/day)
E2	477	0.213/0.104 (0.060/0.710)	0.240/0.147 (0.050/1.200)	0.076/0.021 (0.022/0.166)	0.039/0.010 (0.020/0.070)	-0.095/0.167 (-0.976/0.626)
P2	397	0.160/0.079 (0.060/0.490)	0.140/0.064 (0.030/0.420)	0.023/0.010 (0.010/0.080)	0.020/0.005 (0.008/0.040)	-0.004/0.090 (-0.333/0.341)
E3	225	0.128/0.067 (0.030/0.480)	0.249/0.097 (0.030/0.640)	0.071/0.016 (0.033/0.126)	0.031/0.006 (0.020/0.040)	-0.192/0.115 (-0.653/0.243)
P3	360	0.138/0.080 (0.030/0.600)	0.138/0.088 (0.040/0.650)	0.022/0.007 (0.008/0.049)	0.021/0.002 (0.020/0.030)	-0.020/0.102 (-0.488/0.390)
LD C	463	0.139/0.184 (0.030/3.220)	0.262/0.740 (0.020/12.120)	0.019/0.007 (0.004/0.045)	0.018/0.005 (0.007/0.034)	-0.048/0.443 (-8.231/3.195)
E1	57	0.101/0.060 (0.030/0.270)	0.251/0.129 (0.060/0.660)	0.037/0.011 (0.020/0.077)	0.029/0.012 (0.019/0.058)	-0.096/0.162 (-0.485/0.219)
E2	58	0.162/0.059 (0.090/0.420)	0.303/0.159 (0.090/0.770)	0.056/0.012 (0.032/0.083)	0.036/0.008 (0.023/0.047)	-0.058/0.243 (-0.689/0.947)
E3	56	0.340/0.343 (0.060/1.320)	0.667/0.560 (0.100/2.200)	0.086/0.020 (0.044/0.134)	0.040/0.007 (0.026/0.049)	-0.180/0.579 (-2.052/1.082)
E4	57	0.079/0.043 (0.030/0.240)	0.307/0.179 (0.070/1.020)	0.086/0.020 (0.041/0.132)	0.041/0.003 (0.037/0.048)	-0.190/0.212 (-1.042/0.118)
P	99	0.102/0.049 (0.030/0.420)	0.215/0.090 (0.060/0.460)	0.028/0.006 (0.014/0.049)	0.023/0.004 (0.016/0.032)	-0.053/0.161 (-0.369/0.635)
IF C	339	0.237/0.119 (0.004/0.990)	0.261/0.157 (0.020/1.240)	0.032/0.016 (0.010/0.090)	0.027/0.007 (0.015/0.045)	-0.024/0.204 (-1.122/0.932)
E	56	3.218/0.433 (0.315/3.720)	3.227/1.400 (0.150/6.250)	0.081/0.018 (0.043/0.142)	0.046/0.008 (0.030/0.055)	0.371/1.811 (-4.506/3.587)
P	85	0.162/0.076 (0.030/0.450)	0.225/0.140 (0.020/0.890)	0.036/0.013 (0.014/0.068)	0.040/0.012 (0.030/0.075)	-0.069/0.168 (-0.844/0.283)
DH C	224	0.097/0.058 (0.030/0.420)	0.330/0.258 (0.090/1.760)	0.045/0.012 (0.018/0.087)	0.030/0.006 (0.021/0.053)	-0.103/0.234 (-1.393/0.655)
CNE	15	0.079/0.038 (0.030/0.150)	0.174/0.087 (0.050/0.340)	0.050/0.009 (0.027/0.063)	0.025/0.001 (0.024/0.026)	-0.038/0.147 (-0.272/0.313)
E1	57	0.096/0.055 (0.030/0.240)	0.188/0.080 (0.040/0.380)	0.046/0.011 (0.025/0.072)	0.031/0.005 (0.025/0.043)	-0.071/0.125 (-0.268/0.436)
E2	57	0.097/0.065 (0.030/0.390)	0.175/0.081 (0.050/0.360)	0.040/0.016 (0.017/0.083)	0.026/0.004 (0.019/0.030)	-0.044/0.145 (-0.534/0.475)
E3	57	0.104/0.073 (0.030/0.390)	0.232/0.149 (0.060/0.740)	0.047/0.012 (0.021/0.075)	0.029/0.004 (0.022/0.034)	-0.094/0.181 (-0.728/0.229)
E4	57	0.071/0.028 (0.030/0.150)	0.190/0.115 (0.060/0.560)	0.045/0.015 (0.018/0.075)	0.028/0.003 (0.023/0.032)	-0.099/0.136 (-0.545/0.109)
P	25	0.079/0.044 (0.030/0.240)	0.214/0.125 (0.050/0.620)	0.035/0.010 (0.020/0.070)	0.027/0.002 (0.023/0.029)	-0.066/0.145 (-0.636/0.165)
NK C	202	0.141/0.071 (0.030/0.360)	0.200/0.095 (0.050/0.570)	0.027/0.006 (0.009/0.045)	0.020/0.003 (0.014/0.026)	-0.083/0.098 (-0.484/0.341)
E1	50	0.168/0.114 (0.060/0.600)	0.165/0.070 (0.060/0.390)	0.031/0.006 (0.019/0.047)	0.020/0.004 (0.018/0.028)	-0.007/0.269 (-1.017/0.873)
E2	90	0.140/0.073 (0.060/0.530)	0.160/0.067 (0.070/0.550)	0.030/0.005 (0.013/0.045)	0.021/0.003 (0.015/0.027)	-0.053/0.104 (-0.554/0.346)
E3	57	0.151/0.050 (0.060/0.300)	0.153/0.049 (0.050/0.240)	0.032/0.006 (0.015/0.047)	0.023/0.003 (0.018/0.029)	-0.035/0.080 (-0.261/0.242)
E4	57	0.151/0.192 (0.060/1.170)	0.208/0.316 (0.020/1.720)	0.037/0.008 (0.025/0.064)	0.026/0.004 (0.019/0.031)	-0.090/0.263 (-1.570/0.434)

Table 4
Arithmetic Data Summary For Individuals ^a (continued)

Subject & Period ^b	N ^c (days)	Diet (mg/day)	Feces ^d (mg/sample)	Urine (mg/day)	Blood (mg/100g)	Balance (mg/day)
P1	8	0.135/0.058 (0.060/0.240)	0.147/1.069 (0.060/0.230)	0.035/0.004 (0.030/0.043)	0.025/N=2 (0.025/0.025)	-0.054/0.031 (-0.087/-0.003)
E5	57	0.122/0.066 (0.030/0.360)	0.126/0.054 (0.040/0.300)	0.037/0.006 (0.024/0.057)	0.026/0.005 (0.019/0.035)	-0.041/0.089 (-0.242/0.206)
E6	57	0.298/0.181 (0.060/0.750)	0.146/0.067 (0.030/0.300)	0.045/0.008 (0.028/0.065)	0.030/0.002 (0.028/0.034)	0.109/0.170 (-0.171/0.510)
E7	57	0.137/0.078 (0.030/0.420)	0.146/0.073 (0.020/0.430)	0.038/0.008 (0.020/0.055)	0.029/0.006 (0.021/0.043)	-0.043/0.131 (-0.438/0.343)
P2	55	0.223/0.119 (0.030/0.690)	0.123/0.078 (0.030/0.510)	0.036/0.008 (0.019/0.053)	0.023/0.002 (0.019/0.026)	0.065/0.140 (-0.266/0.594)
HR C	166	0.156/0.095 (0.030/0.690)	0.309/0.169 (0.040/0.850)	0.027/0.010 (0.006/0.063)	0.021/0.003 (0.017/0.029)	0.025/0.231 (-0.610/0.913)
E1	71	0.086/0.054 (0.030/0.270)	0.281/0.117 (0.050/0.640)	0.025/0.008 (0.009/0.051)	0.025/0.007 (0.019/0.045)	-0.053/0.170 (-0.587/0.242)
E2	57	0.065/0.039 (0.030/0.210)	0.321/0.122 (0.140/0.660)	0.027/0.011 (0.009/0.049)	0.021/0.003 (0.017/0.027)	-0.095/0.190 (-0.595/0.166)
E3	31	0.082/0.044 (0.030/0.210)	0.377/0.136 (0.200/0.720)	0.036/0.014 (0.007/0.074)	0.027/0.004 (0.024/0.034)	-0.094/0.227 (-0.686/0.343)
MR C	31	0.261/0.147 (0.030/0.790)	0.425/0.286 (0.010/1.300)	0.024/0.012 (0.013/0.070)	0.036/0.010 (0.025/0.055)	-0.106/0.423 (-1.051/0.940)
E	956	1.333/0.227 (0.045/2.700)	1.409/0.782 (0.090/4.780)	0.079/0.028 (0.016/0.222)	0.053/0.011 (0.025/0.095)	0.069/0.925 (-3.609/3.600)
E-DC1	15	1.546/0.497 (1.050/2.860)	1.429/0.468 (0.730/2.430)	0.089/0.033 (0.050/0.156)	0.052/0.004 (0.050/0.055)	0.123/0.738 (-1.272/1.460)
P-DC1	35	1.247/0.152 (1.050/1.730)	1.510/0.892 (0.920/4.280)	0.086/0.024 (0.040/0.122)	0.067/0.004 (0.065/0.070)	0.049/1.032 (-3.143/1.197)
E-DC2	15	1.611/0.369 (1.120/2.380)	1.583/0.492 (0.830/2.300)	0.076/0.018 (0.045/0.115)	0.072/0.004 (0.070/0.075)	0.057/0.862 (-0.788/2.280)
P-DC2	17	1.172/0.161 (0.850/1.400)	1.168/0.544 (0.230/2.130)	0.065/0.014 (0.034/0.085)	0.062/0.004 (0.060/0.065)	0.214/0.654 (-1.168/1.046)
E-DC3	15	1.229/0.204 (0.980/1.830)	1.213/0.396 (0.530/1.830)	0.066/0.017 (0.044/0.100)	0.055/0.007 (0.050/0.060)	0.192/0.601 (-0.750/1.297)
P-DC3	8	1.552/0.489 (1.140/2.420)	0.995/0.422 (0.500/0.750)	0.056/0.023 (0.020/0.093)	0.060/N=1 (0.060/0.060)	0.750/0.738 (-0.583/1.538)
E-DC4	15	1.378/0.254 (1.130/2.030)	1.598/0.741 (0.590/2.790)	0.067/0.014 (0.038/0.100)	0.057/0.004 (0.055/0.060)	0.139/1.040 (-1.722/1.930)
E-DC5	15	1.210/0.221 (1.030/1.830)	1.315/0.646 (0.320/2.370)	0.097/0.031 (0.056/0.165)	0.047/0.004 (0.045/0.050)	-0.027/0.821 (-1.292/1.350)
P-DC5	17	1.258/0.198 (0.860/1.820)	1.982/1.135 (0.600/4.000)	0.126/0.049 (0.050/0.276)	0.078/0.036 (0.054/0.120)	-0.179/1.220 (-2.740/1.211)
E-DC6	15	1.337/0.114 (1.170/1.540)	1.429/0.461 (0.600/2.120)	0.091/0.018 (0.062/0.120)	0.072/0.018 (0.060/0.085)	-0.107/0.580 (-0.997/1.298)
P-DC6	15	1.425/0.210 (1.080/1.930)	1.641/0.617 (0.640/2.430)	0.125/0.054 (0.066/0.300)	0.056/0.005 (0.053/0.060)	-0.013/0.878 (-1.210/1.260)
E-DC7	8	1.267/0.090 (1.170/1.440)	1.328/0.331 (0.930/1.840)	0.094/0.042 (0.052/0.187)	0.065/N=1 (0.065/0.065)	0.013/0.580 (-0.662/1.148)
P-DC7	22	1.351/0.196 (1.170/1.800)	1.767/0.971 (0.680/3.650)	0.041/0.035 (0.010/0.110)	0.061/0.005 (0.055/0.065)	0.067/1.227 (-2.440/1.662)
P	144	0.236/0.109 (0.090/0.690)	0.319/0.218 (0.020/1.670)	0.055/0.024 (0.014/0.137)	0.041/0.006 (0.035/0.050)	-0.038/0.242 (-1.270/0.550)

Table 4
Arithmetic Data Summary For Individuals ^a (continued)

Subject & Period ^b		N ^c (days)	Diet (mg/day)	Feces ^d (mg/sample)	Urine (mg/day)	Blood (mg/100g)	Balance (mg/day)
JOS	C	392	0.112/0.061 (0.030/0.360)	0.237/0.183 (0.020/1.040)	0.020/0.005 (0.008/0.036)	0.021/0.004 (0.012/0.029)	-0.010/0.182 (-0.789/0.674)
	E1	57	0.119/0.056 (0.030/0.300)	0.231/0.133 (0.040/0.710)	0.035/0.009 (0.021/0.074)	0.032/0.004 (0.026/0.039)	-0.058/0.173 (-0.618/0.274)
	E2	57	0.191/0.087 (0.090/0.570)	0.241/0.155 (0.040/0.740)	0.057/0.011 (0.030/0.090)	0.037/0.005 (0.029/0.043)	-0.014/0.222 (-0.684/0.770)
	E3	57	0.138/0.045 (0.060/0.270)	0.253/0.200 (0.040/0.770)	0.063/0.011 (0.035/0.091)	0.041/0.007 (0.026/0.048)	-0.062/0.203 (-0.757/0.206)
	E4	57	0.116/0.060 (0.060/0.270)	0.247/0.177 (0.030/0.860)	0.076/0.016 (0.011/0.122)	0.046/0.004 (0.036/0.051)	-0.110/0.203 (-0.895/0.151)
	P	90	0.139/0.069 (0.030/0.420)	0.260/0.181 (0.030/1.010)	0.031/0.007 (0.015/0.053)	0.027/0.003 (0.022/0.033)	-0.063/0.214 (-0.928/0.674)
JUS	C	140	0.169/0.074 (0.060/0.480)	0.178/0.083 (0.050/0.450)	0.024/0.011 (0.005/0.054)	0.021/0.005 (0.010/0.030)	0.002/0.117 (-0.342/0.432)
	E	633	0.218/0.095 (0.060/0.690)	0.439/0.198 (0.050/1.430)	0.045/0.012 (0.015/0.099)	0.032/0.006 (0.020/0.050)	-0.171/0.273 (-1.328/0.594)
	P	365	0.110/0.065 (0.030/0.480)	0.141/0.062 (0.020/0.420)	0.020/0.005 (0.009/0.035)	0.019/0.005 (0.011/0.040)	-0.023/0.102 (-0.510/0.347)
SS	C	129	0.146/0.097 (0.030/0.600)	0.237/0.142 (0.030/0.620)	0.025/0.006 (0.008/0.046)	0.019/0.003 (0.014/0.024)	-0.091/0.200 (-0.644/0.704)
	E1	85	0.164/0.112 (0.030/0.540)	0.228/0.117 (0.020/0.490)	0.025/0.006 (0.013/0.044)	0.020/0.003 (0.015/0.025)	-0.012/0.166 (-0.385/0.517)
	E2	55	0.217/0.1567 (0.060/0.870)	0.328/0.139 (0.090/0.590)	0.027/0.008 (0.015/0.054)	0.020/0.293 (0.011/0.027)	-0.004/0.293 (-1.010/0.511)
	E3	57	0.088/0.046 (0.030/0.210)	0.216/0.172 (0.030/0.740)	0.023/0.006 (0.005/0.039)	0.018/0.002 (0.015/0.022)	-0.071/0.179 (-0.706/0.188)
	E4	57	0.149/0.081 (0.030/0.420)	0.261/0.161 (0.040/0.730)	0.027/0.007 (0.017/0.043)	0.019/0.004 (0.016/0.027)	-0.037/0.197 (-0.615/0.388)
	P1	11	0.172/0.060 (0.090/0.270)	0.276/0.140 (0.080/0.510)	0.028/0.012 (0.010/0.046)	0.017/0.004 (0.014/0.020)	-0.016/0.186 (-0.400/0.214)
	E5	57	0.222/0.169 (0.060/0.810)	0.510/0.259 (0.090/1.080)	0.035/0.009 (0.023/0.058)	0.023/0.003 (0.019/0.028)	-0.044/0.324 (-0.941/0.667)
	E6	55	0.156/0.105 (0.060/0.600)	0.297/0.160 (0.120/0.850)	0.029/0.010 (0.006/0.059)	0.024/0.002 (0.020/0.026)	-0.003/0.243 (-0.761/0.935)
	E7	57	0.219/0.125 (0.090/0.610)	0.285/0.145 (0.110/0.740)	0.035/0.010 (0.020/0.059)	0.024/0.004 (0.015/0.030)	0.045/0.252 (-0.649/0.837)
	P2	32	0.245/0.180 (0.030/0.780)	0.235/0.132 (0.060/0.570)	0.031/0.006 (0.019/0.042)	0.021/0.002 (0.018/0.023)	0.057/0.265 (-0.449/0.761)
	B8	71	0.132/0.105 (0.030/0.570)	0.212/0.088 (0.050/0.470)	0.024/0.006 (0.011/0.045)	0.024/0.003 (0.020/0.032)	-0.008/0.188 (-0.317/0.641)
	E9	57	0.171/0.103 (0.030/0.570)	0.314/0.191 (0.110/1.040)	0.027/0.007 (0.011/0.045)	0.021/0.005 (0.015/0.031)	-0.027/0.252 (-0.822/0.628)
	E10	57	0.206/0.132 (0.060/0.720)	0.309/0.161 (0.090/0.900)	0.033/0.008 (0.017/0.055)	0.027/0.003 (0.023/0.032)	-0.011/0.258 (-0.780/0.704)
	E11	53	0.164/0.108 (0.020/0.570)	0.236/0.135 (0.020/0.510)	0.035/0.010 (0.018/0.056)	0.026/0.003 (0.022/0.030)	0.000/0.213 (-0.407/0.720)
	E12	57	0.213/0.178 (0.020/1.270)	0.305/0.166 (0.090/0.740)	0.035/0.014 (0.011/0.075)	0.026/0.004 (0.019/0.033)	0.025/0.339 (-0.635/1.407)
	E13	57	0.290/0.213 (0.030/1.110)	0.216/0.123 (0.040/0.540)	0.038/0.011 (0.010/0.067)	0.029/0.006 (0.024/0.041)	0.098/0.256 (-0.517/0.818)

Table 4
Arithmetic Data Summary For Individuals ^a (continued)

Subject & Period ^b		N ^c (days)	Diet (mg/day)	Feces ^d (mg/sample)	Urine (mg/day)	Blood (mg/100g)	Balance (mg/day)
P3		12	0.460/0.304 (0.090/0.900)	0.436/0.199 (0.190/0.740)	0.037/0.009 (0.024/0.056)	0.036/N=1 (0.036/0.036)	0.169/0.427 (-0.537/0.825)
SW	C	361	0.199/0.104 (0.050/0.710)	0.265/0.138 (0.030/0.820)	0.040/0.016 (0.015/0.086)	0.040/0.009 (0.025/0.060)	-0.031/0.196 (-0.689/0.792)
	E	281	0.507/0.103 (0.300/0.930)	0.542/0.245 (0.100/1.430)	0.043/0.016 (0.014/0.097)	0.039/0.007 (0.020/0.060)	0.028/0.329 (-0.942/0.713)
	P	32	0.284/0.160 (0.120/0.780)	0.398/0.195 (0.150/0.930)	0.029/0.008 (0.015/0.044)	0.025/N=4 (0.025/0.025)	-0.030/0.255 (-0.590/0.778)

^a Data shown as mean/SD over (minimum/maximum values).

^b The C, E and P Periods refer to control, exposure and post exposure periods, respectively.

^c Number of days represented in the means. See text.

^d Per sample (rather than per day). See text.

Table 5
Logarithmic and Median Data Summary for Individuals^a

Subject & Period		Diet (mg/day)	Feces ^b (mg/sample)	Urine (mg/day)	Blood (mg/100g)	Balance (mg/day)
EB	C	0.306/1.517 (0.320)	0.287/1.790 (0.305)	0.034/1.449 (0.035)	0.027/1.169 (0.027)	(-0.057)
	E	2.168/1.119 (2.162)	1.637/1.718 (1.701)	0.112/1.439 (0.110)	0.057/1.387 (0.057)	(0.356)
	P1	0.269/1.489 (0.269)	0.256/1.745 (0.254)	0.046/1.656 (0.047)	0.033/1.459 (0.035)	(-0.042)
	P2	0.282/1.416 (0.280)	0.231/1.492 (0.223)	0.038/1.358 (0.038)	0.028/1.291 (0.029)	(-0.001)
MB	C	0.199/1.368 (0.185)	0.109/1.621 (0.184)	0.037/1.208 (0.038)	0.023/1.227 (0.023)	(-0.012)
	E	0.182/1.476 (0.178)	0.264/1.648 (0.265)	0.075/1.178 (0.075)	0.040/1.153 (0.040)	(-0.118)
	P	0.239/1.607 (0.243)	0.254/1.648 (0.252)	0.044/1.262 (0.044)	0.027/1.200 (0.029)	(-0.020)
MOB	C	1.196/1.442 (0.182)	0.247/1.954 (0.262)	0.030/1.318 (0.030)	0.025/1.315 (0.024)	(0.051)
	E1	0.168/1.585 (0.153)	0.262/1.820 (0.257)	0.055/1.253 (0.056)	0.039/1.208 (0.040)	(0.016)
	P1	0.159/2.000 (0.148)	0.290/1.870 (0.294)	0.038/1.365 (0.037)	0.026/1.282 (0.026)	(0.009)
	E2	0.104/1.589 (0.093)	0.339/1.726 (0.345)	0.050/1.236 (0.050)	0.032/1.186 (0.031)	(-0.261)
	Corn	1.888/1.276 (1.860)	3.945/1.611 (3.470)	0.206/2.624 (0.214)	0.051/1.127 (0.050)	(-1.206)
	PCorn	0.095/1.538 (0.095)	0.189/1.722 (0.191)	0.033/1.330 (0.034)	0.024/1.365 (0.026)	(-0.073)
	P2	0.115/2.958 (0.098)	0.171/1.892 (0.174)	0.025/1.384 (0.025)	0.021/1.161 (0.021)	(-0.018)
PB	C	0.123/1.528 (0.123)	0.181/1.892 (0.195)	0.023/1.486 (0.024)	0.023/1.191 (0.024)	(0.030)
	E	0.105/1.538 (0.106)	0.198/1.538 (0.214)	0.033/1.585 (0.035)	0.033/1.189 (0.034)	(0.027)
	P	0.110/1.800 (0.101)	0.461/1.841 (0.400)	0.030/1.683 (0.029)	0.032/1.091 (0.032)	(0.038)
SB	C	0.089/1.782 (0.088)	0.097/1.614 (0.095)	0.023/1.337 (0.023)	0.021/1.140 (0.020)	(-0.027)
	E	0.083/2.000 (0.085)	0.142/1.750 (0.140)	0.050/1.253 (0.051)	0.032/1.180 (0.032)	(-0.081)
	P	0.069/1.811 (0.063)	0.109/1.560 (0.112)	0.023/1.315 (0.025)	0.019/1.352 (0.020)	(-0.053)
FC	C	0.213/1.592 (0.208)	0.174/1.683 (0.165)	0.021/1.406 (0.021)	0.022/1.253 (0.021)	(0.020)
	E1	0.158/1.690 (0.131)	0.114/1.622 (0.107)	0.023/1.318 (0.022)	0.020/N=1	(-0.008)
	P1	0.130/1.377 (0.125)	0.117/1.687 (0.112)	0.019/1.250 (0.018)	0.020/1.000 (0.020)	(-0.003)
	E2	0.192/1.578 (0.184)	0.207/1.690 (0.204)	0.073/1.303 (0.073)	0.038/1.276 (0.039)	(-0.088)

Table 5
Logarithmic and Median Data Summary for Individuals^a (continued)

Subject & Period	Diet (mg/day)	Feces ^b (mg/sample)	Urine (mg/day)	Blood (mg/100g)	Balance (mg/day)
P2	0.145/1.560 (0.147)	0.129/1.510 (0.127)	0.021/1.419 (0.020)	0.020/1.268 (0.020)	(-0.007)
E3	0.114/1.626 (0.113)	0.230/1.514 (0.244)	0.070/1.259 (0.070)	0.301/1.216 (0.030)	(-0.182)
P3	0.120/1.702 (0.121)	0.120/1.671 (0.119)	0.021/1.349 (0.021)	0.021/1.107 (0.020)	(-0.020)
LD C	0.099/2.138 (0.092)	0.161/2.198 (0.160)	0.017/1.483 (0.018)	0.017/1.321 (0.018)	(-0.026)
E1	0.085/1.841 (0.085)	0.220/1.726 (0.225)	0.035/1.315 (0.035)	0.028/1.400 (0.026)	(-0.100)
E2	0.191/3.404 (0.156)	0.266/1.679 (0.280)	0.054/1.253 (0.055)	0.035/1.250 (0.035)	(-0.006)
E3	0.236/3.420 (0.149)	0.480/2.317 (0.455)	0.084/1.274 (0.086)	0.039/1.227 (0.041)	(-0.186)
E4	0.071/1.596 (0.067)	0.261/1.845 (0.298)	0.083/1.288 (0.087)	0.040/1.076 (0.039)	(-0.166)
P	0.093/1.552 (0.097)	0.197/1.538 (0.195)	0.027/1.262 (0.027)	0.023/1.194 (0.022)	(-0.074)
IF C	0.225/2.051 (0.206)	0.222/1.791 (0.224)	0.028/1.596 (0.027)	0.027/1.268 (0.025)	(-0.024)
E	3.133/1.374 (3.247)	2.799/1.914 (3.085)	0.079/1.256 (0.080)	0.045/1.208 (0.047)	(0.131)
P	0.148/1.549 (0.148)	0.191/1.849 (0.199)	0.033/1.476 (0.034)	0.038/1.274 (0.036)	(-0.067)
DH C	0.084/1.862 (0.089)	0.267/1.862 (0.242)	0.043/1.327 (0.044)	0.029/1.205 (0.029)	(-0.028)
E1	0.094/3.000 (0.086)	0.171/1.574 (0.175)	0.045/1.285 (0.047)	0.030/1.167 (0.030)	(-0.077)
E2	0.081/1.803 (0.088)	0.155/1.706 (0.175)	0.037/1.462 (0.035)	0.026/1.202 (0.028)	(-0.033)
E3	0.087/1.734 (0.073)	0.196/1.778 (0.183)	0.046/1.300 (0.047)	0.029/1.159 (0.029)	(-0.036)
E4	0.065/1.528 (0.067)	0.163/1.754 (0.169)	0.043/1.426 (0.044)	0.028/1.104 (0.029)	(-0.078)
P	0.070/1.622 (0.071)	0.183/1.803 (0.185)	0.034/1.312 (0.035)	0.027/1.096 (0.028)	(-0.010)
NK C	0.125/1.651 (0.124)	0.182/1.542 (0.174)	0.027/1.262 (0.027)	0.020/1.178 (0.019)	(-0.079)
E1	0.212/5.236 (0.137)	0.152/1.500 (0.144)	0.030/1.196 (0.030)	0.020/1.172 (0.019)	(-0.047)
E2	0.127/1.510 (0.123)	0.150/1.406 (0.145)	0.029/1.211 (0.030)	0.021/1.148 (0.020)	(0.047)
E3	0.160/2.518 (0.144)	0.144/1.429 (0.149)	0.031/1.230 (0.032)	0.022/1.153 (0.023)	(-0.037)
E4	0.114/1.849 (0.106)	0.134/2.296 (0.131)	0.036/1.219 (0.036)	0.025/1.167 (0.026)	(-0.058)
P1	0.124/1.560 (0.135)	0.132/1.702 (0.145)	0.035/1.132 (0.034)		(-0.063)

Table 5
Logarithmic and Median Data Summary for Individuals^a (continued)

Subject & Period		Diet (mg/day)	Feces ^b (mg/sample)	Urine (mg/day)	Blood (mg/100g)	Balance (mg/day)
	E5	0.134/3.972 (0.104)	0.114/1.578 (0.115)	0.037/1.186 (0.034)	0.025/1.205 (0.027)	(-0.061)
	E6	0.243/1.968 (0.274)	0.131/1.648 (0.135)	0.044/1.208 (0.044)	0.030/1.079 (0.029)	(0.078)
	E7	0.120/1.671 (0.122)	0.128/1.721 (0.140)	0.037/1.245 (0.039)	0.029/1.205 (0.028)	(-0.053)
	P2	0.219/2.716 (0.200)	0.107/1.660 (0.104)	0.035/1.271 (0.036)	0.023/1.102 (0.023)	(0.057)
HR	C	0.136/1.675 (0.145)	0.259/1.905 (0.276)	0.025/1.500 (0.025)	0.021/1.127 (0.021)	(0.064)
	E1	0.073/1.803 (0.072)	0.257/1.592 (0.275)	0.024/1.403 (0.023)	0.021/1.127 (0.021)	(0.013)
	E2	0.056/1.722 (0.057)	0.301/1.442 (0.310)	0.025/1.545 (0.025)	0.025/1.265 (0.023)	(0.005)
	E3	0.071/1.738 (0.077)	0.358/1.400 (0.350)	0.033/1.567 (0.036)	0.021/1.159 (0.020)	(0.004)
MR	C	0.224/1.832 (0.240)	0.316/2.692 (0.345)	0.022/1.500 (0.020)	0.035/1.300 (0.035)	(-0.128)
	E	1.312/1.208 (1.288)	1.202/1.816 (1.280)	0.074/1.435 (0.076)	0.052/1.242 (0.050)	(0.130)
	DC1	1.483/1.330 (1.290)	1.358/1.400 (1.360)	0.084/1.422 (0.082)	0.052/1.069 (0.052)	(0.059)
	NPDC1	1.239/1.119 (1.230)	1.361/1.528 (1.205)	0.082/1.396 (0.093)	0.067/1.054 (0.067)	(0.135)
	DC2	1.574/1.239 (1.550)	1.507/1.400 (1.610)	0.074/1.262 (0.070)	0.072/1.050 (0.072)	(-0.035)
	NPDC2	1.161/1.153 (1.227)	1.002/1.919 (1.340)	0.063/1.279 (0.066)	0.063/1.059 (0.062)	(0.140)
	DC3	1.216/1.161 (1.152)	1.148/1.435 (1.105)	0.064/1.285 (0.061)	0.055/1.138 (0.055)	(-0.029)
	NPDC3	1.490/1.340 (1.275)	0.927/1.510 (0.860)	0.051/1.000 (0.050)	0.060/1.000 (0.060)	(1.083)
	DC4	1.358/1.186 (1.327)	1.426/1.690 (1.580)	0.065/1.253 (0.065)	0.057/1.064 (0.057)	(0.168)
	DC5	1.194/1.178 (1.147)	1.127/1.879 (1.240)	0.093/1.361 (0.091)	0.047/1.076 (0.047)	(-0.058)
	NPDC5	1.245/1.167 (1.240)	1.683/1.849 (1.780)	0.118/1.449 (0.124)	0.073/1.538 (0.061)	(0.060)
	DC6	1.334/1.089 (1.367)	1.346/1.462 (1.500)	0.089/1.230 (0.090)	0.071/1.279 (0.072)	(-0.276)
	NPDC6	1.413/1.153 (1.360)	1.514/1.567 (1.695)	0.117/1.416 (0.116)	0.056/1.091 (0.056)	(-0.196)
	DC7	1.265/1.072 (1.245)	1.291/1.483 (1.170)	0.088/1.483 (0.085)	0.065/1.000 (0.065)	(-0.140)
	P	0.216/1.496 (0.210)	0.266/1.862 (0.275)	0.050/1.560 (0.050)	0.040/1.151 (0.041)	(-0.041)
JOS	C	0.111/2.858 (0.093)	0.185/2.037 (0.180)	0.019/1.291 (0.020)	0.020/1.213 (0.021)	(0.039)

Table 5
Logarithmic and Median Data Summary for Individuals^a (continued)

Subject & Period		Diet (mg/day)	Feces ^b (mg/sample)	Urine (mg/day)	Blood (mg/100g)	Balance (mg/day)
	E1	0.108/1.563 (0.108)	0.197/1.807 (0.203)	0.035/1.256 (0.034)	0.031/1.153 (0.032)	(-0.062)
	E2	0.197/2.511 (0.173)	0.199/1.910 (0.217)	0.055/1.233 (0.057)	0.037/1.153 (0.038)	(0.013)
	E3	0.131/1.403 (0.132)	0.189/2.223 (0.190)	0.062/1.199 (0.062)	0.040/1.208 (0.043)	(-0.002)
	E4	0.104/1.600 (0.102)	0.194/2.104 (0.205)	0.073/1.368 (0.077)	0.045/1.102 (0.046)	(-0.038)
	P	0.124/1.622 (0.127)	0.204/2.109 (0.217)	0.030/1.262 (0.031)	0.026/1.135 (0.026)	(-0.056)
JUS	C	0.156/1.492 (0.151)	0.161/1.560 (0.160)	0.021/1.570 (0.020)	0.020/1.294 (0.020)	(-0.012)
	E	0.212/2.094 (0.208)	0.398/1.592 (0.406)	0.044/1.294 (0.044)	0.032/1.227 (0.032)	(-0.191)
	P	0.095/1.730 (0.091)	0.128/1.567 (0.132)	0.020/1.276 (0.020)	0.018/1.247 (0.018)	(-0.024)
SS	C	0.121/1.841 (0.124)	0.195/1.923 (0.201)	0.024/1.288 (0.024)	0.018/1.156 (0.019)	(-0.091)
	E1	0.135/1.837 (0.130)	0.194/1.875 (0.200)	0.024/1.256 (0.015)	0.019/1.194 (0.019)	(0.014)
	E2	0.178/1.841 (0.178)	0.294/1.675 (0.337)	0.026/1.333 (0.026)	0.019/1.343 (0.022)	(0.061)
	E3	0.076/0.569 (0.077)	0.166/2.075 (0.175)	0.022/1.358 (0.022)	0.018/1.127 (0.018)	(-0.032)
	E4	0.147/2.767 (0.130)	0.215/1.928 (0.220)	0.026/1.285 (0.026)	0.019/1.189 (0.019)	(-0.032)
	P2	0.163/1.422 (0.155)	0.241/1.828 (0.280)	0.025/1.667 (0.028)	0.017/1.288 (0.017)	(0.035)
	E5	0.199/2.871 (0.157)	0.440/1.811 (0.465)	0.034/1.288 (0.035)	0.022/1.159 (0.021)	(0.062)
	E6	0.132/1.754 (0.135)	0.265/1.607 (0.270)	0.027/1.445 (0.028)	0.024/1.086 (0.024)	(0.030)
	E7	0.216/2.582 (0.219)	0.254/1.633 (0.265)	0.034/1.303 (0.033)	0.023/1.227 (0.025)	(0.060)
	P2	0.195/2.000 (0.187)	0.203/1.742 (0.225)	0.030/1.233 (0.030)	0.021/1.096 (0.021)	(0.034)
	E8	0.103/2.032 (0.100)	0.193/1.603 (0.205)	0.023/1.294 (0.023)	0.024/1.142 (0.023)	(0.006)
	E9	0.146/1.807 (0.153)	0.275/1.652 (0.255)	0.026/1.334 (0.026)	0.020/1.256 (0.019)	(-0.005)
	E10	0.177/1.714 (0.173)	0.271/1.700 (0.275)	0.033/1.271 (0.032)	0.027/1.107 (0.026)	(-0.008)
	E11	0.136/1.879 (0.142)	0.194/0.302 (0.205)	0.034/1.340 (0.034)	0.026/1.122 (0.027)	(0.020)
	E12	0.177/1.820 (0.176)	0.267/1.700 (0.265)	0.032/1.538 (0.033)	0.026/1.183 (0.026)	(0.032)
	E13	0.234/1.914 (0.237)	0.182/1.867 (0.185)	0.036/1.413 (0.037)	0.028/1.205 (0.027)	(0.095)
	P3	0.363/2.133 (0.405)	0.396/1.614 (0.400)	0.036/1.276 (0.030)	0.021/1.096 (0.021)	(0.034)

Table 5
Logarithmic and Median Data Summary for Individuals^a (continued)

Subject & Period		Diet (mg/day)	Feces ^b (mg/sample)	Urine (mg/day)	Blood (mg/100g)	Balance (mg/day)
SW	C	0.178/1.567 (0.177)	0.233/1.667 (0.225)	0.037/1.466 (0.036)	0.039/1.253 (0.040)	(-0.023)
	E	0.498/1.211 (0.484)	0.486/1.618 (0.490)	0.040/1.449 (0.039)	0.038/1.219 (0.040)	(0.031)
	P	0.299/3.170 (0.239)	0.360/1.574 (0.305)	0.028/1.324 (0.028)	0.025/N=2 (0.025)	(-0.009)

^a Data shown as log mean/log SD over (median) except for balance, for which only the median is given. N's for these data are shown in Table 4.

^b Per sample (rather than per day). See text.

TABLE 6
Fecal Evacuation Rate, Adjusted Fecal Lead Per
Day, and Fecal Lead as Percent of Dietary Lead

Subject and Period		Evac. ^a Rate (%)	Fecal Pb ^b Per Day (ug/ug)	Percent of ^c Diet (%/%)
EB	C	100	333/ 305	100/ 95
	E	100	1880/1701	86/ 79
	P	100	304/ 254	104/ 94
MB	C	86	183/ 158	88/ 85
	E	86	257/ 228	130/128
	P	86	247/ 217	94/ 89
MOB	C	60	182/ 157	86/ 86
	E1	57	179/ 146	95/ 95
	P1	57	212/ 168	122/114
	E2	60	233/ 207	199/223
	P2	67	125/ 115	100/117
PB	C	55	119/ 107	89/ 87
	E	47	122/ 101	106/ 95
	P	33	175/ 132	130/131
SB	C	93	102/ 88	95/100
	E	81	135/ 113	124/133
	P	90	109/ 101	133/160
FC	C	99	198/ 163	83/ 78
	E2	98	235/ 200	110/109
	P2	100	140/ 127	88/ 86
	E3	100	249/ 244	109/216
	P3	100	138/ 119	100/ 98
LD	C	72	189/ 115	136/125
	E1	63	158/ 142	156/167
	E2	63	191/ 176	118/113
	E3	69	460/ 314	135/211
	E4	60	184/ 179	233/267
	P	69	148/ 135	145/139
IF	C	87	227/ 195	96/ 95
	E	86	2808/2653	86/ 82
	P	86	196/ 171	121/116
DH	C	52	172/ 126	177/142
	E1	71	133/ 124	139/144
	E2	57	100/ 100	103/114
	E3	65	151/ 119	145/163
	E4	65	124/ 110	175/164
	P	51	133/ 94	168/132

TABLE 6
Fecal Evacuation Rate, Adjusted Fecal Lead Per
Day, and Fecal Lead as Percent of Dietary Lead
(Continued)

Subject and Period	Evac. ^a Rate (%)	Fecal Pb ^b Per Day (ug/ug)	Percent of ^c Diet (%/%)	
NK	C	100	200/ 174	142/140
	E1	100	165/ 144	98/105
	E2	100	160/ 145	114/118
	E3	100	153/ 149	101/103
	E4	100	208/ 131	138/124
	P1	100	147/ 145	109/107
	E5	100	126/ 115	103/111
	E6	100	146/ 135	49/ 49
	E7	100	146/ 140	107/115
	P2	100	123/ 104	55/ 52
HR	C	42	130/ 116	83/ 80
	E1	43	121/ 118	141/164
	E2	41	132/ 127	203/223
	E3	41	155/ 144	189/187
MR	C	83	425/ 345	163/144
	E	85	1409/1280	106/ 99
	P	68	319/ 275	135/131
JOS	C	49	116/ 88	104/ 95
	E1	61	113/ 124	95/115
	E2	66	118/ 143	62/ 83
	E3	54	124/ 103	90/ 78
	E4	60	121/ 123	104/121
	P	71	127/ 154	91/121
JUS	C	83	148/ 133	88/ 88
	E	80	364/ 325	167/156
	P	78	117/ 103	106/113
SS	C	92	218/ 185	149/149
	E1	65	148/ 130	90/100
	E2	54	177/ 182	82/102
	E3	63	136/ 110	155/143
	E4	61	159/ 134	107/103
	P1	58	160/ 162	98/105
	E5	46	235/ 214	106/136
	E6	50	149/ 135	96/100
	E7	54	154/ 143	70/ 81
	P2	67	143/ 151	58/ 81
	E8	64	136/ 131	103/131
	E9	57	179/ 145	105/ 95
	E10	67	207/ 184	100/106
	E11	67	158/ 137	96/ 96
	E12	62	189/ 164	89/ 93
	E13	74	160/ 137	55/ 58
	P3	58	266/ 232	58/ 57

TABLE 6
Fecal Evacuation Rate, Adjusted Fecal Lead Per
Day, and Fecal Lead as Percent of Dietary Lead
(Continued)

Subject and Period		Evac. ^a Rate (%)	Fecal Pb ^b Per Day (ug/ug)	Percent of ^c Diet (%/%)
SW	C	75	199/ 169	100/ 95
	E	82	407/ 402	80/ 83
	P	81	296/ 247	104/103

^a % of days fecal samples were available compared to the number of days on collection.

^b Adjusted fecal lead (ug/day) expressed as mean/median.

^c Adjusted fecal lead as a percent of diet based on mean/median.

Table 7
Urinary Lead Concentrations and Comparisons with
24 Hour Urinary Lead Excretion

Subject and Period		Arithmetic ^a (mg/liter)	Log ^b & Median Data (mg/liter)	Ratio ^c	Subject and Period		Arithmetic ^a (mg/liter)	Log ^b & Median Data (mg/liter)	Ratio ^c
EB	C	0.037/0.012 (0.010/0.050)	0.026/1.48 (0.029)	0.783/0.147 (0.400/1.176)	LD	C	0.020/0.007 (0.005/0.042)	0.019/2.051 (0.019)	1.098/0.308 (0.467/3.556)
	E	0.046/0.029 (0.007/0.190)	0.091/1.365 (0.090)			E1	0.0371/0.010 (0.015/0.064)	(0.037)	
	P1	0.041/0.020 (0.007/0.130)	0.037/1.790 (0.039)			E2	0.060/0.012 (0.031/0.086)	0.059/1.242 (0.059)	
	P2	0.021/0.017 (0.002/0.050)	0.012/3.266 (0.025)			E3	0.085/0.023 (0.050/0.158)	0.082/1.294 (0.080)	
						E4	0.082/0.016 (0.048/0.126)	0.081/1.225 (0.083)	
MB	C	0.034/0.007 (0.020/0.060)	0.033/1.216 (0.033)	1.153/1.406 (0.606/9.756)	P	P	0.030/0.007 (0.018/0.049)	0.030/1.247 (0.030)	
	E	0.065/0.011 (0.040/0.090)	0.064/1.186 (0.064)						
	P	0.043/0.042 (0.010/0.300)	0.044/1.262 (0.036)						
MOB	C	0.030/0.007 (0.020/0.050)	0.030/1.770 (0.029)	1.020/0.632 (0.455/10.000)	IF	C	0.030/0.013 (0.010/0.080)	0.030/2.051 (0.026)	1.033/0.293 (0.319/2.929)
	E1	0.053/0.012 (0.020/0.090)	0.052/1.265 (0.052)			E	0.070/0.017 (0.040/0.110)	0.068/1.264 (0.065)	
	P1	0.041/0.015 (0.020/0.100)	0.040/1.837 (0.039)			P	0.034/0.012 (0.010/0.065)	0.032/1.462 (0.025)	
	E2	0.050/0.012 (0.020/0.090)	0.048/1.288 (0.049)		DH	C	0.026/0.008 (0.009/0.056)	0.025/1.365 (0.033)	0.585/0.150 (0.413/1.436)
	Corn	0.216/0.046 (0.130/0.290)	0.206/1.256 (0.215)			E1	0.023/0.006 (0.013/0.042)	0.022/1.297 (0.024)	
	PCorn	0.032/0.008 (0.015/0.060)	0.031/1.300 (0.030)			E2	0.024/0.009 (0.011/0.044)	0.023/1.449 (0.022)	
	P	0.028/0.022 (0.010/0.200)	0.035/4.819 (0.026)			E3	0.027/0.007 (0.014/0.052)	0.026/1.312 (0.026)	
						E4	0.027/0.009 (0.011/0.046)	0.025/1.429 (0.027)	
						P	0.023/0.006 (0.013/0.036)	0.022/1.291 (0.022)	
PB	C	0.025/0.010 (0.008/0.062)	0.014/1.409 (0.014)	0.629/0.204 (0.258/1.471)	NK	C	0.023/0.005 (0.007/0.036)	0.022/1.282 (0.022)	0.833/0.109 (0.526/1.125)
	E	0.029/0.011 (0.008/0.060)	0.027/1.585 (0.026)			E1	0.027/0.006 (0.006/0.040)	0.026/1.315 (0.026)	
	P	0.026/0.011 (0.009/0.050)	0.024/1.600 (0.023)			E2	0.027/0.005 (0.014/0.045)	0.027/1.219 (0.028)	
SB	C	0.026/0.007 (0.015/0.050)	0.025/1.330 (0.030)	1.133/0.306 (0.625/3.000)		E3	0.028/0.005 (0.015/0.038)	0.027/1.197 (0.029)	
	E	0.052/0.016 (0.015/0.102)	0.049/1.419 (0.052)			E4	0.035/0.005 (0.026/0.050)	0.034/1.164 (0.034)	
	P	0.027/0.008 (0.010/0.052)	0.026/1.489 (0.027)		P1	P1	0.032/0.003 (0.028/0.036)	0.032/1.091 (0.032)	
FC	C	0.023/0.016 (0.010/0.300)	0.021/1.552 (0.021)	1.071/0.698 (0.282/12.500)		E5	0.034/0.007 (0.024/0.057)	0.033/1.216 (0.032)	
	E1	0.039/0.014 (0.030/0.070)	0.037/1.352 (0.034)			E6	0.039/0.007 (0.027/0.054)	0.038/1.213 (0.038)	
	P1	0.034/0.008 (0.020/0.050)	0.033/1.259 (0.033)			E7	0.036/0.006 (0.023/0.053)	0.035/1.175 (0.035)	
	E2	0.098/0.030 (0.030/0.230)	0.099/2.018 (0.094)			P2	0.033/0.008 (0.020/0.057)	0.032/1.250 (0.032)	
	P2	0.027/0.012 (0.010/0.090)	0.027/2.805 (0.025)		HR	C	0.026/0.009 (0.009/0.051)	0.026/2.084 (0.025)	1.143/0.708 (0.265/6.333)
	E3	0.087/0.019 (0.040/0.150)	0.085/1.274 (0.086)			E1	0.021/0.006 (0.008/0.039)	0.020/1.346 (0.021)	
	P3	0.027/0.009 (0.010/0.050)	0.025/1.349 (0.027)			E2	0.024/0.007 (0.008/0.039)	0.023/1.400 (0.023)	

Table 7
Urinary Lead Concentrations and Comparisons with
24 Hour Urinary Lead Excretion (Continued)

Subject and Period	Arithmetic ^a Data (mg/liter)	Log ^b & Median Data (mg/liter)	Ratio ^c	Subject and Period	Arithmetic ^a Data (mg/liter)	Log ^b & Median Data (mg/liter)	Ratio ^c	
MR	E3	(0.008/0.040) 0.026/0.01 (0.007/0.050)	(0.024) 0.024/1.539 (0.024)	0.884/1.274 (0.333/7.500)	JUS C	0.020/0.009 (0.010/0.040)	0.019/1.968 (0.020)	0.912/0.400 (0.303/2.143)
	C	0.016/0.012 (0.010/0.050)	0.018/5.408 (0.011)		E	0.041/0.012 (0.010/0.080)	0.040/1.552 (0.040)	
	E	0.055/0.018 (0.010/0.140)	0.053/1.435 (0.055)		P	0.016/0.003 (0.015/0.030)	0.016/1.618 (0.015)	
	DC1	0.037/0.011 (0.025/0.055)	0.036/1.361 (0.032)		SS C	0.023/0.004 (0.014/0.036)	0.022/1.208 (0.022)	0.962/0.256 (0.588/2.375)
	PDC1	0.057/0.018 (0.035/0.095)	0.055/1.321 (0.054)		E1	0.025/0.005 (0.012/0.039)	0.027/2.535 (0.025)	
	DC2	0.072/0.027 (0.035/0.150)	0.068/1.403 (0.066)		E2	0.029/0.007 (0.012/0.046)	0.028/1.315 (0.030)	
	PDC2	0.067/0.015 (0.040/0.085)	0.065/1.282 (0.071)		E3	0.023/0.005 (0.014/0.035)	0.022/1.245 (0.022)	
	DC3	0.054/0.015 (0.030/0.075)	0.052/1.346 (0.054)		E4	0.026/0.006 (0.014/0.044)	0.025/1.262 (0.024)	
	PDC3	0.073/0.039 (0.030/0.160)	0.066/1.641 (0.067)		P1	0.025/0.008 (0.012/0.039)	0.024/1.429 (0.024)	
	DC4	0.069/0.018 (0.045/0.100)	0.067/1.265 (0.068)		E5	0.033/0.009 (0.019/0.059)	0.032/1.288 (0.033)	
	DC5	0.071/0.014 (0.050/0.095)	0.069/1.233 (0.072)		E6	0.027/0.007 (0.010/0.049)	0.026/1.309 (0.027)	
	PDC5	0.083/0.017 (0.060/0.130)	0.082/1.213 (0.081)		E7	0.034/0.007 (0.018/0.053)	0.033/1.250 (0.034)	
	DC6	0.075/0.013 (0.050/0.095)	0.074/1.202 (0.075)		P2	0.031/0.006 (0.019/0.046)	0.030/1.197 (0.030)	
	PDC6	0.095/0.028 (0.050/0.130)	0.144/6.252 (0.097)		E8	0.022/0.005 (0.012/0.032)	0.022/1.239 (0.022)	
	DC7	0.067/0.017 (0.040/0.085)	0.065/1.321 (0.072)		E9	0.026/0.009 (0.007/0.055)	0.024/1.406 (0.024)	
	PDC7	0.073/0.029 (0.020/0.150)	0.067/1.600 (0.072)		E10	0.029/0.007 (0.012/0.045)	0.029/1.294 (0.030)	
	P	0.040/0.016 (0.010/0.120)	0.037/1.521 (0.040)		E11	0.031/0.007 (0.018/0.048)	0.030/1.250 (0.030)	
	JOS	C	0.019/0.005 (0.007/0.037)		0.019/1.683 (0.019)	0.955/0.178 (0.571/1.733)	E12	0.035/0.010 (0.017/0.057)
E1		0.034/0.007 (0.019/0.052)	0.033/1.250 (0.034)	E13	0.031/0.007 (0.013/0.045)		0.030/1.274 (0.032)	
E2		0.060/0.013 (0.039/0.093)	0.058/1.245 (0.059)	P3	0.035/0.007 (0.025/0.046)		0.035/1.242 (0.035)	
E3		0.063/0.012 (0.040/0.095)	0.062/1.208 (0.063)	SW C	0.028/0.011 (0.010/0.075)		0.027/1.738 (0.025)	0.751/0.232 (0.328/1.538)
E4		0.082/0.013 (0.051/0.102)	0.081/1.189 (0.084)	E	0.027/0.009 (0.010/0.060)		0.029/2.588 (0.025)	
P		0.034/0.007 (0.013/0.051)	0.030/1.247 (0.034)	P	0.021/0.003 (0.010/0.030)		0.020/1.180 (0.020)	

^a Mean/SD over (minimum/maximum).

^b Logarithmic mean/SD over (median).

^c The data refer to the ratios of the urinary concentrations (mg/liter) over the daily urinary lead excretion (mg/day). Shown are the mean/SD over the minimum and maximum values in parenthesis for the control period data only.

Table 8
Coefficients of Variation for Subject Control Periods By Year^a

Date	Subject	Diet (%)	Feces (%)	Urine (%)	Urine Conc. (%)	Blood (%)	Balance (%)
1937	MR	56	67	50	8	28	399
1939	EB	42	52	32	32	19	1152
1941	IF	50	60	50	43	26	850
1943	SW	52	52	40	39	23	632
1950	MOB	41	68	26	23	35	7633
1951	FC	50	60	36	70	27	638
1955	MB	33	54	18	21	21	953
1957	JUS	44	47	46	45	24	5850
1959	SB	75	54	29	27	14	413
1960	LD	132	282	37	35	28	923
1960	JOS	54	77	25	26	19	1820
1963	NK	50	48	22	22	15	118
1963	SS	66	60	24	17	16	220
1966	HR	61	55	37	35	14	924
1967	DH	60	78	27	35	20	227
1970	PB	44	58	40	40	17	1656
Overall av		57	73	34	32	22	1526

^a Coefficients of variation = standard deviation/mean x 100%.

Table 9
Coefficients of Variation ^a for Inhalation Exposure Conditions
and Pulmonary Deposition Conditions

Date	Subject and Period		Concentration (%)	Hours/Day (%)	Deposition (%)	Respiration Rate (%)
1950	MOB	1	16	9	37	
		2	18	0	21	30
1951	PC	1	64	3	2	22
		2	10	3	28	11
		3	44	7	31	18
1955	MB	1	18	9	15	11
1957	JUS	1	23	0	16	3
1959	SB	1	10	35	15	10
1960	LD	1	14	0	10	12
		2	9	0	26	9
		3	9	3	10	11
		4	8	6	9	5
1960	JOS	1	7	0	13	11
		2	8	0	19	7
		3	7	3	21	7
		4	7	4	13	7
1963	NK	1	11	0	20	3
		2	10	0	30	3
		3	20	0	10	5
		4	10	6	26	5
		5	10	1	30	5
		6	11	7	7	10
		7	20	2	9	11
1963	SS	1	20	0	22	7
		2	20	0	27	7
		3	10	6	30	7
		4	10	0	35	14
		5	22	9	11	17
		6	10	6	15	10
		7	20	0	26	13
		8	10	14	12	9
		9	2	8	28	9
		10	20	7	12	7
		11	16	1	12	4
		12	16	5	19	7
		13	17	7	30	7
1966	MR	1	10	14	8	7
		2	15	8	6	7
		3	10	7	39	9

Table 9
Coefficients of Variation^a for Inhalation Exposure Conditions
and Pulmonary Deposition Conditions (continued)

Date	Subject and Period	Concentration (%)	Hours/Day (%)	Deposition (%)	Respiration Rate (%)
1967	DH	1	14	11	29
		2	14	5	37
		3	15	8	11
		4	38	10	35
1970	PB	1	42	10	32
Overall av		<u>16</u>	<u>5</u>	<u>22</u>	<u>9</u>

^a Coefficient of Variation = standard deviation/mean x 100%.

Table 10
Selected Correlation Coefficients Between Various Parameters For Control Periods
According To Year

Year	Subject	B/U	B/D	B/BAL	U/D	U/BAL	D/F
1937	MR	-0.36	0.83 ^b	0.74	-0.13	-0.19	-0.09
1939	EB	-0.24	-0.63 ^b	0.40	0.0	0.05	0.04
1941	IF	-0.01	-0.10	-0.04	-0.01	-0.10 ^b	0.29 ^a
1943	SW	0.22	-0.12	0.0	0.10 ^b	-0.02	0.09
1950	MOB	0.23	-0.09	-0.31 ^b	-0.02	-0.06	0.14 ^b
1951	FC	0.34 ^a	0.03	-0.02	0.14 ^a	0.02	0.21 ^a
1955	MB	0.23	0.32	-0.41	0.06	-0.11	0.82 ^a
1957	JUS	-0.14	0.14	0.37	0.01	-0.18 ^b	0.26 ^a
1959	SB	0.38 ^a	-0.06	-0.08	0.0	-0.08	0.11 ^b
1960	LD	0.32 ^a	0.08	-0.05	0.03	-0.14 ^a	0.32 ^a
1960	JOS	0.10	-0.13	0.06	-0.06	-0.07	0.04
1963	NK	0.45 ^a	0.21	0.04	0.12	0.03	0.16
1963	SS	-0.30	-0.07	0.02	0.12	0.13	-0.01
1966	HR	-0.04	0.31	0.04	-0.06	0.10	-0.05
1967	DH	0.02	-0.08	-0.16	0.25 ^a	-0.26 ^a	0.15 ^b
1970	PB	-0.26	-0.16	-0.01	0.18 ^a	-0.01	0.06

^ap<0.01

^bp<0.05

Table 11
Selected Correlation Coefficients Between Various Parameters
For Combined Exposure and Post Exposure Periods

Subject	Exposure Rate	B/U	B/D	B/BAL	U/D	U/BAL	D/F
	<u>(ug/Day)</u>	<u>Oral Experiments</u>					
SW	300	0.32 ^a	0.34	-0.08	0.05	-0.11 ^a	0.11 ^b
MR	1000	0.10	0.06	-0.09	0.17 ^a	-0.06 ^a	0.34 ^a
EB	2000	0.24 ^a	0.26 ^a	0.03	0.63 ^a	0.06 ^a	0.74 ^a
IF	3000	0.18	0.01	0.05	0.58 ^a	0.10	0.82 ^a
	<u>(ug/m³)</u>	<u>Inhalation Experiments^c</u>					
NK	2.4	0.33 ^a	-0.01	-0.09	0.08 ^a	-0.06 ^b	-0.30 ^a
SS	3.7	0.23 ^a	0.11	0.03	0.21 ^a	0.05	0.02
HR	4.5	-0.07	-0.16	0.05	-0.04	-0.08	0.22
DH	7.3	-0.12	-0.13	-0.14	0.01	-0.13 ^a	-0.04
JOS	22.8	0.67 ^a	0.08	-0.04	0.0	-0.13 ^a	-0.04
LD	23.0	0.64 ^a	0.18 ^b	-0.10	0.17 ^a	-0.12 ^a	0.37 ^a
MOB	25.4	0.37 ^a	0.19 ^a	-0.15 ^a	0.30 ^a	-0.05 ^a	0.37 ^a
SB	27.4	0.42 ^a	-0.03	-0.05	0.14 ^a	-0.10 ^a	0.29 ^a
JUS	28.1	-0.42 ^a	0.06	0.20 ^a	0.28 ^a	-0.33 ^a	0.30 ^a
PB	28.4	0.36 ^b	0.32 ^b	0.10	-0.02	-0.11	-0.12
MB	29.4	0.53 ^a	-0.23 ^a	-0.34 ^a	-0.08 ^a	-0.21 ^a	0.15 ^a
FC	30.4	0.68 ^a	0.14	-0.22 ^a	0.15 ^a	-0.26 ^a	0.19 ^a

^a p<0.01

^b p<0.05

^c Exposure rates for subjects who participated in more than one exposure period (See Table 12) have been averaged.

Table 12
Dose Response Summary for Oral and Inhalation Experiments

Differences from the Control ^a						
Subject & Period	Exposure Rate	Diet ug/day	Feces ug/day	Urine ug/day	Blood ug/100g	Balance ug/day
<u>Oral Experiments</u>						
	(ug/day)					
SW	300	308	208	3	- 1	59
MR	1000	1072	984	55	17	175
EB	2000	1848	1547	80	33	209
IF	3000	2981	2581	49	19	395

<u>Inhalation Experiments</u>							
<u>(ug/m³) b</u>							
NK	1	00.6	27	- 35	4	0	76
SS	1	00.6	18	- 70	0	1	79
NK	2	1.2	- 1	- 40	3	1	30
SS	2	1.2	71	- 41	2	1	87
SS	3	1.8	-58	- 82	- 2	- 1	2
NK	3	1.9	10	- 47	5	3	48
SS	8	2.4	- 14	- 82	- 1	5	83
SS	4	2.4	3	24	2	0	54
HR	1	2.4	-70	- 59	- 2	4	- 78
NK	4	2.4	10	8	10	6	- 7
SS	5	2.7	53	17	10	4	47
SS	9	3.2	25	- 39	2	2	64
NK	5	3.3	- 19	- 74	10	6	42
SS	6	3.4	10	- 69	4	5	88
NK	6	3.6	157	- 54	18	10	192
HR	2	3.7	- 91	11	0	0	-120
NK	7	4.0	- 4	- 54	11	9	40
SS	7	4.3	73	- 64	10	5	136
SS	10	5.4	60	- 11	8	8	80
DH	1	5.6	- 1	- 39	1	1	32
SS	11	6.2	18	- 60	10	7	91
SS	12	7.0	67	- 29	10	7	116
SS	13	7.2	144	- 58	13	10	189
DH	2	7.3	0	- 72	- 5	- 4	0
HR	3	7.5	- 74	28	9	6	-119
DH	3	7.6	7	- 21	2	- 1	9
DH	4	8.8	- 26	- 48	0	- 2	4
LD	1	9.3	- 38	- 31	18	11	- 48
JOS	1	9.4	7	36	15	11	- 48
JOS	2	19.3	79	55	37	16	- 4
LD	2	19.7	23	2	37	18	- 10
MOB	1	22.4	- 23	- 3	25	13	- 43
LD	3	27.1	201	271	67	22	-132

Table 12
Dose Response Summary for Oral and Inhalation Experiments (continued)

Subject & Period	Exposure Rate	Differences from the Control ^a				
		Diet ug/day	Feces ug/day	Urine ug/day	Blood ug/100g	Balance ug/day
JOS 3	27.1	26	15	43	20	- 52
SB	27.4	2	33	27	11	- 57
JUS	28.1	49	192	21	11	-173
PB	28.4	- 19	3	11	10	- 27
MOB 2	28.4	- 94	51	20	6	-272
MB	29.4	- 12	74	38	16	-123
FC 3	30.1	-110	51	49	9	-213
FC 2	30.6	- 25	37	54	17	-116
JOS 4	35.2	4	5	56	25	-100
LD 4	35.9	- 60	- 5	67	23	-142
FC 1 ^c	64.8	- 56	- 73	2	- 2	15

^aExperimental means minus the control means.

^bInhalation exposure rates expressed as average daily concentrations calculated over the whole exposure period. See text.

^cExcluded from other calculations because data represent only 9 days of exposure.

Table 13
Post Exposure Summary for Oral and Inhalation Experiments

Differences from the Control ^a						
Subject	Exposure Rate	Diet (ug/day)	Feces (cg/day)	Urine (ug/day)	Blood (ug/100g)	Balance (ug/day)
<u>Oral Experiments</u>						
	(ug/day)					
SW	300	85	97	-11	-15	1
MR	1000	-25	-106	31	5	68
EB	2000	-41	-29	15	7	-41
IF	3000	-75	-31	4	13	-45
<u>Inhalation Experiments^b</u>						
	(ug/m ³)					
NK	2.4	82	- 77	9	3	148
SS	3.7	314	48	12	17	260
HRC	4.5					
DH	7.3	- 18	- 39	-10	- 3	37
JOS	22.8	27	11	11	6	- 53
LD	23.0	- 37	- 54	9	5	- 5
MOB	25.4	- 86	- 57	- 5	- 4	- 25
SB	27.4	- 25	- 4	0	- 1	- 23
JUS	28.1	- 59	- 31	- 4	- 2	- 25
PB	28.4	0	130	9	9	- 68
MB	29.4	55	64	7	4	- 9
FC	30.4	-100	- 60	0	- 1	1

^a Differences = Post Exposure means - Control means.

^b Exposure rates for subjects who participated in more than one exposure period (see Table 12) have been averaged.

^c HR had no post exposure period.

Table 14
Parameter Correlation Coefficients For Inhalation Exposures

<u>Exposure Rate</u>	<u>vs.</u>	<u>Feces</u>	<u>Urine</u>	<u>Blood</u>	<u>Balance</u>
All Exposures ^a		0.60 ^d	0.85 ^d	0.78 ^d	-0.72 ^d
Lower Exposures ^b		0.11	0.36	0.32	-0.21
Higher Exposures ^c		-0.05	0.43	0.26	-0.53 ^e
<u>Diet</u>	<u>vs.</u>	<u>Feces</u>	<u>Urine</u>	<u>Blood</u>	<u>Balance</u>
All Exposures ^a		0.19	0.11	0.20	0.55 ^d
Lower Exposures ^b		-0.11	0.46 ^e	0.35	0.88 ^d
Higher Exposures ^c		0.68 ^d	0.24	0.46	0.38

^an = 43

^bLess than 10 ug PB/m³, n = 29.

^cGreater than 10 ug Pb/m³, n = 14.

^dp < 0.01

^ep < 0.05

Table 15
Overall Responses to Oral and Inhalation Exposures^a

	Diet (ug/day)	Feces (ug/day)	Urine (ug/day)	Blood (ug/100g)	Balance (ug/day)
Control Averages	181	196	29	25	-32

**Dietary
Supplementation**
(ug/day)

Responses to Oral Supplementation^b

50	231	41.6(238)	2.2(31)	0.8(26)	6.6(-25)
100	281	83.3(279)	4.5(34)	1.7(27)	13.3(-19)
200	381	166.6(363)	9.0(38)	3.4(28)	26.6(- 5)
500	681	416.5(612)	22.5(52)	8.5(34)	66.5(+34)
1000	1181	833.0(929)	45.0(74)	17.0(42)	133.0(+101)
2000	2181	1666.0(1862)	90.0(119)	34.0(59)	266.0(+234)

**Airborne
Supplementation**
(ug/m³)

Responses to Airborne Supplementation^c

1	1.5(198)	1.4(30)	0.6(26)	- 3.3(- 35)
2	2.9(199)	2.8(32)	1.1(26)	- 6.6(- 39)
5	7.4(203)	7.0(36)	2.8(28)	- 16.6(- 49)
10	14.7(211)	14.1(43)	5.7(31)	- 33.2(- 65)
35.7	52 (248)	50.3(79)	20.3(45)	-118.5(-150)

^aShown are the expected parameter increases over control levels based on overall regression curves. The increases plus control levels are shown in parenthesis.

^bRegression coefficients = 0.83, 0.045, 0.017, and 0.133 for feces, urine, blood and balance respectively.

^cRegression coefficients - 1.47, 1.41, 0.57, and -3.32 for feces, urine, blood and balance respectively.

TIME COURSE OF INDIVIDUAL EXPERIMENTS

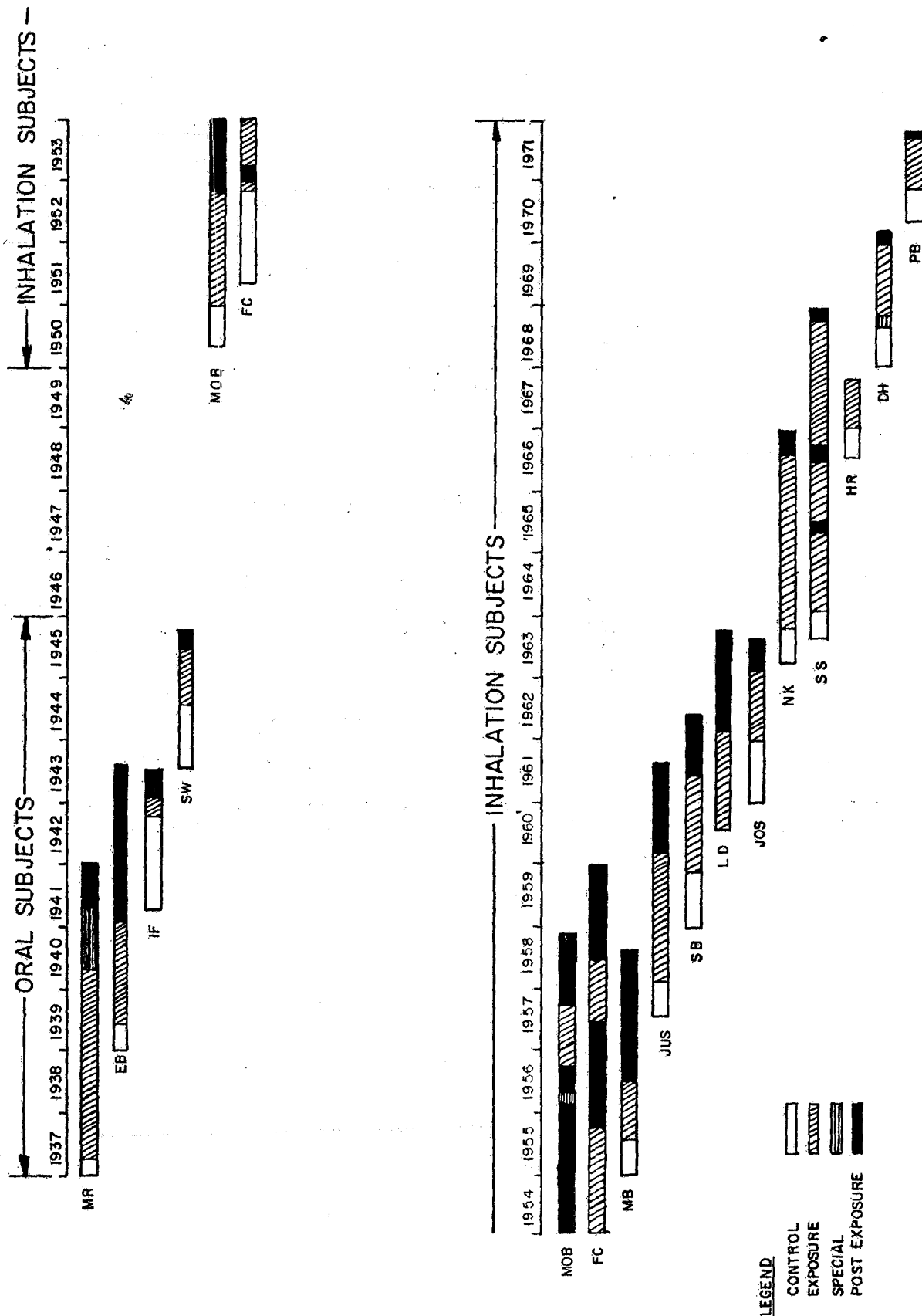


Figure 1. Time Course of Individual Experiments.

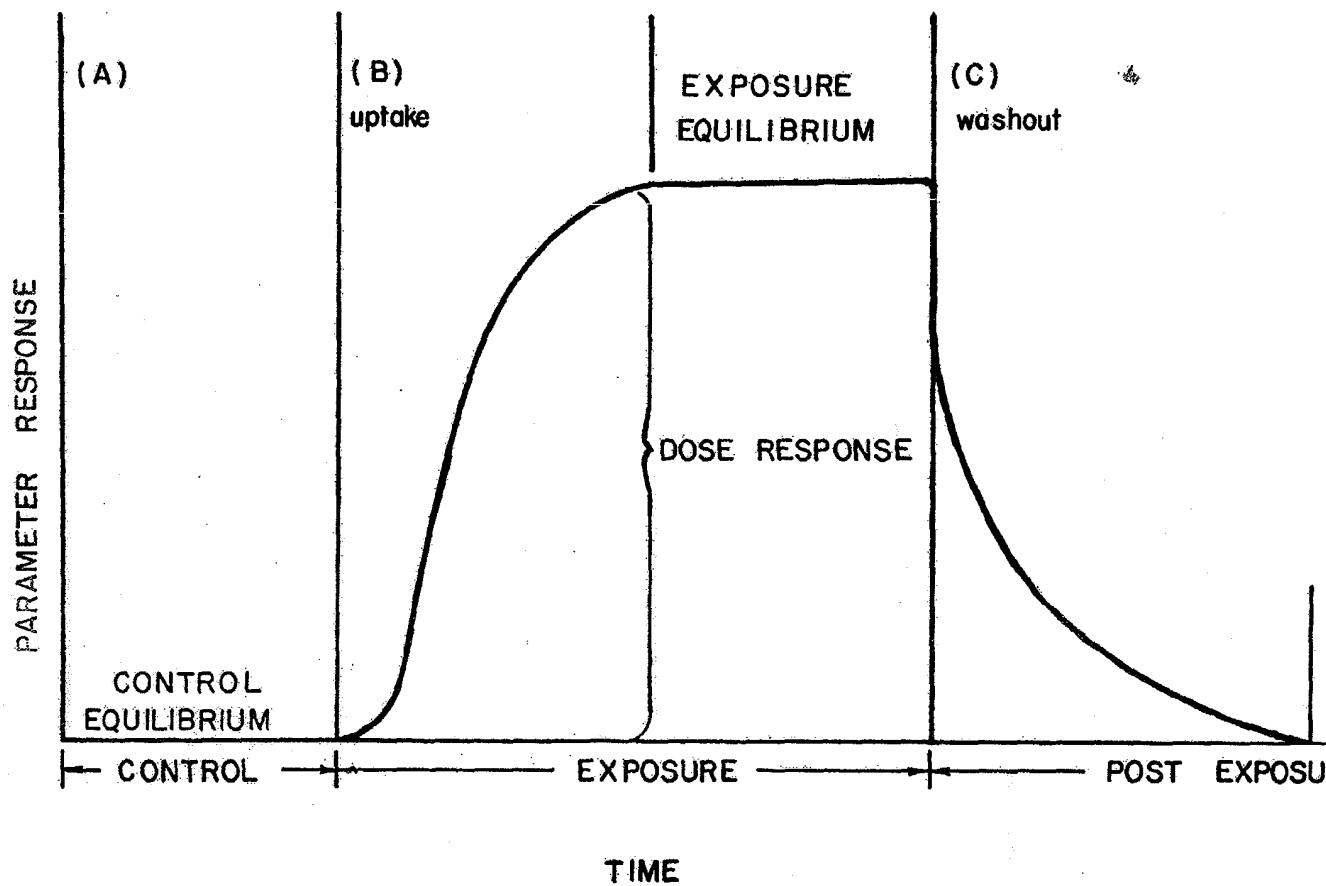


Figure 2. Expected Experimental Responses.

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SUBJECT- SN

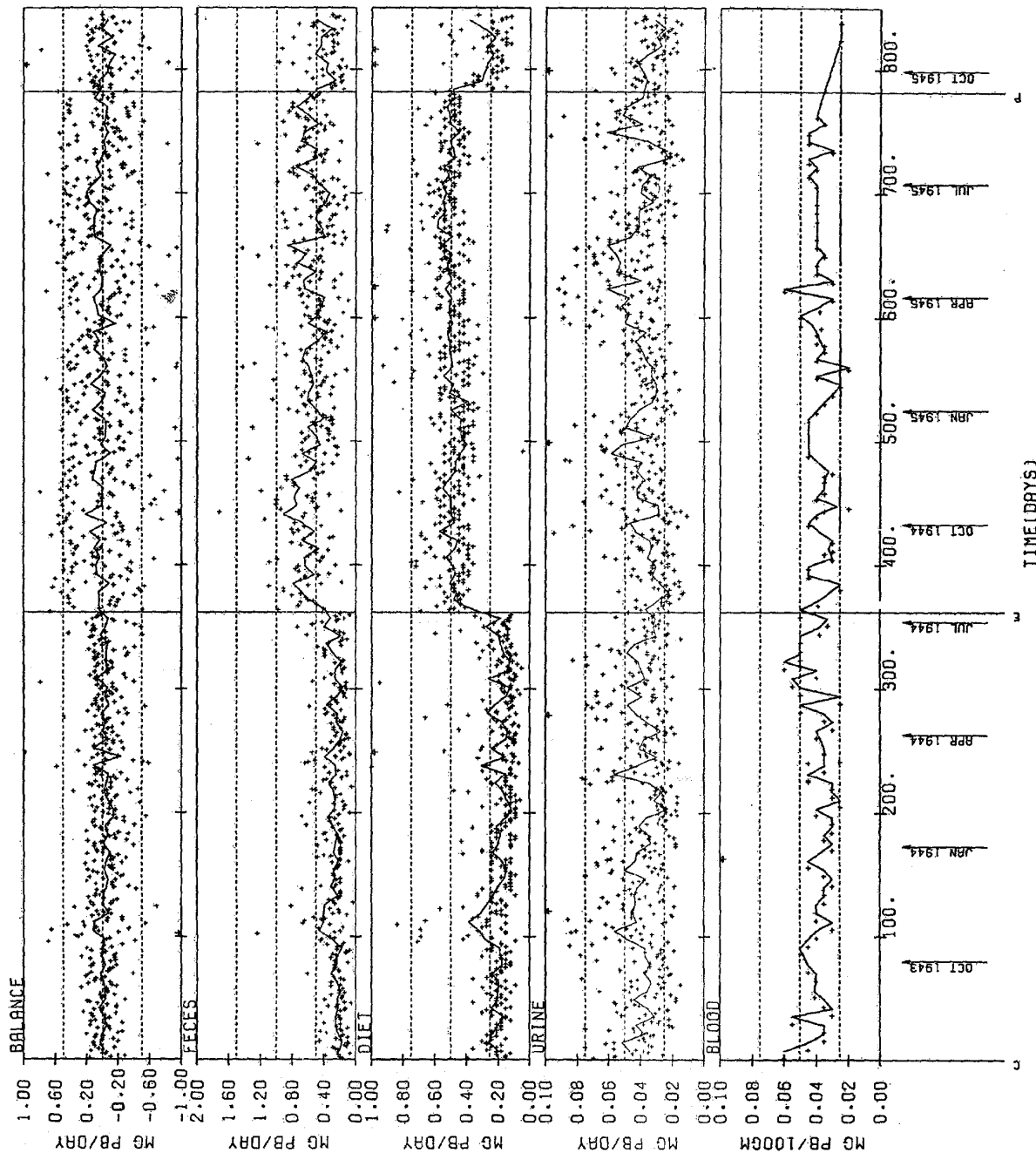


Figure 3A. Data Plots for Individual Subjects with Time.

SUBJECT - MR

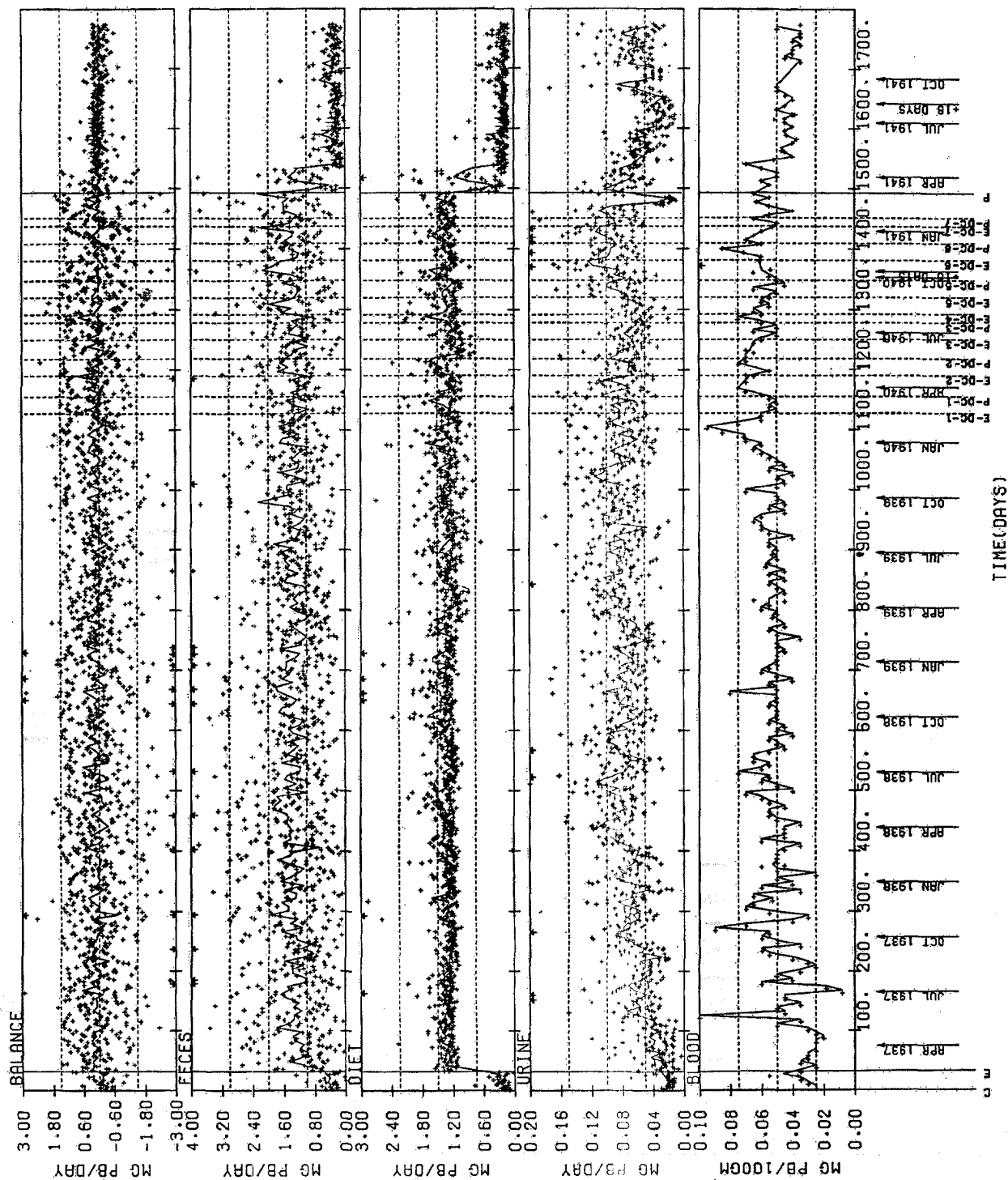


Figure 3B. Data Plots for Individual Subjects with Time.

SUBJECT- EB

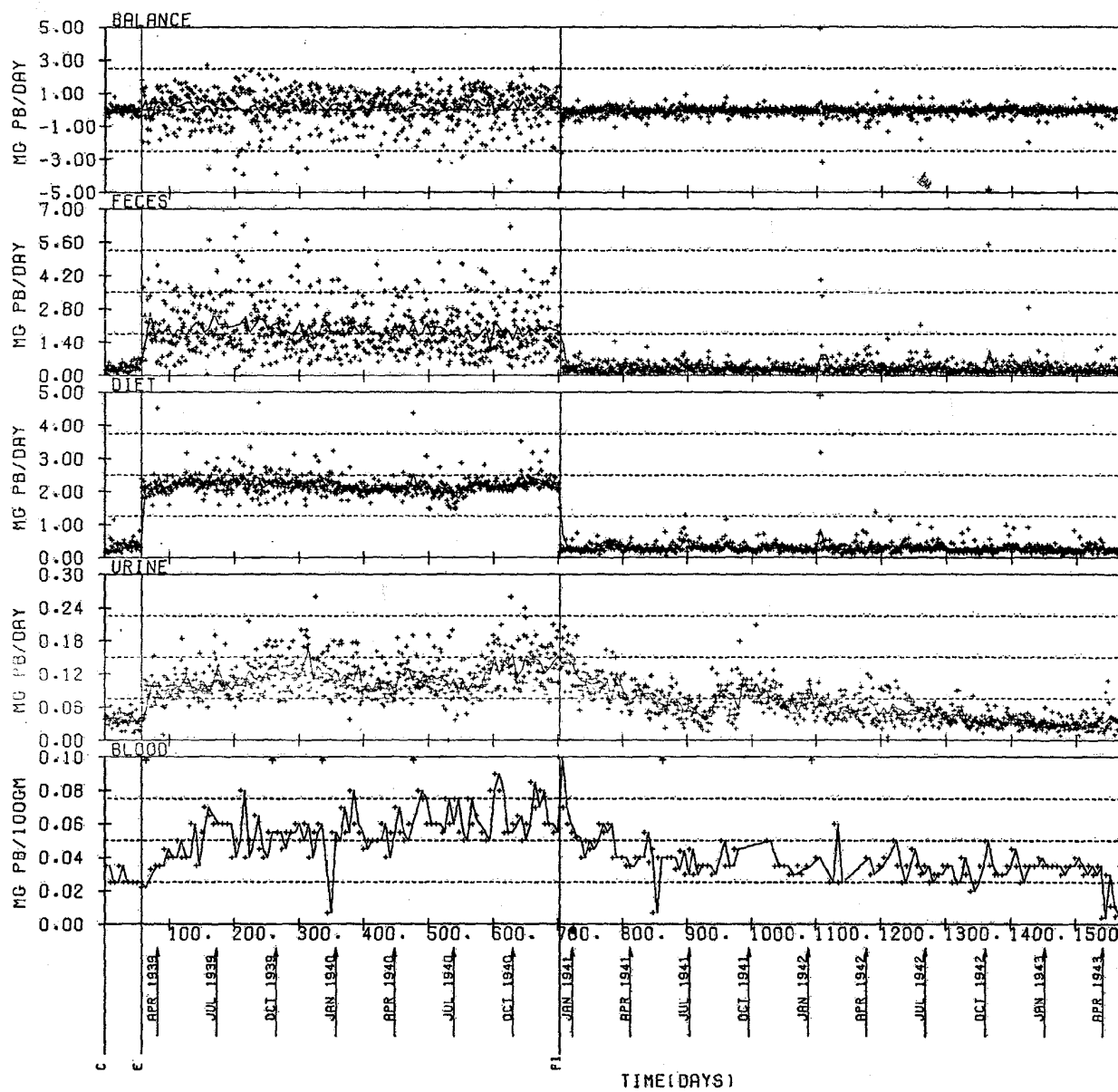


Figure 3C. Data Plots for Individual Subjects with Time.

50

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SUBJECT- IF

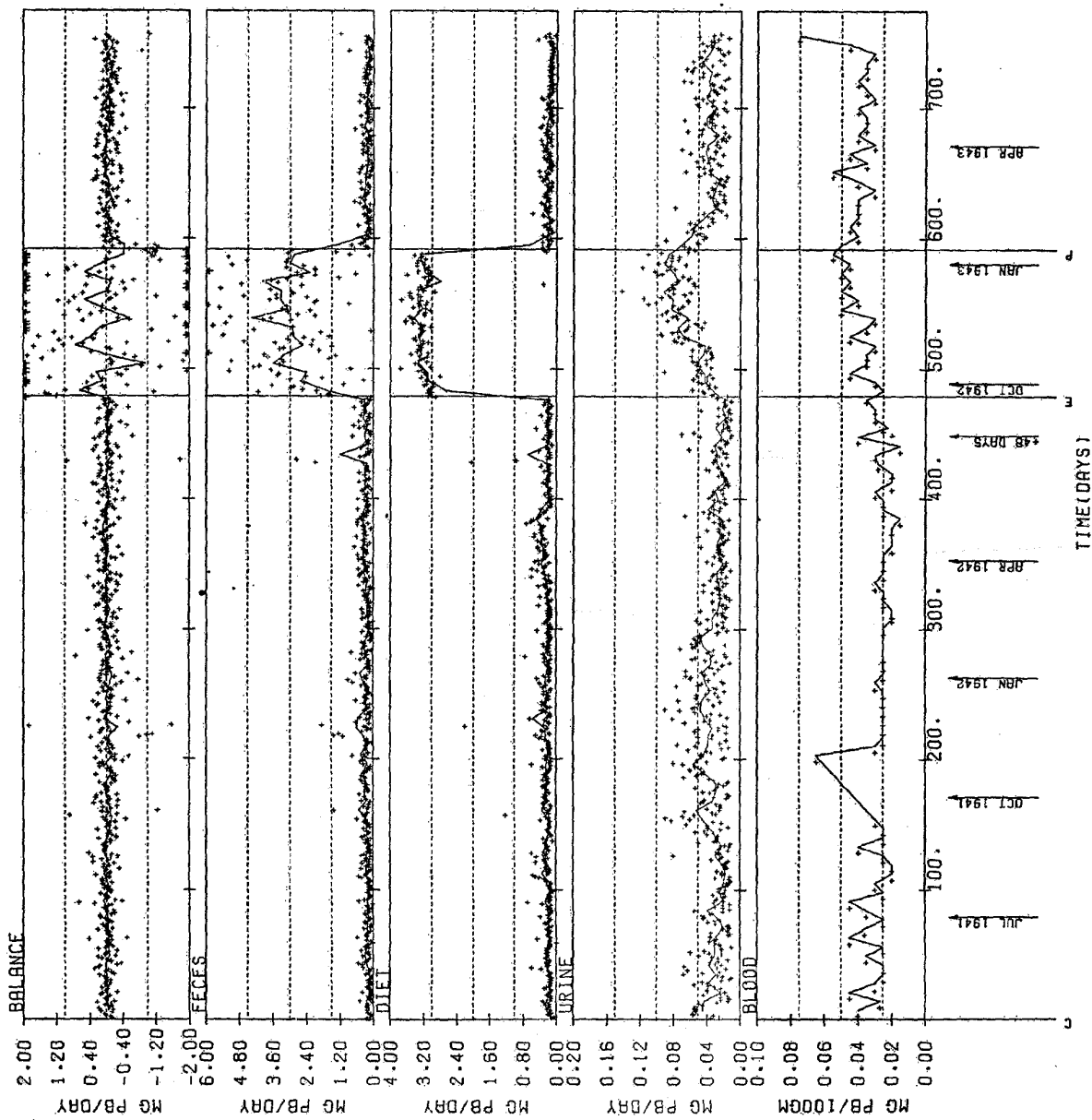


Figure 3D. Data Plots for Individual Subjects with Time.

SUBJECT- NK

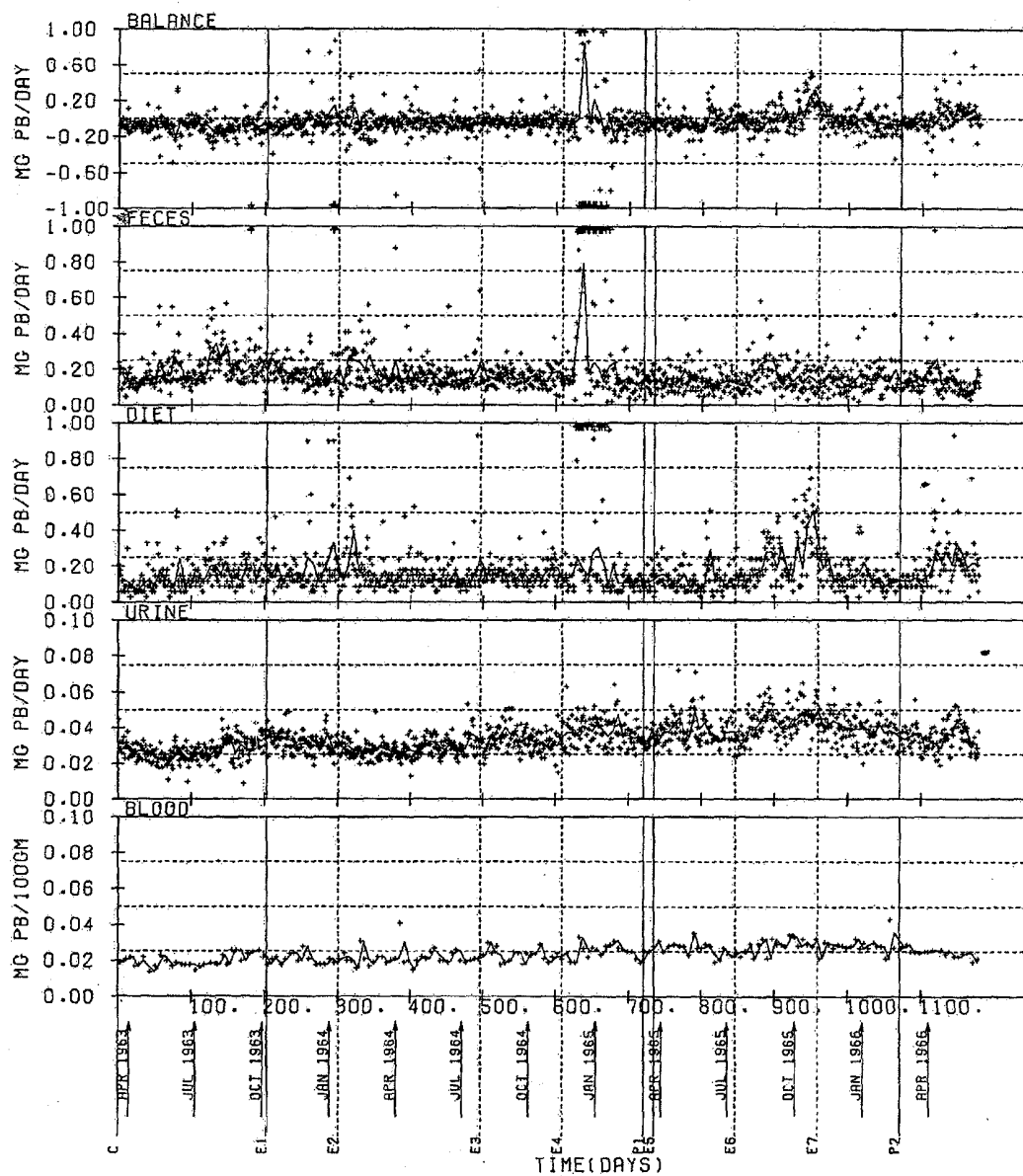


Figure 3E. Data Plots for Individual Subjects with Time.

SUBJECT- SS

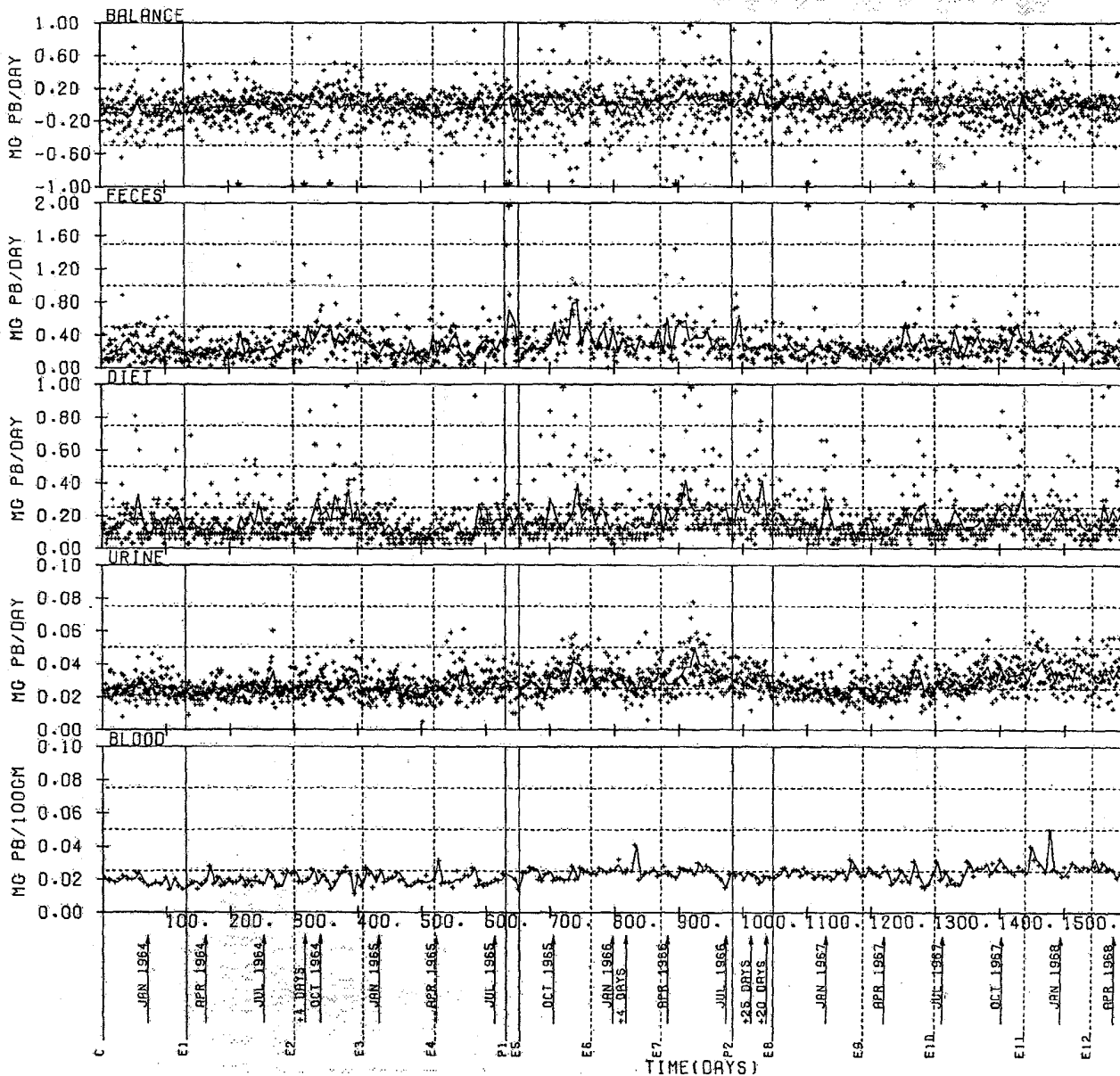


Figure 3F. Data Plots for Individual Subjects with Time.

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SUBJECT- HR

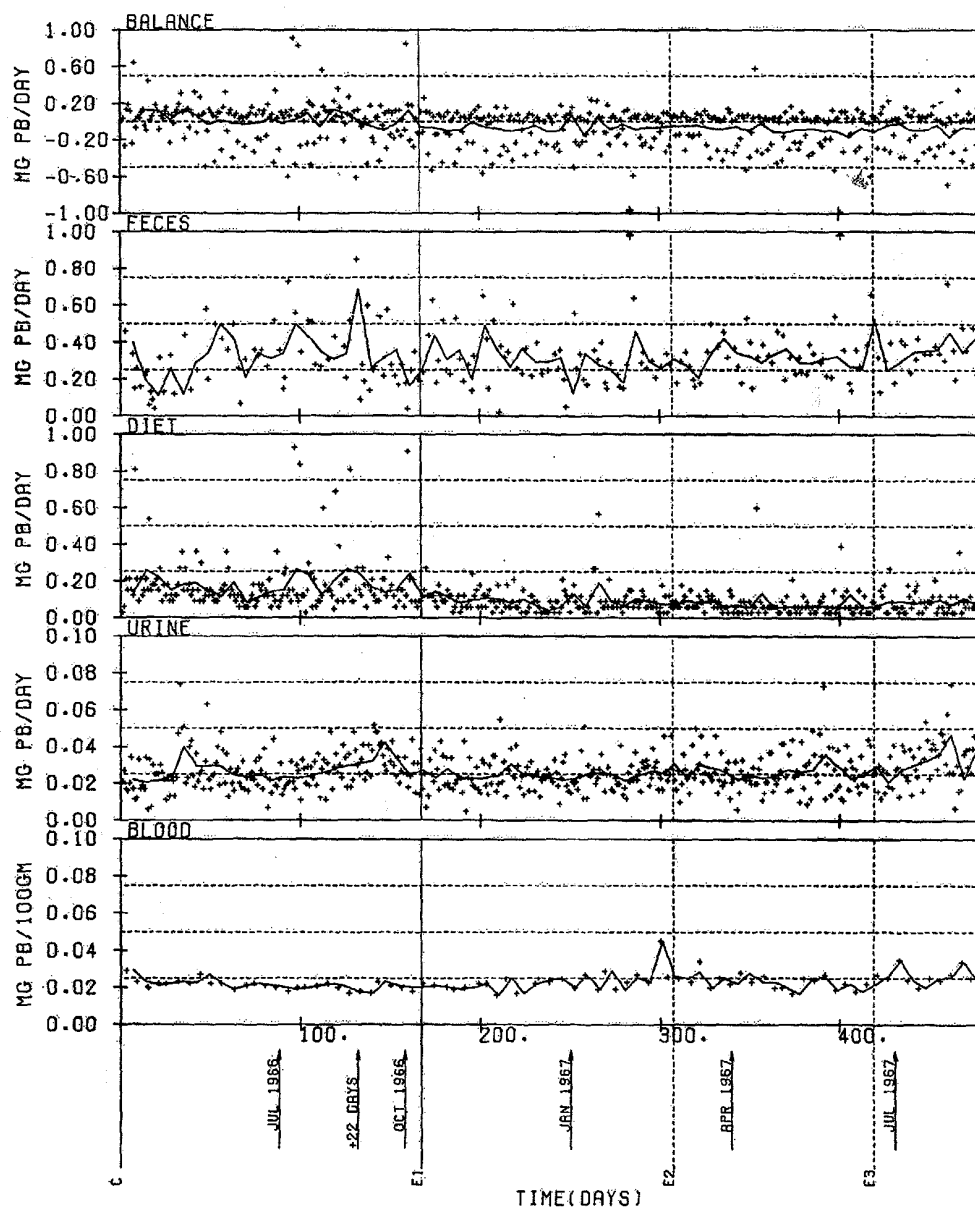


Figure 3G. Data Plots for Individual Subjects with Time.

SUBJECT- OH

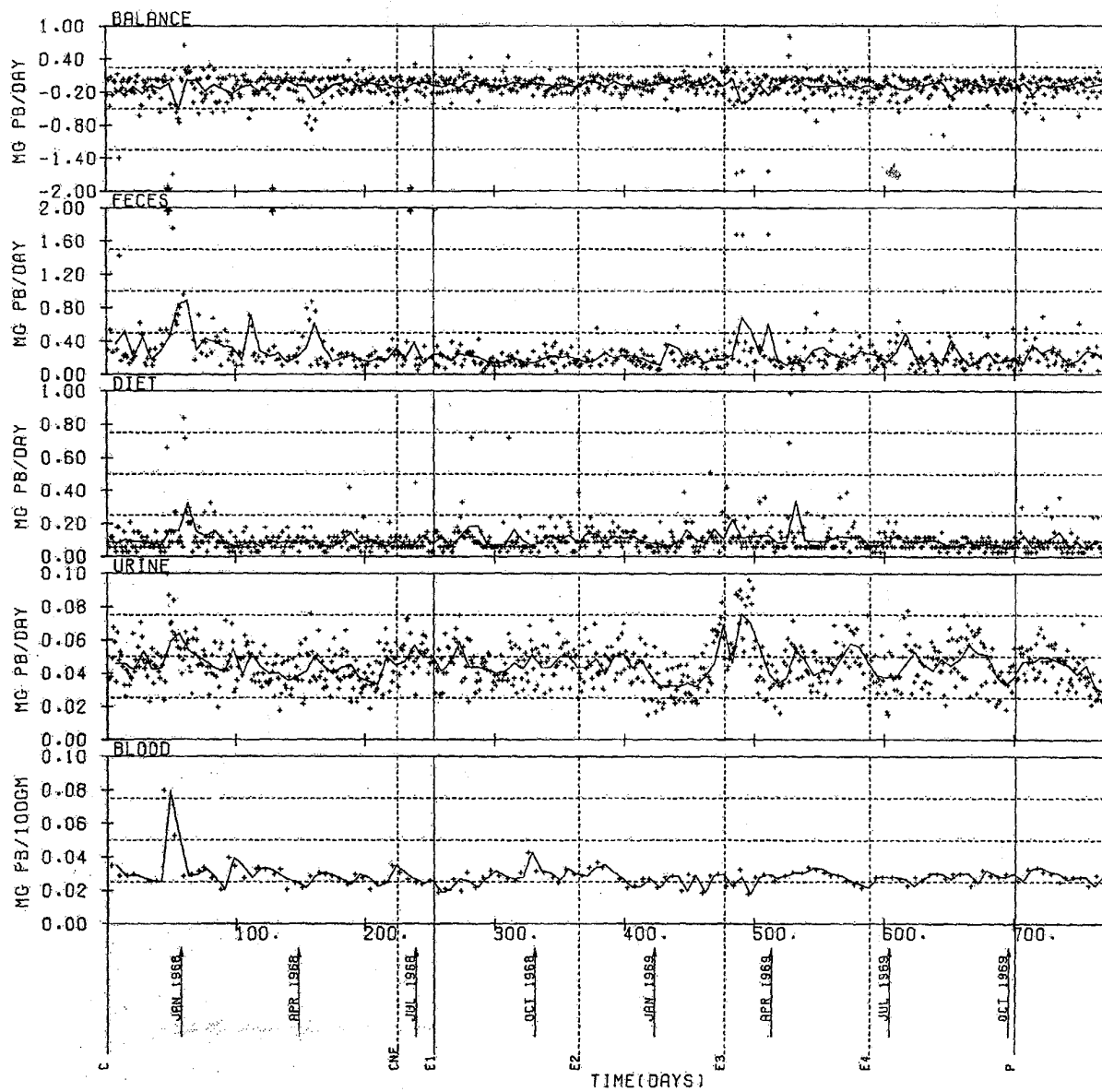


Figure 3H. Data Plots for Individual Subjects with Time.

SUBJECT- LD

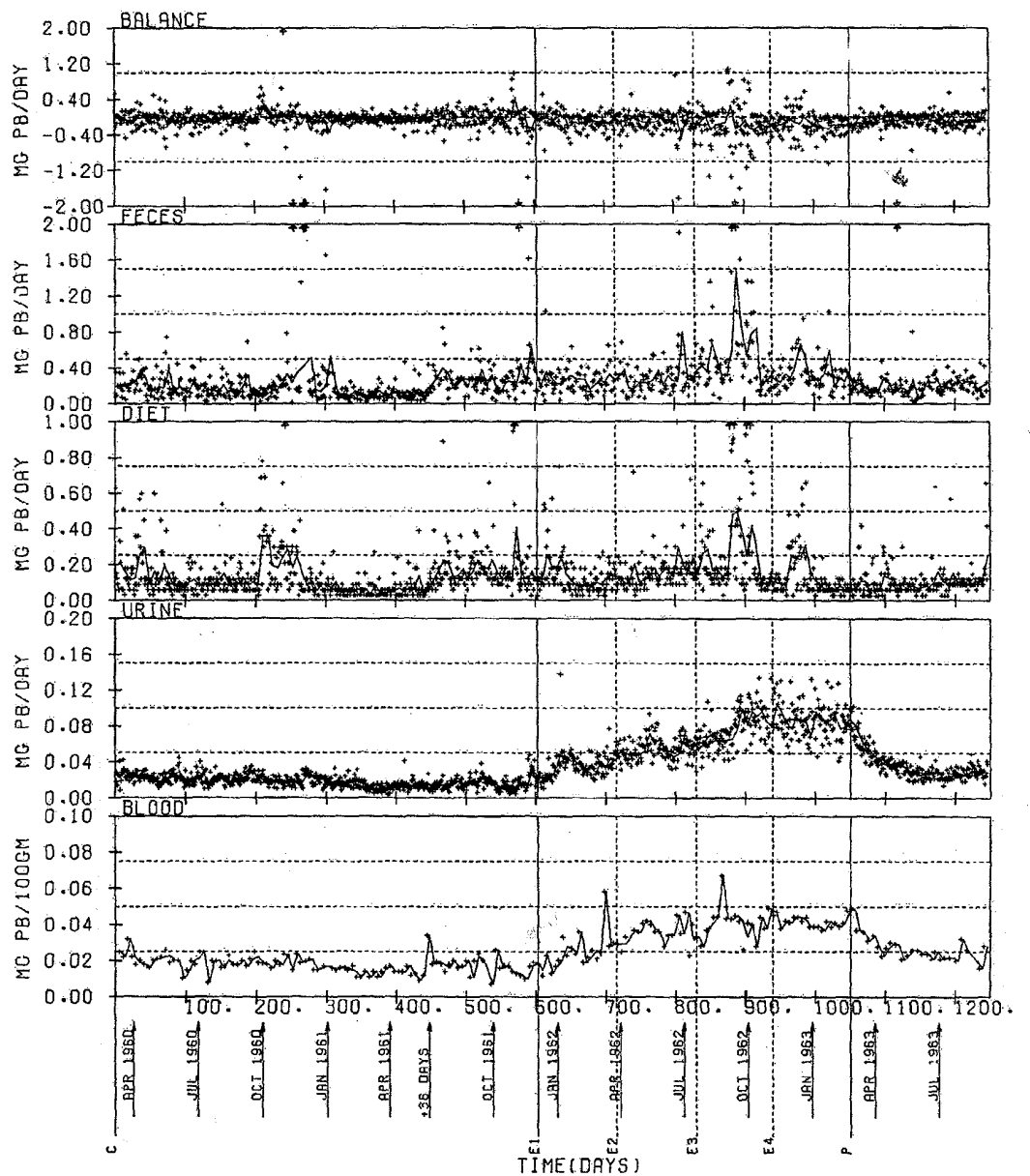


Figure 31. Data Plots for Individual Subjects with Time.

SUBJECT- JOS

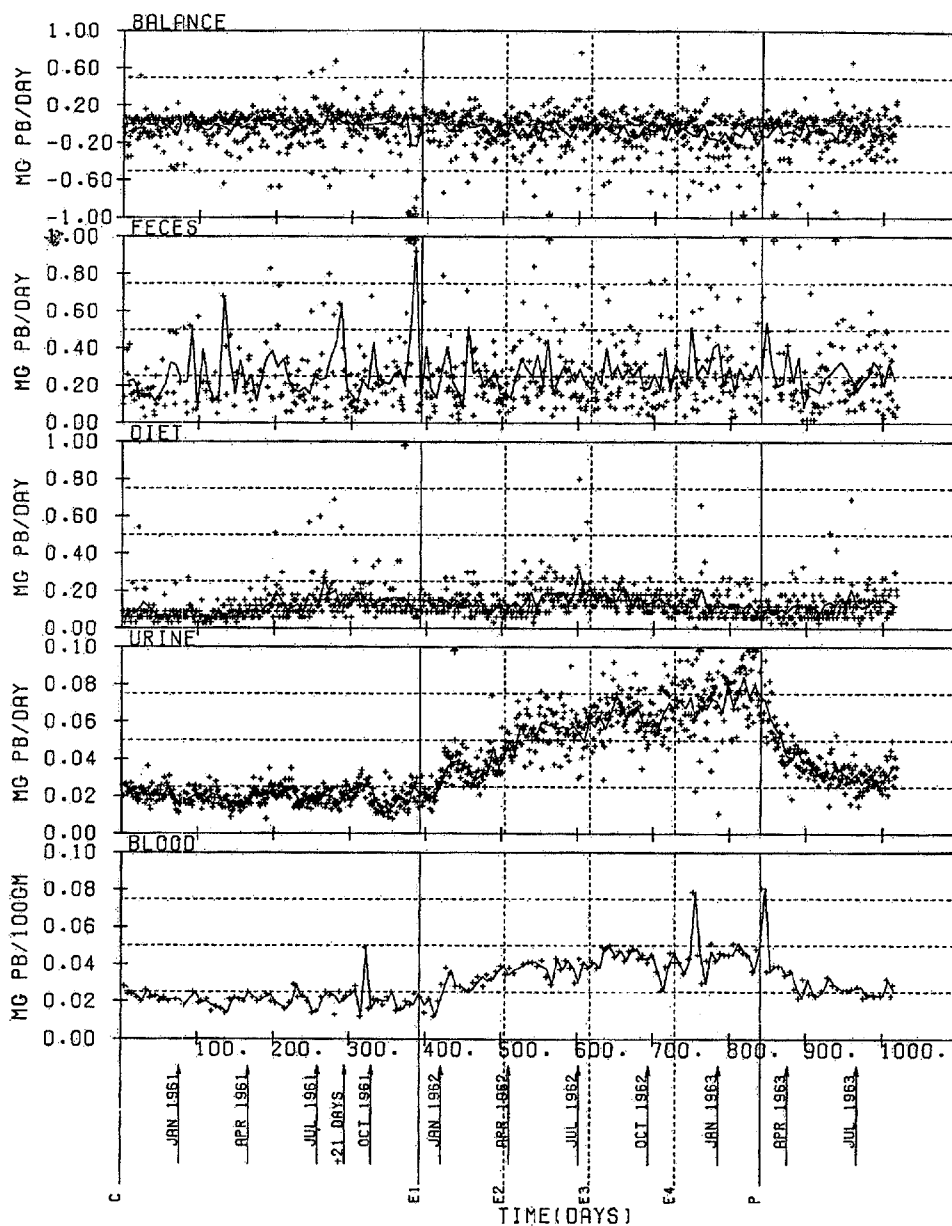


Figure 3J. Data Plots for Individual Subjects with Time.

SUBJECT- M08

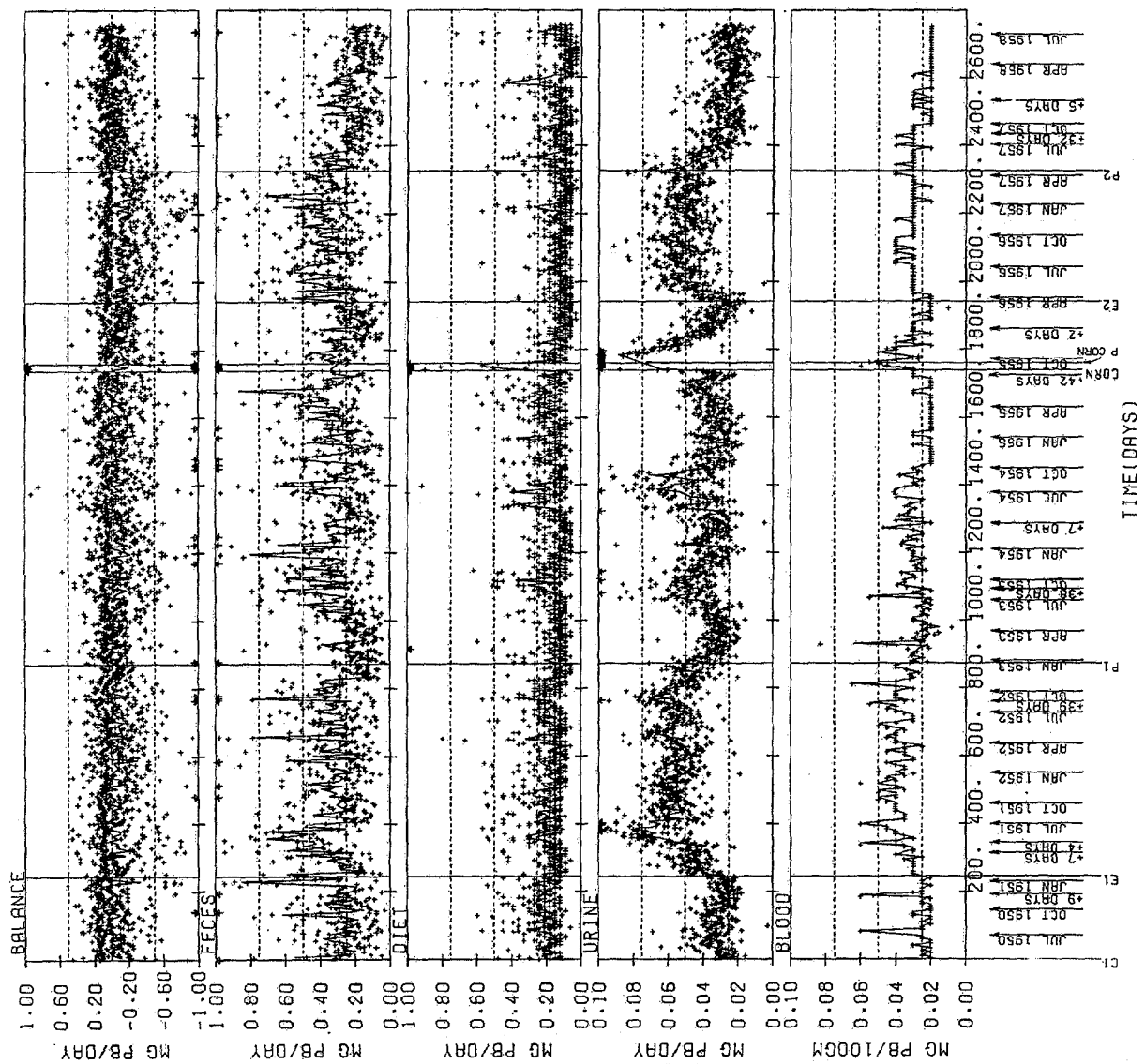


Figure 3K. Data Plots for Individual Subjects with Time.

SUBJECT- S8

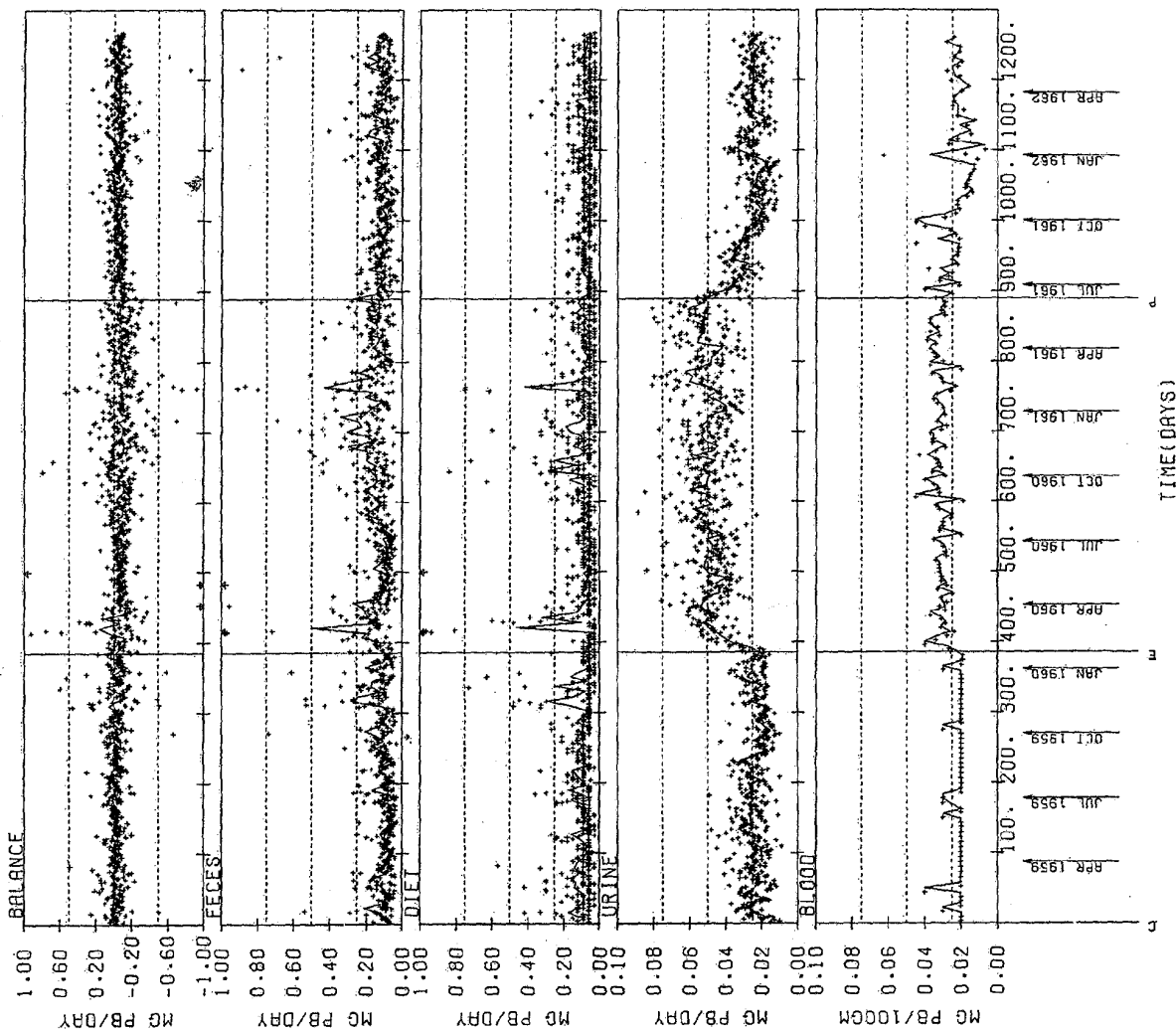


Figure 3L. Data Plots for Individual Subjects with Time.

SUBJECT- SB

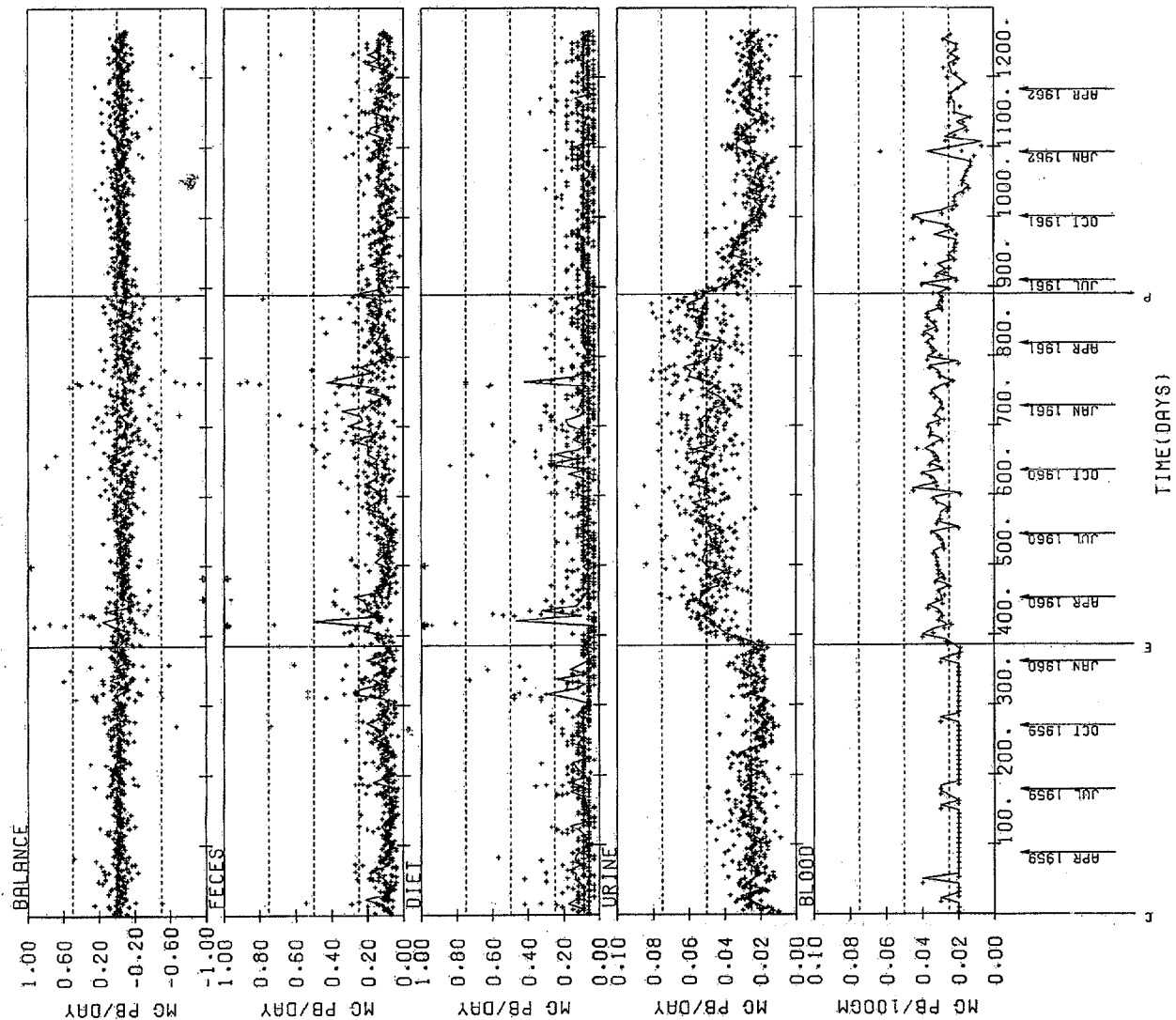


Figure 3L. Data Plots for Individual Subjects with Time.

SUBJECT- JUS

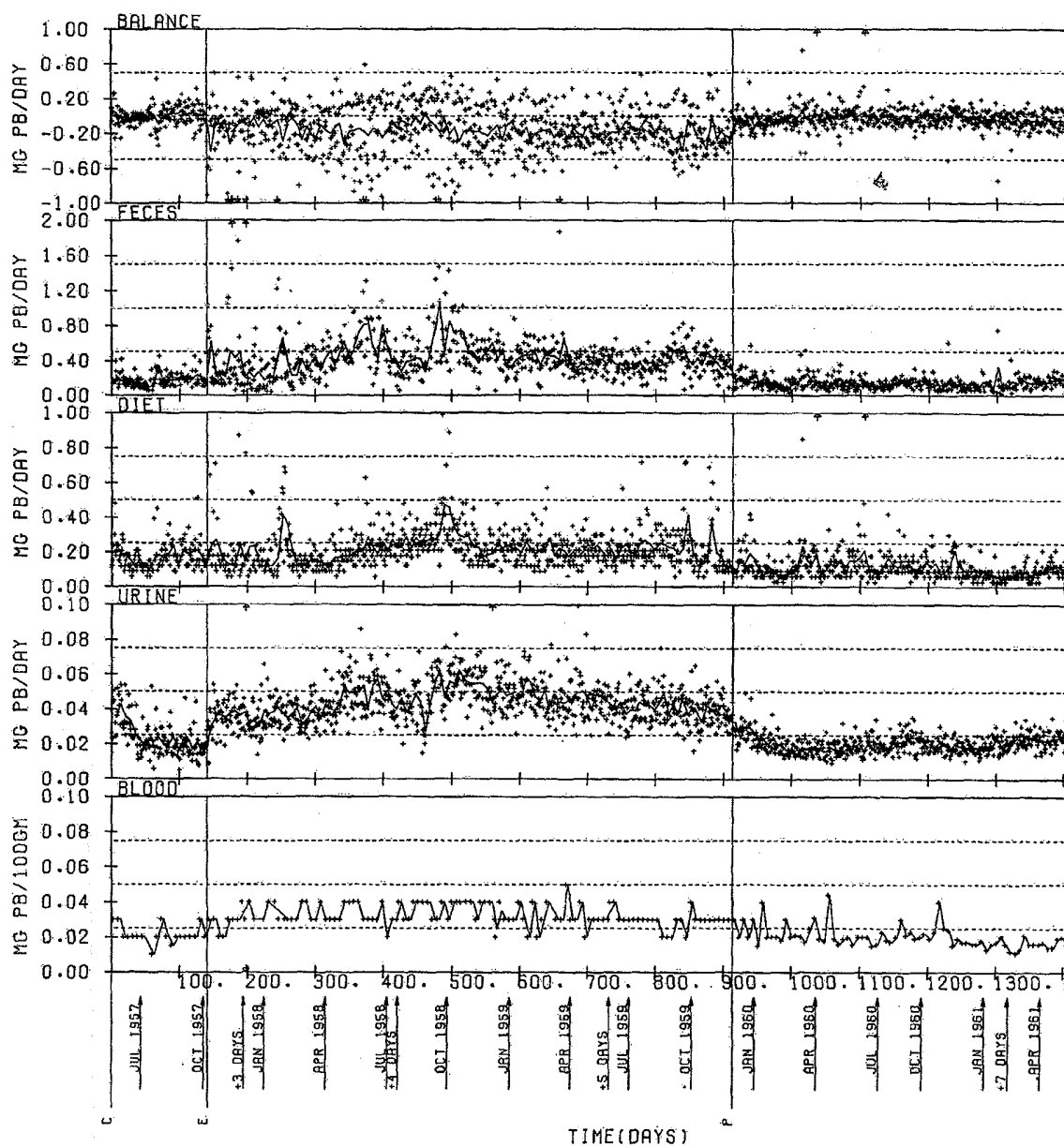


Figure 3M. Data Plots for Individual Subjects with Time.

SUBJECT - PB

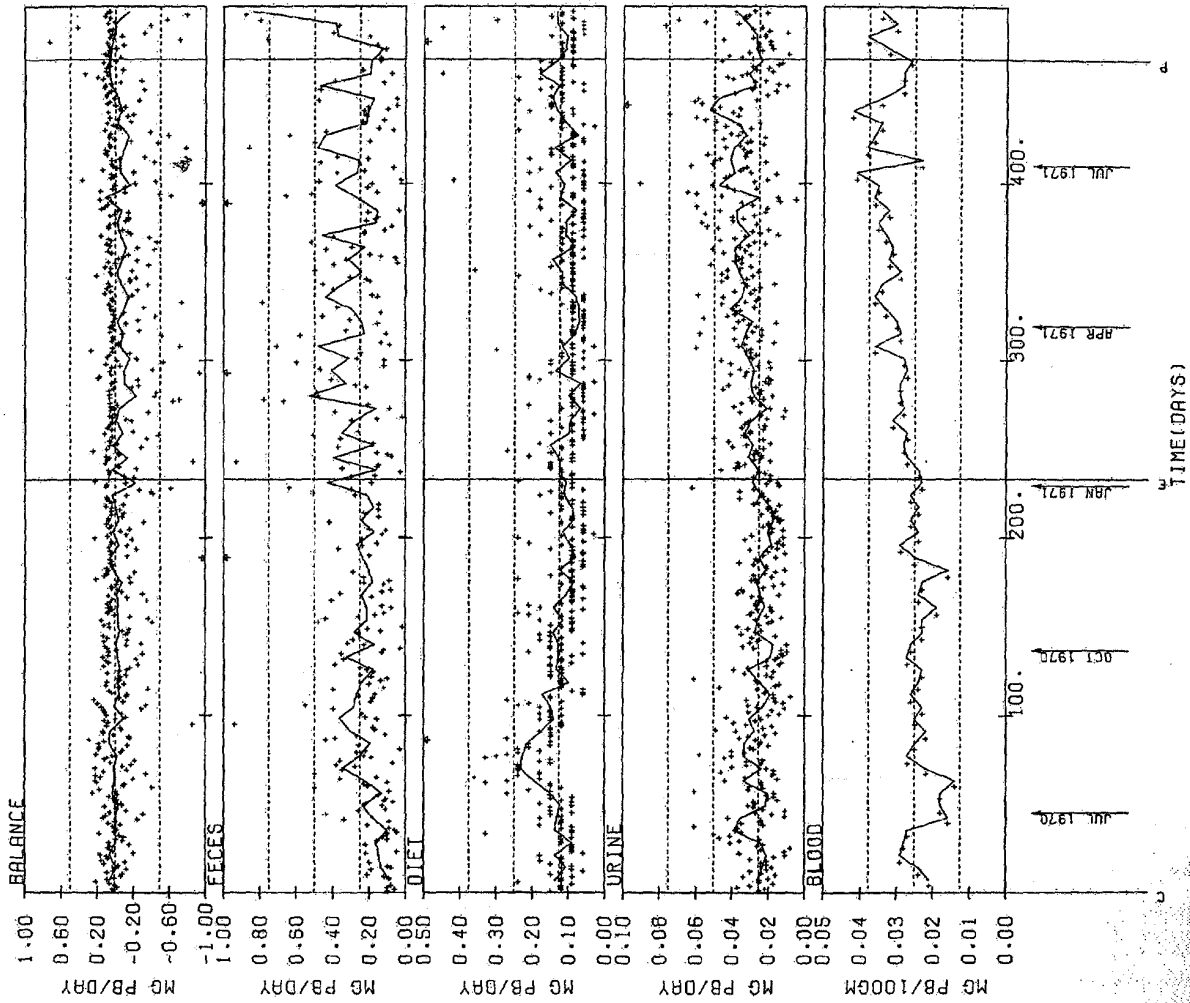


Figure 3N. Data Plots for Individual Subjects with Time.

SUBJECT- MB

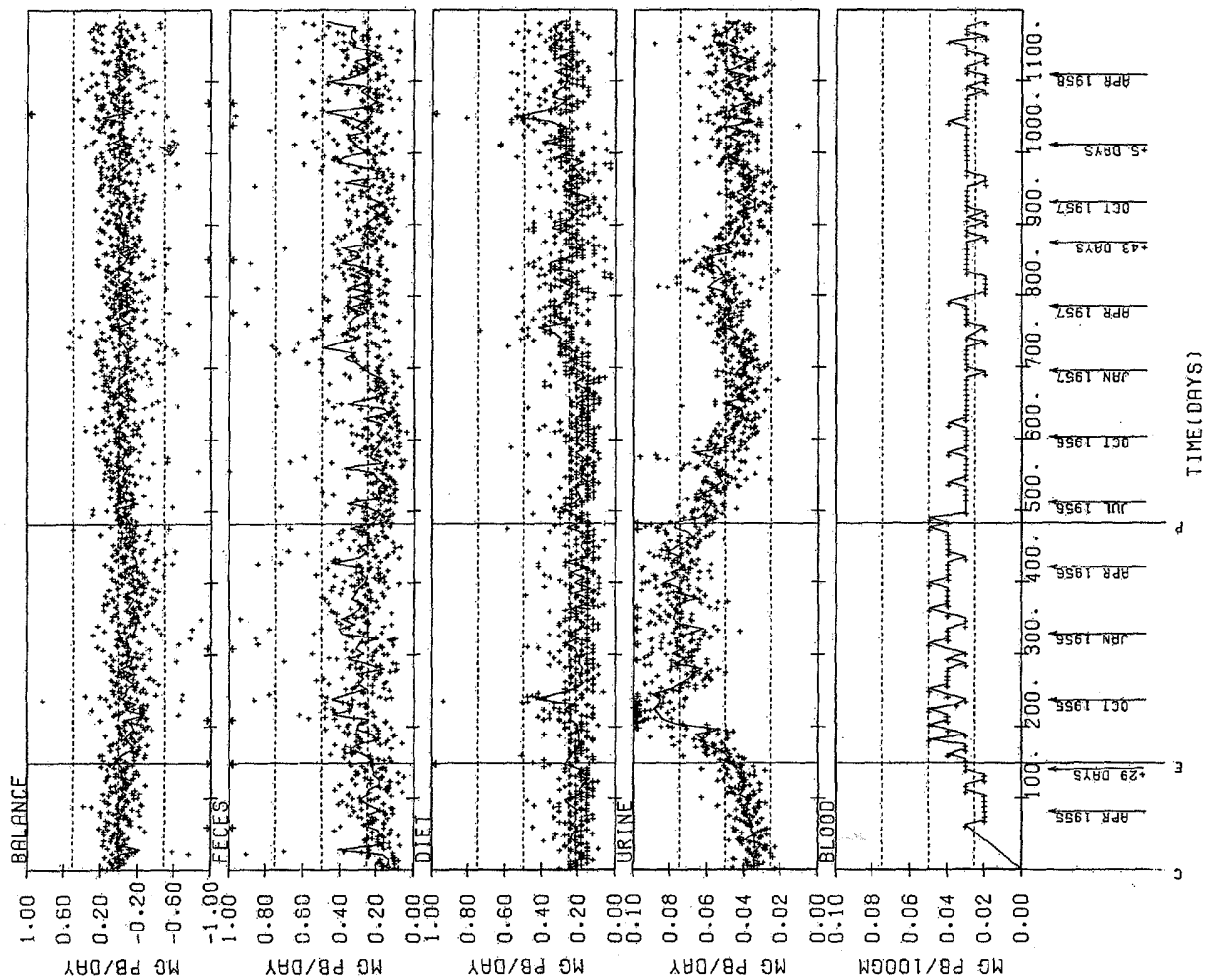


Figure 30. Data Plots for Individual Subjects with Time.

SUBJECT- FC

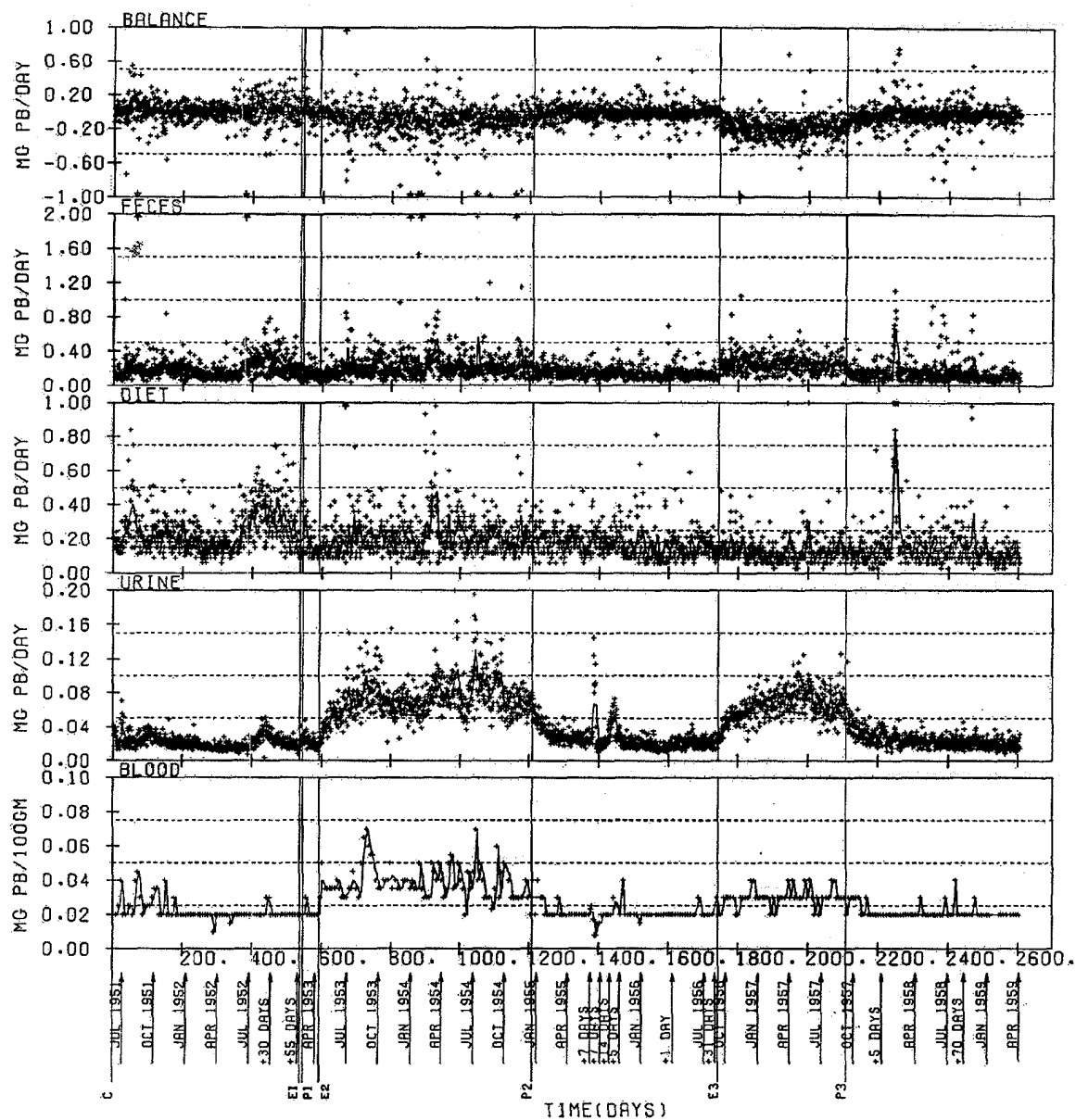


Figure 3P. Data Plots for Individual Subjects with Time.

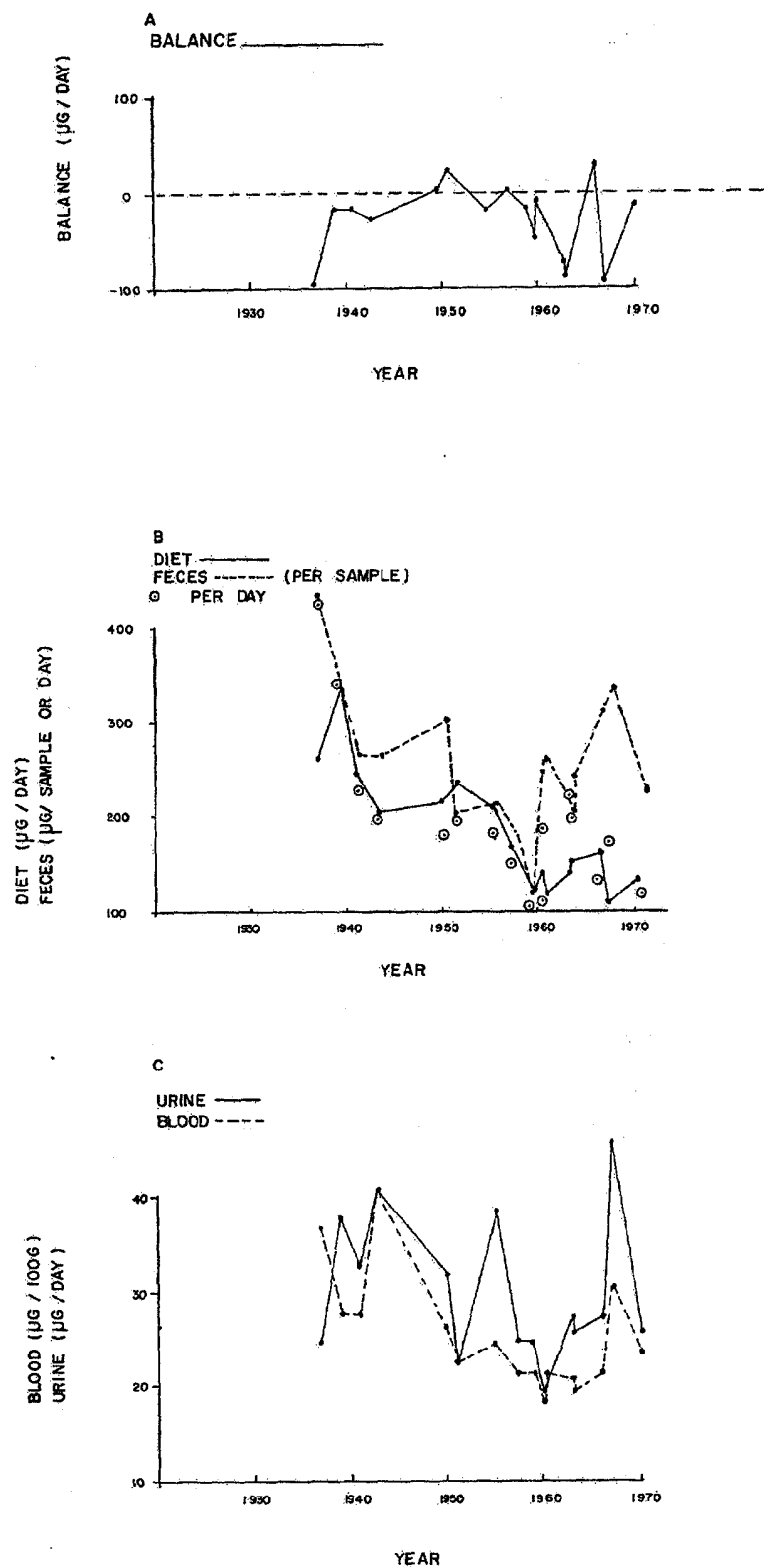


Figure 4. Control Period Means for Each Subject by Year of Experiment.

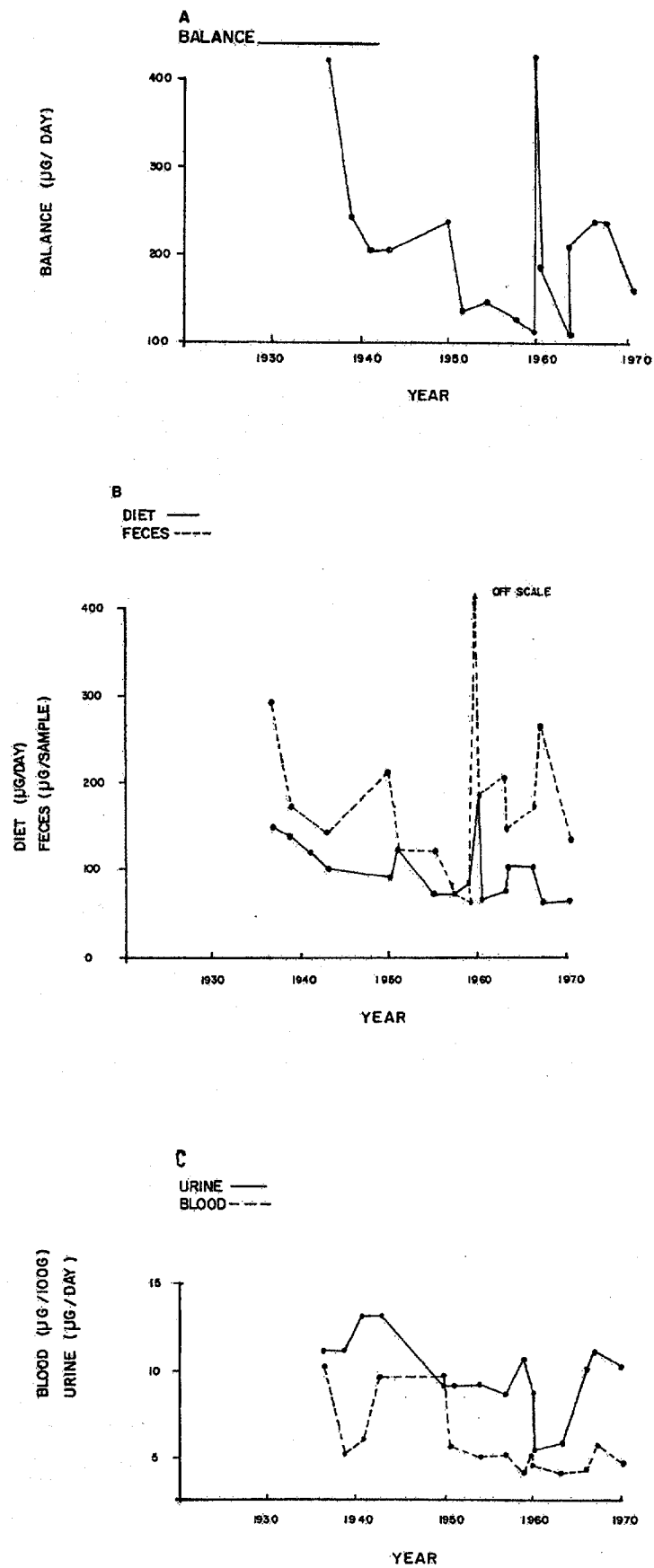


Figure 5. Standard Deviations for Each Control Period by Year of Experiment.

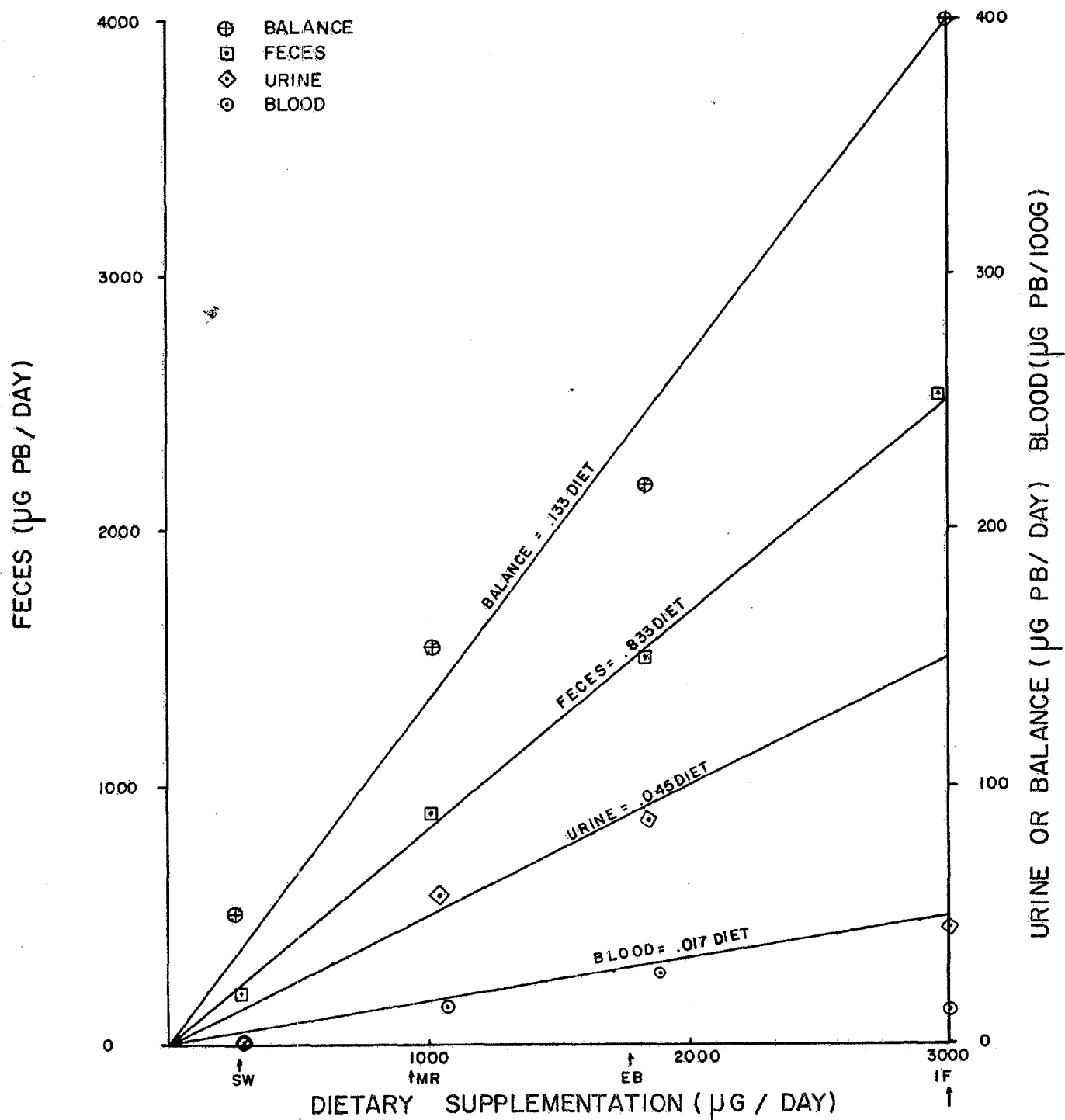


Figure 6. Response Data for Lead Balance and Fecal, Dietary, Urinary and Blood Lead for Oral Supplementation Experiments.

A BALANCE

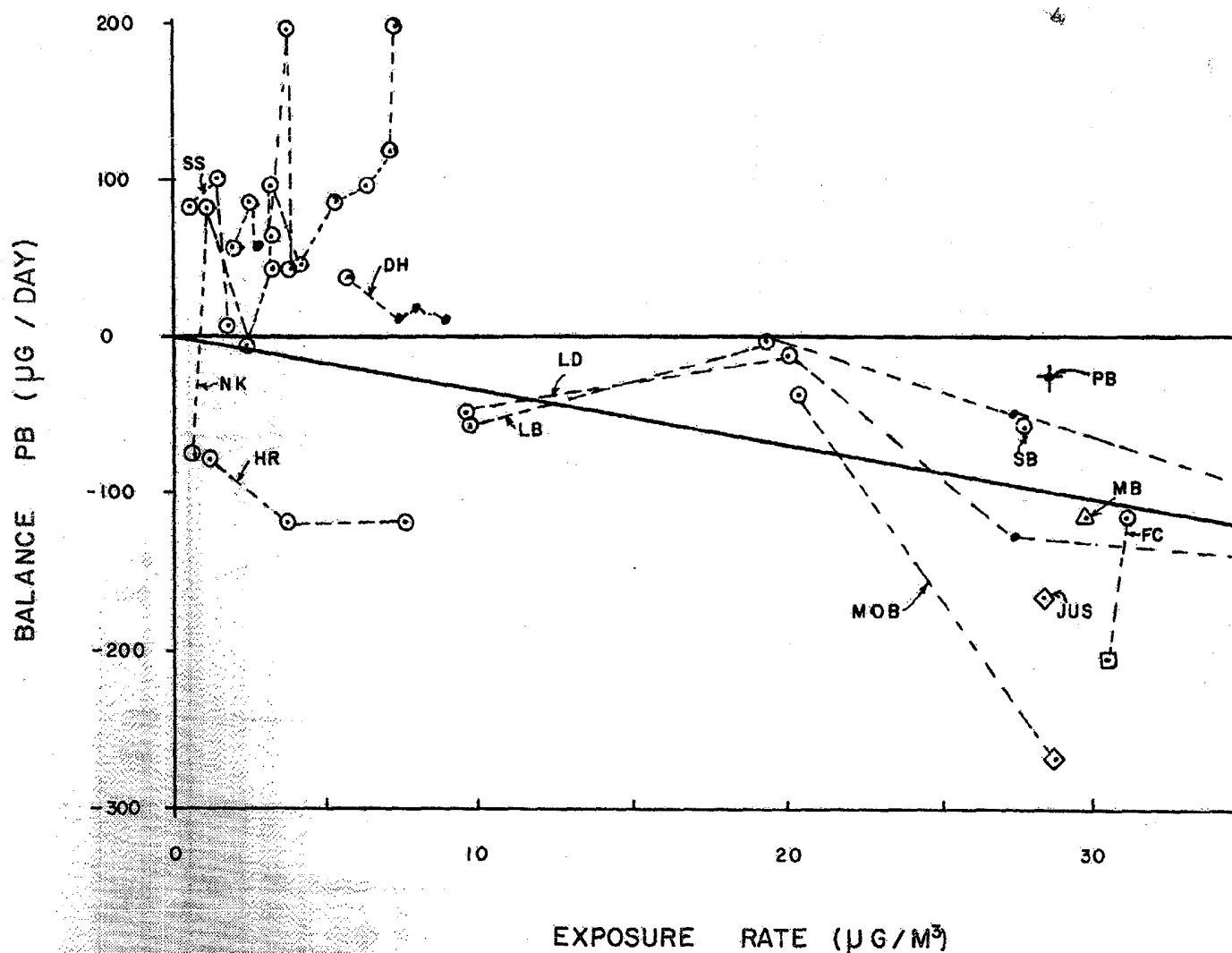


Figure 7A. Response data for lead balance for the inhalation experiments shown as a function of adjusted exposure rates and particle size. Particle sizes are designated as $\odot$, 0.05 μm ; +, 0.11 μm ; $\triangle$, 0.75 μm ; $\square$, 0.90 μm ; and $\diamond$, 1.20 μm .

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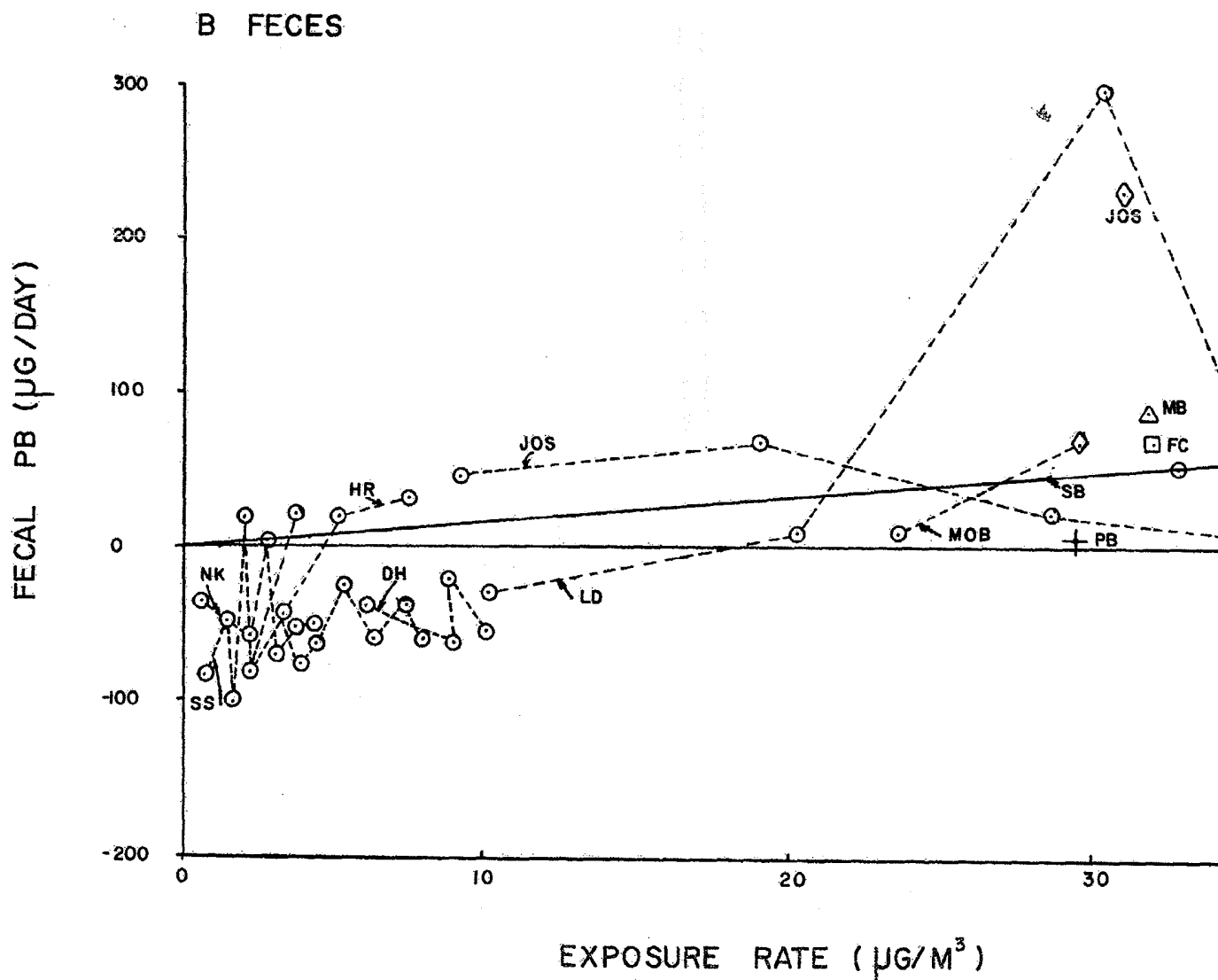


Figure 7B. Response data for fecal lead for the inhalation experiments shown as a function of exposure rates and particle size. Particle sizes are designated as $\odot$, 0.05 μm ; +, 0.11 μm ; $\triangle$, 0.75 μm ; $\square$, 0.90 μm ; and $\diamond$, 1.20 μm .

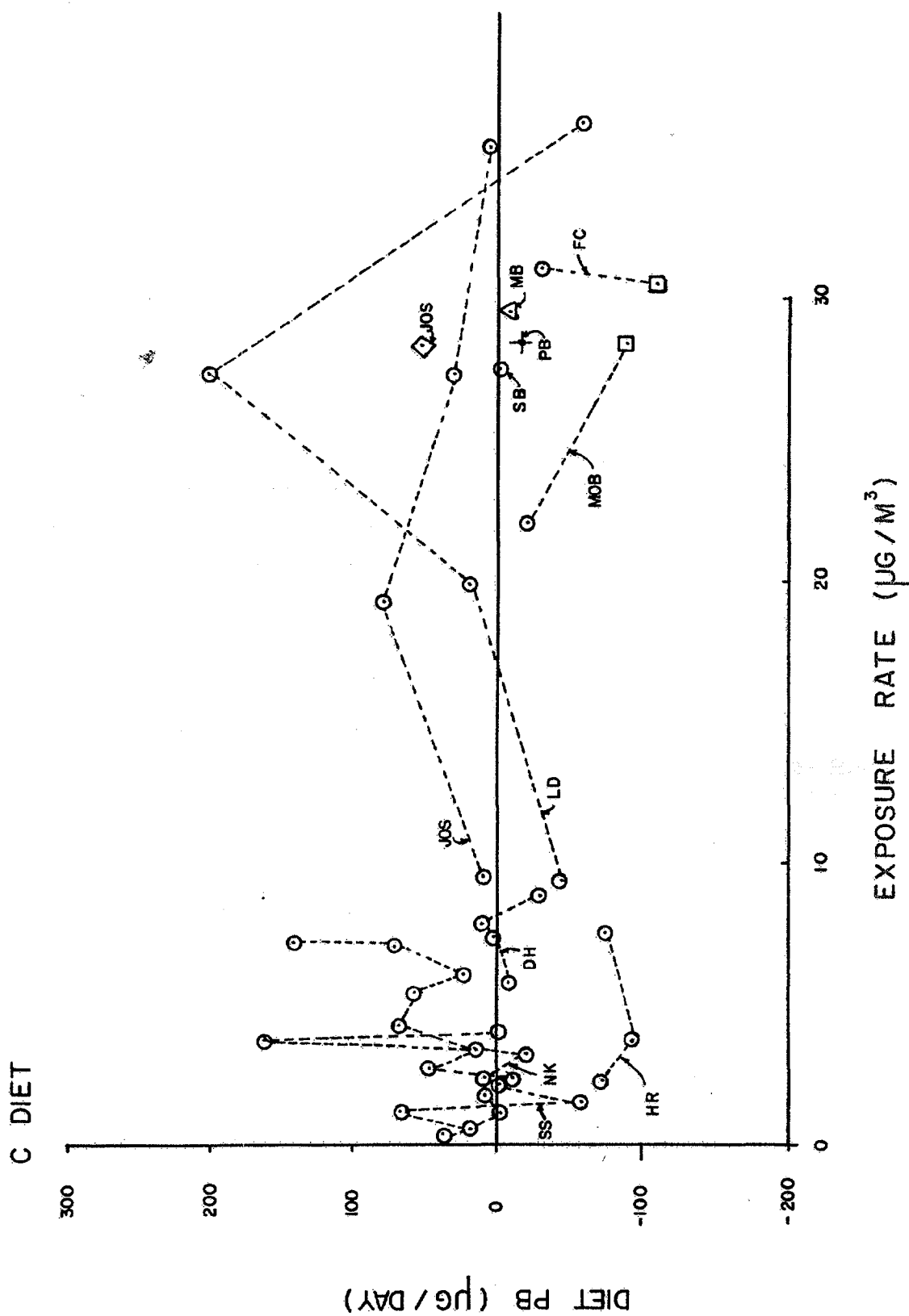


Figure 7C. Response data for dietary lead for the inhalation experiments shown as a function of adjusted exposure rates and particle size. Particle sizes are designated as $\odot$, 0.05 μm ; +, 0.11 μm ; $\square$, 0.75 μm ; and $\diamond$, 1.20 μm .

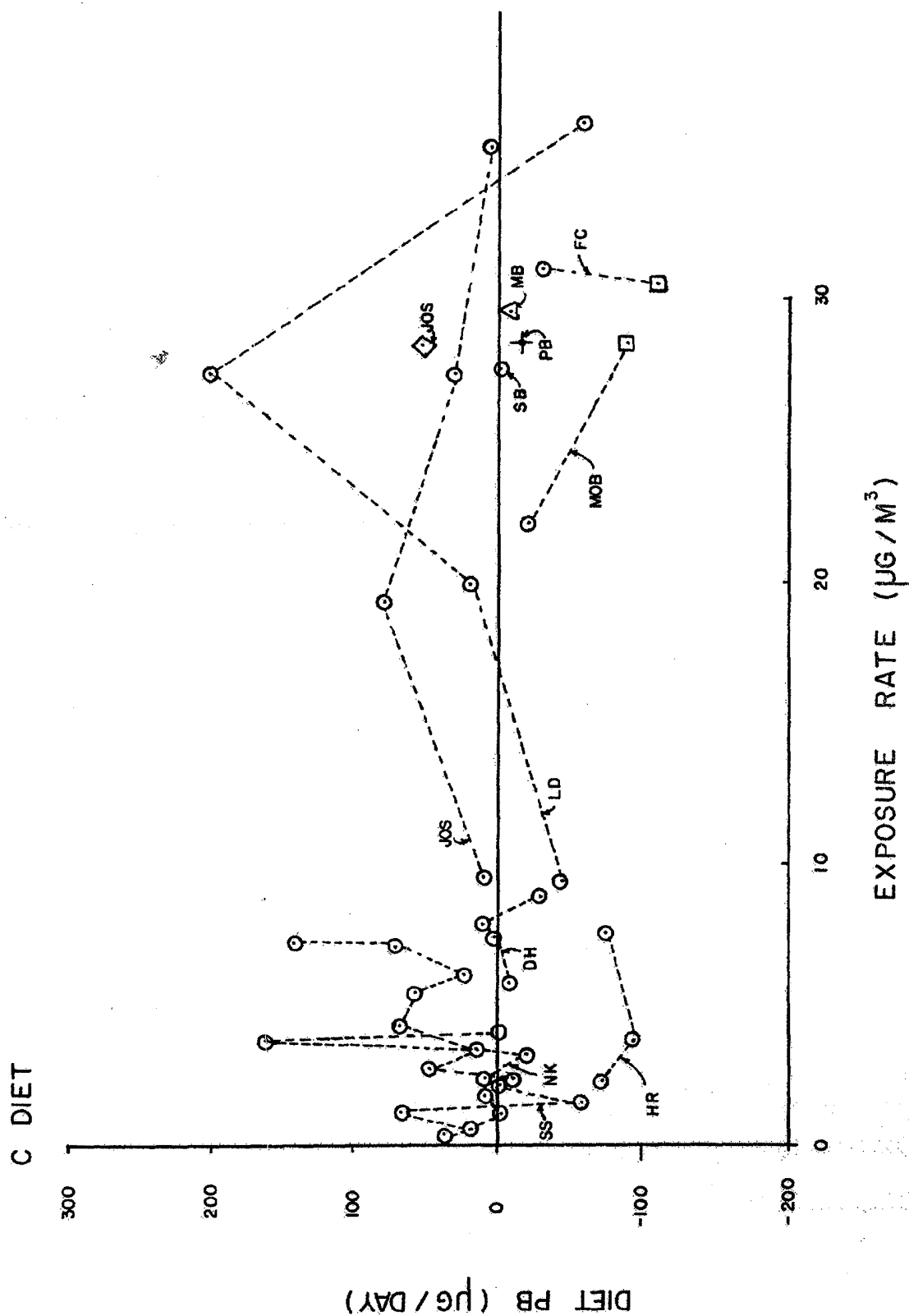


Figure 7C. Response data for dietary lead for the inhalation experiments shown as a function of adjusted exposure rates and particle size. Particle sizes are designated as $\odot$, 0.05 μm ; $+$, 0.11 μm ; $\triangle$, 0.75 μm ; $\square$, 0.90 μm ; and $\diamond$, 1.20 μm .

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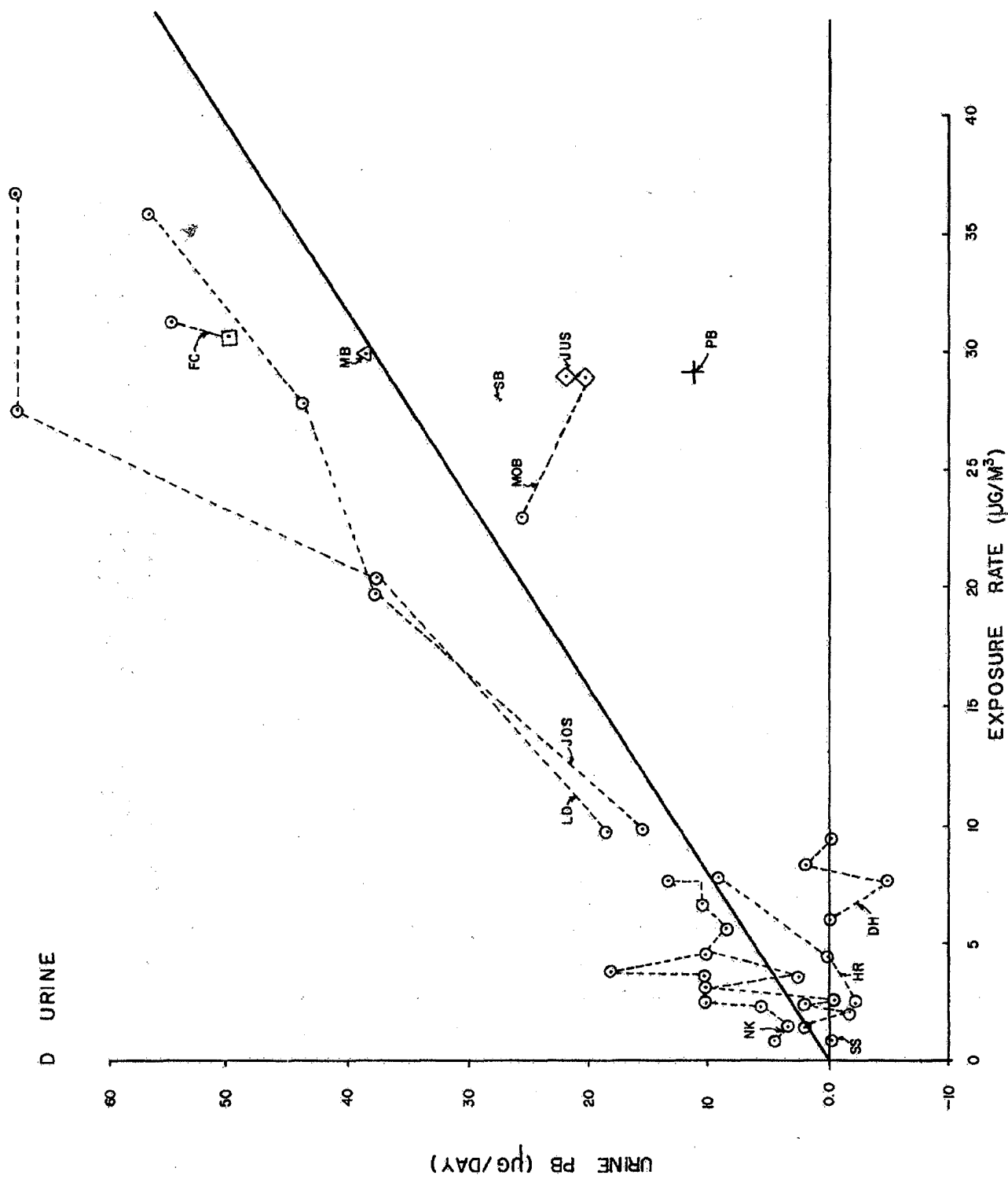


Figure 7D. Response data for urinary lead for the inhalation experiments shown as a function of adjusted exposure rates and particle size. Particle sizes are designated as
 ○, 0.05 um; +, 0.11 um; △, 0.75 um; □, 0.90 um; and ◇, 1.20 um.

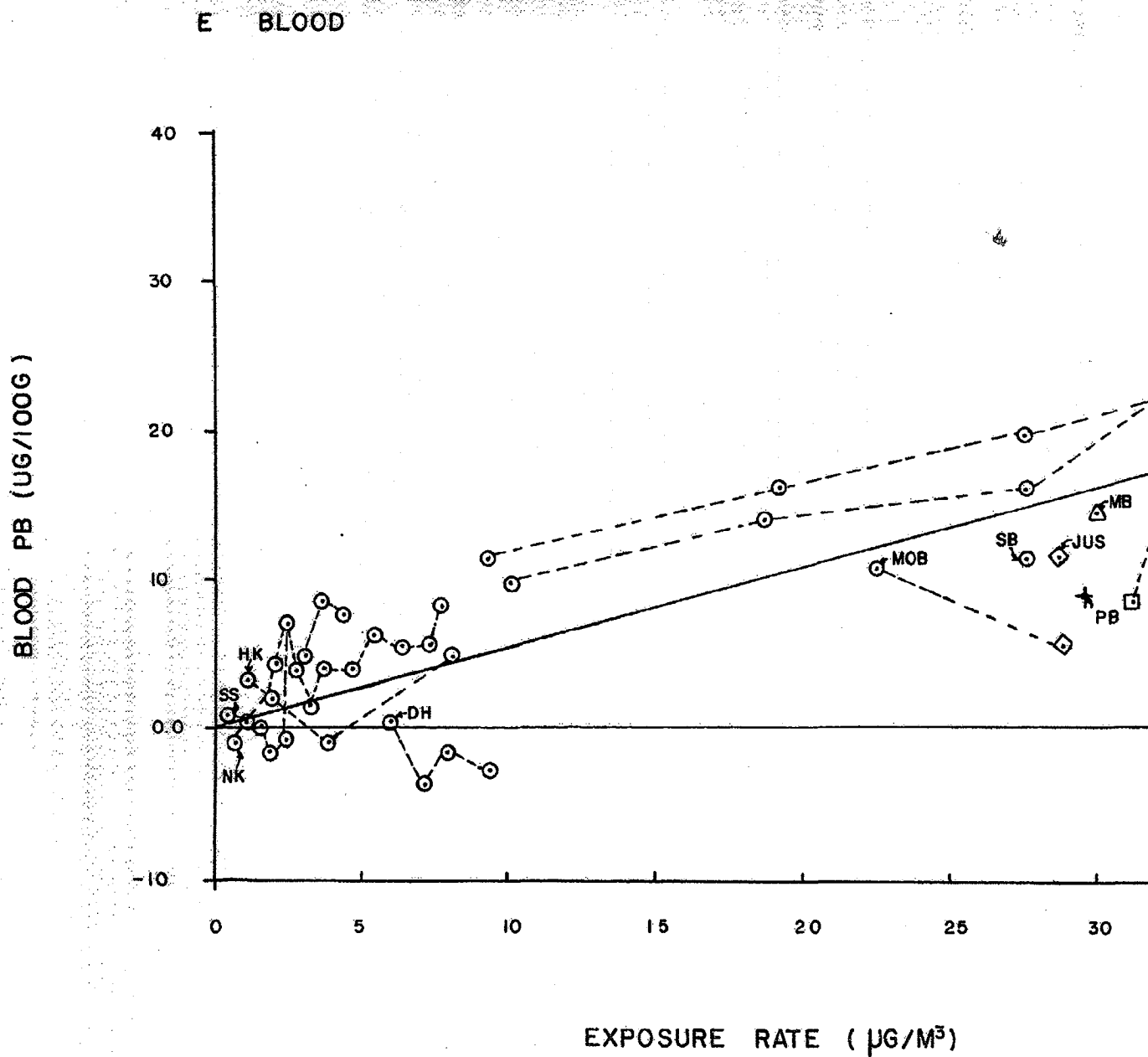
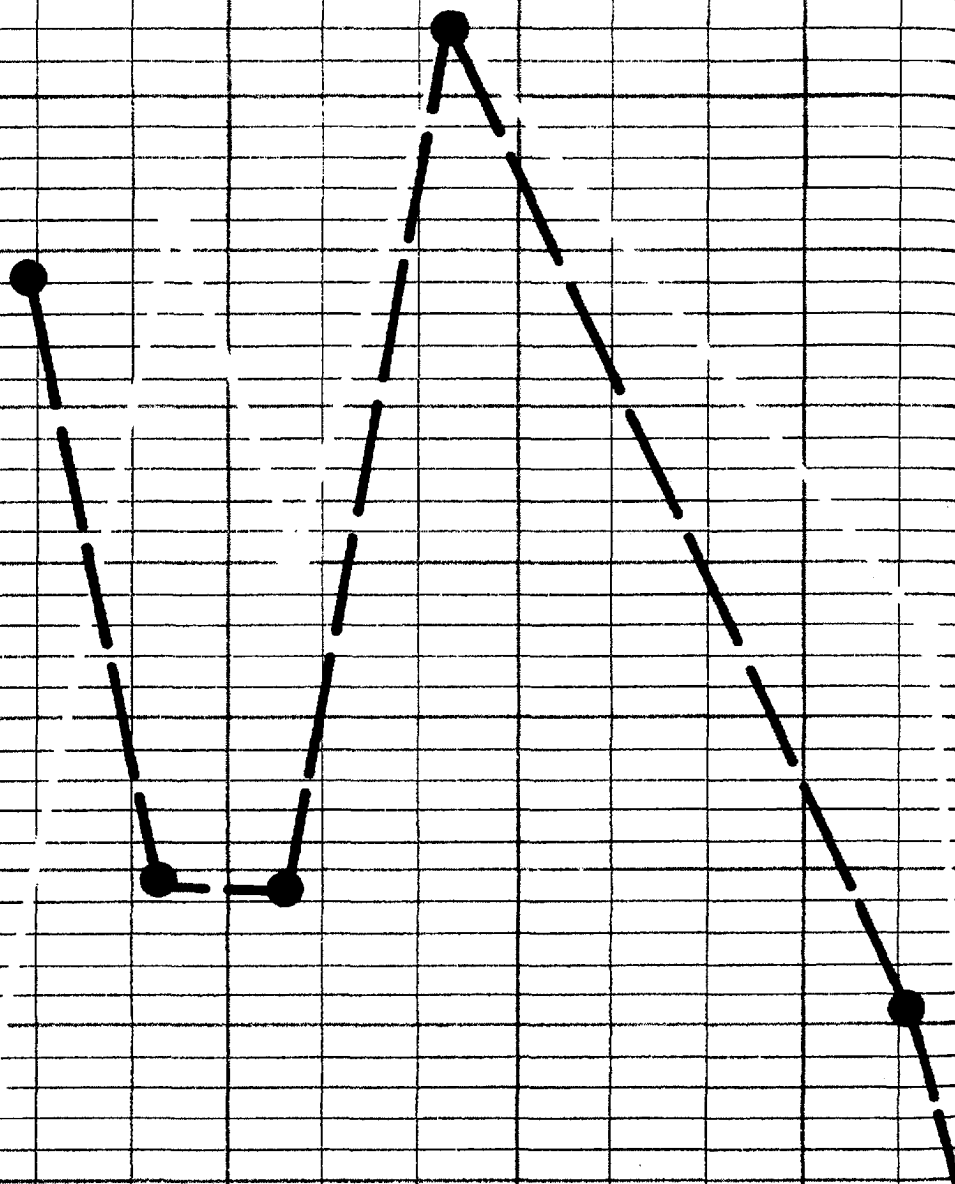


Figure 7E. Response data for blood lead for the inhalation experiments shown as a function of exposure rates and particle size. Particle sizes are designated as $\odot$, 0.05 μm ; +, 0.11 μm ; $\triangle$, 0.75 μm ; $\square$, 0.09 μm ; and $\diamond$, 1.20 μm .

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Lead Industries Association, Inc.

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